CONSERVATION INNOVATION GRANTS
FINAL REPORT

<table>
<tr><td colspan="2">Grantee Name: Klamath Basin Rangeland Trust</td></tr>
<tr><td colspan="2">Project Title:
Public/Private Partnership to Enhance Incentive Programs in the Klamath Basin</td></tr>
<tr><td colspan="2">Agreement Number: 69-3A75-7-114</td></tr>
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<tr><td colspan="2">Period Covered by Report: Final 10/03/2007 - 09/30/11</td></tr>
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***This joint NRCS / KBRT effort has been an unequivocal success, with a complete change in water saving efforts in the Upper Klamath Lake watershed, a clear outlook for future paths, and a real interest from other basins to understand how this approach can be adopted elsewhere*.**

Project Activities & Results

The objective of this project was to use KBRT's unique public/private partnership approach to take the next step with Upper Klamath Lake watershed producers, using federal programs to permanently convert their land management from irrigated to dryland grazing. The premise behind our approach is that NRCS programs can be used to transition landowners to dryland grazing, becoming confident in how to run their operations with less water, and then participate in a water market / transaction program to assure long-term protection of increased instream flows. KBRT has been working with upper basin partners to increase the reach of NRCS programs towards dryland grazing, and develop a water transaction program acceptable to all. ***Please see the attached spreadsheet for detailed tasks***.

1) NRCS Programs:

KBRT conducted outreach to educate landowners about opportunities with NRCS programs, and assisted them with the application process, contracting process, and fulfilling their contract obligations in 2008 through 2011. In 2008 11 landowners enrolled in the EQIP program, and this doubled to a cumulative 22 landowners in the AWEP program in 2011. This includes landowners not only in the Wood River Valley, where

KBRT was previously focused, but also 10 landowners in the Sprague and Williamson river basins, where NRCS and KBRT agreed to expand the focus. Over 10,000 acres have been enrolled in the dryland or reduced irrigation programs.

Additionally, KBRT employed the Wetland Reserve Program to enroll priority areas (riparian zones and wetlands) in easements that would both protect the ecological values of the property, while reducing water use on the ranch. KBRT assisted with the finalization of the restoration plans, survey work, and title issues. KBRT secured match funding for restoration to assure that the WRP applications were competitive. KBRT has supported four producers through the WRP process, and 1,800 acres are now in permanent WRP contracts, with another 400 acres expected to close in the first quarter of 2012.

KBRT worked with producers, the Klamath Soil & Water Conservation District, Farm Service Agency, and NRCS to enroll about 70 acres in the CREP program, providing 15 years of protection to a mile-long priority reach of the Wood River. The producers have leased their water rights instream as part of the contract.

With the CIG in hand, KBRT was able to secure funds from the MJ Murdock Charitable Trust which allowed KBRT to create a new staff position, the Restoration Director, which enabled much of this outreach to landowners and time investments needed to walk landowners through the contracting process, and the intricacies involved with the WRP and CREP programs, and implement with restoration work associated with AWEP, WRP, and CREP.

2) Monitoring:

KBRT continued the flow, water quality, and habitat monitoring effort that was started previous to the CIG, but adjusted it to changes in management on different properties.

KBRT worked very closely with NRCS on the Wood River Valley Conservation Effects Assessment Project to gain a better understanding of the impacts of NRCS programs in the Wood River Valley, and determine a recommended irrigation regime that would maximize productivity and minimize water use. The final CEAP report was released in 2010, and greatly influenced recommendations to producers, and the design of the AWEP program.

KBRT supported repeating a habitat survey that was conducted along Crooked and Sevenmile Creeks in 2002 and 2003. Management along these creeks has changed drastically since that time, with riparian fencing and increased instream flow supported by NRCS programs. This survey showed clear improvement in habitat conditions as a result of the management changes.

While KBRT's instream water quality monitoring continued in the Sevenmile system, there was an additional focus on the water quality impacts of a 700 acre WRP at the bottom of the Wood River system. A previous study of the main areas of poor quality tailwater influx to streams identified the Agency WRP area as one of the main points of poor water quality, as it drains thousands of irrigated acres. While the WRP was not designed to treat water quality, there was a hope that it would improve it. Water quality samples were collected before, during, and after implementation of the restoration plan on the WRP. While it is a relatively small data set, it does clearly suggest a significant (32% - 40%) decrease in nutrient loading to the Wood River system.

KBRT's efforts to document increases in instream flows in the Sevenmile system as a result of NRCS programs continued throughout the project. There are significant increases in instream flows, and we are now working to use that information to better understand true water savings and where diversion structures may be incorrectly set.

3) Water Transaction Program:

The new Water Transaction Program (WTP) is one of the most stunning positive results from this effort. With the support from the CIG in hand, KBRT raised additional funds from the National Fish & Wildlife Foundation, Oregon Water Resources Department, and the Oregon Watershed Enhancement Board to directly support the work needed to develop a functional Water Transaction Program. This program enables producers to take the next step of permanently transferring their irrigation water rights instream after completion of the NRCS AWEP/EQIP program. KBRT hired a new half-time staff member to develop and administer the program.

In the development of the WTP, KBRT completed a regional appraisal to identify a range of values to be expected for water rights within the Upper Klamath Lake watershed. KBRT worked with local stakeholders and biologists to set reach-scale priorities, and worked with groups doing water transactions elsewhere in Oregon to identify administrative processes, budget needs and potential fundraising targets.

KBRT selected two "pilot" transactions to undertake first, in different regions of the basin and set at different price points. These are both currently being processed by Oregon Water Resources Department. KBRT currently has two transactions in process, four agreements with landowners to move forward with transactions, two agreements being negotiated with landowners, and others in early discussion. Without a doubt, the EQIP/AWEP followed by an opportunity to make a permanent transfer of water rights model is one that has worked in the Upper Klamath Lake watershed.

Potential for Transferability of Results

Throughout the process KBRT has been engaged in learning from and sharing with other groups. The most direct effort has been sharing information with organizations focused on water sharing in lower reaches of the Klamath Basin, specifically the Scott and Shasta basins. The National Fish and Wildlife Foundation became quite interested in supporting groups in those regions to do work similar to KBRT, using KBRT's approach with NRCS programs. NFWF viewed it as a natural extension of their existing water transaction work in the Columbia Basin. Representatives from the Scott and Shasta basins visited the Upper Klamath Lake watershed and toured with KBRT, and KBRT toured the lower basin with these groups, including NRCS staff members. NFWF is investing funds in those basins to encourage the continued development of permanent instream water right transfers.

Additionally, KBRT hosted a group of conservationists and producers from the Colorado section of the Colorado River Basin, and a separate group of conservationists and producers from the Arizona reaches of the Colorado River basin. These trips were facilitated through the Colorado Water Institute at Colorado State University and the Water Resources Research Center at University of Arizona. Representatives from Arizona followed up very closely with KBRT and NRCS's work in the watershed. KBRT facilitated direct conversation between Arizona groups and NRCS staff between the basins. There is a very strong interest in the use of the AWEP program in Arizona.

The primary complication that has been encountered is the flexibility of current NRCS programs to meet the individual needs of each area. These include partial season agreements, compatible practices and sufficient payment rates, payments tied to water savings, and concerns about enrolling producers when there is no legal guarantee that the irrigation changes will be adopted. There is discussion about use of the CCPI program instead of AWEP, or encouraging changes to the AWEP program in the next Farm Bill.

Funding Received & Expended

As this project encompassed the major focus of KBRT efforts over the four year period, the total cost was $425,370.

Please see the attached spreadsheet for a detailed breakdown of CIG expenditures by category.

Match funds in the amount of **$214,445** were raised from the following sources:

MJ Murdock Charitable Trust $150,000

The Trust granted three years of support to KBRT to develop a new staff position, the Restoration Director. The Restoration Director became the primary staff member that conducted outreach to landowners, identified needs and sources of support, assisted them through the NRCS contracting process, and help implement the on-the-ground restoration components.

Oregon Watershed Enhancement Board $12,382 &

Oregon Water Resources Department $20,397

OWEB and OWRD provided initial support to build the framework for the Water Transaction Program. As the WTP developed into its own program, additional funds were raised for its support that are not counted as match towards CIG. The funds included as match are only those expended in 2009 for the very first stages of WTP development.

The Brainerd Foundation $9,993

The Foundation provided support towards ecological monitoring that helped shape recommendations to landowners for maximum productivity with minimum water use.

Producer Donations $21,673

KBRT accepts donations from private landowners that are used towards administrative needs and special purposes. The amount counted as match towards CIG is the amount expended on administrative needs related to CIG, and landowner outreach before the Murdock funds were in place.

Conclusion

This effort was truly a resounding success. It has changed the landscape of conservation and the assumed water management practices in the Upper Klamath Lake watershed, and resulted in permanent increases in instream flow. It brought increased resources to the local NRCS office, and helped deliver those resources in an effective, efficient, and strategic manner to on-the-ground priorities. It provided a template for other basins with water allocation issues to use NRCS programs in a watershed-based approach to enable real changes in land and water management. There are other basins that are currently working to implement a similar approach, although the interest and ability of local NRCS offices to tailor their programs for specific watershed needs will be the key to their successes.

Supporting Documentation submitted on the included compact disk:

1) Final Report
2) KBRT Water Transactions Program description
3) Regional Water Rights Appraisal
4) Wood River Valley Aquatic Habitat Study 2008
5) Wood River Valley CEAP Final Report 2010
6) Surface Water Monitoring Report 2007-2010
7) Water Quality Monitoring Report 2008-2010
8) Wood River Valley Wetlands & Water Quality Report 2010

Klamath Basin Rangeland Trust #69-3A75-7-114

Public/Private Partnership to Enhance Incentive Programs in the Upper Klamath Basin

Task Summary

Task	Status
Enroll producers in incentive programs towards permanent transition to dryland grazing	
Meetings with participating landowners Assist landowners to implement contract requirements Outreach to non-participating landowners Consultation with NRCS re: program and contracting opportunities and needs	COMPLETE. 22 producers have enrolled in programs since the inception of the CIG. The initial program targeted was EQIP, then KBRT and NRCS worked closely together to develop the AWEP proposal and subsequently implement it. 10 producers with just under 10,000 acres have either already committed or are currently in discussion towards permanent reduction in irrigation and legal transfer of water rights instream.
Develop a framework for a water market	
Attend Columbia Basin Transaction meetings Identify potential structure, review and adapt structure based on outside input Identify potential funding source, communicate with them to determine possibilities Finalize market structure	COMPLETE. KBRT raised additional funds from the Oregon Watershed Enhancement Board, Oregon Department of Water Resources, and National Fish and Wildlife Foundation to support the effort to develop a functional Water Transaction Program in the Upper Klamath Lake watershed. The program was finalized in June 2011, and is the process through which producers are permanently transferring their water rights instream. The full WTP description is included with this report, and includes the priorities, regional valuation, budget and fundraising plan, and administrative process.
Continue ecological monitoring program	
Determine any necessary changes in monitoring design	COMPLETE.

Conduct ecological monitoring	The instream flow, water quality, and select habitat monitoring work was continued for the duration of the CIG, and the associated reports are included with this report. KBRT is now adjusting its monitoring program to focus on individual water transactions.
Analysis and reporting	
[illegible] identified concerns in priority areas	
Communicate with conservation groups re: projects	COMPLETE. The strongest focus of this effort was to the lower reaches of the Klamath Basin, around the Scott and Shasta watersheds. KBRT worked with the National Fish & Wildlife Foundation to connect with active watershed groups in these basins. Representatives of those groups visited the Upper Klamath Lake watershed, and KBRT visited the lower watersheds. NRCS staff were includedon KBRT's visit to the lower watershed. The private groups are now using NRCS programs to a limited extent … more in the Shasta subbasin. Additionally, KBRT also hosted a group of conservationists and producers from the Colorado section of the Colorado River Basin, and a separate group of conservationists and producers from the Arizona reaches of the Colorado River basin. These trips were facilitated through the Colorado Water Institute at Colorado State University and the Water Resources Research Center at University of Arizona. Representatives from Arizona followed up very closely with KBRT and NRCS's work in the watershed. And KBRT facilitated direct conversation between Arizona groups and NRCS staff between the basins. There was a very strong interest in the use of the AWEP program.
Invite private groups and NRCS staff from priority areas to a KBRT/NRCS gathering in the Wood River Valley	
Follow with one-on-one planning for other priority areas	

Klamath Basin Rangeland Trust: Final Financial Accounting

Grantee: NRCS CIG $210,925 10/3/2007 Conservation Innovation Grant
69-3A75-7-114 9/30/2011

Date	Vendor Name	Check #	Personnel	Travel	Equipment Supplies	Contract	Indirect Costs	TOTALS	CUMULATIVE	REMAINING
	Budgeted Amount		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00	-	210,925.00
1/21/2008	November Payroll		2,573.32					2,573.32	2,573.32	208,351.68
1/21/2008	December Payroll		2,291.56					2,291.56	4,864.88	206,060.12
3/1/2008	Molly Russell				123.76			123.76	4,988.64	205,936.36
3/4/2008	January Payroll		1,919.68					1,919.68	6,908.32	204,016.68
3/4/2008	February Payroll		2,387.32					2,387.32	9,295.64	201,629.36
3/4/2008	Admin						929.56	929.56	10,225.20	200,699.80
3/17/2008	Qwest	2704			64.10			64.10	10,289.30	200,635.70
4/1/2008	Bonnie Ward	2709			120.00			120.00	10,409.30	200,515.70
4/1/2008	March Payroll		1,548.55					1,548.55	11,957.85	198,967.15
4/1/2008	Shannon Peterson	2705			370.34			370.34	12,328.19	198,596.81
4/1/2008	US Cellular	2702			22.60			22.60	12,350.79	198,574.21
4/15/2008	OR Water Resources Dept					300.00		300.00	12,650.79	198,274.21
4/15/2008	Shannon Peterson	2713		281.37				281.37	12,932.16	197,992.84
4/15/2008	Bonnie Ward	2715			120.00			120.00	13,052.16	197,872.84
4/15/2008	US Postmaster	2712			16.40			16.40	13,068.56	197,856.44
4/18/2008	Harland Business	ACH			27.00			27.00	13,095.56	197,829.44
4/29/2008	Klamath Watershed Partnership	2724			68.00			68.00	13,163.56	197,761.44
4/29/2008	Shannon Peterson	2722			911.50			911.50	14,075.06	196,849.94
5/1/2008	April Payroll		2295.08					2,295.08	16,370.14	194,554.86
5/13/2008	Bonnie Ward	2726			120.00			120.00	16,490.14	194,434.86
5/13/2008	Qwest	2730			73.23			73.23	16,563.37	194,361.63
5/13/2008	US Cellular	2732			20.00			20.00	16,583.37	194,341.63
5/13/2008	Admin						635.82	635.82	17,219.19	193,705.81
6/10/2008	Klamath Watershed Partnership	2158			68.00			68.00	17,287.19	193,637.81
6/10/2008	Thomas Family Ltd	2740					600.00	600.00	17,887.19	193,037.81
6/10/2008	US Cellular	2154			35.42			35.42	17,922.61	193,002.39
6/10/2008	Qwest	2155			75.11			75.11	17,997.72	192,927.28
6/10/2008	May Payroll		2,463.42					2,463.42	20,461.14	190,463.86
6/25/2008	Bonnie Ward	2761			120.00			120.00	20,581.14	190,343.86
6/25/2008	Qwest	2763			79.93			79.93	20,661.07	190,263.93
6/30/2008	June Payroll		2,446.67					2,446.67	23,107.74	187,817.26
7/8/2008	Graham Matthews	2767				1,352.52		1,352.52	24,460.26	186,464.74
7/8/2008	US Cellular	2774			29.49			29.49	24,489.75	186,435.25
7/8/2008	Molly Russell	2771			25.82			25.82	24,515.57	186,409.43
7/8/2008	Roto Rooter	2773			122.80			122.80	24,638.37	186,286.63
7/29/2008	Bonnie Ward	2793			120.00			120.00	24,758.37	186,166.63
7/31/2008	July Payroll		2,783.99					2,783.99	27,542.36	183,382.64
8/5/2008	Qwest	2800			78.18			78.18	27,620.54	183,304.46
8/5/2008	US Cellular	2804			28.53			28.53	27,649.07	183,275.93
8/5/2008	Shannon Peterson	2798		89.50				89.50	27,738.57	183,186.43
8/5/2008	Project A	2799			40.00			40.00	27,778.57	183,146.43
8/5/2008	Admin						395.94	395.94	28,174.51	182,750.49

Grantee: NRCS CIG $210,925 10/3/2007 Conservation Innovation Grant

69-3A75-7-114 9/30/2011

Date	Vendor Name	Check #	Personnel	Travel	Equipment Supplies	Contract	Indirect Costs	TOTALS	CUMULATIVE	REMAINING
	Budgeted Amount		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00	-	210,925.00
8/18/2008	Graham Matthews	2809				1,796.63		1,796.63	29,971.14	180,953.86
8/18/2008	Michelle Barry	2806		88.88			129.98	218.86	30,190.00	180,735.00
8/18/2008	Bonnie Ward	2812					120.00	120.00	30,310.00	180,615.00
8/31/2008	August Payroll		638.24					638.24	30,948.24	179,976.76
9/2/2008	US Cellular	2834					26.28	26.28	30,974.52	179,950.48
9/2/2008	Qwest	2831					78.25	78.25	31,052.77	179,872.23
9/2/2008	Project A	2830					20.00	20.00	31,072.77	179,852.23
9/2/2008	Klamath Watershed Partnership	2827					68.00	68.00	31,140.77	179,784.23
9/16/2008	Graham Matthews	2838				2,315.88		2,315.88	33,456.65	177,468.35
9/16/2008	Bonnie Ward	2837					120.00	120.00	33,576.65	177,348.35
9/29/2008	Brian Finegan	2847					975.00	975.00	34,551.65	176,373.35
9/29/2008	Northrup	2857					800.00	800.00	35,351.65	175,573.35
9/29/2008	Qwest	2859					77.72	77.72	35,429.37	175,495.63
9/29/2008	Shannon Peterson	2858		635.40	29.12			664.52	36,093.89	174,831.11
9/30/2008	September Payroll		3,378.64					3,378.64	39,472.53	171,452.47
10/7/2008	Graham Matthews	2878				1,796.28		1,796.28	41,268.81	169,656.19
10/7/2008	US Cellular	2877					35.77	35.77	41,304.58	169,620.42
10/7/2008	Molly Russell	2872					17.73	17.73	41,322.31	169,602.69
10/14/2008	Project A	2874					20.00	20.00	41,342.31	169,582.69
10/28/2009	Qwest	2886					78.00	78.00	41,420.31	169,504.69
10/22/2008	Molly Russell	2885					20.00	20.00	41,440.31	169,484.69
10/22/2008	Bonnie Ward	2899					120.00	120.00	41,560.31	169,364.69
10/28/2008	Shannon Peterson	2888		88.00			21.15	109.15	41,669.46	169,255.54
10/31/2008	October Payroll		1,932.12					1,932.12	43,601.58	167,323.42
11/10/2009	A+ Conferencing	2890					66.58	66.58	43,668.16	167,256.84
11/10/2009	Klamath Watershed Partnership	2893					68.00	68.00	43,736.16	167,188.84
11/10/2009	Project A	2894					20.00	20.00	43,756.16	167,168.84
11/10/2009	US Cellular	2895					35.63	35.63	43,791.79	167,133.21
11/10/2008	Graham Matthews	2891				1,308.63		1,308.63	45,100.42	165,824.58
11/24/2008	Bonnie Ward	2899					120.00	120.00	45,220.42	165,704.58
11/30/2008	November Payroll		2,926.46					2,926.46	48,146.88	162,778.12
12/5/2008	Graham Matthews	2911				2,237.93		2,237.93	50,384.81	160,540.19
12/5/2008	US Cellular	2916					33.46	33.46	50,418.27	160,506.73
12/5/2008	Qwest	2915					77.91	77.91	50,496.18	160,428.82
12/5/2008	A+ Conferencing	2910					70.54	70.54	50,566.72	160,358.28
12/11/2008	Shannon Peterson	2920		201.15			6.82	207.97	50,774.69	160,150.31
12/15/2008	Bonnie Ward	2921					120.00	120.00	50,894.69	160,030.31
12/31/2008	Project A	2932					20.00	20.00	50,914.69	160,010.31
12/31/2008	Printfast	2931					47.46	47.46	50,962.15	159,962.85
12/31/2008	US Cellular	2934					34.51	34.51	50,996.66	159,928.34
12/31/2008	Qwest	2933					79.48	79.48	51,076.14	159,848.86
12/31/2008	Dec Payroll		5,145.03					5,145.03	56,221.17	154,703.83

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	Budgeted Amount		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00	-	210,925.00
12/31/2009	Klamath Watershed Partnership	2942					68.00	68.00	56,289.17	154,635.83
1/6/2009	Molly Russell	2928			38.77			38.77	56,327.94	154,597.06
1/20/2009	Bonnie Ward	2936					120.00	120.00	56,447.94	154,477.06
1/31/2009	January Payroll		3,297.09					3,297.09	59,745.03	151,179.97
2/3/2009	Project A	2944					20.00	20.00	59,765.03	151,159.97
2/3/2009	Qwest	2945					77.92	77.92	59,842.95	151,082.05
2/3/2009	US Cellular	2946					33.04	33.04	59,875.99	151,049.01
2/17/2009	Bonnie Ward	2947					120.00	120.00	59,995.99	150,929.01
2/17/2009	Molly Russell	2949			6.72			6.72	60,002.71	150,922.29
2/17/2009	Shannon Peterson	2952		1,522.38	156.31			1,678.69	61,681.40	149,243.60
2/17/2009	Graham Matthews	2948				240.00		240.00	61,921.40	149,003.60
2/28/2009	February Payroll		4,749.81					4,749.81	66,671.21	144,253.79
3/3/2009	Michelle Barry	2953			16.90			16.90	66,688.11	144,236.89
3/3/2009	Project A	2955					20.00	20.00	66,708.11	144,216.89
3/3/2009	Qwest	2956					77.98	77.98	66,786.09	144,138.91
3/3/2009	US Cellular	2958					32.58	32.58	66,818.67	144,106.33
3/17/2009	Graham Matthews	2959				2,291.40		2,291.40	69,110.07	141,814.93
3/17/2009	Michelle Barry	2960			242.66			242.66	69,352.73	141,572.27
3/17/2009	Bonnie Ward	2961					120.00	120.00	69,472.73	141,452.27
3/30/2009	Shannon Peterson	2966				100.00		100.00	69,572.73	141,352.27
3/30/2009	Molly Russell	2963					15.60	15.60	69,588.33	141,336.67
3/30/2009	Klamath Watershed Partnership	2962					102.00	102.00	69,690.33	141,234.67
3/30/2009	Qwest	2967					77.57	77.57	69,767.90	141,157.10
3/31/2009	March Payroll		2,541.45					2,541.45	72,309.35	138,615.65
4/13/2009	Graham Matthews	2969				2,163.15		2,163.15	74,472.50	136,452.50
4/13/2009	Bonnie Ward	2968					120.00	120.00	74,592.50	136,332.50
4/13/2009	Project A	2972					20.00	20.00	74,612.50	136,312.50
4/13/2009	US Cellular	2973					31.56	31.56	74,644.06	136,280.94
4/28/2009	Qwest	2982					78.39	78.39	74,722.45	136,202.55
4/28/2009	Shannon Peterson	2981		102.50			52.71	155.21	74,877.66	136,047.34
4/30/2009	April Payroll		2,744.52					2,744.52	77,622.18	133,302.82
5/12/2009	US Cellular	2988					31.56	31.56	77,653.74	133,271.26
5/12/2009	Project A	2987					20.00	20.00	77,673.74	133,251.26
5/12/2009	Graham Matthews	2985				2,163.15		2,163.15	79,836.89	131,088.11
5/12/2009	Molly Russell	2986					31.78	31.78	79,868.67	131,056.33
5/26/2009	Bonnie Ward	2989					120.00	120.00	79,988.67	130,936.33
5/26/2009	Shannon Peterson	2990					50.31	50.31	80,038.98	130,886.02
4/28/2009	April Payroll		1,313.60					1,313.60	81,352.58	129,572.42
6/8/2009	Graham Matthews	2992			670.00			670.00	82,022.58	128,902.42
6/8/2009	Project A	2995					20.00	20.00	82,042.58	128,882.42
6/8/2009	Klamath Watershed Partnership	2993					102.00	102.00	82,144.58	128,780.42
6/8/2009	Qwest	2996					78.65	78.65	82,223.23	128,701.77

Grantee: NRCS CIG $210,925 10/3/2007 Conservation Innovation Grant
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Date	Vendor Name	Check #	Personnel	Travel	Equipment Supplies	Contract	Indirect Costs	TOTALS	CUMULATIVE	REMAINING
	Budgeted Amount		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00	-	210,925.00
6/8/2009	US Cellular	2998					32.40	32.40	82,255.63	128,669.37
5/31/2009	May Payroll		1,906.02					1,906.02	84,161.65	126,763.35
6/16/2009	Michelle Barry						34.93	34.93	84,196.58	126,728.42
6/23/2009	Bonnie Ward	3001					120.00	120.00	84,316.58	126,608.42
6/30/2009	June Payroll		1,841.53					1,841.53	86,158.11	124,766.89
7/7/2009	Graham Matthews				608.22			608.22	86,766.33	124,158.67
7/7/2009	Qwest						79.81	79.81	86,846.14	124,078.86
7/7/2009	US Cellular						32.08	32.08	86,878.22	124,046.78
7/7/2009	Molly Russell						16.46	16.46	86,894.68	124,030.32
7/7/2009	Project A						20.00	20.00	86,914.68	124,010.32
7/9/2009	Shannon Peterson			44.00			47.42	91.42	87,006.10	123,918.90
7/21/2009	Bonnie Ward						120.00	120.00	87,126.10	123,798.90
7/31/2009	July Payroll		1,568.46					1,568.46	88,694.56	122,230.44
8/4/2009	Qwest	3017					78.47	78.47	88,773.03	122,151.97
8/4/2009	US Cellular	3018					32.52	32.52	88,805.55	122,119.45
8/4/2009	Project A	3016					20.00	20.00	88,825.55	122,099.45
8/18/2009	Bonnie Ward	3019					120.00	120.00	88,945.55	121,979.45
8/31/2009	August Payroll		2,151.06					2,151.06	91,096.61	119,828.39
9/1/2009	Qwest	3021					78.83	78.83	91,175.44	119,749.56
9/1/2009	Project A	3024					20.00	20.00	91,195.44	119,729.56
9/15/2009	Graham Matthews	3027				3,188.45		3,188.45	94,383.89	116,541.11
9/15/2009	US Cellular	3029					32.56	32.56	94,416.45	116,508.55
9/29/2009	Molly Russell	3030					13.72	13.72	94,430.17	116,494.83
9/29/2009	Bonnie Ward	3032					120.00	120.00	94,550.17	116,374.83
9/29/2009	Michelle Barry	3035					30.37	30.37	94,580.54	116,344.46
9/30/2009	September Payroll		751.46					751.46	95,332.00	115,593.00
10/6/2009	Qwest	3036					78.73	78.73	95,410.73	115,514.27
10/6/2009	Klamath Watershed Partnership	3040					102.00	102.00	95,512.73	115,412.27
10/6/2009	Project A	3041					20.00	20.00	95,532.73	115,392.27
10/6/2009	US Cellular	3043					34.34	34.34	95,567.07	115,357.93
10/26/2009	Bonnie Ward	3045					120.00	120.00	95,687.07	115,237.93
10/26/2009	Graham Matthews	3046				1,526.85		1,526.85	97,213.92	113,711.08
10/31/2009	October Payroll		1,620.60					1,620.60	98,834.52	112,090.48
11/10/2009	Graham Matthews	3055		59.40		1,376.70		1,436.10	100,270.62	110,654.38
11/10/2009	Shannon Peterson	3058		518.58				518.58	100,789.20	110,135.80
11/10/2009	Qwest	3060					79.76	79.76	100,868.96	110,056.04
11/10/2009	Project A	3059					20.00	20.00	100,888.96	110,036.04
11/23/2009	US Cellular	3068					34.30	34.30	100,923.26	110,001.74
11/23/2009	Bonnie Ward	3063					120.00	120.00	101,043.26	109,881.74
11/30/2009	November Payroll		2,733.70					2,733.70	103,776.96	107,148.04
12/1/2009	Graham Matthews	3070		210.65		2,752.80		2,963.45	106,740.41	104,184.59
12/5/2009	US Cellular	3076					33.58	33.58	106,773.99	104,151.01

Date	Vendor Name	Check #	Personnel	Travel	Equipment Supplies	Contract	Indirect Costs	TOTALS	CUMULATIVE	REMAINING
	Budgeted Amount		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00	-	210,925.00
12/8/2009	Shannon Peterson	3071			519.98		54.54	574.52	107,348.51	103,576.49
12/8/2009	Project A	3072					20.00	20.00	107,368.51	103,556.49
12/8/2009	Qwest	3073					79.72	79.72	107,448.23	103,476.77
12/21/2009	Bonnie Ward	3080					120.00	120.00	107,568.23	103,356.77
12/21/2009	A+ Conferencing						32.65	32.65	107,600.88	103,324.12
12/31/2009	December Payroll		1,882.64					1,882.64	109,483.52	101,441.48
12/31/2009	Molly Russell	3094					7.24	7.24	109,490.76	101,434.24
12/31/2009	Klamath Watershed Partnership	3091					34.00	34.00	109,524.76	101,400.24
1/5/2010	Project A	3086					20.00	20.00	109,544.76	101,380.24
1/5/2010	Qwest	3087					78.30	78.30	109,623.06	101,301.94
1/5/2010	US Cellular	3088					32.32	32.32	109,655.38	101,269.62
1/18/2010	Graham Matthews			45.10		660.00		705.10	110,360.48	100,564.52
1/18/2010	Molly Russell	3094					12.55	12.55	110,373.03	100,551.97
1/31/2010	January Payroll		3,887.69					3,887.69	114,260.72	96,664.28
2/2/2010	US Cellular	3101					32.98	32.98	114,293.70	96,631.30
2/2/2010	Qwest	3098					78.53	78.53	114,372.23	96,552.77
2/2/2010	A+ Conferencing	3096					58.37	58.37	114,430.60	96,494.40
2/2/2010	Project A	3097					20.00	20.00	114,450.60	96,474.40
2/16/2010	Bonnie Ward	3105					420.00	420.00	114,870.60	96,054.40
2/28/2010	February Payroll		2,511.30					2,511.30	117,381.90	93,543.10
3/2/2010	Shannon Peterson	3113			450.96		30.94	481.90	117,863.80	93,061.20
3/2/2010	US Cellular	3110					32.98	32.98	117,896.78	93,028.22
3/2/2010	Qwest	3108					78.50	78.50	117,975.28	92,949.72
3/2/2010	Project A	3107					20.00	20.00	117,995.28	92,929.72
3/3/2010	Graham Matthews					440.00		440.00	118,435.28	92,489.72
3/16/2010	Bonnie Ward						210.00	210.00	118,645.28	92,279.72
3/16/2010	Molly Russell						55.92	55.92	118,701.20	92,223.80
3/21/2010	Shannon Peterson			100.00				100.00	118,801.20	92,123.80
3/30/2010	Qwest	3128					78.50	78.50	118,879.70	92,045.30
3/30/2010	US Cellular	3129					33.82	33.82	118,913.52	92,011.48
3/30/2010	A+ Conferencing	3125					6.26	6.26	118,919.78	92,005.22
3/31/2010	March Payroll		2,131.89					2,131.89	121,051.67	89,873.33
4/1/2010	Project A	3135					20.00	20.00	121,071.67	89,853.33
4/20/2010	Molly Russell	3141					11.47	11.47	121,083.14	89,841.86
4/22/2010	US Cellular	3155					33.70	33.70	121,116.84	89,808.16
4/27/2010	Qwest	3142					78.93	78.93	121,195.77	89,729.23
4/30/2010	April Payroll		6,144.67					6,144.67	127,340.44	83,584.56
5/1/2010	Bonnie Ward	3140					210.00	210.00	127,550.44	83,374.56
5/1/2010	Project A	3153					20.00	20.00	127,570.44	83,354.56
5/3/2010	A+ Conferencing	3146					30.20	30.20	127,600.64	83,324.36
5/11/2010	Shannon Peterson	3158		227.80	190.86		248.22	666.88	128,267.52	82,657.48
5/17/2010	Qwest	3169					63.14	63.14	128,330.66	82,594.34

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Date	Vendor Name	Check #	Personnel	Travel	Equipment Supplies	Contract	Indirect Costs	TOTALS	CUMULATIVE	REMAINING
	Budgeted Amount		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00	-	210,925.00
5/22/2010	US Cellular	3173					35.40	35.40	128,366.06	82,558.94
5/30/2010	May Payroll		4,530.90					4,530.90	132,896.96	78,028.04
6/1/2010	Bonnie Ward	3147					210.00	210.00	133,106.96	77,818.04
6/1/2010	Main & Second LLC	3149					425.00	425.00	133,531.96	77,393.04
6/1/2010	Project A	3168					20.00	20.00	133,551.96	77,373.04
6/4/2010	City of Ashland	3186					16.98	16.98	133,568.94	77,356.06
6/7/2010	Chrysten Lambert	3165		170.69	1,341.38			1,512.07	135,081.01	75,843.99
6/17/2010	Qwest	3193					64.83	64.83	135,145.84	75,779.16
6/22/2010	US Cellular	3199					52.98	52.98	135,198.82	75,726.18
6/30/2010	June Payroll		6,006.24					6,006.24	141,205.06	69,719.94
7/1/2010	Chrysten Lambert	3185			603.86			603.86	141,808.92	69,116.08
7/1/2010	Project A	3192					20.00	20.00	141,828.92	69,096.08
7/1/2010	Bonnie Ward	3176					210.00	210.00	142,038.92	68,886.08
7/1/2010	Main & Second LLC	3181					425.00	425.00	142,463.92	68,461.08
7/6/2010	Molly Russell	3190					55.82	55.82	142,519.74	68,405.26
7/8/2010	Shannon Peterson	3214		375.00	11.61		95.35	481.96	143,001.70	67,923.30
7/8/2010	Carolyn Doehring						1.05	1.05	143,002.75	67,922.25
7/8/2010	Ashland Home Net	3202					41.91	41.91	143,044.66	67,880.34
7/10/2010	Ashland Home Net	3202					38.99	38.99	143,083.65	67,841.35
7/17/2010	Qwest	3219					64.70	64.70	143,148.35	67,776.65
7/20/2010	City of Ashland	3209					27.15	27.15	143,175.50	67,749.50
7/22/2010	US Cellular	3225					44.09	44.09	143,219.59	67,705.41
7/26/2010	Carolyn Doehring	3215					1.05	1.05	143,220.64	67,704.36
7/31/2010	July Payroll		10,307.75					10,307.75	153,528.39	57,396.61
8/1/2010	Project A	3218					20.00	20.00	153,548.39	57,376.61
8/1/2010	Bonnie Ward	3204					210.00	210.00	153,758.39	57,166.61
8/1/2010	Main & Second LLC	3208					425.00	425.00	154,183.39	56,741.61
8/3/2010	Molly Russell	3217					98.69	98.69	154,282.08	56,642.92
8/3/2010	Shannon Peterson	3224		168.50	25.32		12.88	206.70	154,488.78	56,436.22
8/3/2010	Chrysten Lambert	3231					71.55	71.55	154,560.33	56,364.67
8/9/2010	City of Ashland	3246					27.63	27.63	154,587.96	56,337.04
8/10/2010	Ashland Home Net	3233					38.99	38.99	154,626.95	56,298.05
8/12/2010	A+ Conferencing	3232					11.10	11.10	154,638.05	56,286.95
8/13/2010	Carolyn Doehring	3235					7.92	7.92	154,645.97	56,279.03
8/16/2010	Chrysten Lambert	3236		156.56				156.56	154,802.53	56,122.47
8/16/2010	Molly Russell						36.90	36.90	154,839.43	56,085.57
8/17/2010	Qwest	3251					64.63	64.63	154,904.06	56,020.94
8/22/2010	US Cellular	3253					40.34	40.34	154,944.40	55,980.60
8/31/2010	August Payroll		8,606.01					8,606.01	163,550.41	47,374.59
9/1/2010	Main & Second LLC	3238					425.00	425.00	163,975.41	46,949.59
9/1/2010	Bonnie Ward	3234					210.00	210.00	164,185.41	46,739.59
9/1/2010	Graham Matthews	3261		199.10		1,080.00		1,279.10	165,464.51	45,460.49

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Date	Vendor Name	Check #	Personnel	Travel	Equipment Supplies	Contract	Indirect Costs	TOTALS	CUMULATIVE	REMAINING
	Budgeted Amount		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00	-	210,925.00
9/1/2010	Project A	3267					20.00	20.00	165,484.51	45,440.49
9/2/2010	Chrysten Lambert	3259		134.33				134.33	165,618.84	45,306.16
9/9/2010	City of Ashland	3275					27.47	27.47	165,646.31	45,278.69
9/10/2010	Carolyn Doehring	3258					21.88	21.88	165,668.19	45,256.81
9/13/2010	Ashland Home Net	3256					38.99	38.99	165,707.18	45,217.82
9/17/2010	Qwest	3294					64.71	64.71	165,771.89	45,153.11
9/22/2010	US Cellular	3297					47.70	47.70	165,819.59	45,105.41
9/30/2010	September Payroll		10,047.93					10,047.93	175,867.52	35,057.48
10/1/2010	Bonnie Ward	3270					210.00	210.00	176,077.52	34,847.48
10/1/2010	Main & Second LLC	3271					425.00	425.00	176,502.52	34,422.48
10/1/2010	Graham Matthews	3288		510.40		2,565.00		3,075.40	179,577.92	31,347.08
10/1/2010	Project A	3293					20.00	20.00	179,597.92	31,327.08
10/6/2010	Ameritittle	3282					125.00	125.00	179,722.92	31,202.08
10/10/2010	Ashland Home Net	3283					38.99	38.99	179,761.91	31,163.09
10/12/2010	Carolyn Doehring	3285					62.53	62.53	179,824.44	31,100.56
10/12/2010	Shannon Peterson	3299		1,014.86			23.04	1,037.90	180,862.34	30,062.66
11/1/2010	Bonnie Ward	3284					210.00	210.00	181,072.34	29,852.66
11/1/2010	Main & Second LLC	3291					425.00	425.00	181,497.34	29,427.66
10/8/2010	City of Ashland	3306					27.39	27.39	181,524.73	29,400.27
10/12/2010	A+ Conferencing	3281					19.51	19.51	181,544.24	29,380.76
10/18/2010	Chrysten Lambert	3307					18.30	18.30	181,562.54	29,362.46
10/25/2010	Molly Russell	3303					29.30	29.30	181,591.84	29,333.16
10/31/2010	October Payroll		7,685.21					7,685.21	189,277.05	21,647.95
11/1/2010	Graham Matthews	3316		114.00		1,105.00		1,219.00	190,496.05	20,428.95
11/1/2010	Project A	3321					20.00	20.00	190,516.05	20,408.95
11/4/2011	City of Ashland						27.87	27.87	190,543.92	20,381.08
11/7/2010	Shannon Peterson	3401		129.00				129.00	190,672.92	20,252.08
11/9/2010	US Cellular	3324					46.94	46.94	190,719.86	20,205.14
11/9/2010	Qwest	3322					65.40	65.40	190,785.26	20,139.74
11/10/2011	Ashland Home Net						38.99	38.99	190,824.25	20,100.75
11/30/2010	November Payroll		6,255.61					6,255.61	197,079.86	13,845.14
12/1/2010	Graham Matthews	3337		137.00		2,239.63		2,376.63	199,456.49	11,468.51
12/1/2010	Bonnie Ward	3335					210.00	210.00	199,666.49	11,258.51
12/1/2010	Main & Second LLC	3334					425.00	425.00	200,091.49	10,833.51
12/9/2010	US Cellular	3345					44.94	44.94	200,136.43	10,788.57
12/9/2010	Qwest	3342					67.02	67.02	200,203.45	10,721.55
12/9/2010	Project A	3341					20.00	20.00	200,223.45	10,701.55
12/10/2010	Ashland Home Net	3347					38.99	38.99	200,262.44	10,662.56
12/14/2010	Shannon Peterson	3352		615.50			70.98	686.48	200,948.92	9,976.08
12/17/2010	Qwest	3357					70.77	70.77	201,019.69	9,905.31
12/21/2010	Molly Russell	3351					36.73	36.73	201,056.42	9,868.58
12/21/2010	City of Ashland	3350					26.62	26.62	201,083.04	9,841.96

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Date	Vendor Name	Check #	Personnel	Travel	Equipment Supplies	Contract	Indirect Costs	TOTALS	CUMULATIVE	REMAINING
	Budgeted Amount		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00	-	210,925.00
12/21/2010	Carolyn Doehring	3349					5.51	5.51	201,088.55	9,836.45
12/22/2010	US Cellular	3359					44.96	44.96	201,133.51	9,791.49
12/31/2010	December Payroll		1,391.78					1,391.78	202,525.29	8,399.71
1/31/2011	January Payroll		2,243.53					2,243.53	204,768.82	6,156.18
2/1/2011	Molly Russell	3368					32.06	32.06	204,800.88	6,124.12
2/28/2011	February Payroll		3,474.79					3,474.79	208,275.67	2,649.33
3/31/2011	March Payroll		1,582.68				124.41	1,707.09	209,982.76	942.24
4/25/2011	Chrysten Lambert			370.35				370.35	210,353.11	571.89
5/10/2011	Molly Russell						30.08	30.08	210,383.19	541.81
5/31/2011	Molly Russell				7.12		114.71	121.83	210,505.02	419.98
5/31/2011	Admin						419.98	419.98	210,925.00	0.00
								-	210,925.00	0.00
	Total Expended		140,640.00	8,310.00	7,800.00	35,000.00	19,175.00	210,925.00		
	Remaining Budget		-	-	-	-	-	-		

Klamath Basin Rangeland Trust

Water Transactions Program

October 2010

Executive Summary

This document provides a detailed review of the Klamath Basin Rangeland Trust's (KBRT's) Water Transaction Program (WTP). The WTP is designed to address the over-allocation of water resources in the Klamath Basin through six primary objectives:

1. Increase instream flows and protect streams from cattle activity in the Fourmile Creek, Sevenmile Creek, Wood River, Sprague River, Lower Williamson River systems, and direct tributaries to the lake.
2. Improve water quality in these stream systems and in flows to Upper Klamath Lake.
3. Provide habitat for endangered sucker species, redband and bull trout, and salmon populations in the tributaries and lake.
4. Contribute to the hydrologic balance of the basin. Modeling suggests that 30,000 acre feet of additional annual water deliveries to Upper Klamath Lake are necessary, which is also the water use retirement goal of the Klamath Basin Restoration Agreement (KBRA).
5. Contribute to the needs of the lower basin by providing additional water to benefit salmon populations and the fishing economy of the mainstem Klamath River, and additional water to benefit downstream irrigators.
6. Work cooperatively with stakeholders in the basin.

Detailed in this document are the initial stream reach priorities where KBRT will focus its efforts to implement the WTP, and the methodology for selecting these areas. In addition, the document provides an extensive review of the administrative and economic aspects of the program, community outreach plans, valuation of the water rights, monitoring plans, and budgets for program operation.

Given that the stakeholders in the Klamath Basin are continuing to work towards a broad settlement of water resource allocation disputes and various conservation and restoration goals through the KBRA, this report also provides information about the role of the WTP in both pre-KBRA and post-KBRA environments. Should the KBRA be implemented, the WTP can provide the critical resources necessary to facilitate the water use retirement program (Section 16.2.2 of the KBRA). If the KBRA is not implemented, the WTP will be essential for achieving fisheries recovery, restoration, and water balance goals in the Upper Klamath Basin.

KBRT will continue to refine and revise the WTP as it is implemented and expanded in the Basin. As such, this document and the associated program will be reviewed annually to ensure that it best meets the needs of the basin and KBRT's goals.

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Chapter 1: Overview of the Klamath Basin and its Critical Needs

Section A: Overview of the Klamath Basin

The Klamath Basin is a large river basin that extends from the high desert areas of eastern Oregon to the Pacific Ocean in California (Figure 1). The Basin covers more than 10 million acres of land and consists of various stream and lake systems that are home to many species of interest including the Lost River and shortnose suckers, coho and Chinook salmon, Klamath River steelhead, redband rainbow trout, and bull trout. The basin also supports substantial amounts of agriculture including pasture animals, hay, and row crops, and is home to several Native American Tribes including the Yurok, Hoopa, Karuk Tribes in the lower basin, and the Klamath Tribes in the upper basin.

The entire Klamath Basin is under constant stress related to water quantity and quality issues, most recently highlighted by the irrigation water shutoff in 2001 and the massive salmon kill in 2002. The Klamath Basin is a flashpoint for water issues as agriculture, fishing, tribal, and endangered species interests are competing for over-allocated water. Almost every year there are struggles between agricultural and fisheries water needs.

Upper Klamath Lake (UKL) is often the focal point of these struggles, making the Upper Klamath Basin an area of critical importance (Figure 2). The US Bureau of Reclamation manages the UKL to meet the needs of endangered sucker species in the lake, endangered salmon downstream, and irrigation on thousands of acres of farms and ranches. Additionally, the prime spawning ground for the endangered suckers is the Sprague River (a tributary to the lake), which faces its own low flow and water quality issues, and is the Klamath Tribes priority for waterway restoration.

One key aspect of most published recovery plans for the Klamath Basin is to increase instream flows / decrease diversions, and to improve water quality. Not only are the streams of the upper basin identified as “highest” and “high” priority for streamflow restoration by the Oregon Department of Fish and Wildlife, but the diversions for agriculture are identified by Oregon Department of Environmental Quality in their Upper Klamath Lake TMDL and WQMP for the region as a major source of phosphorous and water temperature detriment above and in the lake (169, 172). In addition, the Hatfield Science Team 5 Year Plan (Wood River Matrix), the US Fish and Wildlife Services’ 2003 Lost River and Shortnose Sucker Recovery Plan (22, 56, 59-60), the US Geological Survey’s Review of the US Bureau of Reclamations 2004 Water Bank (39-40), and the ODFW Oregon Plan for Salmon and Watersheds: Streamflow Restoration Priorities (Klamath Basin Section) all identify increasing instream flows in the upper basin as a high priority for restoration. Finally, the US Forest Service is currently completing the “Westside Watersheds Action Plan”, which identifies the need to increase connectivity and flows on private lands on streams with headwater and protected habitat in the National Forest.

The Klamath Basin Rangeland Trust (a 501c(3) non-profit) has worked for almost 10 years to address these challenges through partnerships with private landowners and government agencies, and has demonstrated substantial and measurable improvements to the ecosystems where we work, while maintaining viable ranching communities.

Section B: Overview of the Klamath Basin Rangeland Trust (KBRT)
KBRT works to achieve three key objectives in the Upper Klamath Basin:

1. Address the over-commitment of water resources by reducing water use above Upper Klamath Lake. This increases instream flows to provide critical fish habitat, as well as provides additional water to Upper Klamath Lake for the downstream benefit of fish, wildlife, ranching and agriculture.

2. Encourage land, water, and cattle grazing management strategies that improve water quality in rivers and lakes while maintaining a viable ranching economy in the upper basin.

3. Restore and re-establish wetland areas to produce water quality improvements, natural water storage, and other wetland-related environmental benefits.

KBRT seeks to fulfill its mission through four primary activities:

1. **Enable landowner participation in Federal and State programs** that encourage sustainable land and water management choices. Examples of such programs include NRCS' Environmental Quality Incentives Program, Conservations Securities Program, Wetland Reserve Program, Agricultural Water Enhancement Program, and the SWCD's Conservation Reserve Enhancement Program.

2. **Conduct scientific research and monitoring** to assess the effects of different land and water management choices and adapt activities accordingly to assure maximum benefits.

3. **Implement restoration and conservation projects** such as riparian fencing, stream restoration, and fish passage improvements that enhance habitat conditions and relieve stress on native fish and wildlife populations.

4. **Increase and protect instream flows** through individual water transactions and established programs such as AWEP. These efforts make it possible for landowners to leave some or all of their irrigation water instream, augmenting the flow of good quality water to Upper Klamath Lake.

KBRT has a proven track record of success:

- KBRT currently has 10,819 acres of land enrolled in dryland or reduced irrigation programs

- In 2009 KBRT protected 28,269 acre feet (108cfs) of water instream through Oregon Department of Water Resources Instream Leasing program. This represents about 20% of the water leased instream in Oregon.
- Since KBRT began instream leasing in 2004 we have protected 232,695 acre feet of water instream (889cfs)
- KBRT has protected 707 acres of wetlands in permanent conservation easements
- KBRT is in the process of enrolling an additional 1196 acres of wetlands in permanent conservation easements
- KBRT has protected over 30 miles of stream banks and riparian areas with riparian fencing
- KBRT has restored stream and habitat function to 14 miles of stream
- KBRT has removed 8 impediments to fish passage, opening over 20 miles of stream to unencumbered year-round fish access

The KBRT Water Transactions Program (WTP) is designed to leverage KBRT's conservation success to improve and protect instream flows in the critical stream reaches of the Upper Klamath Basin. KBRT currently protects irrigation water instream for periods of 1-5 years through Oregon Water Resources Department's instream leasing programs or other programs, such as the Natural Resource Conservation Services' Agricultural Water Enhancement program, which restrict irrigation water use (Figures 3 and 4). These short-term agreements are important tools for developing landowner interest and confidence to permanently transfer irrigation water instream. KBRT's work increasing instream flows has been highlighted in the 2006 Oregon Conservation Strategy (178) and the NRCS 2007 Klamath Basin Conservation Partnership Accomplishments report (3, 4, 7). The WTP described in this document now provides the opportunity for landowners to make permanent transfers of some or all of their irrigation water rights to instream use, for the benefit of fish, wildlife, and future generations.

The WTP should also be viewed in the context of the "Klamath Settlement". If completed and funded, the Klamath Basin Restoration Agreement (KBRA) would be a landmark settlement in the history of western water issues. The KBRA has brought together the Agricultural, Tribal, Fishing, and Conservation communities to settle longstanding disputes over water allocation and environmental restoration. The KBRA has also bridged the divides between the States of Oregon and California and the Federal Government to ensure regulatory and financial support for the settlement. The KBRA provides a potential roadmap for future settlement of western water conflicts, as well as a process for reducing the cost and time-delays normally associated with the extensive litigation of these complex environmental issues.

Specific Goals of the WTP:
The WTP will utilize instream leasing, transfer, and conserved water programs to achieve six specific goals.

1. Increase instream flows and protect streams from cattle activity in the Fourmile Creek, Sevenmile Creek, Wood River, Sprague River, Lower Williamson River systems, and direct tributaries to the lake.
2. Improve water quality in these stream systems and in flows to Upper Klamath Lake.
3. Provide habitat for endangered sucker species, redband and bull trout, and salmon populations in the tributaries and lake.
4. Contribute to the hydrologic balance of the basin. Modeling suggests that 30,000 acre feet of additional annual water deliveries to Upper Klamath Lake are necessary, which is also the water use retirement goal of the KBRA.
5. Contribute to the needs of the lower basin by providing additional water to benefit salmon populations and the fishing economy of the mainstem Klamath River, and additional water to benefit downstream irrigators.
6. Work cooperatively with stakeholders in the basin.

Section C: Initial Stream Reach Priorities

The WTP intends to increase instream flows throughout much of the upper Klamath Basin in order to achieve a variety of ecological and socioeconomic goals as detailed above. Because of the extreme over-allocation of water resources in the basin, almost every stream reach could benefit significantly from improved flows, and ranking different areas is difficult. However, the area of the upper basin is large and thus completing projects in a scattered or haphazard way is not likely to achieve the same level of benefit to the basin as directed and concentrated efforts. On a long term basis, the WTP will work to increase instream flows in the Fourmile Creek, Sevenmile Creek, Wood River, Sprague River, and Lower Williamson River systems. KBRT will utilize the results of the pending USGS hydrologic study of the basin to identify specific instream flow targets for each of these systems, however the results of this study are not yet complete. In the near term, KBRT has identified several key stream reaches within these groups as initial priorities.

Objectives of Prioritization:
KBRT believes that the initial work of the WTP should be focused in areas that can provide substantial ecological benefit in a reasonably short period of time, areas where additional restoration work is being conducted or is currently proposed, and in areas where measurable improvements can be made. If the KBRA is implemented, the need for prioritization may be somewhat reduced since such a large volume of water rights will be targeted for retirement. Under current conditions though, the WTP needs to be able to accomplish substantial ecological restoration, on a more limited scale. One of the major goals of the prioritization presented here is to identify areas where the resources spent on acquisition will be extremely valuable ecologically, regardless of future activity in the basin. For the initial phase of the project we will focus on stream reaches, which with additional water, can provide critical fish habitat. In the second phase, we will begin to work on projects that specifically deliver additional flows to Upper Klamath Lake to achieve the 30,000 AF goal.

In addition, prioritizing some critical regions of the upper Klamath Basin allows KBRT to conduct intensive, and hopefully more effective, outreach programs to landowners. The goal of this is to identify landowners with large water rights, or blocks of contiguous landowners that are willing to partner with KBRT, to accomplish ecological goals in critical habitat areas. Working in this way allows KBRT to benefit from the synergistic effects of restoring adjacent stream reaches, ideally achieving complete restoration of several critical creek systems in the basin.

Stakeholder Outreach:
The WTP should be viewed in the context of all stakeholders within the Upper and Lower Klamath Basins. In order for the over-allocation of water resources to be resolved, it is necessary for the majority of stakeholders to agree on solutions. The primary goal of the WTP is ecological health, however KBRT also feels that the program should serve as a tool for the stakeholders of the basin to resolve water conflicts.

In this capacity, KBRT conducted outreach to a variety of stakeholders in the basin to obtain their input on initial stream reach priorities for water transactions. These groups included the Klamath Tribes, Oregon Department of Fish and Wildlife, US Forest Service, US Fish and Wildlife, Sustainable Northwest, and the Upper Klamath Water Users Association. The conclusions of this outreach were interesting. Although there are many areas of the basin that are in critical need of increased instream flows to achieve the ecological and socioeconomic goals of the stakeholders, in many cases groups highlighted the same priority areas for initial work. The information provided by these stakeholders was given heavy weight in KBRT's analysis and prioritization.

The WTP initial stream reach priorities are shown in Figure 5, and detailed here:

North Fork Sprague System

North Fork Sprague

The North Fork of the Sprague originates on USFS land and is fed by both snow melt runoff and springs. This system is critical for redband trout under current conditions, but would also provide key habitat for bull trout, and salmon if reintroduced. In addition, the NF Sprague is a high priority for multiple endangered sucker species. The largest diversion on the river is the North Fork Ditch which provides irrigation water for both hay cutting and pasture. The ditch is near the mouth of the North Fork's canyon, which means that very high quality water is being diverted high up in the stream system, preventing the benefit of this water for thermal control and fish habitat and passage throughout the entire system. Water diverted from this ditch appears to return primarily to South Fork of the Sprague. The WTP views all diversions from the North Fork as high priority, but places special emphasis on water rights associated with the North Fork Ditch.

Fivemile Creek

Increased instream flows in Fivemile Creek, a large tributary to the NF Sprague, would provide many of the same benefits as increased flows in the NF Sprague. This tributary is especially critical, as it is one of the few creek systems in the upper Sprague that is large enough to support salmon if reintroduced. The quality of water in this creek is extremely high, and if left instream would provide additional cold, clean water to the lower NF and the upper Main Stem Sprague Rivers. Improving thermal conditions in both of these systems is critical for sucker recovery.

Meryl Creek

Located near Fivemile Creek, this creek historically provided very cold spring water to the North Fork Sprague. Although small in size, if left instream, the water could provide substantial benefit for fisheries recovery.

Wood River Valley and Direct Tributaries to Agency Lake

Sevenmile Creek

Increasing instream flows in Sevenmile Creek provides multiple ecological benefits that are well documented since instream leases have been in place on the creek since 2004. The creek provides habitat for redband trout and likely bull trout, and could provide habitat for salmon (if reintroduced) and endangered suckers. Prior to the instream leases, the creek was essentially dewatered throughout the irrigation season preventing connectivity between the forest service lands in the upper reaches and Agency Lake at the system's mouth. Monitoring of the system 4 years after KBRT began protecting water instream (Graham Matthews and Associates Wood River Valley Aquatic Habitat Study Final Report, 2008) showed that "fish habitat greatly improved as shown by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate."

Fourmile Creek

Fourmile Creek is a spring fed system on the west side of the Wood River Valley that can provide high quality, cold water on a year round basis to UKL-Agency Lake. Cherry Ck and Crane Ck are two large tributaries to the system. In addition to providing excellent fish habitat the wetlands and riparian areas surrounding the stream provide important habitat for many species including the Oregon Spotted Frog. Historically Fourmile Creek provided important spawning habitat for the endangered suckers and with increased instream flows could provide excellent habitat.

Wood River

The Wood River is also a spring fed creek, and historically provided habitat for endangered suckers as well as salmon. Suckers currently use the Wood for spawning and rearing, and historically spawned in the Wood River's major tributary, Crooked Creek, as well. The river also provides habitat for redband trout. Extensive restoration of the Crooked Creek and Agency Creek tributaries has been completed and has improved fish habitat. Substantial instream leases have been in place since 2002 on this system, and permanent protection of this water instream is an obvious priority.

Direct Tributaries to UKL

There are several streams and springs that are direct tributaries to Upper Klamath Lake. These systems are important for providing flows of high quality water to the lake to augment water supply. In addition, they generally remain cold year round and can provide important thermal refuge for endangered suckers. Furthermore the direct inputs to the lake provide critical spawning habitat for both the suckers and trout species.

Main Stem and South Fork Sprague Systems

Major Spring Complexes on the Main Stem Sprague

Spring complexes along the mainstem of the Sprague River are of critical importance for providing rearing and spawning habitat for the endangered suckers, and for providing cold water inputs to the river. Many of the springs are diverted by irrigation pumps set directly into the springs, preventing fish access and water delivery to the natural river system. Allowing the spring to flow naturally into the mainstem is especially critical during the late summer and winter in order to provide refugial habitat for multiple fish populations. In some cases, changes to the Points of Diversion of the water rights for the springs may be sufficient, in other cases a complete purchase of the water rights will be required to achieve ecological goals.

Deming Creek

Increased instream flows in Deming Creek would provide improved redband trout habitat, bull trout habitat, and provide much needed high quality water to the South Fork Sprague to support sucker recovery. ODFW considers restoration of instream flows in this creek a high priority since the low water and poor thermal conditions resulting from irrigation diversions appear to be supporting large brown trout populations which out-compete the native bull trout. Restoration of more natural instream flow conditions should greatly aid the native bull trout populations in the system.

Chapter 2: Water Transactions Program Administration

Section A: Mechanisms for Instream Lease and Transfer

The Oregon Water Resources Department and Oregon Water Law provide several legal mechanisms for landowners to transfer irrigation water rights to instream use for various public benefits including fish and wildlife, scenic values, and water quality. The WTP intends to utilize these legal mechanisms where applicable when completing transactions to ensure that all of our water transactions can be legally enforced by the appropriate Water Master or other State Agent.

In some circumstances, the WTP may lease or purchase water rights that are not eligible for instream protection through OWRD. For example, the purchase of a water right in an ecologically critical stream reach that has not yet been adjudicated but that KBRT reasonably believes will be adjudicated to match the claim. In such cases, other legal mechanisms for enforcing the instream use of the water must be available and utilized. Examples include forbearance agreements or the diminishment of rate/duty/season of use associated with a Certificate.

Although the WTP prioritizes permanent transfers of water rights above other types of transactions, KBRT has successfully used instream leases, forbearance agreements, and in some cases time-limited transfers, to help landowners become comfortable with the idea of a permanent transfer of their water rights. Many landowners want to experiment with the conversion to dryland grazing for several years to assess how their pastures respond to the change, to learn how to best manage their cattle under a dryland system, and to evaluate ranch revenues under a dryland system prior to making a permanent commitment to leaving their water instream.

KBRT has demonstrated success in obtaining Farm Bill funds for supporting instream leases over the last 9 years, and intends to continue to seek funding through these sources and the KBRA interim programs for our short-term water transactions. The WTP fundraising efforts discussed in Chapter 4 Section B will be geared towards developing resources for completing permanent transactions.

While there are multiple options within the OWRD programs for both instream leases and transfers, provided here is some detail on the programs that the WTP anticipates using on a regular basis.

<u>Leases</u>

Standard Instream Lease: A standard instream lease can be filed on most irrigation water rights, so long as the department determines that the protection of that water instream will not injure another existing water right, or enlarge an existing water right. Instream leases can be filed for a period of one to five years and can be renewed an unlimited number of times. Filing of an instream lease protects the water right holder from forfeiture of their water right due to non-use. Filing of the instream lease also prevents junior water rights holders from using this water.

Split-season Instream Lease: Although split-season leases can be used in a variety of ways, the WTP will use them to allow a landowner to irrigate during the initial portion of the season, but convert their water right to instream use for the low flow period of the year to minimize overall water use, to help increase instream flows during critical periods, and/or to help decrease water temperatures and nutrient loading. The findings of the NRCS Wood River CEAP report suggest that a single irrigation event in July, coupled with a 30-day grazing rest period, could produce 95% of the foliage that the standard fully irrigated limited grazing rotation program does, while significantly limiting water use. Some landowners prefer this option since it allows them to maintain a more traditional ranch operation while still providing significant ecological benefit to the system. Anecdotally, land owners have found that stocking rates need to be lower than 95% to maintain pasture quality and animal health. These study results apply primarily to the Wood River Valley, and are still being explored in the Sprague Basin.

<u>Transfers</u>

Standard Instream Transfer: A standard instream transfer functions similarly to a standard instream lease, however the transfer to instream use is permanent.

Time-limited Transfer: A time-limited transfer allows a water right to be transferred instream for a specific period of time (normally more than 5 years) after which the water right reverts back to its original conditions for time and place of use. Such transfers are often completed for a 29-year period to avoid certain tax conditions for land owners, or for a landowner to leave final decision regarding a permanent transfer to the next generation. Thus far in Oregon, all are for less than 20 years. Time-limited transfers are generally not a preferred option for the WTP.

Point of Diversion Transfer: In some cases the point of diversion for a water right can be transferred to another location in order to leave water instream in a particular area to meet critical ecologic needs. For example, if a point of diversion can be relocated from a spring area to the main lake, critical sucker spawning habitat can be protected, and higher instream flows can provide passage to the spawning area. Normally the WTP would reimburse the landowner for the cost of renovating their irrigation system to support the new point of diversion, but would not pay the landowner other compensation since their ranch income should not be impacted.

Allocation of Conserved Water: This program allows a water user who conserves water to allocate the saved water to instream use. Water conservation efforts might include improvements to irrigation or irrigation distribution systems, or other technologic improvements that conserve water. After approval is obtained by the OWRD, a new certificate is issued for the water right, keeping the same priority date, but reducing the quantity of water being used. Then an additional certificate is issued to reflect the State's instream water right, with the same priority date, or one minute junior to the original right.

Section B: Valuation of the Transactions

The WTP intends to conduct all of its water transactions at the fair market value of the water rights. KBRT hired WestWater Research, LLC, a consulting firm renowned for its experience in evaluating the economics of water transactions, to complete a market analysis of the water rights in the Upper Klamath Basin and to make recommendations about the pricing of future transactions. Their full report is attached as Appendix 1.

Brief Summary and Key Findings of the WestWater Report:

The WestWater report describes their use of several methods of estimating the pricing for the permanent sales of water rights in the Upper Klamath Basin. These methods include: analysis of agricultural land sales, a comparative analysis of water markets in other regions of the western US, and capitalization of recent instream leases in the basin.

WestWater determined that using agricultural land sales was not a preferred method since there is little recent land market information to rely on. However, WestWater did complete some anlaysis utilizing this method resulting in a price estimate of $1942-$2330/AF in the Wood ($2000-$2400/acre) and $1250-$1438/AF in the Sprague ($2000-$2288/acre). WestWater concluded that since the consumptive use rate in the Sprague is higher than in the Wood, making the potential to maintain high levels of agricultural revenues on a dryland basis lower, the percentage of the land value associated with the water rights is higher in that basin. However, since land values in the Sprague are generally lower than in the Wood, the total value of the water rights in the Sprague was lower.

The comparative market analysis approach resulted in average purchase price estimates of $1459/AF in the Wood ($1503/acre), and $1062/ AF in the Sprague ($1699/acre). The lower value per AF in the Sprague was primarily attributed to the lower land values and lower agricultural productivity in that basin, however the higher consumptive use rate in that basin resulted in a slightly higher per acre price than in the Wood.

The lease price conversion approach resulted in average purchase price estimates of $2118-$2727/AF in the Wood ($2182-$2809/acre), and $1022-$1364/AF in the Sprague ($1636-$2182/acre). Significantly more leasing activity has occurred in the Wood than in the Sprague, however leases in the Sprague have been completed at much lower rates than in the Wood on a price per AF basis. Once again, consideration for the higher consumptive use rate in the Sprague increased the estimated price for that basin, however not enough to match the recommended prices for the Wood.

The WestWater report also provides some guidance as to what types of considerations might shift the pricing of a transaction between the low and high ends of the price ranges. These include: seniority of the water right, reliability of the water right, potential for the instream transfer to deliver increased flows to Upper Klamath Lake, and potential for the instream transfer to contribute significantly to instream flows high on tributary streams (presumably for improved fisheries conditions). However, the report recommends that regardless of additional considerations, all transactions should be bound with the price range adopted by KBRT and informed by the WestWater analysis.

With consideration to the above factors, WestWater concluded that the appropriate price range for water rights values in the Upper Klamath Basin is $1699-$2320/acre in the Sprague and $1503-$2781/acre in the Wood. The results of their analysis are summarized below in Table 1, which is duplicated from their report.

Table 1
Summary of Estimate Water Rights Values in the Upper Klamath Basin

Valuation Approach	Sprague Basin	Wood Basin
Agricultural Land Prices ($/AF CU)	$1250 - $1438	$1942 - $2330
Comparative Markets Analysis ($/AF CU)	$1062	$1459
Lease Price Conversion ($/AF CU)	$1022 - $1364	$2118 - $2727
Selected Price Range ($/AF CU)	$1000 - $1450	$1500 - $2700
Consumptive Use (AF CU/acre)	1.60	1.03
Selected Price Range ($/acre)	$1699 - $2320	$1503 - $2781

Water Pricing in the WTP

KBRT circulated the WestWater report to a variety of groups in the basin for their comment and review, including the KBRT Governance Board, the Klamath Tribes, the Upper Klamath Water Users, and key members of the OPWAS discussions. In general, each of these groups agreed with the methods used in the report and with the final results. Accordingly, KBRT has elected to adopt the WestWater pricing recommendations for its initial transactions. As the WTP matures, and if the KBRA is implemented, our pricing may need to be revised or adjusted. However, it is important to recognize that substantially shifting the pricing after some initial transactions are completed could result in a poor image for KBRT amongst those individuals and entities that complete the initial transactions.

One additional future consideration for the valuation of water rights will be the source of funding for the acquisitions. If funds from the KBRA are used, the transactions may be subject to federal appraisal guidelines. These guidelines do not allow for the consideration of environmental values when determining price unless Congress specifically authorizes the use of “alternative valuation methods” (AVMs). Without consideration of AVMs, it is possible that the prices offered will not be high enough to entice landowner participation on a broad scale. The WTP will monitor closely the progress of the KBRA and work to adapt our programs as needed to work within the requirements of the KBRA funding while still meeting landowner needs.

Section C: Project Evaluation and Ranking

Projects proposed to KBRT’s WTP will be evaluated by a newly designated WTP Review Board. This board will consistent of 5 people: KBRT Executive Director, President of KBRT Board of Directors, Biological Expert, Legal Expert, and a Water Transactions Expert. Each member of the Review Board will have an equal vote.

The Review Board will evaluate projects based on the ranking criteria provided below. A project must achieve a minimum score in order to be considered for approval. The KBRT Director of Water Transacations Program will submit the projects for review by the board and will provide the project information and details required for the board to complete the ranking and project review.

Water Transactions Program (WTP) Project Criteria

Each project evaluated will be ranked on a scale of 0-3 based on its ability to fulfill the objectives of the WTP listed below. The scores for each category will be totaled to determine the final score for the project. Projects scoring less than 24 points will not be considered by the WTP. The objectives will be reviewed by the KBRT Board of Directors and Staff on an annual basis to ensure that they continue to meet the ecological and social needs of the Klamath Basin.

0 – the project does not fulfill this objective
1 – the project will make a small contribution to this objective

2 – the project will make a significant contribution to this objective
3 – the project completely fulfills this objective for its impact area

1. The project is located in one the KBRT defined High-priority Stream Reaches.

2. The project provides spawning/rearing habitat, improved riparian conditions and/or fish passage for key species including redband trout, bull trout, shortnose and Lost River suckers, and/or coho and Chinook Salmon.

3. The project will dramatically improve water quality in the impacted stream reach or UKL with respect to temperature, dissolved oxygen levels, and/or nutrient loading.

4. The project is contiguous to other restoration or water transaction projects and there will be synergistic effects if implemented.

5. The water rights associated with the transaction are highly reliable due to seniority or other conditions in the transaction area.

6. The water rights associated with the transaction are adjudicated and the instream conditions of the project can be legally enforced for the appropriate term.

7. The landowner is willing to make a permanent commitment to the water transaction.

8. The project will deliver a reliable increase in flows to UKL.

9. The degree of improvement to the ecological system resulting from this project is substantial.

10. KBRT can realistically expect to obtain funding to support this project.

11. The transaction can likely be completed with ease and minimal challenges to the transfer or lease.

12. The price being paid for the water transaction is reasonable with respect to the pricing for other water transactions in the local area and surrounding region.

Section D: Administrative Process for Completing Instream Transfers
The WTP expects that most permanent transfer projects will follow a prescribed process for project review, pricing evaluation, legal review, landowner review, and other due diligence steps. This administrative process may need to be adjusted as the program gains experience working in the basin. (Instream leases that will be funded through farm bill programs do not require the same length and type of evaluation and will be handled under KBRT's standard practices).

Step 1: Project Identification
KBRT personnel will identify potential projects that meet the objectives of the WTP through community outreach activities including group meetings, one-on-one landowner meetings, and joint work with various other NGO's and State and Federal Agencies. KBRT personnel will work jointly with the landowner to identify the best conservation steps to be taken in the project area and will assess if water rights transfers should be included in the conservation plans for the property. At this time, assessing landowner interest and support for a water transaction and the type of transaction is critical.

Step 2: Formal Project Review
During this phase, KBRT personnel or consultants will formally review the water rights associated with the project, the ecological impact of the project, initiate communications with OWRD to gain their input on the proposed transfer, and communicate with potential funding sources to assess their interest. In addition, the WTP Director will determine the appropriate pricing of the transaction giving consideration to other transactions in the local and regional markets (see Chapter 2 Section B for more detail).

Step 3: Letter of Intent
A written offer drafted as a Letter of Intent (LOI) will be made to the landowner including a summary of the transaction details including the water rights and place of use that would be transferred instream, any points of diversion that will be relocated, and the price that will be paid for the water rights. The price offer will be made subject to the actual duty approved by OWRD, satisfactory completion of the due diligence process regarding the land title and water rights, WTP Review Board Approval, and to KBRT obtaining funding for the project. The landowner will be expected to give their written agreement to the offer in order to proceed to Step 4. In some cases, the offer may include a short term lease on the water rights with those payments being credited towards the final purchase price in order to provide KBRT with adequate time to complete the due diligence and obtain projecting funding, while still meeting ecological objectives in the interim period.

Step 4: Review Board Approval
If KBRT personnel deem the project to be viable and the landowner signs the LOI, the project details will be submitted to the WTP Review Board for evaluation. If the Review Board approves the project, it will proceed to Step 5.

Step 5: Formal Option letter
A formal option letter will be drafted to the landowner (generally with legal review by KBRT's water attorney). The option letter will contain details of the transaction, definition of the option term, transaction price and considerations, details of the due diligence process, copies of monitoring easements and requirements, Reps and Warranties, etc. A copy of a sample Option Letter is included with this report as Appendix 2. The Option will need to be signed by the landowner to make it legally binding.

Step 6: Complete the transaction

With the Option signed, KBRT personnel and consultants will complete the transactions. Remaining activities include: due diligence, filing of the instream transfer with OWRD (with the landowners assistance), if appropriate settlement of any challenges to the transfer, negotiate any revisions to the pricing or contract terms as needed, complete the fundraising for the transaction, and finalize the transaction if determined appropriate to do so.

Section E: Monitoring

KBRT is committed to ensuring that the water rights purchased through our WTP remain instream for the appropriate reach, and to monitoring the results of that increased instream flow as it pertains to our organizations objectives. KBRT's objectives for the WTP are to:

1. Increase instream flows and protect streams from cattle activity in the Fourmile Creek, Sevenmile Creek, Wood River, Sprague River, Lower Williamson River systems, and direct tributaries to the lake.
2. Improve water quality in these stream systems and in flows to Upper Klamath Lake.
3. Provide habitat for endangered sucker species, redband and bull trout, and salmon populations in the tributaries and lake.
4. Contribute to the hydrologic balance of the basin. Modeling suggests that 30,000acre feet of additional annual water deliveries to Upper Klamath Lake are necessary, which is also the water use retirement goal of the KBRA.
5. Contribute to the needs of the lower basin by providing additional water to benefit salmon populations and the fishing economy of the mainstem Klamath River, and additional water to benefit downstream irrigators.
6. Work cooperatively with stakeholders in the basin.

As discussed in Section A, KBRT will file formal instream leases and transfers with the OWRD so that the Watermaster will have authority to ensure the water is not diverted by the Seller and that the water is protected instream from use by junior water users (for the reach determined to be appropriate). In many cases, KBRT may deem that additional monitoring beyond the OWRD programs is necessary to determine if our program is meeting its objectives. As such, KBRT will engage in three additional monitoring activities which we believe will be most effective to analyze the success of our program, while limiting on-going costs:

1. Flow and water quality
2. Riparian habitat
3. Landowner compliance

KBRT will maintain its current instream flow and water quality monitoring programs to help ensure that all program goals are met, and KBRT will obtain easements for monitoring access on all properties that are involved in the WTP to facilitate habitat and compliance monitoring. As the WTP expands, KBRT may need to add additional monitoring stations to its network.

Overview of the recommended monitoring network:

1. Flow and water quality monitoring

KBRT currently maintains a network of 8 flow gauges in the Wood River Valley, and measures nutrient loads and other water quality parameters at 4 of those gauges (Figure 6 and Table 2). In addition, KBRT monitored a variety of other locations in the past which are also shown. Many of the gauge sites in areas of spring inflow were discontinued since the flows were very consistent and little new information was gained by monitoring them. In other cases, organizations such as the Klamath Tribes or USGS are maintaining gauges at those locations and are willing to provide their data to KBRT, and duplication of monitoring is not a good use of funds. Finally, some of the gages were established to assess baseline conditions and can be reinstated if new projects warrant additional monitoring in the future.

KBRT does not currently maintain any monitoring sites in the Sprague River because both the Klamath Tribes and the USGS are conducting extensive monitoring in that basin. When WTP completes projects in the Sprague, consideration will be given to the sufficiency of the current monitoring networks and additional stations may be added as appropriate.

2. Riparian habitat monitoring:

KBRT has conducted habitat monitoring at several locations in the Wood River Valley on a periodic basis. While it probably is not cost-effective to do this work on an annual basis, we recommend that habitat surveys be completed every 5-years until the WTP is fully implemented. After such time, recommendations may be made for additional future monitoring. This work should be completed at a handful of sites in each of the key basins.

3. Landowner compliance monitoring:

KBRT staff will conduct regular visits to each of the properties included in the WTP to ensure that all landowners are complying with the terms of our agreements. KBRT will evaluate stock water diversions, headgate settings, and assess pasture conditions for signs of inappropriate irrigation. If KBRT dissolves, our access easements to private lands for monitoring can be rolled over to other NGO's or State and Federal Agencies for maintenance.

The budget for the WTP (Chapter 4) includes funding for the maintenance of and small expansions to the existing monitoring network. The monitoring program will be evaluated on an annual basis for improvement opportunities and for potential budget reductions.

Chapter 3: Community Considerations

Section A: Community Outreach

Community outreach is a critical component to the WTP. Coordination of our program with a variety of NGOs, Tribes, Local, State, and Federal Agencies is essential to meeting the objectives of the program and is critical to the efficient use of funding. In addition, one-on-one sessions with landowners as well as larger town hall style meetings are important outreach activities to ensure that our programs can serve all members of the community. Below is a brief list of the outreach activities KBRT currently plans to engage in, and a summary of the benefits and objectives of that work.

KBRA OPWAS Participants

This includes several key groups working on the Off Project Water Settlement component of the KBRA: Upper Klamath Water Users Association, Sustainable NW, Klamath Tribes. One key component of the KBRA is the target of increasing flows to Upper Klamath Lake by 30,000ac-ft annually, and a primary mechanism for achieving this goal will be the permanent transfer of irrigation water to instream use. The WTP intends to be a primary facilitator of these water transactions utilizing our extensive experience with instream leasing, assisting landowners with the conversion to dryland production, and with the monitoring of instream projects. KBRT believes that our experience working on these types of projects in the basin will be essential to ensuring the success of the KBRA in the upper basin. In addition, we will rely on our partners at NFWF and their experience with the Columbia Basin WTP to provide information and recommendations about the management of our program.

An additional aspect of the KBRA is restoration of fisheries habitat in critical stream reaches throughout the upper basin. Although KBRT's restoration work is outside of the WTP, coordinating our work with both instream flow recovery and restoration is critical to the holistic recovery of the basin. The strategy for coordinating this work is described in more detail in Chapter 3 Section C of this report.

Government Agencies

Local, State, and Federal Agencies including US Fish and Wildlife, US Bureau of Reclamation, US Forest Service, Natural Resource Conservation Service, Environmental Protection Agency, Oregon Water Resources Department, Oregon Watershed Enhancement Board, Upper Klamath Watershed Council, and others are engaged in a variety of restoration activities in the Upper Klamath Watershed. Coordination of the WTP with the riparian restoration activities of these groups can provide for synergistic benefits in the basin and provides for the most efficient use of funding. Furthermore, many of these agencies have jurisdiction over the permitting of restoration projects and the implementation of various resource management and environmental laws. Coordination of KBRT's work with the Agencies streamlines project implementation, which ultimately saves money.

Landowners

The key to success for the WTP and all of KBRT's work is the landowners. Without their support and willing participation, nothing can be accomplished. KBRT has worked with landowners in the Wood and Sprague for 9 years and in that time has developed the trust and mutual respect of many of them. The WTP will leverage these critical relationships in order to implement its work.

The most successful method of working with landowners so far is one-on-one meetings. The WTP will work directly with landowners in the priority geographic areas and stream reaches to implement successful transactions and to take advantage of the synergistic effects of working with adjacent landowners. In many cases, this effort takes a significant investment of time to develop the interest and trust of the landowner, and to identify how water transactions can be implemented to meet conservation needs while maintaining a ranch as a working landscape. In KBRT's experience though, projects that develop this way are the most successful as the work has the complete and full support of the landowner as well as the conservation community.

KBRT will also host periodic town hall style meetings in the Sprague River basin to provide education and outreach to a broader community. Since there are relatively few landowners in the Wood River Valley, one-on-one outreach is most effective in that basin. In contrast, there are hundreds of landowners in the Sprague River basin making it beneficial to use broader outreach techniques in order to serve the entire community there. While our priority areas for the WTP are identified, the landowners and tribe members that live in these landscapes are a critical source of knowledge and ideas. Broad community outreach helps to increase community awareness of the opportunities provided by KBRT and specifically the WTP, as well as generates new project ideas and opportunities. These types of meetings are also invaluable for obtaining input and critiques of KBRT's work to facilitate continuous improvement of our programs.

Section B: Economic Impacts and Benefits

The implementation of KBRT's instream leases often raises questions in the community about the economic impacts of conversion to dryland grazing. KBRT recognizes that the implementation of permanent water transfers is likely to raise similar questions in the community, and so we have completed some initial analysis of this issue in the development of the WTP. While the work completed thus far is neither robust nor complete, it does provide the basic information necessary to inform individual landowner decisions, as well as a strong foundation of information should additional work be required in the future to address broader community issues.

The key economic questions identified to date include:

1. What is the long term income potential for a dryland ranch in the basin? How will that reduced income impact the landowners?
2. What is the impact of reduced annual income on the county's tax basis? What is the potential benefit of the one-time sale of water rights on the tax basis?

3. Will the conversion of some ranches to dryland negatively impact the income of adjacent landowners that want to continue to irrigate?
4. Is there a critical mass of agricultural activity that needs to be maintained in the basin in order for the communities and associated services to remain viable?
5. Are there alternative economic models that could increase income in the basin given the restoration and conservation activities (green recreation opportunities, marketing of sustainably grown beef, etc.)?

KBRT has worked with both the NRCS and WestWater Research LLC to partially address question 1 and KBRT's monitoring work (conducted jointly with NRCS and USGS) to address question 3. The remaining questions have only been studied in a cursory manner and may warrant further exploration in the future, particular as the KBRA moves towards implementation. At this time, the WTP does not have the funding or expertise to address these questions. NFWF has provided some funding to Sustainable Northwest to explore the economic impacts of the KBRA/OPWAS, and KBRT will coordinate closely with them to address these important questions as fully as possible when Sustainable Northwest is ready to proceed with their project.

Question 1:
The NRCS worked with landowners in the Wood River Valley to "quantify the environmental benefits of conservation practices used by private landowners participating in selected USDA conservation programs". In their report (Wood River, Upper Klamath Basin, Oregon; Conservation Effects Assessment Project (CEAP) Special Emphasis Watershed; April 2010) the NRCS utilized data from KBRT monitoring efforts, worked with landowners participating in the KBRT programs to measure conservation results, and also studied nonparticipating properties as controls for evaluating the relative benefits of conservation. The primary aspect of conservation that the NRCS evaluated was KBRT's work converting ranches from flood irrigation to dryland grazing, and the protection of that water instream. This evaluation included review of riparian, aquatic, vegetation, and hydrologic impacts, as well as a review of economic impacts. The economic review assessed the optimal levels of grazing and irrigation water management that could be sustained both economically and environmentally without public financial support. This information can be used to extrapolate specific economic information for landowners, although the NRCS unfortunately declined to fully quantify the monetary aspects of their analysis. It should be noted that the CEAP results are based on only two years (2007-2008) of productivity data, and are thus somewhat limited.

The CEAP report suggests that with reduced irrigation (one application in the summer, generally July/August), and improved cattle rotation programs (30 day rest cycles for pastures), landowners could sustain 94% of their standard production capacity. The report also suggested that with no irrigation and improved rotation, landowners could sustain 90% of their standard production capacity. This high level of production without irrigation was attributed to better quality, more vigorous forage in non-irrigated pastures and the higher rate of weight gain landowners have observed in cattle on the dryland pastures. The CEAP further reported that both of these management scenarios provide substantial environmental benefit to the watershed.

In monetary terms, the CEAP study finds that this level of reduction in productivity correlates to a $15/acre decline in annual revenue under the reduced irrigation scenario and a $27/acre decline in annual revenue under dryland conditions. Anecdotal evidence from ranchers (as summarized in the WestWater Research Report, Development of a Water Pricing Framework: Upper Klamath Lake Watershed; Appendix 1 of this document), indicates larger annual declines in ranch revenue, typically around $80 to $90/acre. This differential may be attributed to landowner's failure to fully optimize their rotational grazing approach, a conservative approach by landowners to stocking rates, or incorrect modeling scenarios being completed in the NRCS study. Regardless, the free market approach should result in an optimization of stocking rates and a maximization of ranch revenues with additional time.

The WTP will facilitate optimization of the grazing programs, and therefore annual ranch income, by combining our programs water efforts with KBRT's existing programs that assist landowners in obtaining support for ranch management activities through various Farm Bill programs. For example, KBRT has previously assisted landowners converting to dryland grazing in obtaining financial support for the installation of cross-fencing, riparian fencing, improved cattle watering supplies, and similar support through existing NRCS programs. This is discussed in more depth in Chapter 3 Section C.

No evaluation of the economic impacts of dryland grazing has been conducted in the Sprague basin thus far. The WestWater Research Report does theorize that due to the higher consumptive use rate in the Sprague Basin, relative to the Wood Basin, the percentage loss of income will be greater in the Sprague. However, this differential is likely offset by the lower potential revenue of land in the Sprague since this land is generally less productive than land in the Wood.

The determination of how a reduction in income due to dryland conversion will impact the ranching community is much more subjective and dependant on the economic situation of each individual landowner. Theoretically the income derived from the purchase of the water rights should be sufficient to offset the reduction of annual revenue, or a landowner will not complete a transaction. However, the overall environmental situation in the basin might drive landowners to make different decisions. If a landowner fears that they will lose their irrigation rights without any compensation due to settlement decisions made through the KBRA or the Klamath Adjudication, the landowner may be willing to sell their water for less money. How the impact of an individual's negative economic outcome weighs against the public benefit of environmental restoration and fisheries recovery is a complex and subjective question that is outside the scope of this project.

Question 3:
Monitoring work completed in the Wood River Valley indicates that the impact of a ranch converting to dryland grazing on adjacent irrigated ranches is negligible. KBRT, with support from consultants including Pacific Groundwater Group and Dr. Richard Cuenca, monitored groundwater levels within individual grazing seasons and between

seasons on dry ranches and their irrigated neighbors and found no impact to groundwater levels on the irrigated ranches (KBRT Monitoring Reports 2004 and 2005). Even though the monitoring data did not identify it, some minimal impact at the margin between the properties is theoretically likely, but it should not significantly impact revenues or production.

Section C: Integration with Other Conservation Programs

A hallmark of the WTP is its ability to coordinate with other KBRT conservation and restoration efforts to provide a holistic approach to restoration in the basin. While the transfer of irrigation water rights to instream use achieves substantial environmental benefit, this benefit can often be maximized through coordinated restoration efforts to protect riparian areas, eliminate barriers to fish passage, and to restore heavily damaged stream reaches. In addition, coordination of these types of conservation activities across property boundaries provides synergistic benefits and maximizes the value of expended funds.

KBRT has demonstrated substantial success over the last 9 years in developing, funding, and implementing these kinds of restoration projects. The WTP will coordinate all projects with the KBRT Restoration Director to identify additional restoration needs in a particular stream reach. The Restoration Director will work closely with participating landowners to develop strategic management plans for the properties that address all necessary aspects of restoration to obtain fisheries recovery. Summaries of KBRT successful restoration projects are detailed on our website, www.kbrt.org.

The WTP will also stay appraised of the restoration and conservation activities of other groups in the basin through its community outreach activities to ensure that all key opportunities are identified. Projects are being conducted by a variety of federal and state agencies as well as NGO's. In addition, the proposed KBRA contains a significant emphasis on restoration and substantial funding for the restoration effort. The priority geographic areas and stream reaches detailed in Chapter 1 Section C of this report, as well as the project ranking criteria that the WTP Project Review Board will utilize, consider the synergistic effects of work with adjacent properties and work in stream reaches where other restoration is being conducted. These priorities are to be reviewed annually to keep them current and will also be well coordinated with the KBRA if it proceeds.

Chapter 4: Program Budget and Fundraising

Section A: Program Resources and Budget

This section of the report outlines the resources and budget that are required to implement the program as planned (Table 3). If the structure or objectives of the program change, for example if the KBRA is implemented, corresponding changes in the staffing and budget would likely be required.

Key Assumptions

- The program goal is to transfer 4500AF of water per year to instream use, for five years.
- Short-term leases will be managed through alternative funding sources, including Farm Bill programs.
- Restoration project management will be handled through alternative funding sources.

KBRT Staff Needs

The primary activities the WTP staff will be responsible for include:

- Identification of targets for water transactions
- Evaluation of ecological benefits of potential transactions and development of materials for the WTP Review Board to evaluate potential transactions
- Outreach to the landowner community to develop transaction opportunities
- Outreach to State and Federal Agencies, Klamath Tribes, and other watershed groups to assess how water transactions can support restoration activities and ecological needs in the basin
- Management of all legal activity for permanent transactions including landowner contracts, filing for the instream transfers, and resolving challenges to proposed transfers
- Program coordination with OWRD and other regulatory bodies regarding transactions
- Obtain funding to support transactions activity
- Manage and report on grants as needed

The personnel requirements in order to achieve these objectives include:

- Director of Water Transactions Program (75% time)
- Program Financial and Administrative Support (25% time)
- Executive Director Oversight (15% time)

Consulting Needs

Monitoring:

KBRT will retain consultants to measure surface water flows and nutrient levels at key points in the Wood River Valley and Sprague River Basin associated with the WTP. These measurements will be used to ensure that 1) instream flows are being maintained at the appropriate level, and 2) that the expected benefits of the instream transfers are being realized with respect to water quality improvements. Every 5 years KBRT will conduct habitat monitoring to ensure that ecological goals are being met. In the future, groundwater level monitoring may also be necessary. Additional details about the WTP monitoring are included in Chapter 2 Section E.

Legal:

KBRT will utilize legal consultants as needed to support the WTP activities. The primary legal services that will be needed include:

- Drafting of contracts for the purchase of water

- Evaluating the validity of water certificates
- Representing KBRT in contested case hearings at OWRD related to proposed instream transfers
- Drafting of monitoring easements for properties that complete water transactions

Additional expert consultants may be hired as needed.

Section B: Program Funding

Overall Strategy

We have identified three possible funding strategies for the WTP which can be used individually or jointly: Individual grants, establishment of an endowment, and KBRA or other significant federal funding.

Sustaining a substantial watershed transactions program that will truly meet the ecological needs of the Upper Klamath Basin will be extremely difficult if individual grants are the only funding mechanism available to the WTP. As detailed in the program goals in Chapter 1, the water resources of the Upper Klamath Basin are extremely over-appropriated and a large scale retirement of water usage is essential to achieve full recovery of the endangered and threatened species in the basin. Given the cost of achieving permanent instream water transfers in all of the key stream reaches, and the substantial ecologic benefit of completing this work, the WTP feels that an endowment or large public fund for the support of this work is essential.

Initial work by the WTP will focus on obtaining individual grants to support our key initial projects. However, KBRT will continue to seek endowment funds and to participate and support the KBRA settlement in hopes of achieving the large scale watershed improvements that are so desperately needed in the Klamath. KBRT hopes that partner organizations such as NFWF and OWEB can provide assistance in the development of the endowment.

Potential Funding Sources

Private Partners:

Private Foundations and Individual Contributors are expected to be an important source of funding for completing KBRT's water transactions and sustaining the operations of the WTP. We have identified several Foundations that are good targets for obtaining funding and these include:

Resource Legacy Fund (manager of the Packard, Getty, and Hewlitt Foundations)

> The RLF is primarily focused on work in California and the desert southwest, however they also have a strong interest in salmon recovery. The application process is rigorous, however the contribution levels made are significant. The program that most closely matches KBRT's WTP activities is the Western Conservation Initiative whose purpose is to "increase land trust capacity and efficacy throughout the west".

Bonneville Environmental Foundation (BEF)

BEF already has a strong interest in water marketing in order to support their voluntary off-sets program titled the Water Restoration Certificates Program. BEF has supported several other regional groups, including the Freshwater Trust, Deschutes River Conservancy, and the Montana Water Trust, with the procurement of water rights. In addition, BEF's Model Watershed program could provide an important source of monitoring funds for the WTP.

Bella Vista Foundation

This small foundation is currently working on water transactions in the John Day basin of Oregon, and has previously expressed interest in working in the Klamath.

Bullitt Foundation

The Bullitt Foundation currently operates a fund called the Ecosystem Services Program. The goal of this program is to "support efforts, based on sound science, to restore and protect ecosystems that provide goods and services to the regions major metropolitan areas". One of the key priorities for this program is fresh water ecosystems. KBRT will need to further explore with the Foundation if the Klamath Basin sufficiently meets the program criteria.

National Fish and Wildlife Foundation (NFWF)

NFWF is already KBRT's key partner in the development of the WTP. NFWF is a strong partner, not only due to the funding that they have provided, but also due to their extensive experience with water markets through their management of the Columbia Basin Water Transactions Program. KBRT plans to utilize NFWF's expertise to support the growth and development of our WTP, and in addition will seek financial support from NFWF to sustain the program.

State and Federal Agencies:

State and Federal Agencies play a critical role in the conservation and restoration of ecosystems. There are a variety of funding mechanisms in those agencies that can be used to support water transactions in the capacity of environmental restoration. In addition, the support and participation of these agencies are critical since they are often the regulatory bodies that oversee conservation work.

Oregon Watershed Enhancement Board (OWEB)

OWEB is already operating a a key partner to the WTP by providing funding support for the program development, as well as funding for our initial transactions. OWEB has expressed interest in setting up an endowment style fund for future transactions, however the current state budget situation makes this difficult. KBRT will continue to seek their support in a variety of capacities for our future transactions.

Klamath Basin Restoration Agreement Water Use Retirement Program (KBRA-WURP)

Significant State and Federal funds are expected to be earmarked towards the overall settlement of the Klamath Basin water issues. The funds will be targeted to dam removal, conservation, restoration, and in some cases procuring water rights. The

Off-Project Water Program portion of the KBRA (Section 16) contemplates an Off-Project Water Settlement (OPWAS) to resolve the disputes between the Off-project Irrigators, Klamath Tribes, and the Bureau of Indian Affairs. A portion of this settlement is the WURP however there are also provisions to implement the WURP if the OPWAS is not achieved.

The primary goal of the WURP is to change in surface and near-surface groundwater management (including retirement of water rights) to achieve an average annual increase in flows to Upper Klamath Lake of 30,000ac-ft. The KBRA further specifies that water rights may be acquired at fair market values to achieve these goals. KBRT therefore expects that funding for water transactions that support the goals of the KBRA will become available in the next few years.

Additional sources of agency funding may be available from the OWRD, EPA, NRCS, USFWS, USFS, and others.

Chapter 5: Hurdles and Challenges

KBRT believes that the WTP detailed in this document can be fully implemented and effective without any changes to state or federal law. However, we have identified some hurdles and challenges within current State and Federal law that create limits on the program. Ideally these challenges can be addressed through various legislative processes, or by changes to Agency policies. KBRT will engage in efforts to address each of the identified challenges in order to provide as many options as possible for water conservation efforts. The implementation of the KBRA provides an excellent opportunity to address many limitations to water transaction programs on both a State and Federal Level.

Limitations of Oregon Water Law

Although Oregon Water Law recognizes instream use as a protectable water right and provides several mechanisms for creating instream water rights, there are three key limitations within the current laws that could be improved to better facilitate water transactions.

A. Diminishments cannot be protected instream

   If the rate, duty, or season of use of a water right is permanently diminished, there is not a mechanism for protecting the additional water instream. Instead that water becomes available for additional appropriations. Some studies of the upper Klamath Basin suggest that the most efficient use of water is to complete one irrigation event in the early season, but curtail all water use after July 1 or August 1 when low flow conditions exist in the rivers. Unfortunately, the legal mechanism to complete and enforce this kind of transaction is not available.

   There are two options within the existing Oregon Water Law that can partially address diminishments, but neither is robust enough to encompass all water conservation options. The first is Split-season Leasing and the second is the Allocation of Conserved Water Program.

1. The split-season leasing program is described in detail in Chapter 2 Section A. The main limitation of this program are that:
    a. The law sunsets in 2014, although it may be renewed at that time
    b. The law does not provide for permanent split-season transfers, only leases of 1-5 years, all of which must terminate by 2014.
    c. The monitoring burden associated with the leases is often prohibitively expensive as all water use by the landowner must be monitored in detail prior to the dry period.

2. The Allocation of Conserved Water program is also detailed in Chapter 2 Section B. The main limitation of this program is that it can only be used with "technological changes" to the irrigation system result in the conserved water. As a result, simply forbearing water use during a given period of time does not qualify.

B. Limited Measurement Capabilities

Oregon water law does not require most diversions to be monitored or metered, as a result it is difficult to enforce or regulate water use. In order for an instream water right to be protected by the water master, an individual or organization generally must bear the cost of monitoring and contact the watermaster for regulation of the rights when needed. Unless Oregon follows the lead of Washington State to require metering and monitoring of most surface water diversions, any instream leasing or transfer program will need to ensure that they have adequate resources to manage and protect the leases.

C. Estimated Average Natural Flow (EANF)

Oregon Water Law requires that for a water right to be protected instream, it must not exceed the EANF occurring for the drainage system, except where periodic flows that exceed the EANF are significant for the applied public use (OAR 690-077-0015(4)). In some cases, the water rights on a given stream system, exceed the EANF for a period of time and as a result, OWRD may not be willing to protect an entire water right instream, even during "wet" years.

<u>Limitations of the Federal Appraisal Process</u>

In order for the Federal Government to procure real property, the property must undergo an appraisal utilizing the Uniform Appraisal Standards for Federal Land Acquisitions or "yellowbook" process. If a key source of funding for water transactions in the basin is the WURP, and if the funds allocated to this purpose are Federal as is currently stated in the KBRA, many water transactions in the basin may be subject to Yellowbook appraisals. This process is burdensome and highly restrictive of what information and benefits of the transaction can be considered in the appraisal. As discussed in Chapter 2 Section B, the only federal alternative to this is for Congress to specifically authorize the use of

Alternative Valuation Methods (AVMs) for the transaction. In the case of KBRA funding being utilized for the transactions, it might be possible to obtain authorization for the use of AVMs when the KBRA is approved by congress.

Alternatively, more creative options should be considered. For example, the Federal Government could provide funding to a nonprofit organization, such as NFWF, to complete water transactions on their behalf. In such circumstance, the transactions might not be subject to Federal Appraisal guidelines.

Development of a Water Pricing Framework: Upper Klamath Lake Watershed

FINAL REPORT

Prepared for

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Background and Purpose

The Klamath Basin Rangeland Trust (KBRT) is working to improve instream flows in the Upper Klamath Lake Watershed to enhance the natural ecosystem for native fish and wildlife populations and supply water for downstream agriculture. KBRT has been actively engaged in leasing water for environmental purposes since 2002. From 2002 through 2009, KBRT added nearly 90,000 acre-feet (AF) to Upper Klamath Lake through lease agreements with agricultural producers in the Wood and Sprague river basins. The leases have consisted of short-term, annual agreements involving a combination of funding from KBRT, USBR, and NRCS.

The Klamath Basin Restoration Agreement (KBRA) calls for improved inflows to Upper Klamath Lake through water right acquisitions and other methods. The KBRA is flexible regarding the acquisition methods (lease, purchase, conservation, etc.) and specific geographic location of the agreements within the watersheds that contribute flows to Upper Klamath Lake. However, it is anticipated that there will be an increasing interest in developing longer-term or permanent water right agreements to provide greater assurance of water availability to achieve the objectives of the Water Use Retirement Program component of the KBRA. This report provides an analysis of water right pricing in the Upper Klamath Lake Watershed with a focus on permanent transactions. The analysis contained in this report provides KBRT with the information needed to establish an equitable water pricing framework that will promote long-term success of the transactions program.

This report begins with a brief description of the alternative water right valuation methods available and their application in this report. The second section provides a brief description of the Upper Klamath Basin to provide information on the economic and agricultural conditions in the region. This is followed by the implementation of several approaches to estimate the permanent sale value of water rights including an analysis of agricultural land sales, a comparative analysis of water right markets, and capitalization of water right lease prices. The comparative markets analysis describes water right market activity in selected regions to provide context and comparison for water right values in the Upper Klamath Lake Watershed. In addition to the comparative markets analysis, this report develops an equivalent purchase price from lease prices paid in the Upper Klamath Lake Watershed through development of an income capitalization rate.

Water Valuation Methods

The selection of appropriate water valuation technique(s) is determined by the characteristics and nature of the water right being valued as well as the availability and quality of information. There are several methods that can be appropriate for valuing water rights including the Sales Comparison Approach, Cost Approach, Income Approach, and Land Price Differential Approach (also referred to as "before and after" analysis). In addition, it has been suggested under some circumstances that environmental values should be considered when determining the market value for water rights acquired for instream uses. Consequently, the use of environmental values for establishing market prices for water is also addressed below.

Sales Comparison Approach

This method involves comparing the water right(s) proposed for acquisition with similar water rights that have been sold or leased. Sufficient sales data is required to make accurate comparisons. Sales that were not completed or that do not represent "arms-length" transactions should be excluded from the comparison. This is the preferred approach when sufficient transaction information is available. Water market activity in the Upper Klamath Lake Watershed has consisted of short-term annual leases involving agreements not to irrigate in combination with reduced cattle stocking rates on participating land. It is anticipated that this history of leasing activity will guide future price decisions for short-term water right transactions. However, there is little market experience in the Upper Klamath Basin with long-term and permanent water right transactions to establish reasonable price expectations for buyers and sellers. To address this limitation, this analysis presents information on water market activity from other regions to provide context for the water lease prices that have persisted in the basin and establish a relevant price range for permanent contracts in the Upper Klamath Lake Watershed.

Land Price Differential Approach

This land price differential approach compares sale prices of agricultural land with and without water rights. The difference between the two prices represents the value that can be attributed to the water right. To correctly implement, the method requires extensive information on recent land sales. This approach has been effective at estimating market values for water rights in areas with a limited history of water right trading and limited competing demands for water. However, the approach is data and time intensive and is not generally suitable to regions with few agricultural land sales.

Where adequate land sales information exists, the land price differential approach can be a suitable, and even preferred, valuation method. This is particularly true in regions where water rights are sold with agricultural land and there is no observable market for water rights sold separately from property. This analysis presents some limited information on land values in order to provide context for alternative water right valuation methods. This analysis does not solely rely upon agricultural land values as a guide to determining the value of water rights in the Upper Klamath Lake Watershed due to the following:

- There are few farm and ranch sales available in the region to accurately isolate water right values from other property included in the sales. Agricultural land sales have been especially limited in recent years due to overall economic conditions.[1] As a result, this indirect approach to valuing water rights is likely to be data limited.
- According to the KBRA, the Water Use Retirement Program will be focused on acquisitions of water rights separate from land. As such, it is unlikely that buyers for environmental purposes (e.g. instream flow and lake levels) will be able to price discriminate according to the characteristics of the land that water rights are appurtenant to.
- Land sales data is too limited to determine if the agricultural land market has accounted for differences in the priority dates of water rights especially in the unadjudicated Sprague Basin. It is anticipated that water right priority date will represent an important factor in both water right and land acquisitions in the future as the water rights are managed according to the Prior Appropriations Doctrine.
- As evidenced from other market regions, water right values quickly adjust as new demands enter the marketplace. As such, market established prices for water rights sold separately from other property in other regions may provide a more accurate measure of the prices that will be established for water rights in the Upper Klamath Basin through negotiation between willing sellers and buyers.

[1] Personal communication with Klamath County Assessors Office, February 2010.

Income Approach

The income approach values water rights as an input to production processes. This method, which is primarily used for estimating the current use value of water, involves determining water's contribution to the net revenue. Values generated using this approach typically represents the minimum amount that can be paid to a water right holder to compensate for income that is foregone during the term of a water right lease. In practice, a premium above this amount is generally required to procure the right in most cases. Variations of the income approach have been applied to the Klamath Basin by Adams and Cho (1996), Jaeger (2004), and Boehlert (2009), among others. Typically, the method is applied through the use of crop production budgets and mathematical programming techniques to simulate the response of agricultural producers to changes in water supply. Using the approach, Jaeger (2004) estimated annual water values in the area above Upper Klamath Lake ranging from $28 per acre on land with poor soils to $232 per acre for the land with the highest agricultural productivity.

The income approach is most suited to estimating annual water right values. Application of the approach to estimate long-term and permanent water right values requires information and assumptions regarding future crop and livestock prices, production costs, and resource availability as well as selection of an appropriate capitalization rate. Further, it requires an assessment of any premium above agricultural value that would be required to bid the water away from its current use. Due to the high number of analysis inputs and required assumptions, the income approach is prone to speculation and can often lead to wide variation in water value estimates. As a result, the income approach is less preferred to other available methods for determining permanent water right values and is not pursued in this analysis.

Cost Approach

The cost approach estimates the current cost of reproducing or replacing an equivalent quantity of water to that supplied by the surface water right. The approach is commonly used in areas where the market price for water rights is dominated by investment alternatives to increase water supply. The cost approach is typically viewed as an alternative approach to comparable sales or income capitalization methods. It should be noted that in areas where water supplies are constrained, the cost of developing new water sources theoretically represents the maximum value that a buyer would pay for access to water associated with an existing water right provided the water supplies have comparable characteristics (e.g. quality, reliability). Consequently, when considered from the potential buyer's perspective, the cost approach typically represents an upper bound on the market value for an existing water right.

It is important that a cost approach analysis only consider projects that are likely to be pursued rather than hypothetical projects that have little chance of being pursued due to financial, political, or physical constraints. It is possible that surface storage in the Upper Klamath Basin could be expanded to support new and existing water uses. For example, the

Bureau of Reclamation is exploring opportunities to enhance water supplies in the basin through increased surface water storage capacity and conjunctive use of groundwater resources. However, there are no completed analyses from which to gage technical feasibility and costs of the alternatives. Further, it appears unlikely that any water supply enhancement decisions will provide a substitute source of water that will diminish the need for water right acquisitions above Upper Klamath Lake. In some cases, groundwater can represent an alternative to surface water. For example, the Bureau of Reclamation instituted a groundwater leasing program in 2001 to improve streamflows and lake levels. However, the development of new groundwater sources in the Upper Klamath Lake Watershed is not a viable option as OWRD is no longer issuing groundwater rights. Opportunities to conjunctively manage ground and surface water resources to benefit streamflows and lake levels in the Upper Klamath Basin are unknown at this time but may be limited due to groundwater availability, hydraulic connectivity between surface and ground water sources, and regulatory constraints on water right uses. Due to these circumstances, there does not appear to be a suitable basis for valuing water rights according to the costs to develop alternative water supplies. As a result, the cost approach is not a relevant consideration for determining the value of water rights in the Upper Klamath Lake Watershed.

Environmental Pricing Considerations

As previously stated the primary purpose of KBRT's water right acquisitions above Upper Klamath Lake is to increase inflows to the lake to assist in the maintenance for lake levels for the benefit of resident and anadromous fish species as well as downstream irrigated agriculture. However, a co-equal goal of the acquisitions is to improve conditions in streams above Upper Klamath Lake for the benefit of fish species that rely upon them for habitat. There are many water rights located above the lake that have the potential to increase inflows to the lake. As such, the potential environmental benefit to Upper Klamath Lake of a water right with a point of diversion located near the lake may be the same as one located many miles upstream. However, the acquisition opportunities differ with respect to the environmental benefits that they will produce within the streams that flow to the lake. For example, water rights with diversions located higher in a stream system have the potential to benefit more habitat than those with diversions located downstream. As a result, there may be a desire to price water rights, in part, according to their relative abilities to contribute to flows in streams above Upper Klamath Lake in order to incentivize owners of the most desirable water rights to enter into an agreement.

Establishing a pricing framework that incorporates the relative environmental benefits of water rights is possible although problematic for a variety of reasons relating to quantification difficulties and appraisal regulations, among other factors. Quantification of environmental benefits in monetary terms is often used to assist public agencies in allocating funds among available opportunities and is frequently used in cost-benefit analyses. For example, the National Oceanic and Atmospheric Administration (NOAA) is currently leading an economic study to assess the environmental benefits associated with the removal of hydroelectric dams on the Klamath River. Such an analysis could be used to justify and inform a broad water rights acquisition and restoration program. However, the direct use of economic estimates to establish a market price for a water right or set of water rights is, in general, inappropriate. The economic techniques used to value environmental goods and services (such as instream flow and lake level maintenance for fish protection) are imprecise and costly to implement. Further, they would be difficult to apply to individual water right acquisitions that contribute a relatively small amount to base flows due in part to the challenges associated with quantifying the biological benefits from the action.

Even if environmental values could be measured with precision, their use in appraisals appears to be inconsistent with federal appraisal guidelines. It is clear from appraisal literature that direct incorporation of environmental values into the appraisal of a property (including water rights) is not an accepted practice for establishing market value in support of acquisitions.[2] This creates particular difficulty when a government entity bound to appraised prices enters the marketplace to acquire water rights for environmental purposes that have traditionally been developed and applied for agricultural purposes. While there is some limited ability to offer a premium above appraised market value, it may be inadequate to secure the water right even when it is determined that the public benefit from the acquisition warrants a higher purchase price.[3]

According to Bureau of Reclamation Manual LND 05-01, the use of “alternative valuation methods (AMV)” in appraisals is not allowed unless authorized by Congress. In the document, AMVs are associated with public interest value, biological value, habitat equivalency analysis, among others. The document further states that market value should basis of value for water rights that Reclamation is acquiring.

There is little precedence for establishment of a water right price schedule that accounts for environmental benefits (e.g. increased stream flows in tributaries to Upper Klamath Lake). If established, such a price schedule would likely need to be based upon qualitative or physical assessments (e.g. stream miles improved, percent contribution to base flows) given the difficulties associated with quantifying environmental benefits in monetary terms. While it is possible and may be beneficial in the future to establish a price schedule that incorporates environmental benefits, there are no known market examples that provide clear guidance. This analysis does not attempt to incorporate environmental benefits into the valuation of surface water rights in the Upper Klamath Lake Watershed.

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[2] “Guidelines for Appraisal of Water Rights in California,” USFWS Pacific Southwest Region.
[3] Bureau of Reclamation Manual, Directives and Standards, LND-06-01.

Upper Klamath Basin Overview

Study Area

The Upper Klamath Basin is located in both Oregon and California east of the Cascade Mountains. In general, the upper basin includes the area that drains into the Klamath River above Iron Gate Dam. The Klamath River and its tributaries generally flow south and then west to the Pacific Ocean. This area includes approximately 5 million acres and is located within Klamath County, Oregon and Siskiyou and Modoc counties in California. The area is relatively high in elevation ranging from 4,000 to 9,000 feet above sea level. Winters tend to be cold and moderately wet while summers are hot and dry. The basin contains a variety of fish species include two species listed as endangered under the Endangered Species Act (ESA) namely: the Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*), and another listed as threatened, the bull trout (*Salvelinus confluentus*).

This analysis focuses on the irrigated land above Upper Klamath Lake located primarily within the Wood, Williamson, and Sprague basins. This area is referred to as the "study area" and "Upper Klamath Lake Watershed" within this report. The irrigated land in the region is not associated with the Klamath Basin Reclamation Project and consists of ranches and farm properties with private water rights.

Water Resources

The Williamson, Wood, Sycan, and Sprague Rivers support irrigated agriculture in the northern portion of the basin before flowing into Upper Klamath Lake. There are six dams on the Klamath River that were developed as part of the Klamath Hydroelectric Project. The project is owned and operated by PacifiCorp under a license from the Federal Energy Regulatory Commission (FERC) and has approximately 169 megawatts of capacity. Construction of the hydroelectric project eliminated nearly 300 stream miles of habitat for salmon and steelhead. The future of the hydroelectric dams and establishment of environmental conditions necessary to support fish populations has been the subject of more than five years of negotiation between federal, state, tribal, and other interest groups. On

February 18, 2010, the Klamath Basin Settlement Agreements were signed. The agreements consist of the "Hydroelectric Settlement" and the "Restoration Agreement." The Hydroelectric Settlement identifies the process for transfer, decommissioning, and removal of the dams while the Restoration Agreement focuses on rebuilding fisheries in the Klamath Basin through improvements in fish passage, water quality, and additional water supplies for fish obtained through water leases and purchases, conservation, and storage.

The Williamson River is the largest source of inflow to Upper Klamath Lake. Tributaries to the Williamson River include the Sprague and Sycan rivers and Spring Creek. The Wood River contributes approximately 18 percent of inflows to Upper Klamath Lake. Tributaries to the Wood River include Annie and Sun creeks, Fort Creek, and Crooked Creek. Sevenmile Creek originates from springs on the west side of the Wood River Valley and also contributes inflows to Upper Klamath Lake. In addition, Fourmile Creek flows directly into Upper Klamath Lake.

Water Rights

Some of the water rights in the study area have been adjudicated although many have not and are involved in the ongoing Klamath Basin adjudication. Under the adjudication process, water rights that were established prior to adoption of Oregon's water code in 1909 are quantified. The adjudication will establish the legal characteristics of each water right including water source, annual quantity, and priority date, as well as other attributes. Water users in the north and south forks of the Sprague River, Annie Creek, Cherry Creek, Four and Sevenmile creeks and the Wood River have had water rights determined through previous adjudication proceedings. However, the ongoing adjudication may affect the ability to exercise these previously adjudicated water rights in the same manner that they have been exercised to date.

Agricultural Production

Irrigated land above Upper Klamath Lake is primarily planted to livestock forage and feed crops. Due to topography, soils, and available water supplies, land in the Wood Basin is primarily surface irrigated using gravity flow. The majority of the land is irrigated pasture. Due in part to a high water table, the estimated consumptive use water directly applied to hay and pasture crops in the basin is approximately 1.03 AF per acre. Stocking rates in the Wood Basin are reported to be approximately one cow-calf pair per 1.0 to 1.5 acres for six months. Steers are generally stocked at rates of 1.5 to 3 steer per acre for six months. Some producers that do not operate their own herd are paid according to the head while others are paid according to the weight gain on steers.

Some ranchers in the Wood Basin have been participating in programs that, for as far back as 2001, have reduced water use and livestock stocking rates on irrigated pasture. This extended experience with dryland operations have demonstrated that, if managed properly, pasture can remain productive for cattle grazing. In general, participating ranchers have reduced stocking rates by 50 to 60 percent on land where irrigation has been removed although contracts have required reductions beyond this level in some years. According to ranchers interviewed during this analysis, cattle production earns approximately $150 to $180 per acre on fully irrigated pasture. Without irrigation, revenues reportedly fall to $60 to $100 per acre. While the financial returns to cattle production varies among producers and fluctuates with market conditions, the ongoing irrigation/livestock reduction program in the Wood Basin has demonstrated that traditional land uses can continue under some circumstances without irrigation.

In the Sprague Basin, more lands are irrigated using sprinklers due to the topography, soils, and the need to lift water from the Sprague River to fields. As a result, irrigation costs tend to be higher. Power costs for irrigation users in the region are expected to rise significantly in the future as power contracts with PacifiCorp are renewed. The higher power costs will negatively affect the net returns to irrigated crop production and may make some lands with high lifts unprofitable to irrigate. The higher costs and somewhat less reliable water supplies have resulted in reported irrigated land values in the Sprague Basin that are lower than the Wood Basin. However, as previously described, there have been relatively few land sales in recent years to confirm this and differences in amenities may partially explain some of the price disparity. Reported rental rates for pasture in the Sprague Basin are somewhat lower than those in the Wood Basin due to the shorter carrying season and lower forage production. At current rates, landowners in the Sprague Basin earn approximately $120 to $130 per acre for pasture rental. It is common for all vaccination, irrigation, and maintenance costs are borne by the renter. Average hay yields in the Sprague Basin are reported at 4.0 tons per acre.

Due to climate and soil conditions, the consumptive use associated with applied irrigation water in the Sprague Basin varies between 1.0 and 2.0 AF per acre. This study assumes a consumptive use of 1.6 AF per acre. When compared to the Wood Basin, more land in the Sprague Basin has more limited agricultural productivity without irrigation. As a result of this, there is lower potential for dryland production on some ground in the Sprague Basin which may affect the willingness of landowners to participate in water right transactions and the price at which transactions can be negotiated.

Upper Klamath Basin Water Transactions

Reclamation began leasing water in 2001 to balance irrigation water use with instream and tribal water needs. Initially, the program was named the "Demand Reduction Program." Later the name changed to the "Water Bank" and finally the "Water Supply Enhancement Study." In general, irrigators are compensated to voluntarily forgo their contractual entitlement for one irrigation season in order to make more water available to support instream uses.[4] In addition to water leased from land within the Klamath Project, water was also leased from "Off-Project" land located above Upper Klamath Lake, primarily in the Wood River Basin. Initially, the Off-Project leasing was funded by Reclamation. In subsequent years, Off-Project water leasing has been completed through a combination of funding sources provided by the Natural Resource Conservation Service (NRCS) and Reclamation.

Klamath Basin Water Leasing: Within the Klamath Project

In 2001, Reclamation operated the "Irrigation Demand Reduction Program" and received bids from water users within the Klamath Project that were willing to reduce irrigation through crop idling. In 2002, Reclamation operated the "Water Bank" and accepted proposal for groundwater substitution but did not pursue crop idling contracts within the Klamath Project. In 2003, Reclamation solicited bids from water users through public announcements early in the year. Reclamation offered $76.46 per acre-foot ($187.50/acre) for idled crop land and $75 per acre-foot for groundwater substitution. In 2004, Reclamation allowed payments for water leases to vary according to bid price. This process has continued in 2005 and 2006 with irrigators submitting bids to participate in the program either by forgoing water use ("dry land operation") or by irrigating with well water ("groundwater substitution"). 2006 was the last year that Reclamation pursued crop idling contracts within the Klamath Project. This analysis focuses solely on the water provided through crop idling contracts.

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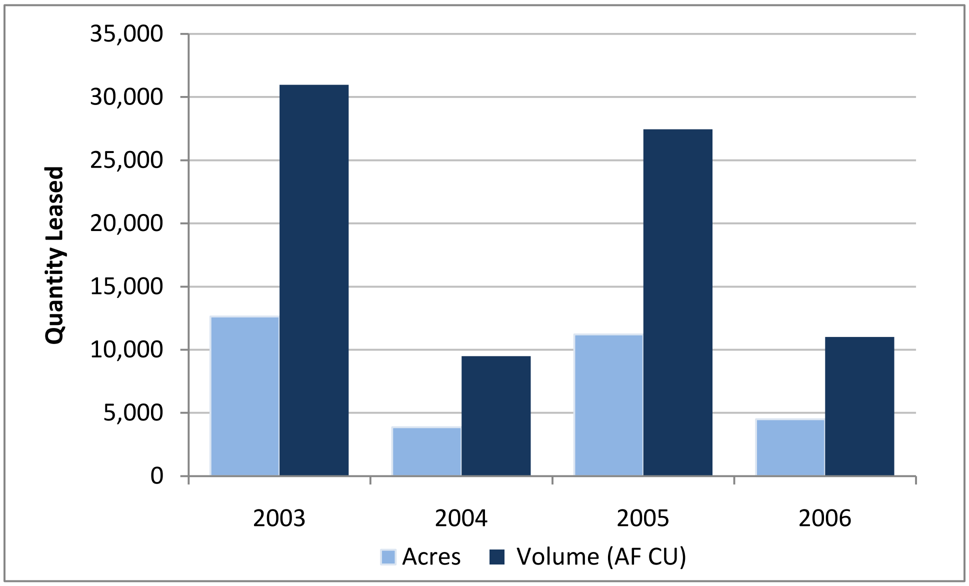
[4] General Accounting Office. March 2005. "Klamath River Basin." Report to Congress. GAO-05-283.

Figure 1 provides a summary of the volume of water leased under the Klamath Basin water leasing program.

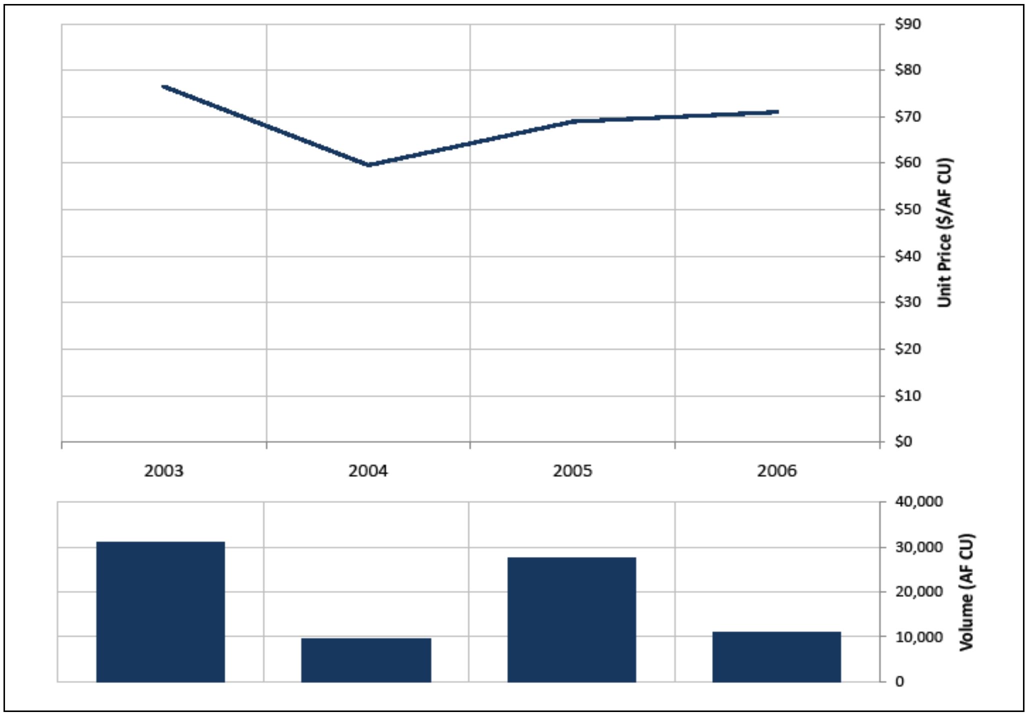
Figure 1
Acres and Volume of Water Leased in the Klamath Project
(Crop Idling Contracts)



. Source: U.S. Bureau of Reclamation, Klamath Basin Area Office.

As shown by Figure 2, average lease prices remained relatively constant over time ranging between $60 per AF in 2004 and $77 per AF in 2003. In 2006, the last year in which the program operated, the average price was approximately $71 per acre-foot ($174 per acre) on average for dryland farming.

Figure 2
Price and Volume of Water Leased in the Klamath Project
(Crop Idling Contracts)

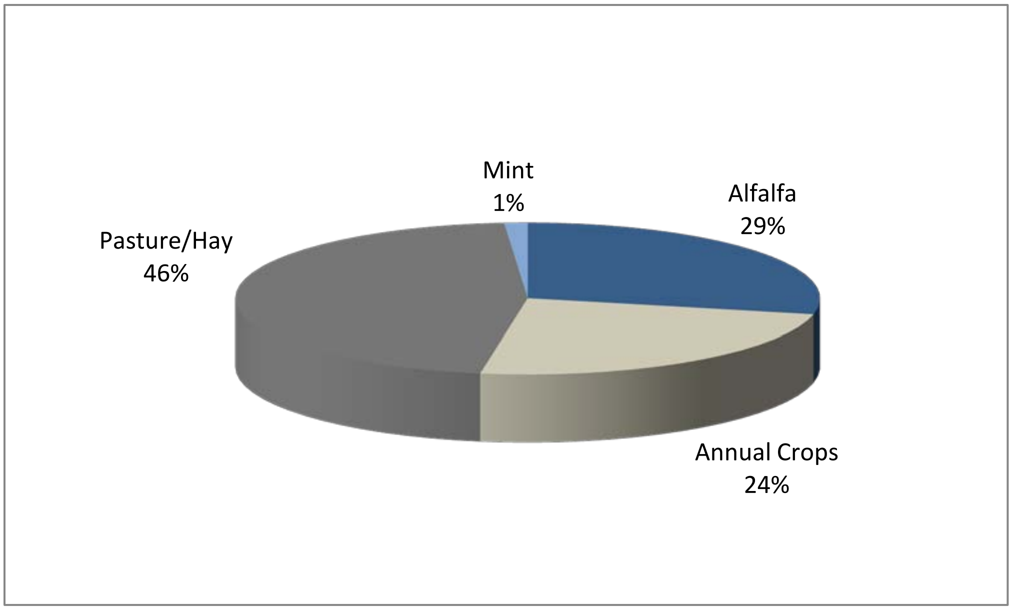


For crop idling/dryland farming, contracts were awarded under the following conditions:

- The enrolled land must remain idle during the irrigation season or is farmed using dryland farming.
- The land must have been irrigated in the past three years.

The applications were scored according to the volume of consumptive use associated with the irrigation, which varies by crop and soil type and the bid price. Preference is given to large volume bids with low bid prices. Most crop idling contracts have involved hay and pasture, as shown by Figure 3. Other annual crops made up 24 percent of the crop idling while mint comprised one percent of the total.

Figure 3
Crops Idled for Water Leasing in the Klamath Project



Klamath Basin Water Supply Enhancement: Off-Project Water Leasing

As previously described, the majority of the Off-Project water leasing has taken place in the Wood River Basin. Over time, the funding sources and payment structure for Off-Project water lease agreements have changed. Initially, the program paid water users according to estimated reductions in water use. Following 2002, enrolled acres were also required to reduce cattle stocking rates as part of the agreement. This analysis considers the combined payments from all funding sources to estimate the price paid for water. Nearly all land enrolled in the program has been utilized as irrigated hay and pasture for livestock production. Table 1 provides a summary of the payments from 2002 through 2009.

Table 1. Summary of Funding for Off-Project Water Leases

Year	USBR ($/Acre)	NRCS EQIP ($/Acre)	NRCS CSP ($/Acre)	NRCS AWEP ($/Acre)	Total ($/Acre)
2002	$300				$300
2003	$180				$180
2004	$62	$56 - $110			$118 - $172
2005	$75	$38 - $81			$113 - $156
2006	$80	$29 - $56	$38		$147 - $174
2007	$80	$26 - $56	$38		$144 - $174
2008		$125	$38		$163
2009			$38	$120	$158

In 2002, four landowners in the Wood River Basin participated in the Reclamation "Pilot Project Water Bank." Under this program, the participating irrigators were paid $175 per acre to cease diverting water in addition to a $125 per acre payment for an estimated reduction in crop consumptive use. The combined payments totaled $300 per acre. At the time, the reduction on crop consumptive use was estimated to be 2.5 AF per acre. The estimated consumptive use was revised downward in 2003 to 2 AF per acre in 2003. In subsequent years, analysis revised the estimate downward further to 1.03 AF per acre. This analysis applies 1.03 AF per acre to estimate the volume and price of all Off-Project water lease agreement. From 2004 through 2007, NRCS payments for reduced stocking rates supplemented payments by Reclamation. In 2008 and 2009, all funding for the agreements was provided through NRCS programs. The Conservation Stewardship Program (CSP) payments are the share of the payments that support practices related to dryland production but cover production practices that differ from those included in the Environmental Quality Incentives Program (EQIP) and the Agricultural Water Enhancement Program (AWEP).

Figure 4 provides a summary of the total acres and volume leased from 2002 through 2009. Following the initial year of the program, participation in the program has remained high fluctuating between 8,649 and 11,612 acres. The total irrigated area in the Wood Basin is estimated to be approximately 30,000 acres.

Figure 4
Lease Acres and Volume by Year, Upper Klamath Lake Watershed

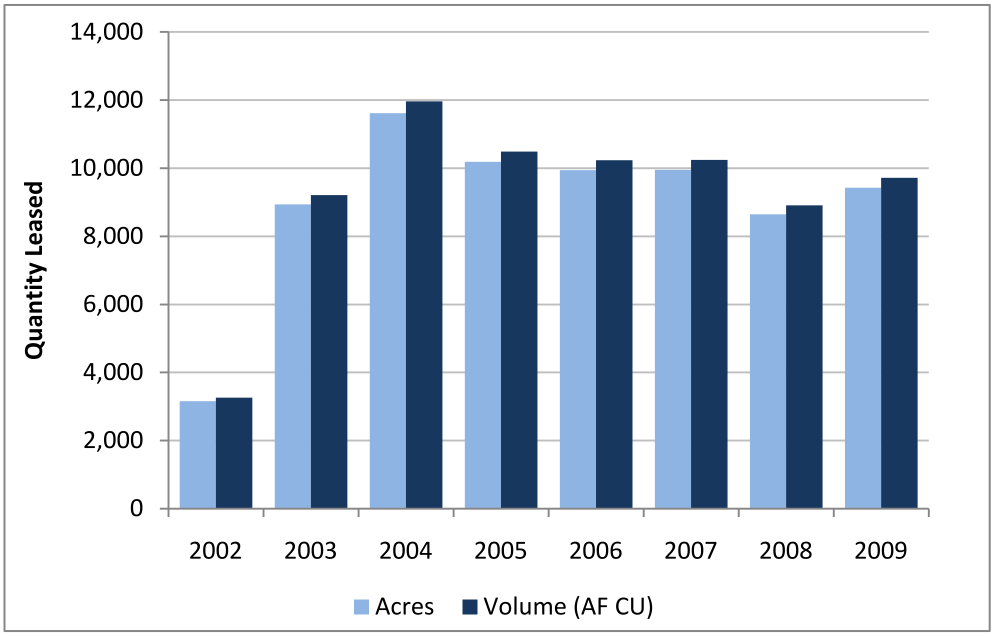
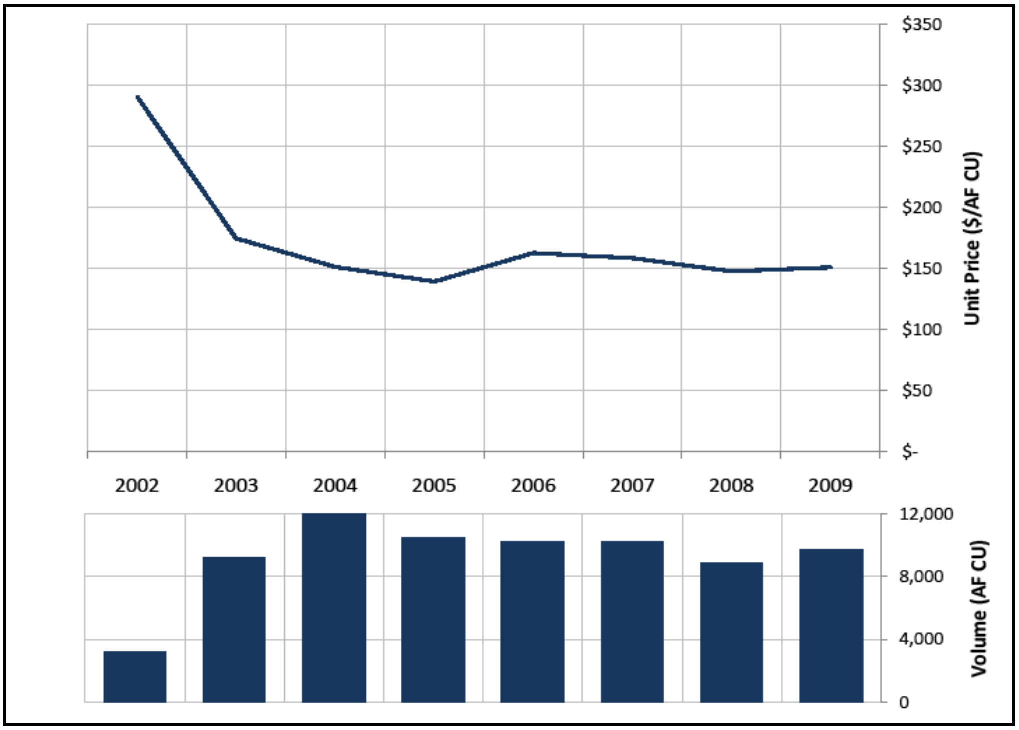


Figure 5 shows the average unit price paid for Off-Project leases and the total annual volume leased. As shown, the price was nearly $300 per AF during the first year of the program due, in part, to the unique contract structure and overestimates of crop consumptive use. In subsequent years, prices have fluctuated around $150 per AF. Despite the large price decline from the level set in 2002, total annual volume leased has remained high.

Figure 5
Lease Prices and Volume by Year, Upper Klamath Lake Watershed



Valuing Water Rights in the Upper Klamath Lake Watershed

Methodology

There are numerous methods available to estimate the market value of water rights. The selection of appropriate water valuation technique(s) is determined by the characteristics and nature of the water right being valued, the proposed contract terms, and the availability and quality of information. This analysis focuses on estimating the permanent sale value of water rights in the study area. Research completed for this study did not reveal any permanent sales of water rights separate from land within the study area. Further, there are an inadequate number of sales of agricultural land in recent years from which to determine the market value of water rights. However, the history of water right leasing in the Upper Klamath Lake Watershed as well as the prices observed in other markets can be used to develop estimates of permanent water right values in the study area. These valuation approaches are addressed below.

Agricultural Land Prices

As previously described, the land price differential method estimates the value of water rights by comparing market sale of agricultural land with and without water rights. The approach was applied to the Upper Klamath Basin by Jaeger (2004) using land price information provided by the Klamath County Assessor.[5] Following Faux and Perry (1999), Jaeger determined that the value of land and associated water rights in the basin varies according to land classification and geographic location.[6] According to the study, irrigated land values above Upper Klamath Lake are lower than irrigated land in other parts of the basin for the

[5] Jaeger, W.K., January 2004. "Conflicts over Water in the upper Klamath Basin and the Potential Role for Market-Based Allocations." Journal of Agricultural and Resource Economics 29(2):167-184.
[6] Faux, J., and G. M. Perry. "Estimating Irrigation Water Value Using Hedonic Price Analysis: A Case Study in Malheur County, Oregon," Land Economics. 75(1999):440-452.

same soil class. At the time, estimated water values above Upper Klamath Lake reported in the study ranged from approximately $200 to $1,500 per acre depending upon soil class.

More recent ranch appraisals in the Wood River Basin have estimated irrigated land values between $3,750 and $5,000 per acre although there is little market evidence in recent years to confirm this value range. Anecdotally, a large ranch property in the Wood River Basin has been listed at approximately $5,000 per acre for an extended period suggesting that the upper end of the range may be above market in the current economic climate. Knowledgeable experts in the area indicated that the current market value for irrigated land in the Wood Basin is approximately $3,800 to $4,000 per acre. According to some, these prices incorporate the amenity values associated with property in the Wood Basin and may exceed the agricultural productivity of irrigated land. As is the case in the Wood Basin, there have been few agricultural land sales in the Sprague Basin in recent years to support the reported value range. Knowledgeable experts in the area report irrigated land prices of $2,200 to $2,800 per acre. Land with groundwater rights and senior water rights are reportedly more marketable and valuable given the uncertain outcomes of the ongoing adjudication.

In the Wood Basin, previous water leasing has demonstrated that the property can remain agriculturally productive without irrigation. Reported cattle stocking rates and revenues in the Wood declined to approximately 50 to 60 percent of irrigated pasture values. Using this proportion, the value that water rights contribute to land in the Wood Basin is between $2,000 and $2,400 per acre.[7] In the Sprague Basin, there is generally less opportunity for viable agricultural production without irrigation. As a result, it is likely that the presence of a water right contributes a larger proportion to land value than in the Wood Basin – perhaps $2,000 to $2,300 per acre. In either case, there is little recent land market information from which to estimate water right values. As a result, the following sections estimate water right values in the Upper Klamath Watershed using alternative valuation approaches.

Comparative Market Analysis

This report identifies the relevant range of permanent values for water rights in the study area through a comparison of market prices paid in other regions. For consistency, all prices are presented in dollars per AF of consumptive use. This section provides a summary of water right sales in five selected market regions. Each market region differs according to characteristics of the basin, competing water demands, and the level of participation. However, water use in each of the regions is dominated by irrigated agriculture. In each of the markets, the majority of the water rights made available for sale were previously used in the production of hay, pasture, and annual crops. Water right buyers in the markets include agricultural producers seeking water rights for permanent crop production (e.g. wine grapes,

[7] This assumes that the value of land in the Wood Basin is entirely attributable to its ability to support agricultural production. Anecdotally, land prices in the Wood Basin include some amenity value. As a result, this estimate may overstate the contribution of water rights to land prices.

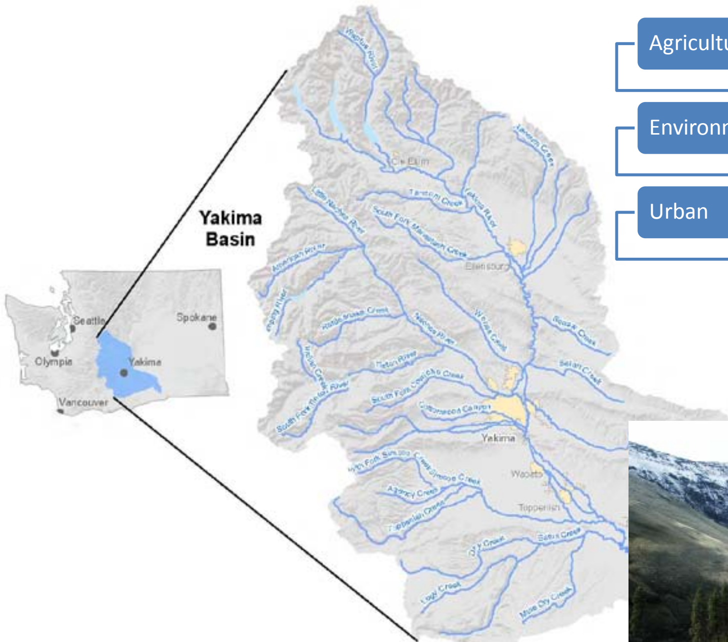
tree fruits), governmental and non-profit buyers for environmental and regulatory purposes, and purchases in support of urban water uses.

Water right sale activity in the following basins is considered in this analysis:

- Yakima River Basin, Washington
- Deschutes River Basin, Oregon
- Pecos River Basin, New Mexico
- Newlands Project (Truckee-Carson Basin), Nevada
- Platte River Basin, Nebraska

A summary of each of the market regions is provided in the sections that follow.

Yakima River Basin, Washington



Market Buyers

- Agriculture
- Environment
- Urban

Region Description

Washington's Yakima River Basin includes nearly 6,000 square miles of Yakima, Benton, and Kittitas counties. The Yakima River and tributaries originate in the Cascade Mountain Range, and flow southeast to the confluence with the Columbia River. Annual precipitation for low elevation areas ranges from seven to eight inches, with ten inches or more falling in the basin's higher elevations. Most of this precipitation occurs during the winter months from November to April necessitating irrigation throughout the spring and summer months to produce most crops.

The warm climate and rich volcanic soil in basin, combined with surface storage and an extensive irrigation network capable of supplying water to more than 450,000 acres, facilitate highly productive agricultural activity in the basin's Tri-County area. The Yakima basin river system serves as the area's primary source for irrigation water. Most of the area's population is employed in agriculture or in associated industries such as food processing, trucking, and warehousing. The farm sector is highly diversified, cultivating a variety of tree fruits (apples, apricots, cherries, pears, and peaches), vegetables (sweet corn, potatoes, and asparagus), grapes (wine and other), and field crops (hay and wheat), and a significant dairy and beef industry.

While the demand for water supplies in the area is growing, the Yakima basin is closed to new appropriations. To meet growing demand and obtain a reliable water source, agricultural, environmental, and urban interests frequently purchase and lease surface water rights. Sellers generally make water rights available by agreeing to temporarily or permanently fallow crop land planted to hay and pasture located in the upper portion of the basin. Agricultural users acquire water rights in support of permanent crop plantings (e.g. tree crops and wine grapes). Urban users lease and purchase water to provide reliable supplies during dry years and expand water right capacity to meet future demand. Environmental interests such as non-governmental organizations, the Department of Ecology, and the Bureau of Reclamation actively purchase and lease water to increase instream flows in the basin to improve habitat for migrating and rearing salmonids.

Water Right Sales

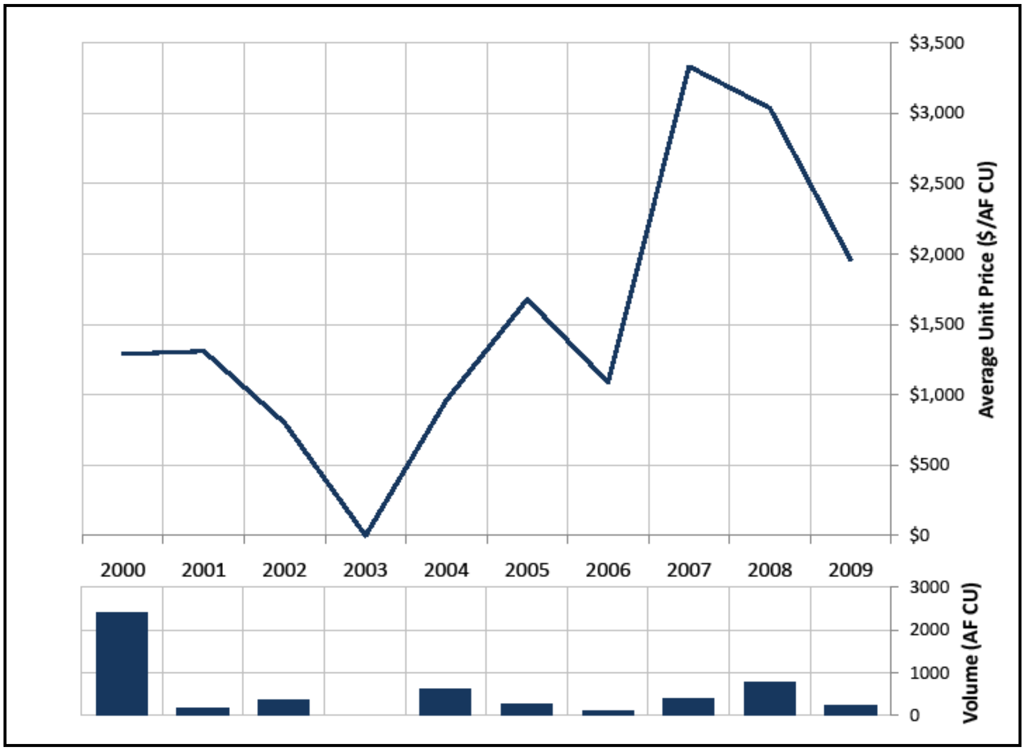
In addition to a lease market, there have been a number of permanent water right sales in the Yakima Basin. Consistent with the lease market, water right buyers consist of a mix of urban, agricultural, and instream interests. There have been a number of permanent sales of water rights involving nonconsumptive uses (e.g. hydropower, conveyance). These nonconsumptive water rights were purchased by environmental buyers to improve instream flow conditions for salmonids. The sales analyzed in this section are limited to transfers of consumptive surface water rights to be consistent with the source of water for leases in the basin. In addition, water right transactions involving partial exchanges or noncash payments were removed from the analysis. Table 2 summarizes the selected water right sales.

Table 2
Summary of Selected Yakima Basin Water Right Sales

	Volume (AF CU)	Unit Price ($/AF)
Average	146	$1,811
Median	112	$1,367
Max	880	$8,144
Min	1	$537
Count	36	36

Figure 6 provides the average unit price for the selected transactions by year. While prices varied as a result of differences in the volume of water involved in each transaction, buyer type, and location in the basin, prices have been increasing over the selected time period.

Figure 6
Permanent Water Right Sale Prices by Year in the Yakima Basin



The majority of water right transactions in the basin have transferred water rights to urban uses such as municipal water supply and real estate development. Agricultural and environmental buyers completed few of the selected water right sales, and account for a relatively small percentage of the volume transferred (see Figure 7). Aside from wine grape and tree fruit producers, there is limited demand for water rights by individual agricultural producers because much of the land in the basin is served by irrigation districts that are not actively seeking permanent water right acquisitions. Further, most agricultural users rely upon the lease market to supplement existing water supplies during drought years.

Figure 7
Percentage of Volume Purchased by End Use

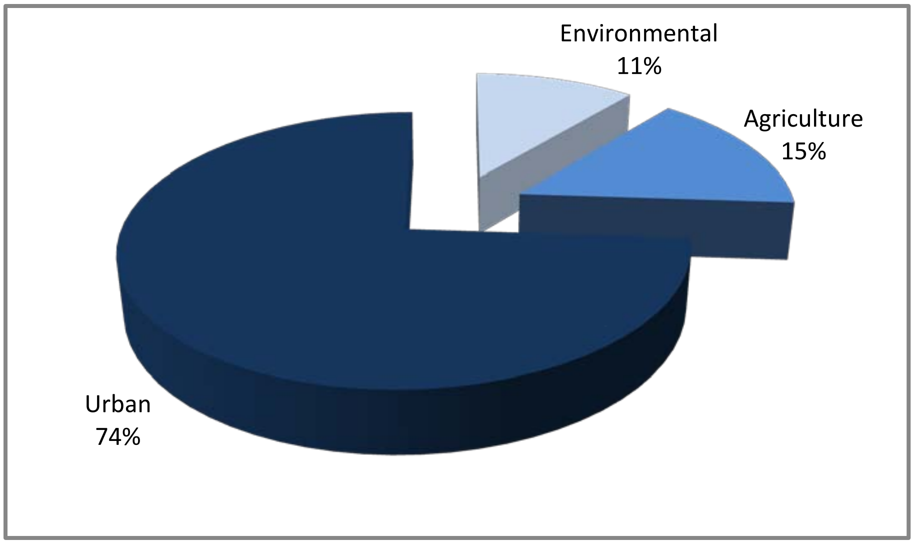
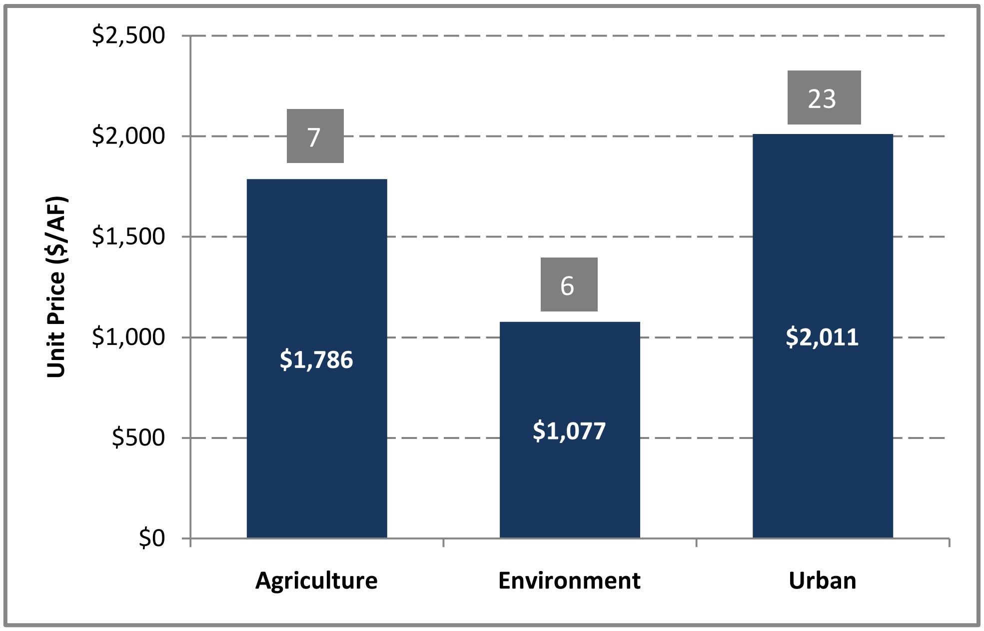
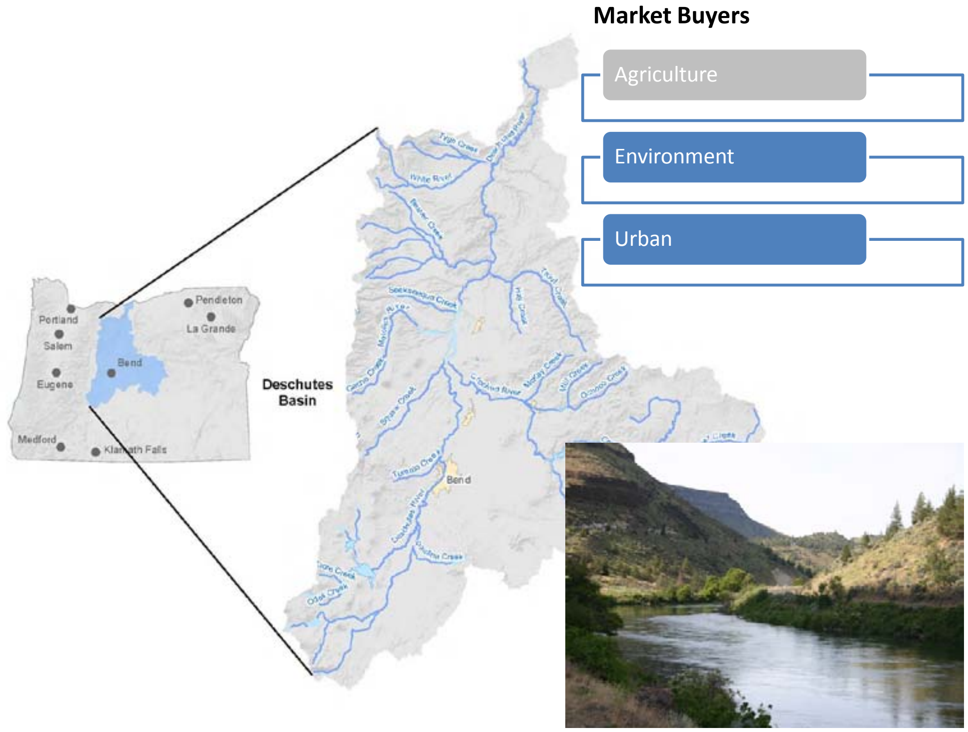


Figure 8 summarizes the average prices and number of transactions by end use category. As shown, urban buyers have paid higher prices than irrigation and instream buyers which is consistent with other markets where there are multiple buyer types. Urban buyers completed 23 purchases, where as agricultural and environmental buyers completed 7 and 6 transactions, respectively. Permanent water right sales in the Yakima Basin are expected to continue to consist primarily of purchases in support of urban uses due to growth in the region and regulatory conditions requiring mitigation for new groundwater uses.

Figure 8
Permanent Water Right Sale Prices by End Use in the Yakima Basin



Deschutes River Basin, Oregon



Region Description

The Deschutes River basin encompasses 172,517 acres north of the Klamath Basin in Central Oregon. The river flows from south to north where it enters the Columbia River east of The Dalles, Oregon. The basin includes portions of Crook, Jefferson, and Deschutes Counties as well as the Bend and Redmond metropolitan areas. Water from the Deschutes River has been traditionally diverted to support irrigated agriculture in the basin affecting flows in the "middle" Deschutes River from Bend to Lake Billy Chinook. Approximately 175,000 acres are irrigated in the basin. The majority of the irrigated land is located within Reclamation projects and private irrigation districts. In the upper basin, farm size has been decreasing over time as land has been divided into smaller parcels, or "ranchettes." A majority of the farms in the region are less than 50 acres in size and are not economically self-sustaining. Irrigated crops consist primarily of hay and pasture in support of livestock production. The upper basin in the Bend/Redmond area has been rapidly urbanizing. Between 2000 and 2005, Bend and Redmond populations expanded by approximately 30 percent with that state's overall population grew by 6 percent. The population in the Upper Deschutes Basin is expected to double by 2040.

Additional development of groundwater resources in the basin to support new water uses threatened to further reduce streamflows in the Deschutes River. To help manage the changing demands for water resources in the basin, the Deschutes Ground Water Mitigation Program was developed. The program requires mitigation for all new groundwater withdrawals and established rule under which mitigation can be developed. The program also allowed for the formation of mitigation "banks" to facilitate and manage the supply and demand for mitigation credits. In general, mitigation can be provided through temporary and permanent retirement of water rights as well as conserved water projects. Currently, there are two authorized mitigation banks operating in the Deschutes Basin.

Water Right Sales

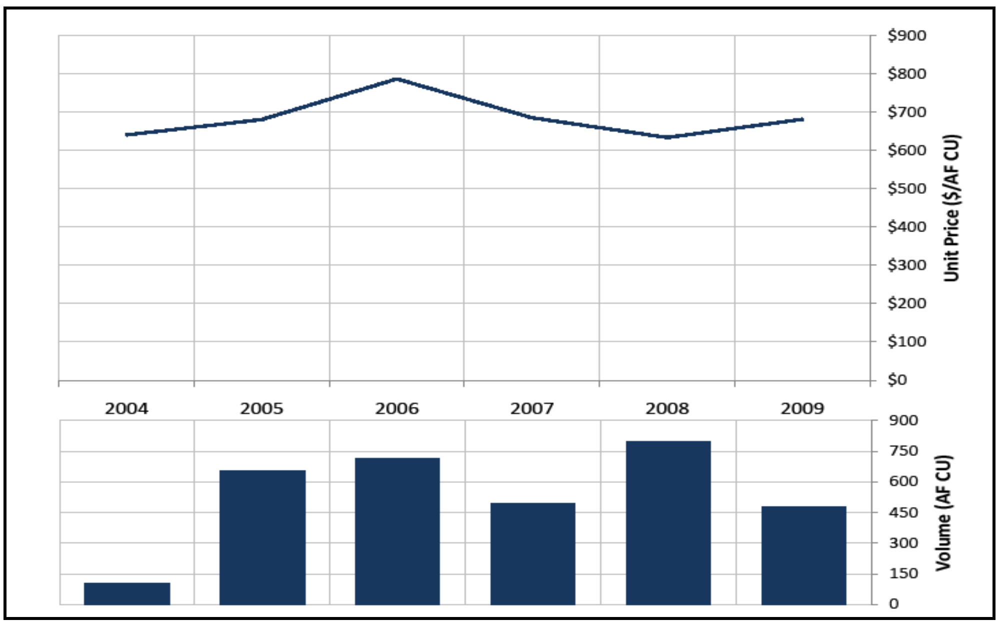
In addition to temporary water leasing activity primarily in support of instream flows, there have been a large number of permanent water right purchases in the Upper Deschutes Basin. The majority of the transactions have involved water rights within Central Oregon Irrigation District (COID) and Swalley Irrigation District (SID). Both of the irrigation districts have standing offers to purchase water rights from patrons that no longer have a need for the water. Prices are fixed by the district and are varied according to supply and demand conditions. Because patrons are not able to sell water rights to uses located outside of the district, the district represents the only practical buyer. On an annual basis, the district boards can elect to make a portion of the purchased water available for sale to outside entities. This "surplus" water is made available to Deschutes Water Alliance Water Bank members who include DRC, Redmond, Bend, and Avion Water Company. As shown in Table 3, permanent water right sale prices average $707 per AF in the Deschutes Basin and transfer an average volume of 10.76 AF. All prices and volumes were estimated according to a consumptive use volume of 1.8 AF per acre.

Table 3
Summary of Deschutes Basin Water Right Sales

	Volume (AF CU)	Price ($/AF CU)
Average	10.76	$707
Median	3.42	$556
Max	396	$3,778
Min	0.16	$79
Count	301	301

As described above, irrigation districts in the Deschutes Basin facilitate transfers of portions of their water rights among water users. Districts buy water from district members and new water users purchase water rights from the districts. As a result of this capacity as an intermediary, irrigation districts act as a regulating force in the water rights market. The districts set water right purchase prices at levels they deem appropriate. Due to the relatively low agricultural productivity in the region, the conversion of irrigated land, and the slowdown in real estate development, prices have remained steady and comparatively low. Figure 9 shows the average annual permanent purchase prices in the Deschutes Basin.

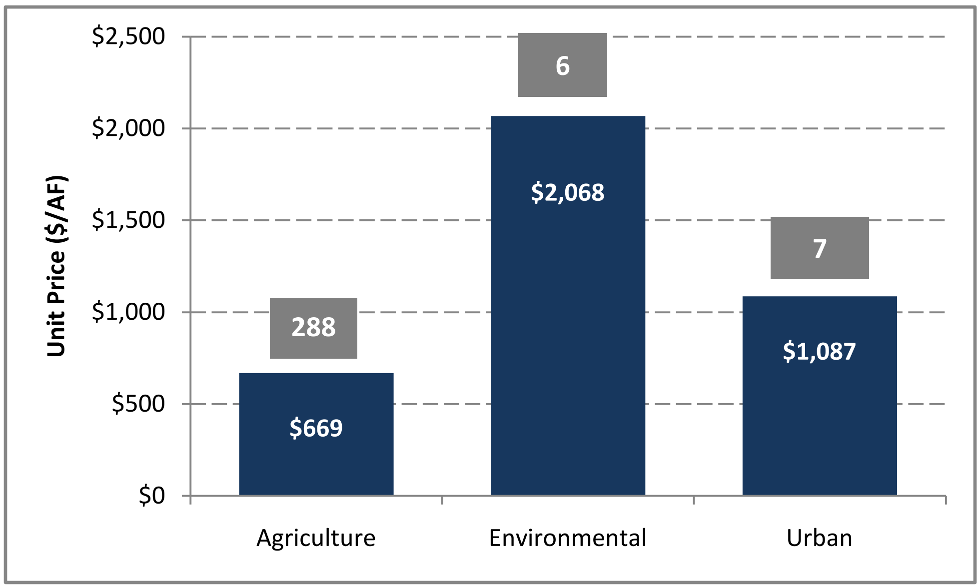
Figure 9
Permanent Water Right Sale Prices by Year in the Deschutes Basin



Irrigation districts are the most active buyers of Deschutes River water rights as they serve as an intermediary between water right buyers and sellers in the basin. The districts allow some water each year to be purchased by other users. To facilitate the "out of district" transfers, the districts charge "exit fees" which are designed to compensate the district for forgone annual assessment revenues. Exit fees amount to the present value of lost future assessment and O&M charges, discounted at a rate equivalent to the yield of 10-year Treasury Notes. Central Oregon Irrigation District exit fees amount to $611/AF CU, while the Swalley Irrigation District levies a $1,111 charge on each consumptive acre-foot permanently leaving district ownership.

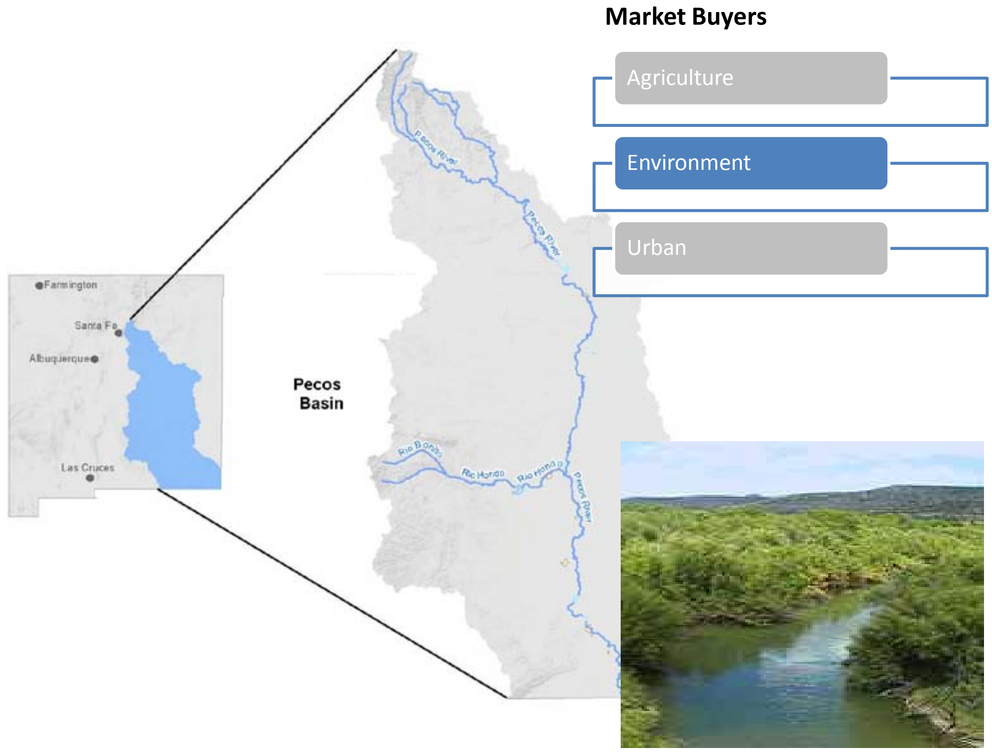
Figure 10 provides the average sale price by end use buyer type. The "exit fees" have been applied to purchases by environmental and urban buyers. As shown, there have been relatively few permanent purchases by environmental and urban buyers to date as most of the purchased water remains with the irrigation districts. Approximately 700 AF have been sold to non-district uses while more than 3,000 AF has been purchased by the districts over the years. The large inventory of water supply suggests that overall prices in the Deschutes Basin will remain low in the coming years.

Figure 10
Permanent Water Right Sale Prices by Buyer in the Deschutes Basin



Note: This analysis does not consider purchases of conserved water for environmental purposes. Conserved water purchases are characterized by unique conditions that make them incomparable to other permanent water right transfers.

Pecos River Basin, New Mexico



Region Description

New Mexico's Pecos River Basin occupies most of the eastern half of the state. The Pecos River flows southeast from the Sangre de Cristo Mountains to the Texas border. The basin's climate is characterized by warm, rainy summers, with average annual precipitation ranging from 10 inches per year in the south basin to 16 inches per year in the northern mountain region. While the Pecos Basin experiences frequent droughts and highly variable river flows, extensive storage and irrigation infrastructure facilitate cultivation of cotton, vegetables, and row crops in the lower basin.

As a result of its transboundary location, the Pecos Basin has a long history of interstate competition for Pecos River water. Water users in both Texas and New Mexico rely on Pecos River supplies to satisfy water demands. To resolve water conflicts the states, federal agencies, and irrigation districts entered into a series of compacts and settlement agreements beginning in 1948. These agreements stipulate a minimum quantity of Pecos River water that New Mexico must leave instream for Texas' use. By the early 2000's, water use in New Mexico's Pecos Basin had grown significantly, and New Mexico could no longer deliver the minimum water quantities to Texas required under the Pecos River Compact. When Compact deliveries were not met in previous years, New Mexico provided monetary compensation to Texas. However, in 2005, the Interstate Stream Commission (ISC) began purchasing and retiring existing water rights and farmland to increase Pecos River deliveries rather than making payments to Texas. This ISC water right acquisition program established a market for Pecos Basin water rights.

Water Right Sales:

The ISC is the most active water right buyer in the Pecos Basin. Because crop production and municipal populations are not growing substantially, agricultural and urban water users complete water right transfers infrequently. From 2005 through 2007, the state prohibited the ISC from acquiring water rights separately from land to avoid perceived negative third-party impacts of water right transfers on farming communities. The ISC received authorization to buy water rights separately from land in 2008. The prices the ISC offers for land with appurtenant water rights do not differ significantly from prices paid for water rights separate from land as bare land has little production potential and market value in the region. As a result, this analysis considers both transaction types. As displayed in Table 4, the ISC completed 53 acquisitions between 2005 and 2009 at an average purchase price of $1,913 per AF CU.

Table 4
Summary of Pecos Basin Water Right Sales

	Volume (AF CU)	Price ($/AF CU)
Average	437	$1,913
Median	278	$1,685
Max	2,100	$4,786
Min	23	$1,236
Count	53	53

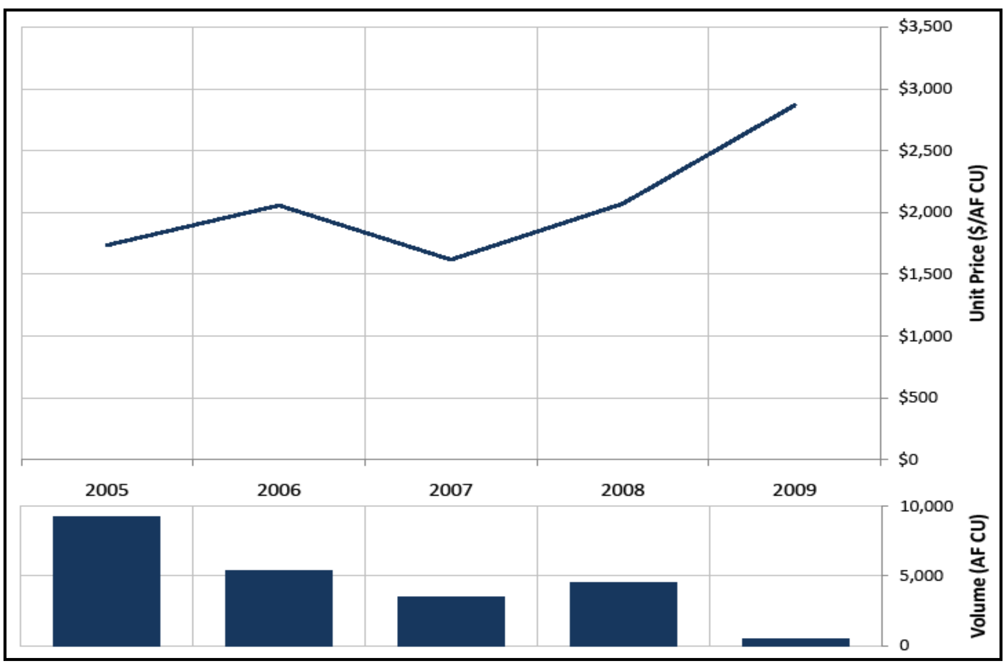
The ISC bases the prices it offers water right holders on a schedule that accounts for water right seniority, quantity, source, location, and characteristics of the land to which the water is appurtenant. Table 5 provides a summary of the general pricing guidelines by type of water right. Actual prices can vary somewhat from the ranges provided in the table according to individual negotiations. Senior water rights withdrawing from a source with a high level of hydraulic connectivity to the Pecos River attract the highest prices. The ISC's purchasing activity has increased the demand for water rights in the Pecos Basin and, over time, has increased water right prices (see Figure 11).

Table ___. Pecos Basin Water Rights Pricing Guidelines

Category	Price Range ($ Per Acre)
Hagerman Irrigation Company	$3,250 - $4,250
Senior Artesian	$3,750 – $5,250
Senior Shallow	$2,750 - $4,250
Senior Surface	$2,750 – $5,250
Junior Artesian	$2,250 – $3,250
When a purchase includes stacked water rights the price range will cover all appurtenant water rights, including stacked water rights. For example, for 10 acres that has senior artesian water rights with 5 acres of senior shallow water rights stacked on it the price range will be $3,750 - $5,250 per acre for the 10 acres plus $2,750 - $4,250 for the 5 acres with stacked senior shallow rights.	
1) One acre of water rights is equivalent to 2.1 AF CU. 2) The term 'Senior' indicates water rights with a priority date of December 31, 1946 or earlier.	

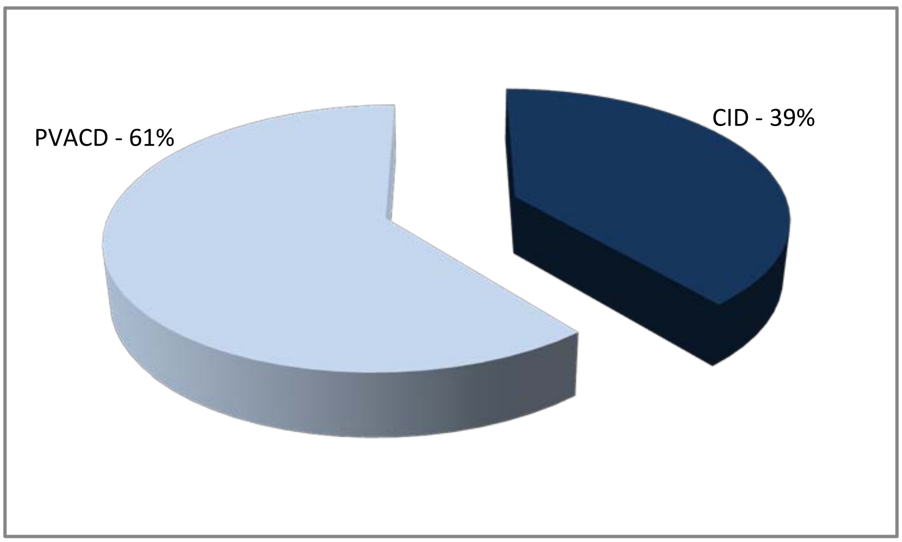
As shown, average prices have generally increased in the Pecos Basin since the ISC purchase program began. In 2005, the average sale price was $1,734 per AF CU. The price increased to more than $2,800 per AF CU in 2009. Over the same time period, the total annual volume acquired by the ISC has declined from more than 9,000 AF in 2005 to less than 500 AF in 2009.

Figure 11
Permanent Water Right Sale Prices and Volume by Year, Pecos Basin



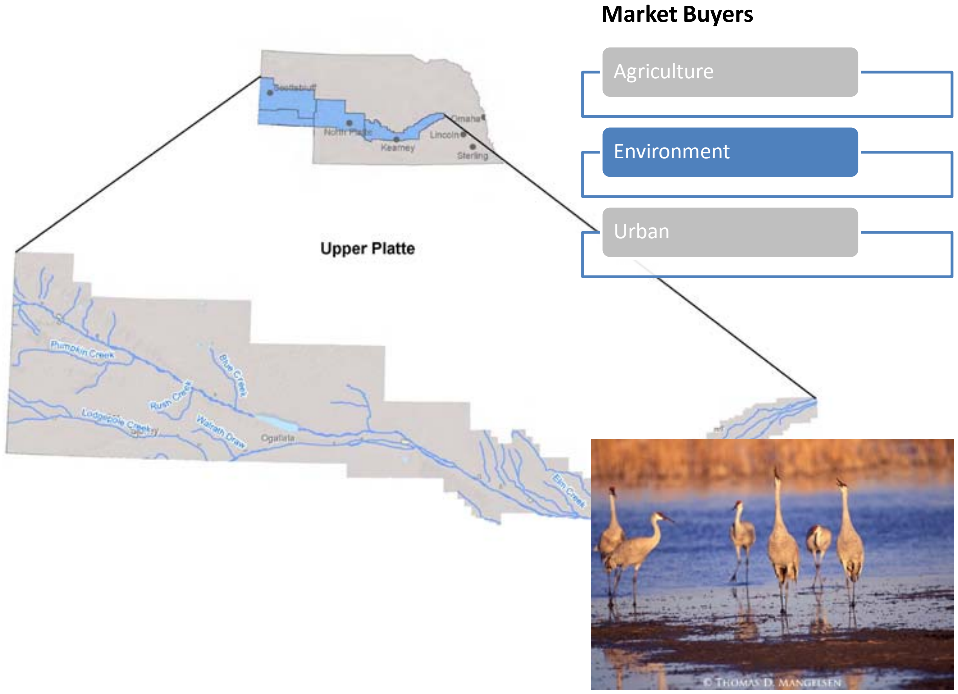
To date, the ISC has expended approximately $100 million on acquisitions to increase flows in the Pecos River to meet its obligations to Texas. These purchases have occurred in two areas: The Carlsbad Irrigation District (CID) and the Pecos Valley Artesian Conservancy District (PVACD). Purchases in the CID have primarily transferred irrigated land with appurtenant senior surface water rights. CID includes more than 25,000 irrigable acres and serves approximately 235 individual farms. In the PVACD, the ISC has acquired irrigated land with appurtenant groundwater rights, and senior groundwater rights separately from land. As shown in Figure 12, PVACD water rights serve as the source for the majority of the water transferred to instream use. There are a total of approximately 60,000 irrigated acres within PVACD. Hay is a principal crop grown in the region with an average annual yield of approximately 6.25 tons per acre.

Figure 12
Percentage of Volume Purchased by District



The New Mexico State Legislature allocated no funding to the ISC's water right acquisition program for 2010. This funding stoppage arose from reductions in the state budget necessitated by economic downturns. As a result, the ISC will not purchase water rights in 2010. The obligation to make compact deliveries to Texas will necessitate evaluating other options for increasing streamflows. In 2005, the state considered regulating junior water users as an alternative to the water purchase program. However, junior water rights primarily authorize groundwater use, and limited connectivity exists between groundwater and surface water in the Pecos basin, undermining the effectiveness of curtailing withdrawals. Since the purchase program is no longer funded, the OSE may reconsider curtailing junior water rights. In addition, while the ISC has not completed water right leases in the past, it may negotiate short-term leases and dry-year option agreements in the future to increase river flows during drought years.

Platte River Basin, Nebraska



Region Description

The Platte River basin encompasses approximately 90,000 miles of Colorado, Nebraska, and Wyoming. The North Platte and South Platte Rivers flow east from their Rocky Mountain headwaters to Nebraska, where they meet to form the Platte River. The Platte River spans the length of Nebraska to connect with the Missouri River at the state's eastern border. While the lower portion of Nebraska's Platte River Basin receives approximately 30 inches of precipitation annually, the upper basin receives only 16 inches.

Despite its limited rainfall, Nebraska's Platte Basin is characterized by active agricultural production. Irrigation withdrawals from the Platte River, its tributaries, and hydraulically connected aquifers facilitate cattle and corn cultivation in the area. As a result of the significant streamflow reductions stemming from high levels of irrigation water use, Nebraska declared the Upper Platte Basin over-appropriated in 2004. This declaration stipulated that all new water users offset stream depletions by adding water to the river. The 2004 decision, in conjunction with the 2006 Platte River Recovery Implementation Program (PRRIP), further requires that Natural Resource Districts (NRD's) increase instream flows to 1997 levels to improve fish and wildlife habitat.

To accomplish the water level improvement objectives outlined in the 2004 declaration and the PRRIP, NRD's began planning water banking programs in 2007. Currently, only the Central Platte NRD (CPNRD) maintains an active water bank. The CPNRD buys irrigation water rights from farmers, retires the land from agricultural production, and leaves the acquired water instream. New water users buy offset credits from the CPNRD water bank to mitigate for reductions in water levels associated with new withdrawals. The CPNRD has also made progress toward increasing streamflows to 1997 levels, but the district must complete additional purchases for water levels to fully recover.

Water Right Sales

The CPNRD has completed 31 permanent water right purchases since the water bank's inception in 2007. Each of these acquisitions transferred water appropriations from agricultural water uses to instream flow purposes. The CPNRD has added a total of approximately 1,863 AF CU to the Platte River for an average price of $1,459 per AF CU. However, municipal and industrial developers purchased a significant portion of the CPNRD's acquired water to offset new water uses, resulting in limited net increases in water levels. Until recently, new water users purchased water from the bank at a rate of $2,750 for each acre-foot of streamflow reductions caused by their withdrawals. Because selling banked water to new users slows the CPNRD's progress toward achieving 1997-level streamflows, the bank is no longer offering mitigation water for sale.

Table 6
Summary of Platte Basin Water Right Sales

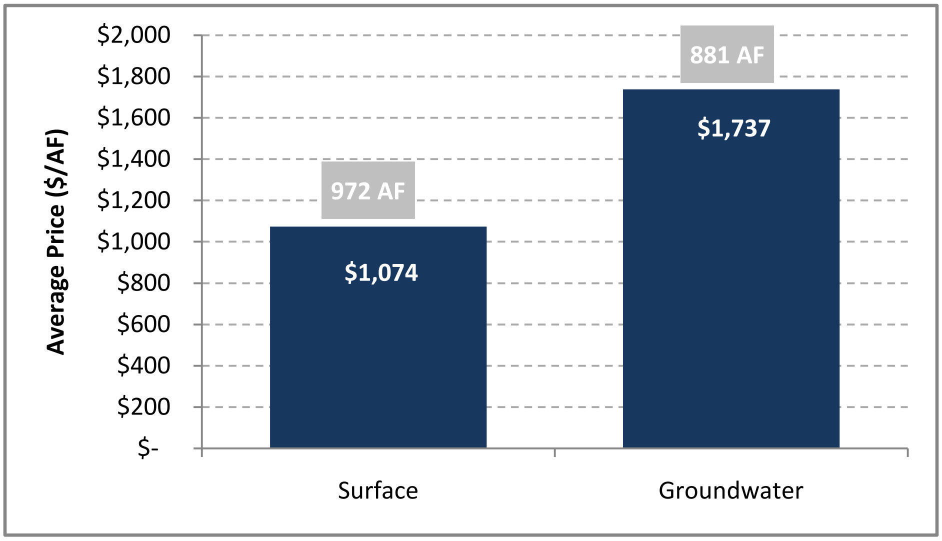
	Volume (AF CU)	Price ($/AF CU)
Average	60	$1,459
Median	52	$1,636
Max	130	$2,280
Min	4	$401
Count	31	31

The price variability among CPNRD acquisitions is primarily attributable to differences in the impact of each purchased water right on Platte River flows. The CPNRD bases its offer price on the quantity of water added to the river by retiring land from agricultural production. The seller receives compensation only for the portion of transferred water rights that increases streamflows. As a result, unit prices are higher for water rights more directly connected to the Platte River than for water rights exerting little influence on river levels. Other factors influencing prices the CPNRD pays for water rights include source and point of diversion. Prices for surface water rights are lower than for groundwater rights (see Figure

13), and water rights located further upstream attract higher prices than downstream appropriations.

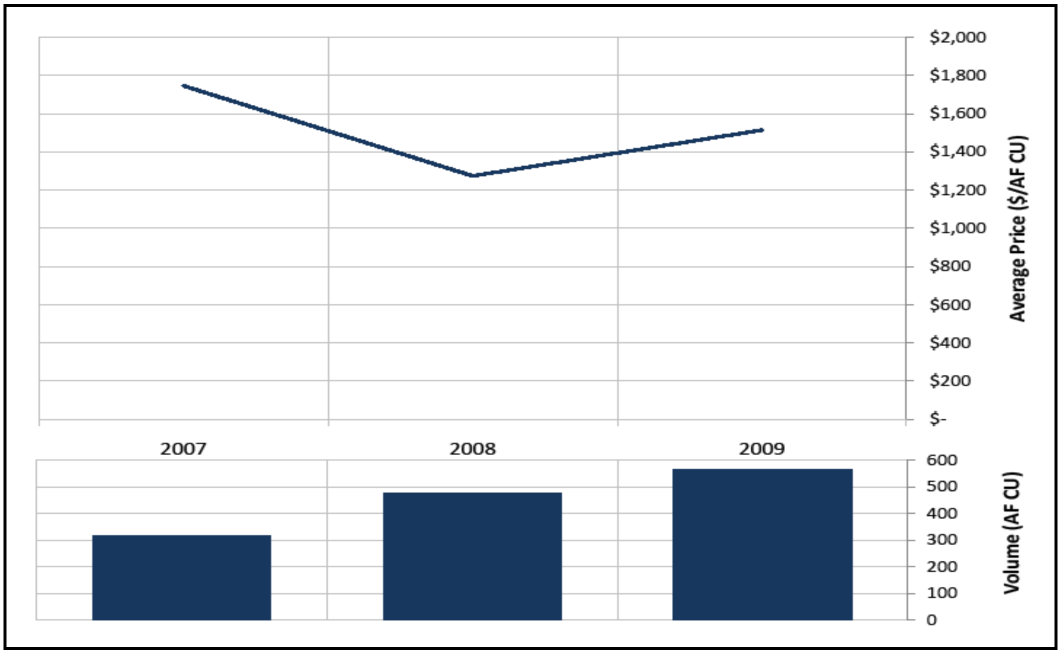
The majority of the water purchased was previously used to irrigate corn in the region. Corn has a relatively low consumptive use of approximately 0.9 AF per acre. Unlike many other regions, agricultural producers can grow a viable crop in the region without the aid of irrigation. Non-irrigated crop choices include soybeans and sorghum.

Figure 13
Price and Volume Traded by Source



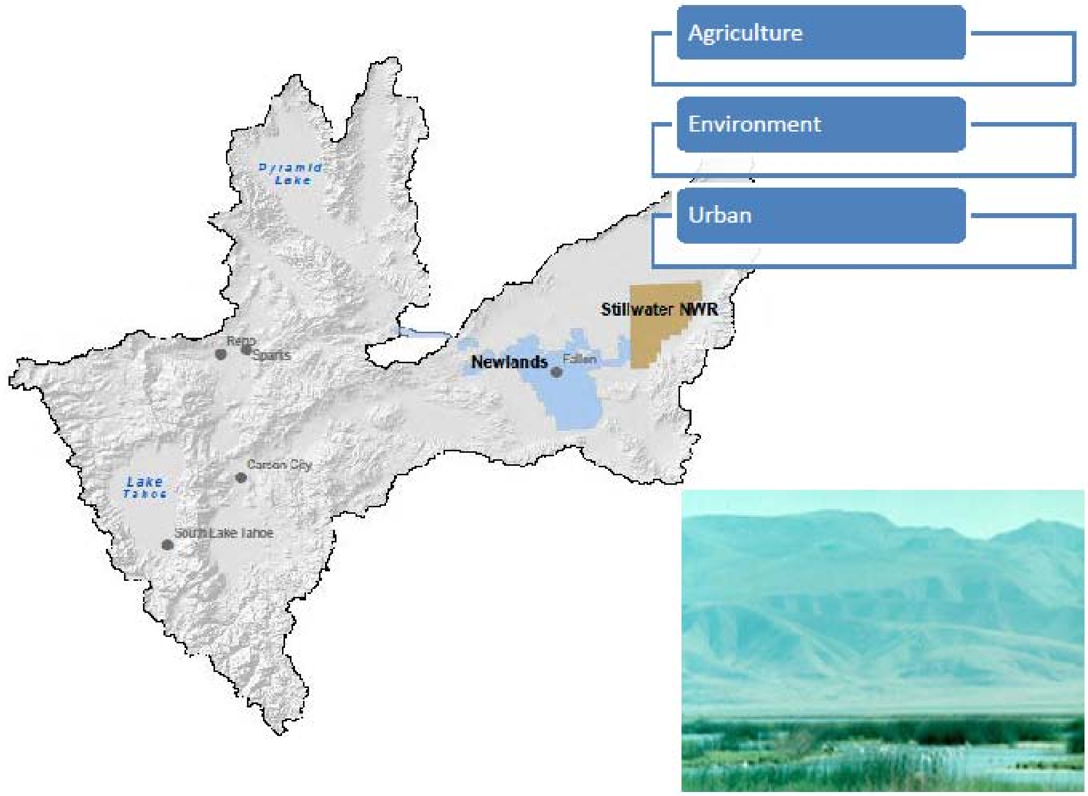
Annual average water right prices have fluctuated since the water bank's inception (see Figure 14). In 2008, the CPNRD primarily purchased surface water rights that held an indirect hydraulic connection with the Platte River, resulting in a low annual average price. The CPNRD's purchasing activity has increased over time, with 52% of the CPNRD's total acquisitions reaching completion in 2009.

Figure 14
Annual Transaction Activity and Average Price



While the CPNRD is the most active water right buyer in the Upper Platte Basin, three additional NRD water banks are in planning and development phases. Water right transaction activity and prices are expected to increase as the Twin Platte NRD, the North Platte NRD, and Tri-Basin NRD implement banking programs and begin acquiring water rights.

Newlands Project-Carson Division, Nevada



Region Description

Nevada's Truckee River Basin includes 3,060 square miles of Northeastern California and Western Nevada. The Truckee River originates in the Sierra Nevada Mountains, and flows northeast from Lake Tahoe to Pyramid Lake, where it terminates. Despite the basin's arid climate, reservoirs near the Truckee River headwaters allow large cities and crop cultivation to flourish. While the rapidly-growing municipal areas of Reno and Sparks account for a large portion of water use in the upper basin, water use in the lower Truckee Basin below the Derby Diversion Dam primarily supports agricultural production and water levels in Pyramid Lake.

The Truckee-Carson Irrigation District (TCID) diverts an average of 183,000 AF annually at the Derby Diversion Dam for agricultural use within the Newlands Reclamation Project in the Lower Carson River Basin. This interbasin water transfer, in conjunction with Lahontan Reservoir's substantial storage capacity, facilitates agricultural production in the Newlands Project where precipitation averages only 3.9 inches annually. Newlands Project irrigators primarily cultivate alfalfa hay, grass hay, corn, pasture, and grains.

The market for Truckee River water rights upper portion of the basin has been characterized by competition among high-value urban users. Rapid growth and development activity in the Reno-Sparks urban area caused water right prices to reach $50,000 per AF during 2005 and 2006. Currently, prices have fallen to below $8,000 per AF in the Reno-Sparks region due to the decline in the real estate market. In the lower portion of the basin, where the Newlands Project is located, there is limited urban demand for water rights. As a result, the market prices and trading activity have not experienced the high prices and variability observed in the Reno market. Water right sales within the Newlands Project are described below.

Water Right Sales

Water right transactions in the Newlands Project region primarily transfer privately owned TCID water rights to new users. Because the Newlands Project area is growing less rapidly than the Truckee basin, lower levels of competition for water supplies exist in the region, resulting in significantly lower trading activity and water right prices than observed in the Truckee Basin near Reno. Over the 43 transactions observed in the Newlands Project between 2002 and 2009, prices have averaged $1,062 per AF CU. The average volume traded per transaction is 51 AF CU.

Table 7
Summary of Selected Newlands Project Water Right Sales

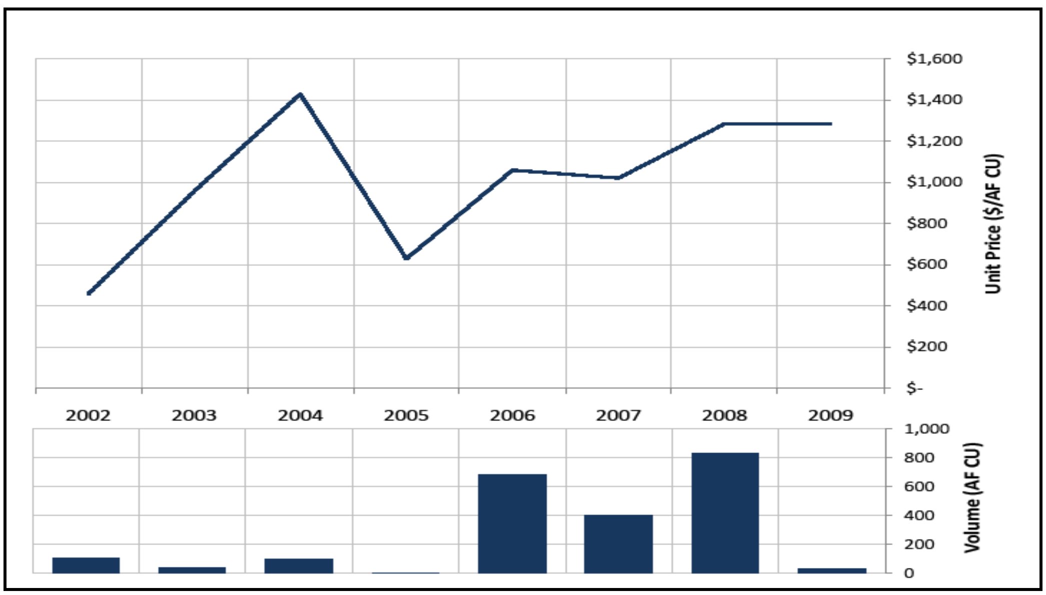
	Volume (AF CU)	Unit Price ($/AF)
Average	51	$1,062
Median	13	$1,086
Max	315	$1,500
Min	0.63	$457
Count	43	43

The U.S. Fish and Wildlife Service (USFWS) is the most active buyer of water rights in the Newlands Project. Section 206 of Public Law 101-618 (The 1990 Fallon Paiute-Shoshone Indian Tribal Settlement Act/Truckee-Carson-Pyramid Lake Water Rights Settlement Act) directed the United States Secretary of the Interior, through the U.S. Fish and Wildlife Service, to purchase water rights in the Newlands Project, with or without land, and to transfer the water to sustain and expand the Stillwater Wildlife Refuge. The goal of the Water Right Acquisition Program is to sustain a long term average of 25,000 acres of wetlands in the Lahontan Valley. Currently, the program is offering between $3,000 and

$4,000 per acre for water rights. The program is targeting 75,000 acre-feet and to date has acquired approximately 39,000 acre-feet.

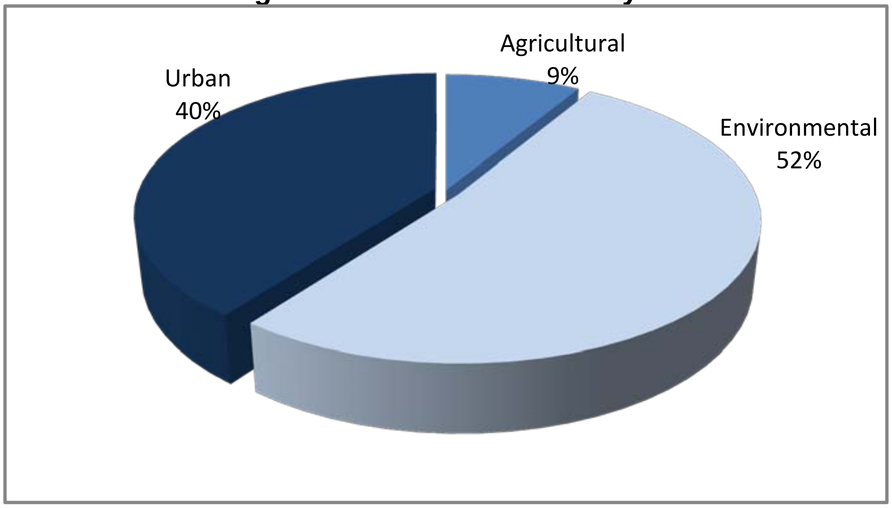
Nevada Assembly Bill 380 established a second water purchasing program in the Newlands Project. The bill, which became law in June of 1999, established the "Newlands Project Water Right Fund" with the goal of settling water right disputes between the Pyramid Lake Paiute Tribe and irrigators in the Fallon area. The Fund has been used to purchase disputed water rights, with a stated goal of acquiring 6,500 water right acres from willing sellers. The purchased water rights are subsequently retired. The Carson Water Subconservancy District has been administering the fund and the acquisition program. AB 380 was initially targeting 6,500 water right acres. The program was launched in 1999 and legislatively authorized for 5 years. It was delayed in implementing because of the need to conduct a federal EIS and as a result obtain a 2 year extension. The program officially ended in June of 2006 having acquired between 4,300 and 4,500 acres. Because the program did not reach the target, there is currently a "son of AB 380" program that is being contemplated but has not yet been enacted.

Figure 15
Water Right Sale Prices by Year and Volume, Newlands Project



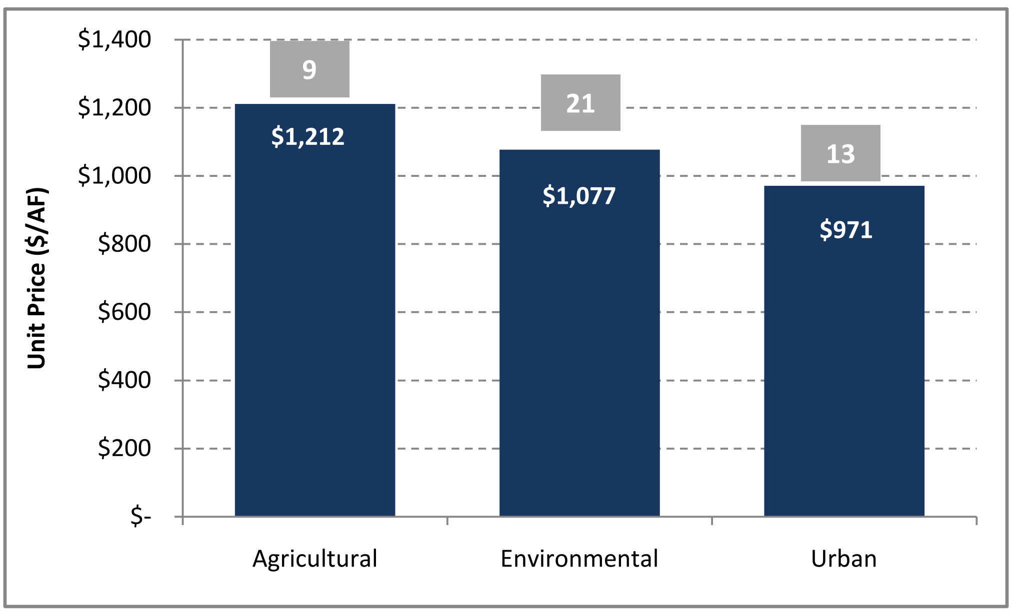
As shown by Figure 16, the majority of the water right purchases have been in support of environmental improvements at the Stillwater National Wildlife Refuge or associated with the AB 380 program. Churchill County represents the most active urban water right buyer in the area, and has paid prices ranging from $356/AF to $1,111/AF CU for water rights.

Figure 16
Percentage of Volume Purchased by End Use



In general, the prices paid by buyer type are fairly uniform in the region. As shown on Figure 17, agricultural buyers have paid the highest prices on average while urban buyers have paid the lowest prices. This is counter to most markets where urban buyers pay the highest prices.

Figure 17
Permanent Water Right Sale Prices by End Use in the Newlands Project



Comparison to Upper Klamath Basin

The market examples provide a price range for water right sales that can be compared to conditions in the Upper Klamath Basin to assist in establishing an estimate of value for future permanent acquisitions of water rights. As describes, water right prices vary significantly among the market regions complicating their use as benchmarks of value for the Upper Klamath Basin. For example, average prices range from $707 per AF CU in the Deschutes Basin to $1,913 per AF CU in the Pecos Basin. This section summarizes general differences in basin characteristics and water right market activity in order to assess relative value in the Upper Klamath Basin. The selected determinants of water value considered in the table include the following:

- **Physical Characteristics:** The general physical characteristics of each market region are provided as a comparison to the Upper Klamath Basin. The amount of irrigated acreage in a region represents the total potential supply of water rights available to support new water uses. In general, the more irrigated acreage there is relative to new water demands, the lower the market price for water rights.
- **Agricultural Production:** Agriculture represents the primary water user in each of the market regions, including the Upper Klamath Basin. Therefore, consideration of the characteristics of agricultural production in the market regions can assist in identifying those most similar to the Upper Klamath Basin. Water right prices in regions with the most similarity are the most relevant to selecting an appropriate water right value range for the Upper Klamath Basin. This analysis considers the average crop yield for hay, a crop that is commonly fallowed to make water rights available for new uses. In addition, this analysis considers the amount of permanent crop plantings (e.g. wine grapes, tree fruits, etc.) in the market regions. Markets with more permanent crop plantings tend to exhibit a higher level of competition and water right prices.

- **Water Right Buyers:** In all of the market regions considered, irrigators represent the primary water right sellers. Further, most water right sales come from land used to produce hay and pasture. However, the types of water right buyers vary among the market regions. This analysis aggregates buyer types into three categories – agriculture, environmental, urban. Markets with more buyer types competing for the same water rights are expected to exhibit higher water right prices. Similarly, market regions with active urban water right buyers are expected to have the highest prices.
- **Socioeconomic Factors:** Socioeconomic factors provide an important indication of the highest and best use (highest value) for water in a region. Generally, areas experiencing a high level of development activity have higher water prices. This report presents information on population growth and water right transactions by buyer type to assess the influence of urban development on water market activity and

water right prices. The Upper Klamath Basin is sparsely populated and has experienced limited population growth and urban development.

- **Water Market Exchange Process:** Water markets can be classified according to the process governing water right trades. In some markets, the trading is "centralized" because there is a single buyer or coordinated group of buyers operating in the marketplace. Other markets are "de-centralized" in that there are many individual agents seeking to buy and sell water rights. In general, centralized markets tend to exhibit lower and more uniform water right prices.

- **Climate (Rainfall and Crop Consumptive Use):** Climate conditions can influence water right prices by affecting the importance of water supplies for agricultural production as well as crop suitability and productivity. Average precipitation during the growing season is included in this analysis as one measure of the importance of irrigation supplies. In addition, the reported crop consumptive water use for alfalfa hay is provided. In general, it is expected that markets with a higher level of summer precipitation will have more water supply available and more dryland crop alternatives thereby reducing the incremental importance of irrigation and lowering water right prices. Similarly, market regions with higher crop consumptive use levels will tend to have higher water right prices due to higher overall water demand and fewer dryland crop alternatives.

- **Water Right Sale Activity:** The average water right price is reported for each market according to the price per AF CU as well as the price per acre. In addition, the average annual sale volume is provided.

- **Comparison to Upper Klamath:** A relative comparison to conditions in the Upper Klamath (Wood and Sprague) is provided in order to identify those market regions that are the most similar to the study region. The most similar market regions are used to establish a relevant price range for water rights in the Upper Klamath Basin. A "+" indicates that the average reported price is higher than the expected permanent water right sale price in the Upper Klamath Lake Watershed. Similarly, a "-" indicates that the average price is lower. Markets that are considered to be the most comparable to the Upper Klamath Lake Watershed are indicated with a "+/-".

The following table summarizes the characteristics of each basin included in this analysis and provides an assessment of expected water right values in the study region through the comparative markets analysis. As shown, there is significant variation in the average prices paid across market regions although 4 of the 5 markets have average prices above $1,000 per AF CU. As previously described, the low end of the range reflects prices paid in the Deschutes Basin for water rights associated with land that is not actively irrigated. The high end of the range is associated with prices paid to irrigators in the Pecos Basin where crop yields are generally higher than the other markets.

	Wood Basin	Sprague Basin	Yakima Basin	Deschutes Basin	Pecos Basin	Platte Basin	Newlands Project
Physical Characteristics							
Basin/Market Area (Acres)	465,300	1,021,300	1,366,818	1,838,000	6,386,700	1,385,900	151,960
Irrigated Acres	30,000	81,650	450,000	164,000	85,000	586,244	61,000
Water Supply Reliability	Good	Moderate	Moderate	Good	Good	Good	Moderate
Agricultural Production							
Average Hay Yield (tons/Acre)	n/a	3.8	4.6	2.7	6.0	3.9	4.6
Avg. Irrigated Land Value ($/Acre)	$4,000	$2,800	$3,500	$2,000	$5,000	$3,000	$3,750
Avg. Hay Crop Revenue ($/Acre)	n/a	$380	$414	$335	$785	$291	$368
Dryland Crop Opportunities	Yes	Limited	Limited	Limited	Limited	Yes	Limited
Permanent Crop Area (%)	0%	0%	40%	0%	0%	0%	0%
Water Right Buyers							
Urban			Yes	Yes	Limited		Limited
Agricultural			Yes				Limited
Environmental	X	X	Yes	Yes	Yes	Yes	Yes
Water Market Exchange Process							
Centralized				X	X	X	
De-Centralized			X				X
Climate Conditions							
Summer Precipitation (inches)	8.6	5.7	6.3	5.8	11.1	14.6	3.0
Crop Consumptive Use (AF/Acre)	1.03	1.6	2.5	1.8	2.1	0.9	3.5
Socioeconomic Factors							
Basin Population (2000)	263	2,341	309,506	159,970	176,107	234,059	29,310
Population Growth (2000-2007)	10.1%	3.9%	11.2%	29.1%	2.4%	2.8%	13.4%
Water Right Sale Activity							
Average Price ($/AF CU)			$1,811	$707	$1,913	$1,459	$1,062
Average Price ($/Acre)			$4,348	$1,247	$4,018	$2,052	$3,757
Avg. Annual Sale Vol. (AF CU)			526	540	4,632	453	274
Comparison to Upper Klamath			+	-	+	+/-	+/-

Yakima Basin – Competition for water right in the Yakima Basin is high with environmental, urban, and agricultural water users seeking to acquire senior water rights to support new uses. Due to the high level of competition and comparatively higher valued agricultural production in the Yakima Basin, water right prices are expected to be above those in the Upper Klamath Basin where there is no history of permanent water right sales separate from land.

Deschutes Basin – Due to rapid urban growth in formerly irrigated areas and relatively poor agricultural production conditions, there is a large supply of water rights available to support new uses in the Deschutes Basin. The irrigation districts control the supply of water rights and represent the only potential buyers for patrons within a district. As a result, they have the ability to set prices as well as control the volume of water available for new uses. Due to these factors, water right prices in the Deschutes Basin are considered to be below prices applicable to the Upper Klamath Basin.

Pecos Basin – The primary sales of water rights in the Pecos Basin have involved purchases of water rights by the state of New Mexico to support flow improvements in the Pecos River. There is limited urban growth in the basin and therefore limited demand for water rights in support of new urban uses. Crop yields and crop suitability in the Pecos Basin is significantly higher than in the Upper Klamath Basin. As a result, the prices observed in the Pecos Basin are considered to be above those that are relevant to the Upper Klamath Basin.

Platte Basin – The state of Nebraska is purchasing water rights in an effort to improve streamflows in the Platte River for environmental benefit. Like the Upper Klamath Lake Watershed, agriculture represents the primary user of water in the basin. Commonly grown crops include irrigated corn and hay. The market is "centralized" in that the NRDs represent the primary water right buyers in the market. While there is demand for water in support of new urban uses due to regulation requiring mitigation, to date the mitigation has been provided through sales of water previously purchased by the NRDs. As a result, there is limited competition for water rights in the Platte Basin. This market structure is anticipated to be similar to that which will be present in the Upper Klamath Lake Watershed. As a result, prices in the Platte Basin are considered to be directly comparable to the Upper Klamath Lake Watershed.

Newlands Project - Within the Newlands Project, agricultural water rights are being purchased in support of wetlands at the Stillwater National Wildlife Refuge and some water rights have been purchased by Churchill County for new urban uses. In addition, water rights have been purchased and retired as part of a state program designed to resolve a dispute over water rights. Similar to the Klamath Basin, hay and pasture are the primary crops produced within the Newlands Project. Land values, crop yields, and crop revenues are also similar to those in the Upper Klamath Lake Watershed. As a result, prices in the Newlands Project are considered to be directly comparable to the Upper Klamath Lake Watershed.

There are a number of challenges associated with using information from other market regions to establish market prices for the study region. However, in the absence of transaction information specific to the Upper Klamath Lake Watershed, the comparative markets analysis can assist in identifying a relevant range of market value. As described above, the Newlands Project and Platte Basin were selected as the most comparable to the Upper Klamath Lake Watershed. Water right market activity is dominated by a central buyer in these two markets and there is limited to no competition from other agricultural and urban water right buyers. This is considered to be consistent with market conditions that have and will exist in the study region. Similarly, agricultural production in the two market regions is dominated by irrigated annual crops. This is also consistent with agricultural production conditions in the Upper Klamath Lake Watershed. Reported prices range from $1,062 per AF CU in the Newlands Project to $1,459 per AF CU in the Platte Basin. Due to the lower land values and lower agricultural productivity the lower end of the value range is considered appropriate for Sprague Basin. The higher end of the value range is considered appropriate for the Wood Basin where agricultural production costs are relatively lower and the growing season is somewhat longer. Due to the higher estimated consumptive use in the Sprague Basin, the total estimated value per acre is higher than in the Wood Basin. Table 8 summarizes the estimated water right values obtained from the comparative markets analysis.

Table 8
Estimated Water Right Values – Comparative Markets Analysis

Basin	Purchase Price ($/AF CU)	AF CU/Acre	Purchase Price ($/Acre)
Wood	$1,459	1.03	$1,503
Sprague	$1,062	1.60	$1,699

Lease Price Conversion

The market comparison included above is one method of using available water market price information to establish an appropriate water right price range for the Upper Klamath Basin. Another possible method is to use the lease prices that have been established in the Upper Klamath Basin since 2001 to estimate the equivalent sale value. This memorandum provides empirical analysis supporting the selection of an appropriate lease-to-purchase price ratio in the Upper Klamath Basin. This ratio provides a method to convert annual lease prices to permanent sale prices.

In recent years, several academic articles have explored western water markets and pricing. Of these, two have estimated an "implicit capitalization rate" (ICR) by comparing lease and purchase prices for water rights. The ICR is the rate at which perpetual annual payments at the lease price must be discounted to yield a present value equal to the sale price.[8] Generally, the ICR is calculated using the mean or median lease price over a 100 year period. This is essentially equivalent to dividing the mean or median lease price by the mean or median purchase price. According to the Brown (2006) study, the average ICR across all states using water market data from 1990 through 2003 is 1.94%. Another study by Brewer et. al (2007) found similar results using data from 1990 through 2005 calculating an average ICR of 1.6%.[9] Interestingly, the Brewer study calculated an ICR for each year using data from all regions and determined that the rate has been steadily falling over time from 2.7% in 1990 to 0.3% in 2005 as sale prices have increased and lease prices have not kept pace. The authors suggest that the decline in the ICR is largely due to the preference for permanent acquisitions by urban buyers. In general, urban buyers are willing to pay the highest prices for water rights but are often unwilling and/or unable to participate in lease markets.

The two studies rely solely upon data published by the Water Strategist, a monthly journal that has reported on water market activity for more than two decades. Data published by the Water Strategist is incomplete and imperfect in many markets but does provide a general sense of market activity and price levels. As a result of the incomplete data available from the Water Strategist, both the Brewer and Brown studies elected to aggregate water market data to the state level. Despite the aggregation and the extended time period, the number of transactions in some states remained inadequate for a comparison of lease and purchase prices. In addition, the aggregation of market data to the state level is questionable as water markets tend to be contained within smaller geographic regions defined by basin boundaries and available water conveyance infrastructure. By mixing data from different markets, the authors have not controlled for important supply and demand factors that affect water market prices and contract terms (lease vs sale). For example, some markets are dominated by

[8] Brown, T. C. 2006. "Trends in Water Market Activity and Price in the Western United States." Water Resources Research, Vol. 42.

[9] Brewer, J., Glennon, R., Ker, A., Libecap, G. April 2008. "Water Markets in the West: Prices, Trading, and Contractual Forms." Economic Inquiry, Vol. 46 No. 2.

leasing activity while in others permanent purchases are more frequently observed. There are relatively few water right markets where both leases and sales occur with regularity. Due to the data issues, the two studies may not provide reliable ICR estimates.

In order to address the potential data problems with previous academic studies, primary research was conducted in selected markets where there is both water right leasing and purchase activity involving multiple demand sectors (e.g. agriculture, environmental, urban). The three selected markets include:

- Yakima River Basin, Washington
- Central Valley, California
- Mojave Basin, California

Other markets were considered for the analysis. However, it was determined that there were an inadequate number of sales and leases from which to calculate an ICR. In some markets, it was determined that there were too few buyers in competition for water rights to establish market-based prices to support an ICR calculation.

Table 9 provides a summary of the analysis results. As shown, the lease-to-purchase price ratio ranges from 5.2 to 5.7 percent using market data from the three regions.

Table 9
Lease-to-Purchase Price Analysis Summary

Market Region	Number of Leases	Average Lease Price ($/AF/yr)	Number of Sales	Average Purchase Price ($/AF)	Lease-to-Purchase Ratio (%)
Yakima Basin, WA	78	$100	36	$1,811	**5.5%**
Central Valley, CA	149	$122	15	$2,148	**5.7%**
Mojave Basin, CA	1,895	$87	137	$1,673	**5.2%**

Table 10 provides a summary of the annual lease prices in the Upper Klamath Basin from 2002 through 2009. As shown, the lease price was initially high in 2002. As more was learned about pricing and water supplied from the leasing program, prices were adjusted downward to approximately $150 per AF CU.

Table 10
Wood River Basin Lease Prices

Year	Unit Price ($/AF CU)
2002	$291
2003	$175
2004	$151
2005	$139
2006	$163
2007	$159
2008	$148
2009	$151
2010	$120

Lease prices in the Wood Basin have declined to $120 per acre ($117 per AF CU) for 2010 and reported participation has not fallen as a result. Applying an ICR of 5.5 percent to an annual lease price range of $120 to $150 per AF CU results in an equivalent permanent purchase price range of $2,118 to $2,727 per AF CU. Assuming 1.03 AF CU per acre in the Wood River Basin, the equivalent per acre price range is $2,182 to $2,809.

There have been relatively few leases of water rights in the Sprague River Basin. In the early years of Reclamation's leasing program, they accepted a limited number of water rights from the Sprague Basin. Reported prices for the leases were approximately $90 to $120 per acre. Using an ICR of 5.5 percent, the equivalent permanent price per acre is $1,636 to $2,182. In the Sprague River Basin, the consumptive use is approximately 1.6 AF CU per acre which results in an average lease price of $56 to $75 per AF CU. Applying an ICR of 5.5 percent to this annual lease price range results in an equivalent permanent purchase price of $1,022 to $1,364 per AF CU.

The estimated per acre prices assume that there is full water supply reliability to each acre. It may be necessary to adjust the water right values downward to account for differences in water supply reliability. A proposed method of adjusting water right values is provided in the "Water Right Values Adjustment" section that follows. Table 11 summarizes the results from the lease-to-purchase price comparison.

Table 11
Estimated Water Right Values – Lease Price Conversion

Basin	Lease Price ($/AF/yr CU)	ICR	Purchase Price ($/AF CU)	Purchase Price ($/Acre)
Wood	$120 - $150	5.5%	$2,118 - $2,727	$2,182 - $2,809
Sprague	$56 - $75	5.5%	$1,022 - $1,364	$1,636 - $2,182

Water Right Value Adjustments

The legal characteristics of a water right and the physical characteristics of the associated water source can significantly affect value. Each water right has a priority date that refers to the date it was established. The priority date has particular importance in a region because it determines the likelihood that water will be available for use under low-flow conditions. During times of water shortages, older, or senior water rights are the first to receive their water allocation. Junior water rights are required to forgo or curtail diversions in order to ensure that the water needs of senior water right holders are met. Senior water rights can provide a reliable claim to water, even during low flows, and therefore, command a premium price. The determination of seniority (reliability) is an important characteristic in estimating the value of water rights.

In markets where there is active trading, it is possible to quantify the relationship between market value and water right reliability. For example, in Colorado's South Platte Basin, WestWater developed a statistical model of water market trading which estimated that the most reliable water rights sold for more than twice the value of the least reliable water rights traded in the market. Similarly, in the Yakima Basin, a reverse auction was conducted for the acquisition of water rights to a tributary stream to benefit streamflows for fish. The surface water rights had several different "classes" that determined water supply reliability. The most reliable class was priced approximately six times higher than the least reliable class accepted by the buyer. As described above, the state of New Mexico established a price schedule for water rights in the Pecos Basin that accounts for water source and reliability (junior vs senior). Junior water rights were discounted due to the potential that they would be out-of-priority under low flow conditions.

In the Upper Klamath Lake Watershed, water rights will be purchased under the Water Use Retirement Component of the KBRA to increase inflows to Upper Klamath Lake as well as to benefit instream flows in tributary streams. Therefore, it may be appropriate to develop a price schedule that accounts for the relative abilities of different water right classes to satisfy the two environmental objectives. For example, senior water rights with points of diversion high on tributary streams could be priced at the upper end of the range due to their ability to contribute to instream flows as well as add water to Upper Klamath Lake that would have been consumptively used by crops or lost to evaporation. However, care should be exercised to avoid double-counting of water quantity and paying market values for consumptive use in addition to payments for instream flow benefits. While instream flow benefits can be recognized in the pricing schedule, it is recommended that the total payments for a water right be bound by the relevant range of market value adopted by KBRT.

Summary and Conclusions

The Klamath Basin Rangeland Trust (KBRT) is working to improve instream flows in the Upper Klamath Lake Watershed to enhance the natural ecosystem for native fish and wildlife populations and supply water for downstream agriculture. As a result of the Klamath Basin Restoration Agreement, it is anticipated that future efforts may involve permanent purchases of water rights to improve instream flows in tributaries to Upper Klamath Lake and to maintain lake levels. This report provides an analysis of water right pricing in the Upper Klamath Lake Watershed to assist KBRT with the establishment of an equitable water pricing framework that will promote long-term success of the transactions program. The water right price ranges estimated in this analysis are intended to serve as a guide to KBRT and other engaging in water right market activity. Due to the uniqueness of individual water rights, actual negotiated values may differ from those presented here.

Water right prices vary according to a large number of factors. Due to the lack of permanent water right sales history in the Upper Klamath Lake Watershed, this analysis considered a variety of sources of information to estimate a range of relevant water right prices. Sources of information include irrigated land values in the Upper Klamath Lake Watershed, water right pricing observed in other market regions, and capitalization of observed water lease prices in the Wood and Sprague basin. The findings of this analysis are summarized below.

Agricultural Land Values: As described above, there have been limited sales of agricultural land in the Wood and Sprague basins in recent years. As a result, it is difficult to reliably infer the value that water rights contribute to irrigated land and the price that would be necessary to compensate owners for the reduction in land value following the purchase of water rights to improve streamflows and lake levels in the Upper Klamath Lake Watershed. Irrigated land prices in the Wood Basin were reported at approximately $4,000 per acre and $2,800 per acre in the Sprague Basin. In the Wood Basin, previous water leasing has demonstrated that the property can remain productive without irrigation. Reported cattle stocking rates and revenues in the Wood declined to approximately 50 to 60 percent of irrigated pasture values. Using this proportion, the value that water rights contribute to land in the Wood Basin is between $2,000 and $2,400 per acre. In the Sprague Basin, there is generally less opportunity for viable agricultural production without irrigation. As a result, it is likely that the presence of a water right contributes a larger proportion to land value than in the Wood Basin – perhaps $2,000 to $2,300 per acre.

Comparative Markets Analysis: Due to the lack of water right sales history in the Upper Klamath Lake Watershed, this analysis considered water right sales activity in other market regions where environmental buyers are active. Agricultural production characteristics, water right buyer types, water market exchange process, and climate conditions in the selected market regions were compared to the Wood and Sprague basins in order to identify a relevant price for water rights in the study area. Average water right prices ranged from $707 to $1,913 per AF CU ($1,247 to $4,018 per acre) among the market regions. Average prices in the Yakima Basin ($1,811 per AF CU) and Pecos Basin ($1,913 per AF CU) were determined to be higher than expected prices in the Upper Klamath Lake Watershed due to comparatively better agricultural production conditions in the Pecos Basin and the comparatively higher level of competition for water rights in the Yakima Basin. While agricultural production conditions in the Deschutes Basin are somewhat similar to those in the Upper Klamath Lake Watershed, the average water right sale price in the Deschutes Basin ($707 per AF CU) is expected to be lower due to the urbanization of previously irrigated land which has "freed up" a large volume of water rights. In addition, the lack of individual water right ownership within irrigation districts and the market control maintained by the primary buyers and sellers have kept prices relatively low. Prices in the market regions determined to be most comparable to the Upper Klamath Lake Watershed range from $1,062 per AF CU in the Sprague Basin to $1,459 per AF CU in the Wood Basin. This is equivalent to values of $1,699 per acre in the Sprague Basin assuming 1.6 AF CU per acre and $1,503 in the Wood Basin assuming 1.03 AF CU per acre. The estimated consumptive use may vary among different properties, particularly in the Sprague Basin where less analysis has been completed.

Lease Price Conversion: Water right owners in the Upper Klamath Lake Watershed have been leasing water rights (or agreeing to not irrigate) to USBR and NRCS for a number of years. The prices and participation in the lease market inform the values that will be necessary to permanently purchase water rights. In order to convert the lease prices to an equivalent purchase price, it is necessary to select an appropriate income capitalization rate (ICR). This analysis reviewed several markets where both water right leasing and purchase activity occur with regularity to support selection of the ICR. From the analysis, it was determined that lease prices are 5.5 percent of sale prices, on average. Lease prices in the Wood Basin have been approximately $150 per AF CU in recent years. Lease prices are expected to decline to approximately $120 per acre ($117 per AF CU) in the Wood Basin for 2010. Using an ICR of 5.5 percent, the equivalent purchase price range is $2,118 to $2,727 per AF CU. While there has been more limited leasing activity in the Sprague Basin, the reported lease prices have ranged from $56 to $75 per AF CU. The equivalent purchase price range is $1,018 to $1,364 per AF CU.

Table 12 provides a summary of the estimated water right values from the different approaches and the selected range for the Wood and Sprague basins. As shown, the selected price range for the Sprague Basin is $1,000 to $1,450 per AF CU. This is equivalent to a price of $1,760 to $2,320 per acre. In the Wood Basin, the selected price range is $1,500 to $2,700 per AF CU. This is equivalent to a price of $1,545 to $2,781 per acre. The upper end of this price range is significantly above prices observed in other comparable markets and is based upon previous water leasing prices in the basin. Water lease prices for 2010 have been reduced. As a result, the relevant high end of the price range may be somewhat overstated.

Table 12
Summary of Estimated Water Right Values

Valuation Approach	Sprague Basin	Wood Basin
Agricultural Land Prices ($/AF CU)	$1,250 - $1,438	$1,942 - $2,330
Comparative Markets Analysis ($/AF CU)	$1,062	$1,459
Lease Price Conversion ($/AF CU)	$1,022 - $1,364	$2,118 - $2,727
Selected Price Range ($/AF CU)	$1,000 - $1,450	$1,500 - $2,700
Consumptive Use (AF CU/acre)	1.60	1.03
Selected Price Range ($/acre)	***$1,699 - $2,320***	***$1,503- $2,781***

Other Pricing Considerations: This analysis and the values presented above do not specifically account for differences among water rights within the Upper Klamath Lake Watershed. As previously described, there is a need to adjust values according to the reliability of individual water rights. This can be accomplished through estimation of the average crop consumptive use for an individual water right which will account for the annual variability in surface water availability. Estimation of water right reliability in the Sprague Basin may be difficult due to the uncertainty associated with the ongoing adjudication. Until the adjudication is complete, it may be necessary to only pursue senior water rights with solid use histories that are located relatively low in the basin. It may also be desirable to develop a pricing schedule that accounts for the ability of a specific water right to contribute to instream flows as well as inflows to Upper Klamath Lake. It is anticipated that recognition of instream flow contributions in the pricing schedule with be based upon a policy decision by KBRT. While instream flow benefits can be incorporated into the pricing schedule, it is recommended that the total payments for a water right be bound by the relevant range of market value adopted by KBRT and informed by this analysis.

WOOD RIVER VALLEY AQUATIC HABITAT STUDY 2008 MONITORING REPORT

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WOOD RIVER VALLEY AQUATIC HABITAT STUDY
2008 MONITORING REPORT

1.0 INTRODUCTION

The Wood River Valley is located within the Upper Klamath Basin on the eastern slopes of the Cascade Mountains in South Central Oregon. The Wood River Valley once contained over 60,000 acres of wetlands; however, throughout the last century most of its marshes have been eliminated and many of its stream systems have been modified as a result of diking, draining, channelization, irrigation diversion and other activities primarily associated with agricultural management practices. By 1989 the wetland area had been reduced to about 44,000 acres (Carlson 1993). In addition to the reduction of wetland habitat, the hydrology and channel form within many of the important creeks and rivers, such as Sevenmile Creek, Crooked Creek, and the Wood River have been significantly impacted and modified by these management actions.

In 2002, the Klamath Basin Rangeland Trust (KBRT) developed a new land and water management plan for the Wood River Valley, and began a pilot project to evaluate the feasibility and effectiveness of the new plan. The goal of the program is to increase the quantity and quality of water in the Klamath Basin by conserving irrigation water in the Wood River Valley, while restoring pastures and wetlands to maximize ecological value. The primary means to accomplish this goal was eliminating irrigation diversions for project lands, thus leaving this water instream, providing important ecological benefits and increased flows for downstream use. Other actions include various cattle management strategies, including substantial reductions in cattle numbers, riparian fencing, and active stream restoration.

Extensive monitoring of the project lands was begun in 2002, including surface water, water quality, fish habitat, and stream condition. Initial thoughts on the potential timeframe until changes caused by KBRT management were detectable suggested a 5-10 year period. Now that over five years have passed since initiation of the KBRT program, it is appropriate to evaluate changes. This current monitoring and comparison to 2002/2003 data has been funded by the USDA Natural Resources Conservation Service.

1.1 Previous Work

Baseline conditions were established in 2002 and 2003 (Pacific Groundwater Group, et al 2003, Kann and Reedy 2004) for fish habitat and geomorphic conditions of Crooked Creek and Sevenmile Creek (Figure 1), two streams affected by management actions of KBRT. Additional monitoring work has occurred on Crooked Creek since the late 1990s, primarily associated with planning and implementation of stream restoration work on the Root Ranch.

1.2 Scope and Objectives

This report describes the monitoring objectives, methods, results, and analyses. Most of the methods were established in the 2003 Fisheries Habitat Monitoring Report (Kann and Reedy 2004) and the basics will not be reiterated here unless methods were altered or new methods added. The results are compared to those from 2003 to evaluate general trends for predictive purposes. Figures follow the body of the report. Tables are included in the text. Photo point comparisons are included in appendices.

The primary objective of the present study was to measure changes in fish habitat and fish numbers on Crooked Creek and fish habitat on Sevenmile Creek after five years of the KBRT program. Monitoring efforts included repeating surveys of geomorphic conditions, fish habitat, and fish abundance.

2.0 SEVENMILE CREEK STUDY AREA

2.1 Sevenmile Monitoring Locations

Sevenmile Creek was delineated into seven contiguous segments for the 2003 study (Kann and Reedy 2004) differentiated by hydrologic and morphological characteristics. Three of those segments (Figure 2) were selected for detailed measurements and one reach from each (Reaches 2, 5, and 6) was chosen which contained at least 1000 linear feet of stream, 30 or more habitat units and conditions that were representative of the overall segment. 2008 monitoring in reaches 2, 5, and 6 consisted of repeating survey methods used in 2003 and comparing results to determine changes.

2.2 Sevenmile Monitoring Methods

2.2.1 Geomorphic Survey Methods

Channel mapping focused on repeating the survey methods from 2003 with some minor changes. Mapping was performed with survey-grade real time kinematic (RTK) GPS (Trimble 4700/4800) almost exclusively and focused on surveying tops and toes of banks, water surface elevations and thalweg (deepest part of channel). Ten cross sections had been surveyed in 2003 but were based on the top, toe, riveredge, and thalweg points only and were not monumented in the field. In 2008, the endpoints were approximately located using the coordinates from 2003 and resurveyed in a more traditional manner with considerable more detail. Cross section changes were difficult to determine between the 2003 and 2008 surveys since the survey methods were so different (one fairly crude (2003), and one fairly detailed (2008) but they should serve to detect geomorphic changes in the future.

The baseline parameters of depth, width, and width to depth ratio were established in 2003 for geomorphic monitoring and were repeated for 2008 with some changes to the widths and width to depth ratios. In 2003, the mapping data was used to generate channel widths from the left edge of the water to the right edge every 100 feet and then generating width to depth ratios using those widths and depths below the water surface. These parameters were felt to be non-standard geomorphic measurements and, since both widths and depths were dependant on discharge, difficult to repeat during later monitoring. Thus, for the 2008 effort, a more standard bankfull channel width was generated every 50' (along the 2003 thalweg line) between the tops of banks, while depths for width to depth ratios were calculated from the top of the bank surface to the thalweg depth. These same width and width to depth ratios were generated from the 2003 survey data at the same 50' locations along the 2003 thalweg for comparison.

In 2003, depths were generated using AutoCAD by comparing a digital terrain model (DTM) from the tops, toes and thalweg points and to a DTM built from water surface elevations. The difference between the two surfaces equals the depth along the thalweg and points (with elevation equal to depth) were generated every foot along the thalweg. Since water stage was higher in 2003 than during the August, 2008 survey period, it was felt that the 2008 top, toe and thalweg DTM was best compared to the 2003 water surface DTM to generate standardized depths along the thalweg to properly compare changes between the two years. 2008 widths, depths, and width to depth ratios were compared to the equivalent 2003 parameters for each reach.

2.2.2 Habitat Typing Methods

Fish habitat typing used the same methods from 2003 but delineated habitat units using more accurate survey-grade RTK GPS rather than the handheld units used in 2003. Habitat units were typed as either lateral pools, straight pools, glides, or riffles and the quality was determined based on combined depth and cover factors. The presence and number of large wood pieces and rootwads were counted for each unit and the composition of the streambed substrate was estimated as the percentage of cover by various sediment size classes and aquatic vegetation. The length of undercut banks and eroding stream banks was measured for each unit using the RTK GPS. Habitat types measured in 2008 were sorted and compared to the 2003 habitat types.

2.2.3 Photo Point Monitoring

Photo points were established in representative locations in 2003 and marked with 5/8" rebar topped with yellow plastic caps stamped "PHOTOPOINT". These were relocated where possible, and at each location, 3 or more photographs were taken of the stream reach in an upstream, across and downstream orientation to duplicate the 2003 efforts and visually compare the photos to detect changes.

2.3 Sevenmile Monitoring Results

Planform 2008 survey maps of the three reaches along Sevenmile Creek are shown in Figures 3, 4, and 5 for Reaches 6, 5, and 2 respectively, presented in a downstream direction. The maps are overlain on a 2005 orthophoto and show top, toe, and thalweg point groups connected by line work, as well as cross section, control point, and photo point locations.

2.3.1 Longitudinal Profile and Cross Section Results

Lest the water surface levels in the longitudinal profiles and cross sections for Reaches 5 and 6 confuse, it must be pointed out that the 2003 surveys were conducted in October after the irrigation season while the 2008 surveys were completed in mid July at a lower streamflow.

The Reach 6 longitudinal profile (Figure 6) documents a noticeable thalweg deepening as evidenced in Table 1. The downstream end of Reach 6 has steepened as virtually all of the higher points of the channel (not technically riffles) in the lower 800 feet of the reach have dropped in elevation in 2008. The average bed slope has increased from .0023 to .0026, while the water surface slope has remained the same. The number and depth of pools has also increased. Data in Table 1 show that the mean channel depth has increased by 0.33 feet, primarily in the lower half of the reach, and that the percent of channel thalweg deeper than 4 feet has doubled from 0.76% to 1.53%. The thalweg length increased by 57 feet, or 0.38%, from 2003 to 2008, although this change could be an artifact of survey methods.

The Reach 5 longitudinal profile (Figure 7) has experienced a similar drop in elevation at the "riffles" in its lower section. The mean bed slope of this quite low-gradient reach has more than doubled from .0002 to .0005, while the water surface slope remained the same at .0004. Four pools deepened, while three filled in a little. Overall, though, there was essentially no change in mean depth (Table 1). The percentage of the channel thalweg greater than 4 feet deep decreased from 8.9% to 5.4%.

There is little change in the longitudinal profile of Reach 2 (Figure 8) except several of the deeper pools have filled in and some bed features in the upper half of this reach have shifted around somewhat, resulting in a thalweg length 65 feet (4%) longer than in 2003. Overall, mean channel depth declined from 4.68 feet to 4.44 feet.

Comparison of the cross sections (Figures 9a, 9b, and 9c) from all three reaches do not provide any useful trends since they were generated in much different manners between the two study periods. The following section on channel geometry involves analysis of reach-wide depths, widths, and width to depth ratios, which reveal changes over time better than the present cross sections. Future monitoring can take more advantage of the improved cross section survey methods.

2.3.2 Channel Geometry Results

Table 1 summarizes the 2003 and 2008 widths, depths from water surface, width to (channel) depth ratio, and thalweg length. Some of the parameters from 2003 are different than reported in the 2003 report, due to differing methods in determining channel widths, width to depth ratio, and using slightly different channel lengths. The differences represent results using methods that should be more repeatable in future monitoring efforts.

Table 1: *Width, Depth, Length and W/D Ratio Summary for Sevenmile Creek Reaches 2, 5, and 6 for 2003 and 2008.*

REACH	YEAR	THALWEG LENGTH (ft)	MEAN DEPTH (ft) [1]	DEPTH Std.Dev.	MEAN WIDTH (ft) [2]	WIDTH Std.Dev.	MEAN WIDTH TO DEPTH RATIO [3]	W/D Std.Dev.	PERCENT THALWEG > 4' DEEP
2	2003	1487	4.68	1.54	60.43	10.39	8.20	1.98	64.40
2	2008	1552	4.44	1.30	59.54	10.98	7.98	2.34	58.36
5	2003	2157	2.75	0.83	27.04	7.18	10.16	5.12	8.87
5	2008	2174	2.78	0.68	19.30	3.34	6.47	1.96	5.44
6	2003	1580	2.11	0.72	26.90	7.82	6.19	2.01	0.76
6	2008	1637	2.44	0.70	23.05	7.84	5.00	2.03	1.53

1) Depths calculated every 1' along thalweg based on 2003 water surface survey.
2) Bankfull channel widths determined every 50'.
3) Width to depth ratio uses bankfull channel widths and matching bankfull channel thalweg depths every 50'.

Figures 10 through 15 chart the distribution and changes of depths, widths, and width to depth ratios for the three reaches over the monitoring period from 2003 to 2008. Figures 10, 12, and 14 are box and whisker plots, where the outsides of the box are 25 and 75 percentile values, the line through the box is the 50% value or median, the blue diamond is the mean, and the whiskers are the maximum and minimum values. Figures 11, 13, and 15 are frequency plots, showing the relative frequency of computed values that have been divided into various bins.

In 2003, Reach 6 and Reach 5 both had mean bankfull channel widths around 27 feet and in both the channel width has decreased: to 23 feet in Reach 6 and 19 feet in Reach 5 (Table 1 and Figure 10). Photo comparison also demonstrates this channel narrowing which is likely a result of reduced or eliminated grazing pressure, encroaching vegetative growth, and consequently less bank erosion. Reach 2 had a slight (less than 1 foot) decrease in mean channel width. Figure 11 shows the shift in the frequency histogram towards narrower widths in Reach 6 and 5. This is particularly noticeable for Reach 5, where 63% now are in the 20 foot width bin, while only 15% had been in 2003.

Overall, depths still increase downstream from Reach 6 to Reach 2 (Table 1 and Figure 12). Pools >3' deep are important for large adult trout (KBRT 2003) and the percentage of thalweg depths greater than or equal to 3' deep has increased in Reach 5 (80% to 88%) and 6 (52% to 72%) since 2003 (Figure 13). Depths increased in Reach 6, remained essentially constant in Reach 5, and declined slightly in Reach 2, over the study period.

The width to depth ratios follow accordingly with the narrowing of Reach 6 and 5 (Table 1 and Figure 14). The mean ratio has dropped slightly from 6 to 5 in Reach 6 but significantly from 10 to 6.5 in Reach 5 indicating a narrower, deeper channel in 2008. In addition, the range of width to depth ratio values was much greater (Figure 14) in Reach 5 in 2003 compared to 2008. 73% of the ratio values are now in the 6 and 8 bins (Figure 15).

The most downstream Reach 2 is still the deepest and widest of the three study reaches. Mean depth has decreased slightly and the percentage of depths >4' has dropped 6% to 58%. There has been very little change in channel width and width to depth ratio.

2.3.3 Habitat Typing Results

The results of habitat typing are presented in Table 2 and Figures 16 and 17. The most significant changes in fish habitat between 2003 and 2008 occurred in Reach 6 where large woody debris (LWD) increased substantially, rising from 2.8 to 18.9 pieces per 1000 feet (Table 2). This large wood presence resulted in glides (50% of the habitat units in 2003, but only 29% in 2008) changing into lateral scour pools (formerly 31%, now 52%) (Figure 16). Pool numbers increased sharply from 19 to 32 and their quality also increased from 2 to 2.5. Bank stability improved as evidenced by a doubling of the percentage of undercut banks and a large decrease in the percentage of bank erosion (Table 2). Coupled with less erosion is a coarsening of the substrate, as gravel and sand now dominate with a large reduction in silt and aquatic vegetation. Figure 17 shows that in Reach 6, gravel substrate increased from 2.8 to 22%, while combined silt and aquatic vegetation dramatically declined from 54.6 to 15.6%.

Table 2. Habitat Summary for Sevenmile Creek Reaches 2, 5, and 6 for 2003 and 2008.

Reach	Sample Year	Habitat Units	Number of Pools	Mid-Channel Length (ft)	Mean Pool Quality	Mean Pool Max. Depth (ft)	Percent Undercut Bank[1]	Percent Eroding Bank[1]	Large Wood per 1000 Ft.
2	2003	17	10	1461	2.11	na	1.9	17.8	16.4
2	2008	15	9	1461	3.33	6.8	6.3	19.1	4.1
5	2003	35	19	1997	2.6	4.5	8.4	0.3	8.5
5	2008	38	20	1997	2.5	4.1	7.8	0.0	5.5
6	2003	37	19	1428	2	3.3	3.5	16.1	2.8
6	2008	50	32	1428	2.53	3.5	7.1	6.8	18.9

1) Percentages of undercut and eroding banks are based on accumulated occurrences from both sides of the creek and percentage calculated using the mid-channel length and halving it. Percentages are lower than presented in KBRT 2003 which were based incorrectly on one mid-channel length.

Reach 5 habitat remained generally similar to conditions in 2003 with the exception of a loss of LWD, which declined from 8.5 to 5.5 pieces per 1000', a small increase in the amount of gravel substrate (0 % in 2003, 2.5% in 2008), and a small decline in percent undercut bank.

Reach 2 habitat conditions improved with a large pool quality increase from 2.1 to 3.3 due to increased percentage of undercut bank (from 1.9% to 6.3%) even while the amount of LWD decreased from 16 to 4 pieces per 1000'. In terms of substrate, a substantial increase in aquatic vegetation occurred thereby reducing the percentage of exposed silt.

2.3.4 PhotoPoint Monitoring

The photos are assembled in two PowerPoint files (Appendix 1), for 2003 and 2008. Photos from the nine photopoints along the three reaches suggest a general trend of channel narrowing, increased vegetative cover, and reduced bank erosion, particularly in Reach 6. Figure 18 shows an example of the photo point comparisons.

2.4 Sevenmile Discussion

2.4.1 Changes in Streamflow

Figure 19 compares streamflow (mean daily discharge or MDQ) at the Sevenmile Creek at Sevenmile Road gage for 2003 and 2008. The most noticeable change is the summer baseflow. Between July 1 and September 10, 2008 streamflow was essentially double that of 2003. However, because the 2003 surveys were made in October, well after the end of the irrigation diversion season, while the 2008 surveys were completed in July-August, streamflows were actually higher in 2003 than in 2008 at the time of field work. Significantly more habitat was available in the summer of 2008 than in 2003 due to the large increase in flow.

2.4.2 Riparian Management Changes

Decreased grazing pressure has had the most impact on Reaches 5 and 6 by allowing riparian vegetation to grow and stabilize banks thereby reducing erosion, narrowing and deepening the channel, and reducing the width to depth ratio.

2.4.3 Summary of Channel and Habitat Changes

Reach 6 has experienced the most dramatic changes resulting from the KBRT Project land management changes, which directly affected water diversions and grazing practices. Fish habitat greatly improved as shown by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased, and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Reach 6 clearly demonstrates the possible improvements in channel and riparian conditions over a 5 year period with new management prescriptions. We believe Reach 6 saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches, (2) it has a much steeper gradient than the other reaches (4-5 times steeper) thus providing considerably more energy with the increased streamflows to scour the bed, and (3) it likely saw the highest percentage increase in baseflow, as prior to the management changes, it was essentially dewatered much of the summer.

Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This is likely due to the very low gradient of this reach. With less energy available to promote change, change will take a much longer period of time. Although the mean depth and LWD decreased in Reach 2, there was an increase in pool quality, partly due to an increase in percentage of undercut banks. Being the most downstream (and lowest gradient) reach, one would expect Reach 2 to improve the slowest, both due to low energy available and that much of the sediment released from upstream as those reaches recover will move through the downstream reaches.

A significant increase in amount of habitat available, although not directly measured, is suggested by the increase of base stream flow during the critical summer months as shown in Figure 19. To evaluate such changes this directly, habitat would need to be measured at the same time of year, then, not only would the physical changes be apparent, but the available habitat (not just physically based but also dependent on the base flow amount) during critical periods could also be determined.

3.0 CROOKED CREEK STUDY AREA

3.1 Crooked Creek Monitoring Locations

Crooked Creek was delineated into four contiguous segments for the 2003 study differentiated by hydrologic and morphological characteristics (Figure 20). Data were collected through all 4 reaches (1-4). Reach 4 contains two sites where channel restoration work (channel narrowing) was performed in 2001. Reach 4 also contains 4 other sites where habitat improvement work (large wood placed, willows planted, and eroding banks sloped and stabilized) was undertaken in 1998.

3.2 Crooked Creek Monitoring Methods

3.2.1 Geomorphic Survey Methods

In 2003, it was determined that the channel morphology was different than Sevenmile Creek and that somewhat different methods be used to characterize the system. Four contiguous reaches were delineated for study encompassing 3.2 miles measured as the centerline of the channel. Mapping surveys varied for the previous study period which was spread out over several years but will be referred to as 2003 in this report. The current study mapped the four reaches in August 2008 exclusively using the RTK GPS system referred to earlier. In Reaches 1 to 3 (numbered from upstream), tops, toes and thalweg points were mapped, while in the lowest Reach 4 only toes and thalweg were mapped to repeat the 2003 procedures. During the survey, the extents of any exposed stream banks exhibiting soil erosion were also mapped. Six cross sections in Reaches 1 and 2 were monumented and surveyed in 2003 and were recovered and resurveyed for this study.

As on Sevenmile Creek, the 2003 study established depth, width, and width to depth ratio as parameters to assess and monitor geomorphic conditions on Crooked Creek. The methods established during 2003 were more appropriate for Crooked Creek and thus were more closely duplicated than on Sevenmile. Depths were developed every foot along the 2008 thalweg by comparing the 2008 water surface DTM with a DTM developed from the top, toe and thalweg points. Bankfull channel widths were calculated at the same 2003 locations every 100' along the 2003 thalweg line between channel tops. The depths used for the width to depth ratios were the thalweg depths described above at the location of the channel width.

3.2.2 Habitat Typing Methods

The most important fish habitat variables for Crooked Creek were determined to be undercut banks and pool depths in 2003. Fish habitat surveys then, and in 2008, focused on undercut banks in pools that were >3' deep. One person with a mask waded with a stadia rod in an upstream direction looking for undercut banks and, when one was located, would have a second walking person survey the upstream and downstream margin of the undercut with a RTK rover unit. The diver then used the stadia rod to probe the horizontal depth of the undercut bank at several locations and call them out to the bank person who recorded the measurements in a fieldbook. From these data, average water depth, average width (depth of undercut) and length were calculated and then the area (length * average width) and volume (area * average water depth) were calculated. Results for undercuts and exposed soil areas were standardized on a per mile basis in order to compare different length reaches.

3.2.3 Snorkel Surveys

A fish abundance survey of the four reaches was conducted in late September 2008 using snorkeling methods established between 2000 and 2002 on Crooked Creek. The objectives were to quantify differences in abundance and habitat use among the four reaches and to compare fish numbers to those of past counts in order to detect changes resulting from KBRT project activities. Two snorkelers moved downstream together counting all fish observed by species and age class. The lower section of Reach 4 was an index section in which repeat counts were made to determine a coefficient of variation.

3.2.4 Macroinvertebrate Surveys

Repeating the effort of the August 2002 macroinvertebrate assessment, sampling was performed in Reaches 1 and 4. Five sites were sampled in Reach 4, including four sites within the restoration treatment area (XS #22, XS #23, XS #26, and XS #40) and one reference site immediately upstream of the treatment area (XS #19). One site was sampled in Reach 1, just below the old bridge on the Thomas property (XS #1). At each sample site, a series of three replicate transects, extending laterally across the active channel, was established. An effort was made to avoid large macrophyte beds when placing transects. Wetted channel width was determined for each transect, and benthic macroinvertebrates were collected at distances of 0.25, 0.50, and 0.75 times the total wetted width using a 15.2 cm x 15.2 cm ($0.0023m^2$) Petite Ponar dredge. For a given transect, all three dredge samples were composited to produce a single sample per transect (effective sampling area = $0.0069\ m^2$), with three replicate samples per sample site. Dredge contents were passed through a 500 µm sieve and the retained material was preserved in 95% ethanol for later processing in the laboratory.

Samples were later sorted to remove a 500-organism subsample from each preserved sample following the procedures described in Oregon DEQ’s Level 3 protocols (WQIW 1999) and using a Caton gridded tray (Caton 1991). Contents of each sample were first emptied onto the gridded tray and then floated with water to evenly distribute the sample material across the tray. Squares of material from the 30-square gridded tray were removed to a Petri dish which then was placed under a dissecting microscope at 7-10X to sort aquatic macroinvertebrates from the sample matrix. Macroinvertebrates were removed from each sample until at least 500 organisms were counted, or until the entire sample had been sorted. Macroinvertebrates were then identified to the lowest practical taxonomic level under 10-110X magnification.

Raw macroinvertebrate data were entered into an Excel Spreadsheet, and then all taxonomic determinations were standardized to those used in the 2002 assessment in order to compare 2008 results with those obtained in 2002. Raw taxonomic count data were converted to density estimates for each replicate sample from each site, and then the average density of each taxon was calculated. Ten metrics were computed for each site from these site-wide average density data. Taxonomic attribute coding (Table 6) and metric calculations were identical to those performed on the 2002 data to facilitate comparisons between the two sampling periods.

3.3 Crooked Creek Monitoring Results

Planform 2008 survey maps of the four reaches along Crooked Creek are shown in Figures 21 and 22, for Reaches 1-2, and 3-4, respectively, presented in a downstream direction. The maps are overlain on a 2005 orthophoto and show top, toe, and thalweg point groups connected by line work, as well as cross section and control point locations.

3.3.1 Longitudinal Profile and Cross Section Results

The only change that stands out from the longitudinal profile (Figure 23) is that the channel bed high points in Reach 4 have deepened thereby causing a slightly steeper bed slope. The change seems to be limited to that reach. Cross sections 1-3 in Reach 1 and 4-6 in Reach 2 do not reflect the rather large channel narrowing in both reaches (Figure 24).

3.3.2 Geomorphic Survey Results

Table 3 summarizes the 2003 and 2008 thalweg lengths, channel widths, depths from water surface, width to (channel) depth ratio, and percent thalweg greater than 4’ deep. Figures 25 through 32 chart the distribution and changes of depths, widths, and width to depth ratios for the four reaches over the monitoring period from 2003 to 2008 and also include comparisons within Reach 4 of restored (4B) versus un-restored areas (4A). It should be noted that the 2003 channel dimensions for reach 4 were actually surveyed in 2001, soon after the channel restoration was completed. In some cases, the channel width was reduced by more than 30' during the project construction. Figures 25, 26, 28, 30, and 31 are again box and whisker plots. Figures 27, 29, and 32 are frequency plots, showing the relative frequency of computed values that have been divided into various bins.

Channel widths decreased in all four reaches (Table 3 and Figure 25) indicating the reduction in grazing under the KBRT program has helped to stabilize banks. Mean widths decreased about 10% in Reaches 1 and 2, almost 15% in Reach 3, but only 2% in Reach 4. Reach 4 remains the narrowest section but only slightly now that the other reaches have narrowed over the past 5 years. In addition, it should be noted that the Reach 4 channel widths are taken from the channel toes because the tops of the banks are in many places under water and difficult to distinguish. Figure 26 compares Reaches 4A and 4B and shows very slight changes from 2003, with un-restored areas slightly decreasing in width and restored areas slightly increasing in width. These values are well within the range of measurement error. The frequency distribution of channel widths for the 4 reaches (Figure 27) show that the range of the population of widths has been reduced as the channel narrowed, many of the wider channel areas (the upper tail of the histogram) have disappeared, leaving the channel narrower and more consistent in width.

Table 3. *Width, Depth, Length and W/D Ratio Summary for Crooked Creek Reaches 1, 2, 3, and 4 for 2003 and 2008.*

REACH	YEAR	THALWEG LENGTH (ft)	MEAN DEPTH (ft)[1]	DEPTH Std Dev	MEAN WIDTH (ft)[2]	WIDTH Std Dev	MEAN WIDTH TO DEPTH RATIO[3]	W/D Std Dev	PERCENT THALWEG >4' DEEP
1	2003	2071	3.95	0.69	42.37	9.10	11.51	4.12	41.02
1	2008	2010	4.04	0.62	38.26	6.64	9.90	2.67	48.76
2	2003	6052	3.93	0.74	41.02	7.19	11.11	3.27	40.86
2	2008	5806	3.99	0.61	37.58	5.57	9.73	2.26	43.30
3	2003	5240	3.53	0.74	47.55	8.76	14.09	4.13	19.94
3	2008	5156	3.32	0.68	41.39	8.28	12.89	3.84	15.22
4	2003	4994	3.59	0.85	37.87	8.65	10.77	3.06	29.17
4	2008	4768	3.88	0.71	36.97	5.29	10.00	2.32	39.84

1) Depths below current water surface (2003 or 2008) calculated every foot along the thalweg.
2) Channel widths from top of left bank to top of right bank every 100’ along 2003 thalweg line.
3) Width to depth ratio uses channel widths every 100’ and depth from 1’ depths at channel width location.

Overall, mean thalweg depths changed only slightly, with Reaches 1, 2 and 4 increasing in depth while Reach 3 decreased (Table 3 and Figure 28). Interestingly, the maximum depths measured decreased by over a foot in Reach 2 and 3, while Reach 1 and 4 had smaller declines, however, overall the percentage of the thalweg deeper than 4' substantially increased in Reach 1 and 4 and less so in Reach 2, while Reach 3 declined considerably. All of the frequency distributions, with the exception of Reach 3, have shifted towards an increased percentage of deeper depths (Figure 29).

Channel width to depth ratios decreased accordingly with the width decrease and the depth increase (Figure 30). The size of the boxes as well as the range shown by the min-max values indicate that the channels are becoming more homogeneous as they narrow and deepen. This is particularly true for Reach 4A and 4B (Figure 31), as the range between the max and the min values has decreased by about two-thirds. The frequency distribution clearly depicts this shift as the percentages for bin 12 increased substantially, into a very sharp peak.

3.3.3 Habitat Typing Results

Although it doesn’t show up in the habitat summary (Table 4), large woody debris remains sparse throughout most of the Crooked Creek study area with the notable exception of lower Reach 4 where channel narrowing projects established numerous new rootwad features along the restored banks. This lack makes undercut banks especially important as adult fish habitat throughout the study reaches.

Table 4. *Habitat Summary for Crooked Creek Reaches 1, 2, 3, and 4 for 2003 and 2008.*

Reach Number	Year	Habitat Feature	Number of Segments	Total Length (ft)	Total Area (ft2)	Total Volume (ft3)	Number of Segments per Reach Mile	Total Length per Reach Mile (ft)	Total Area per Reach Mile (ft2)	Total Volume per Reach Mile (ft3)
1	2003	UCR	2	55	51	199	5.6	154	142	555
1	2003	UCL	4	135	225	1043	11.2	377	630	2914
1	2003	ESR	1	63			2.8	176		
1	2008	UCR	8	119	217	901	22.3	332.4	606.2	2517.1
1	2008	UCL	4	267	549	2577	11.2	745.9	1533.7	7199.2
1	2008	ESR	2	63			5.6	176.0		
1	2008	ESL	1	17			2.8	47.5		
2	2003	UCR	9	295	379	1034	8.6	283.3	364.4	992.9
2	2003	UCL	14	754	1134	4685	13.4	724.1	1088.6	4498.9
2	2003	ESR	8	1263			7.7	1212.9		
2	2003	ESL	1	225			1.0	216.1		
2	2008	UCR	10	251	522	2391	9.6	241	501	2296
2	2008	UCL	18	334	655	2847	17.3	321	629	2734
2	2008	ESR	14	1060			13.4	1018		
2	2008	ESL	3	300			2.9	288		
3	2003	UCR	1	14	16	56	1.1	15.3	17.6	60.7
3	2003	UCL	7	288	313	1263	7.7	314.8	342.2	1380.4
3	2003	ESR	4	635			4.4	694.0		
3	2003	ESL	1	111			1.1	121.3		
3	2008	UCR	6	171	306	1045	6.6	186.9	334.4	1142.1
3	2008	UCL	6	197	338	1309	6.6	215.3	369.4	1430.7
3	2008	ESR	6	455			6.6	497.3		
4	2003	UCR	6	148	182	670	6.9	169.7	209.1	768.6
4	2003	UCL	4	148	259	1182	4.6	169.7	297.6	1355.9
4	2003	ESR	2	149			2.3	170.9		
4	2003	ESL	1	92			1.1	105.5		
4	2008	UCR	4	192	463	1744	4.6	220.2	531.0	2000.1
4	2008	UCL	6	127	208	923	6.9	145.6	238.5	1058.5

UCR = Undercuts on Right Bank, UCL = Undercuts on Left Bank, ESR = Exposed Soil on Right Bank, ESL = Exposed Soil on Left Bank

Figures 33-35 standardize undercut banks and eroded banks per reach mile to better compare the different length study reaches. Total length of undercut banks has decreased overall but the loss is entirely in Reach 2, particularly along the right bank. The other three reaches have experienced an increase in total length of undercuts. The largest increase in undercuts since 2003 was in Reach 1, in particular along the right bank where cattle grazing was more dominant prior to the KBRT program. In the 2003 study, Reach 2 had the most undercut length and area and is now second to Reach 1.

Bank erosion has overall decreased in length through the four reaches since 2003. The number of exposed soil segments increased in Reaches 1 and 2 (and slightly in 3) but the length of erosion per reach mile decreased in all four reaches. The right bank of Reach 2 continues to have the most bank erosion.

3.3.4 Snorkel Survey Results

Annual snorkeling surveys of fish present in Crooked Creek began in 2000, focusing on the Root Ranch section (Reach 4) first and then in 2002 expanding to include all four reaches. The main objectives have been to: 1) quantify differences in abundance and habitat use among the four reaches, and 2) provide baseline and continued monitoring data for the detection of changes resulting from the KBRT project activities.

The 2008 snorkel survey was conducted in late August with water temperature ranging from 46-53° F. Visibility was generally around 9' and when it dropped much below that, diving ceased for the day. The diving necessarily had to proceed downstream because velocities were too high to swim upstream but several problems arose. Any time the bed was disturbed, turbidity increased thereby lowering visibility and probably causing fish movement away from the disturbance. It is likely that snorkeling downstream alarms fish anyway and consequently some fish were probably not seen and counted. On the other hand, the index section 4B was repeat snorkeled 3 times with more than an hour between dives and the coefficient of variation for adult counts was 0.05 indicating that the snorkel counts were not missing many adult fish.

Very few juvenile fish (<100mm and 100-200mm) were observed so either they are rare at this time of year or more likely they are better able to avoid divers with limited visibility. The remaining discussion includes only adult trout (> 200mm). Of the 43 adult trout observed (Table 5), 49% were identified as redband rainbow, 1 as a definite brown trout and the rest counted as unknown trout (assumed to be rainbow or brown). Approximately 19% were positively associated with woody debris and about 21% with undercut banks but it is likely that many of the remaining adult trout were associated with wood since they were observed moving from areas with wood present.

Table 5. *Adult Trout Snorkel Counts for Crooked Creek Reaches 1, 2, 3, and 4 from 2000 to 2008.*

Reach	Top	Bottom	Jul-00	Jul-01	Aug-02	Oct-02	Jul-03	Oct-03	Aug-08
1	Old Bridge	Departure from Terrace				4	4		2
2a	Departure from Terrace	Agency Creek			24	21	25	20	7
2b	Agency Creek	Thomas Bridge				30	44	45	1
3	Thomas Bridge	Root prop. Line					25		5
4a	Root prop. Line	Index top	12	8			28	11	12
4b	Index top	Index bottom	15	16	10	19	39	36	18

It is notable that total numbers of adult trout are considerably lower than in summer or fall, 2003 and that the Reach 4 numbers are similar to the counts in 2000-2002. This is probably not surprising since anecdotal evidence suggests that fish numbers are down throughout the Wood River system. Despite the lower numbers, the index Reach 4B which has undergone restoration by channel narrowing and installation of LWD, encompasses 13% of the total length studied but contained almost 42% of the adult trout present in 2008. This reach contains a much higher density of LWD than the rest of the study reaches. When the 2008 fish counts are standardized per reach mile, Reach 1 through 3 had 5.6, 6.7, and 5.5 fish/mile respectively, yet Reach 4A has 27.7 fish/mile and Reach 4B (Index) has 41 fish/mile. The obvious indication is that the addition of LWD in Reach 4B has improved the fish habitat and has attracted more adult trout.

3.3.5 Macroinvertebrate Results

Across all six Crooked Creek sample sites, 16 insect taxa representing 8 orders were collected from Crooked Creek in August 2008. This is similar to the insect richness (18 families) reported in 2002, and suggests that the significant increase in insect diversity has been maintained over the 1999 levels of 8 families representing 3 orders. Including other phyla and orders, 25 families were collected, which is very similar to that reported in 2002 (24 families). Family richness was highest at two sites within the restoration treatment reach (XS #23 and XS #40) and lowest for XS #1, the upstream Thomas property site (Table 7). Total family richness was similarly low in the reference site, XS #19, immediately upstream of the restoration treatment area. Total family richness in each of the restoration sites exceeded that from either of the reference sites in 2008 (Table 7). This pattern is generally similar to that observed in 2002, with treatment sites generally supporting a higher richness than did reference sites (Figure 36).

Total macroinvertebrate densities in 2008 ranged from 2,569 organisms per m^2 (XS #26) to 19,967 organisms per m^2 (XS #19), and averaged 11,986 organisms per m^2 across all six sites. Densities were generally higher than those reported in 2002, which ranged from 1,909 to 3,766 organisms per m^2. Higher densities in 2008 are attributable to a significant increase in the Amphipoda species, *Hyalella azteca*, which exceeded densities of 8,000 organisms per m^2 in four of the six sites. Increases in densities to this extent suggest a potential increase in nutrient loading into the system or an increased capacity for nutrient retention within Crooked Creek.

Ten macroinvertebrate families were sampled from the reference site (XS #19) and 8 were sampled from the upstream Thomas property site (XS #1). Each of these reference reaches supported 2 mayfly families (*Baetis tricaudatus* from the Baetidae family and *Ephemerella excrucians* from the Ephemerellidae family), while no stonefly or caddisfly families were sampled from either reach. In contrast, four or five Ephemeroptera, Plecoptera, and Trichoptera (collectively referred to as “EPT”) families were collected from each of the 4 sites within the treatment reach (Table 7). A number of EPT taxa were collected from one or more treatment reach sites that were not sampled from the reference site (XS #19) or the Thomas property site (XS #1), including the mayflies *Pseudocloeon dardanum* and *Centroptilum* sp., the stonefly genera *Sweltsa* (Chloroperlidae) and *Malenka* (Nemouridae), and the caddisflies *Glossosoma* (Glossosomatidae), *Hydroptila* (Hydroptilidae), and *Psychoglypha subborialis* (Limnephilidae).

All sites were numerically dominated by Amphipoda, Oligochaeta, Chironomidae, and Pelecypoda. Treatment reach sites XS #22, XS #23, and XS #40 also supported moderately high densities of Baetidae mayflies and Simuliidae. Community dominance by the two most abundant families was high across all sites, ranging from 75% at XS #26 to 92% at XS #1 (Table 7). These values are generally higher than those reported in 2002 (Figure 36) and are likely the result of the significant increase in abundance of Amphipoda. The contribution of EPT orders to the observed assemblage (% EPT) was generally lower in 2008 than in 2002, also a result of the increased Amphipoda abundance (Figure 36). Among all sites, % EPT was lowest in XS #1 and highest in XS #26.

HBI values ranged from 4.8 in XS #40 to 5.5 is XS #22, and were similar between reference and treatment sites (Table 6), suggesting that benthic communities at the six sites are similarly tolerant to organic enrichment pollution. HBI values were slightly lower at all sites in 2008 than in 2002, again a result of the increase in Amphipoda densities. It is noteworthy that, while the HBI tolerance value (TV) for the order Amphipoda is 4 (that used to calculate HBI in 2002 and 2008 for this study) the tolerance value for the Amphipoda species, *Hyalella azteca*, occurring in the study area is 8 (Clark and Maret 1993). Therefore, while HBI values have slightly decreased using the order-level HBI tolerance value, using a tolerance value of 8 for both years (this is the TV for both the species, *Hyalella azteca* and the family, Talitridae) results in an increase in the HBI score from 2002 to 2008.

Collectively, results of the 2008 macroinvertebrate sampling suggest that benthic conditions have not significantly changed since the 2002 sampling; the significant increase in Amphipoda densities was the only noteworthy deviation from 2002 assemblage conditions. Furthermore, 2008 results once again suggested that the restoration area potentially supports a higher taxonomic richness and higher EPT richness than do the upstream reference sites.

Table 6. *Functional Feeding Group (FFG) designations and pollution tolerance values (TV) of organisms collected from Crooked Creek in August 2008.*

Class	Order	Family	FFG	TV
OLIGOCHAETA			Collector-Gatherer	10
HIRUDINEA		Erpobdellidae	Predator	10
ARACHNOIDEA	Acarina		Predator	8
CRUSTACEA	Amphipoda		Collector-Gatherer	4
	Ostracoda		Collector-Gatherer	8
INSECTA	Coleoptera	Dytiscidae	Predator	5
		Elmidae	Collector-Gatherer	4
		Haliplidae	Macrophyte Herbivore	7
INSECTA	Diptera	Chironomidae	Omnivore	6
		Empididae	Predator	6
		Simuliidae	Collector-Filterer	6
		Tipulidae	Omnivore	3
INSECTA	Ephemeroptera	Baetidae	Collector-Gatherer	4
		Ephemerellidae	Collector-Gatherer	1
INSECTA	Plecoptera	Chloroplerlidae	Predator	1
		Nemouridae	Shredder	2
		Perlodidae	Predator	2
INSECTA	Trichoptera	Glossosomatidae	Scraper	0
		Hydroptilidae	Collector-Gatherer	4
		Limnephilidae	Omnivore	3
INSECTA	Megaloptera	Sialidae	Predator	4
MOLLUSKA	Gastropoda	Ancylidae	Scraper	6
		Planorbidae	Scraper	7
	Pelecypoda	Pisidiidae	Collector-Filterer	8
NEMATA			Parasite	5

Table 7. *Macroinvertebrate community metrics calculated from samples collected from six Crooked Creek sites in August 2008.*

Metric	Sample Site					
	XS 1	XS 19	XS 22	XS 23	XS 26	XS 40
Family Richness	8	10	14	17	12	17
EPT Richness	2	2	4	5	4	4
EPT/Chironomidae + Oligochaeta Ratio	0.01	0.02	0.11	0.18	0.05	0.26
% Dominance	92.05	80.24	77.33	82.56	74.89	85.32
% Filterers	2.07	11.06	9.69	10.16	6.74	7.49
% EPT	0.15	0.46	2.94	2.19	1.50	2.93
% Ephemeroptera	0.15	0.46	2.77	1.70	1.12	2.74
% Plecoptera	0	0	0.06	0.11	0.19	0.15
% Trichoptera	0	0	0.11	0.38	0.19	0.04
Hilsenhoff's Biotic Index	5.4	5.1	5.5	4.9	5.2	4.8

3.4 Crooked Creek Discussion

3.4.1 Changes in Streamflow

Comparison of mean daily discharge between 2003 and 2008 (Fig. 37) indicates that streamflow was higher in the spring and fall of 2008 but about the same both years during the critical summer period July through September.

3.4.2 Riparian Management Changes

Decreased grazing pressure has caused channel narrowing and a decrease in width to depth ratio throughout the monitoring reaches. There is a current effort to increase the cattle exclusion area along the right bank through most of reaches 3 and 4 which should further reduce bank erosion and increase bank undercuts.

3.4.3 Summary of Channel and Habitat Changes

Overall, channel widths and width to depth ratios decreased as bank erosion has decreased. Undercut banks have not increased as much as one would expect except in Reach 1 where the difference is significant.

The most dramatic change between 2003 and 2008 has been with the distribution of adult trout in the four reaches. Although the number of fish was lower than in 2003, a much higher percentage of the fish counted were in the index section of Reach 4. It is likely that the increase in depth and decrease in width and even more so the increase in LWD incorporated with the channel narrowing projects have improved the fish habitat and encouraged fish use.

4.0 CONCLUSIONS

The changes in irrigation and grazing management through the KBRT program have had several positive effects on the channel morphology and fish habitat for Sevenmile Creek and Crooked Creek. On Sevenmile Creek, Reach 6, the uppermost section studied, showed the most improvement in fish habitat with increases in pool numbers, depth, large woody debris, and a decrease in deleterious fine sediment. Reaches 5 and 6 both have more stable banks and narrower, deeper channels.

The effects of the new management were somewhat less but still substantial for the Crooked Creek study reaches. Channel width and width to depth ratios decreased and bank erosion decreased. The areas of Crooked Creek Reach 4 that have undergone restoration in the form of channel narrowing and LWD enhancement showed an increase in adult trout usage.

The rate of recovery for channels affected by grazing appears to be strongly influenced by the flow and sediment regime available to initiate change. Sevenmile Creek has a more extensive watershed and higher winter storm and spring snowmelt runoff compared to the spring-dominated Crooked Creek. In addition, upstream areas have higher gradients, providing more energy to scour the bed, creating deeper pools and improving substrate by selectively winnowing fines. As a result, lower gradient reaches will take longer to recover.

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WOOD RIVER VALLEY STUDY SITES LOCATION MAP

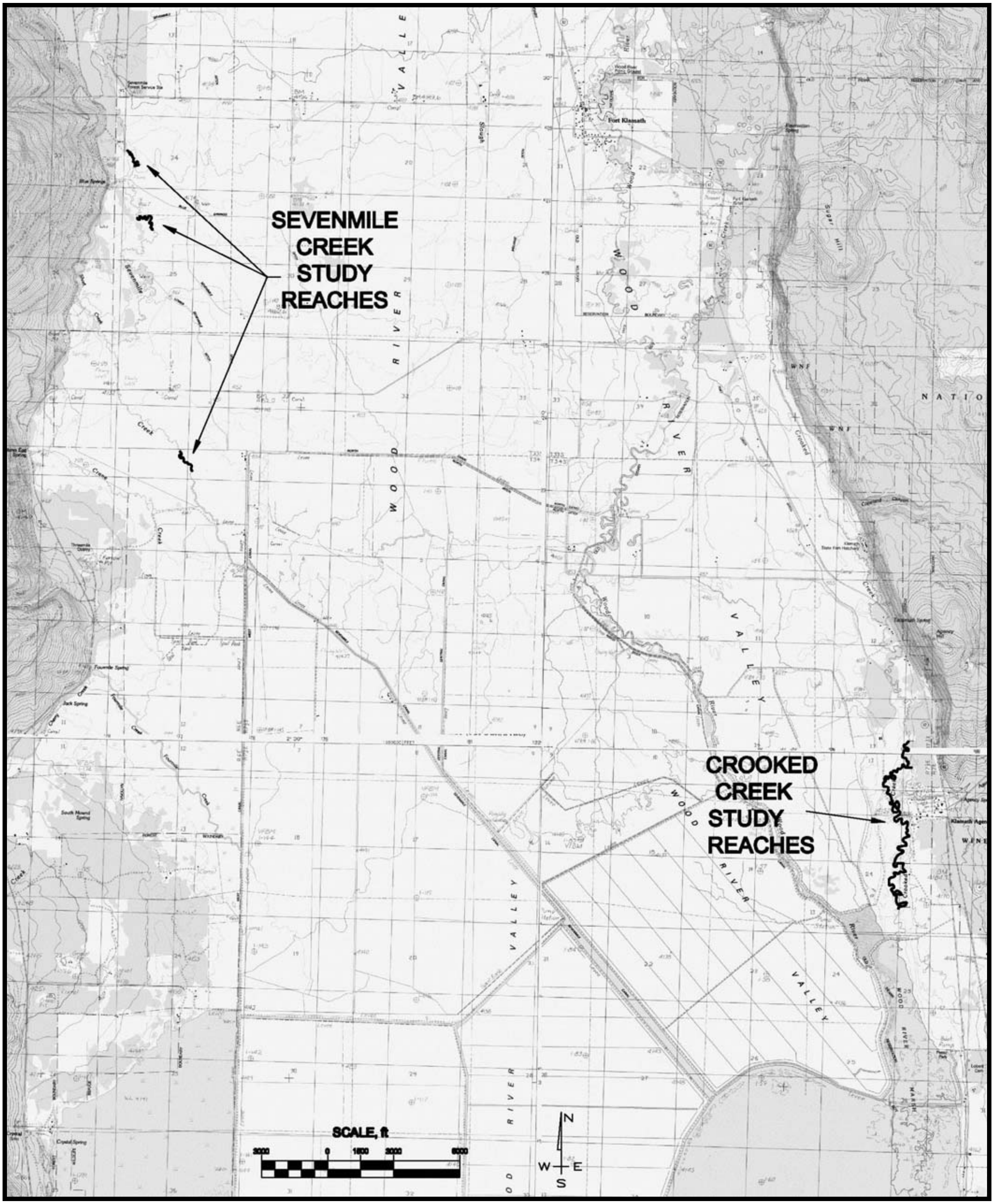

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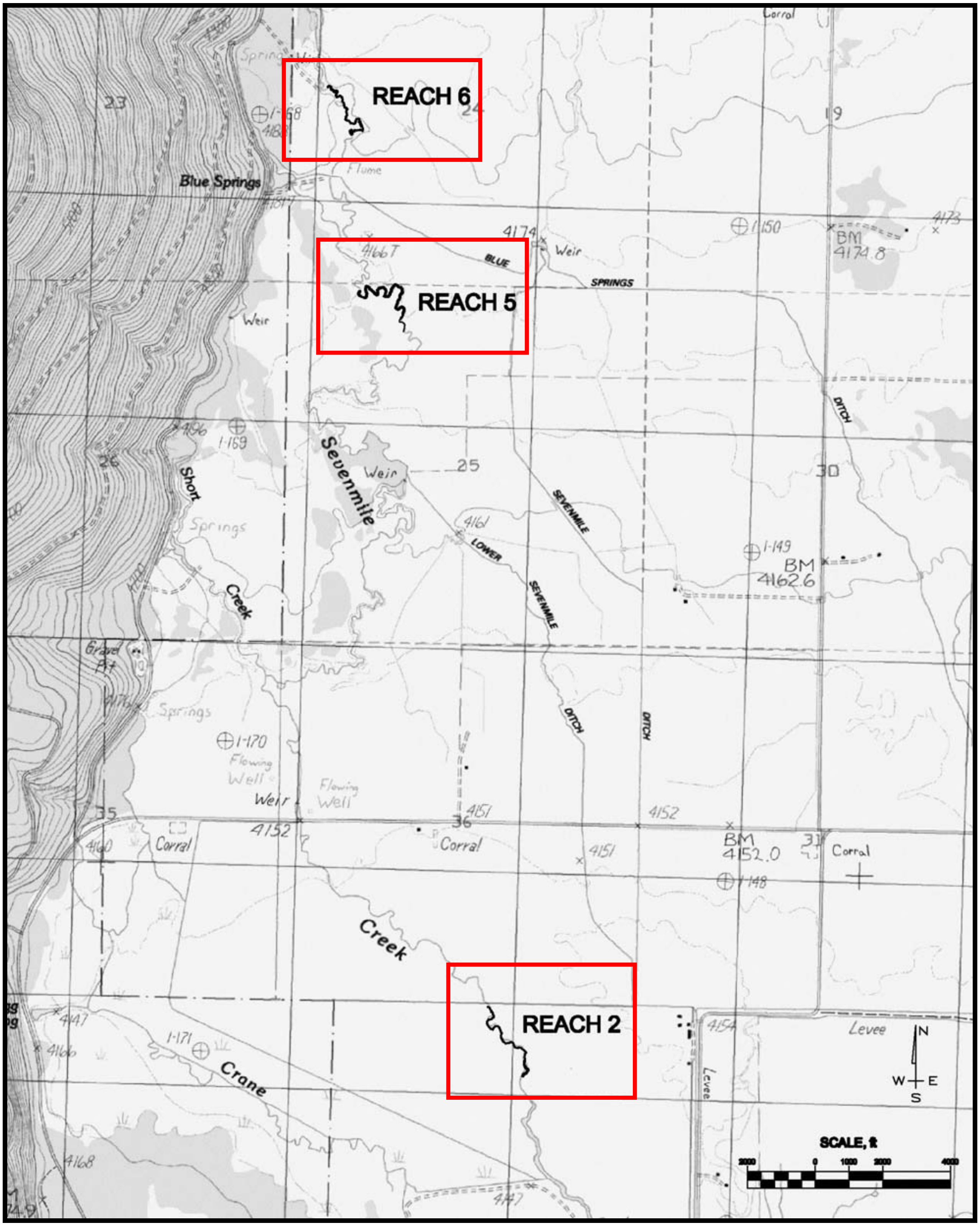
FIGURE

1

SEVENMILE CREEK STUDY SITES LOCATION MAP



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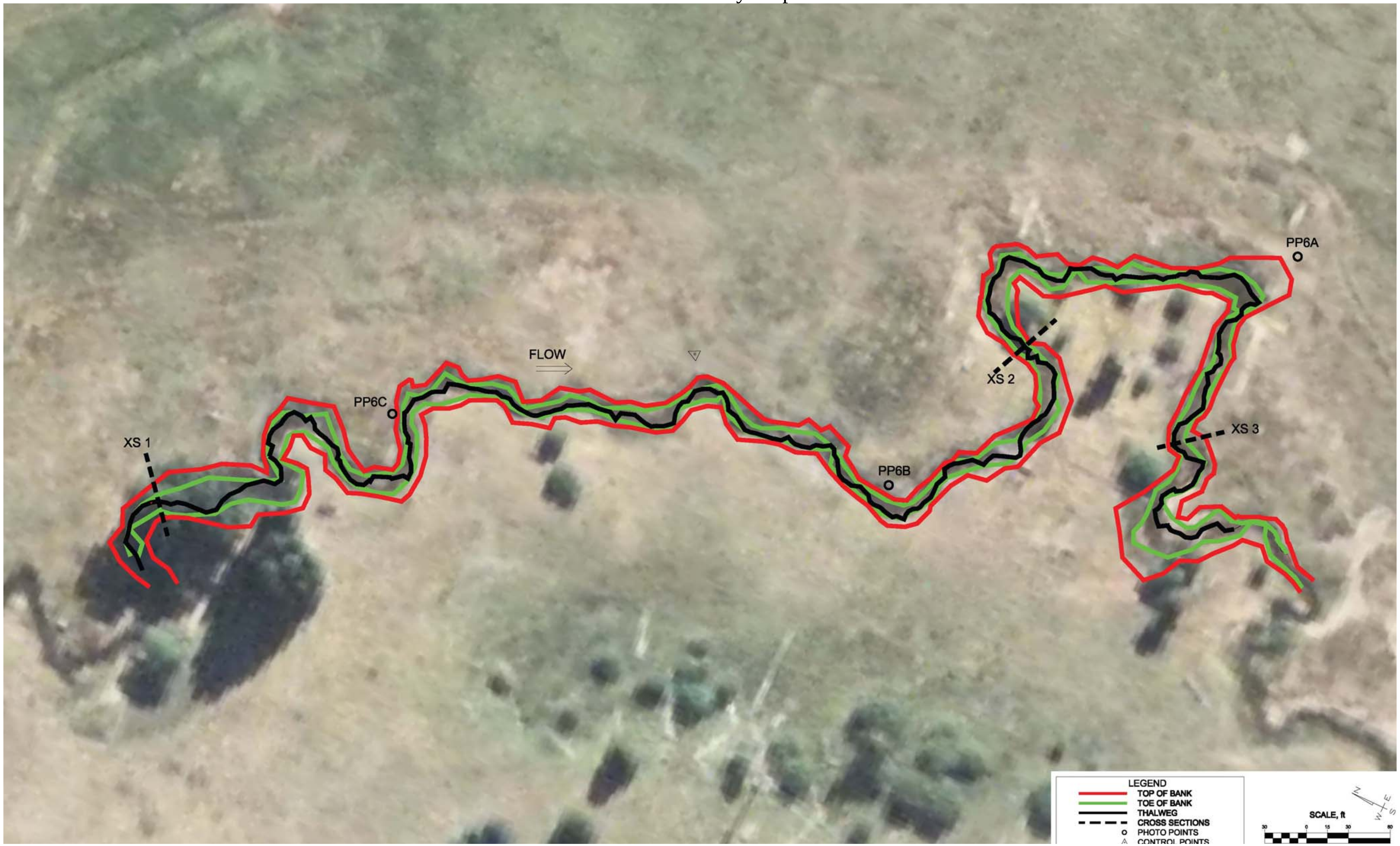
SEVENMILE CREEK

Reach 6 Survey Map



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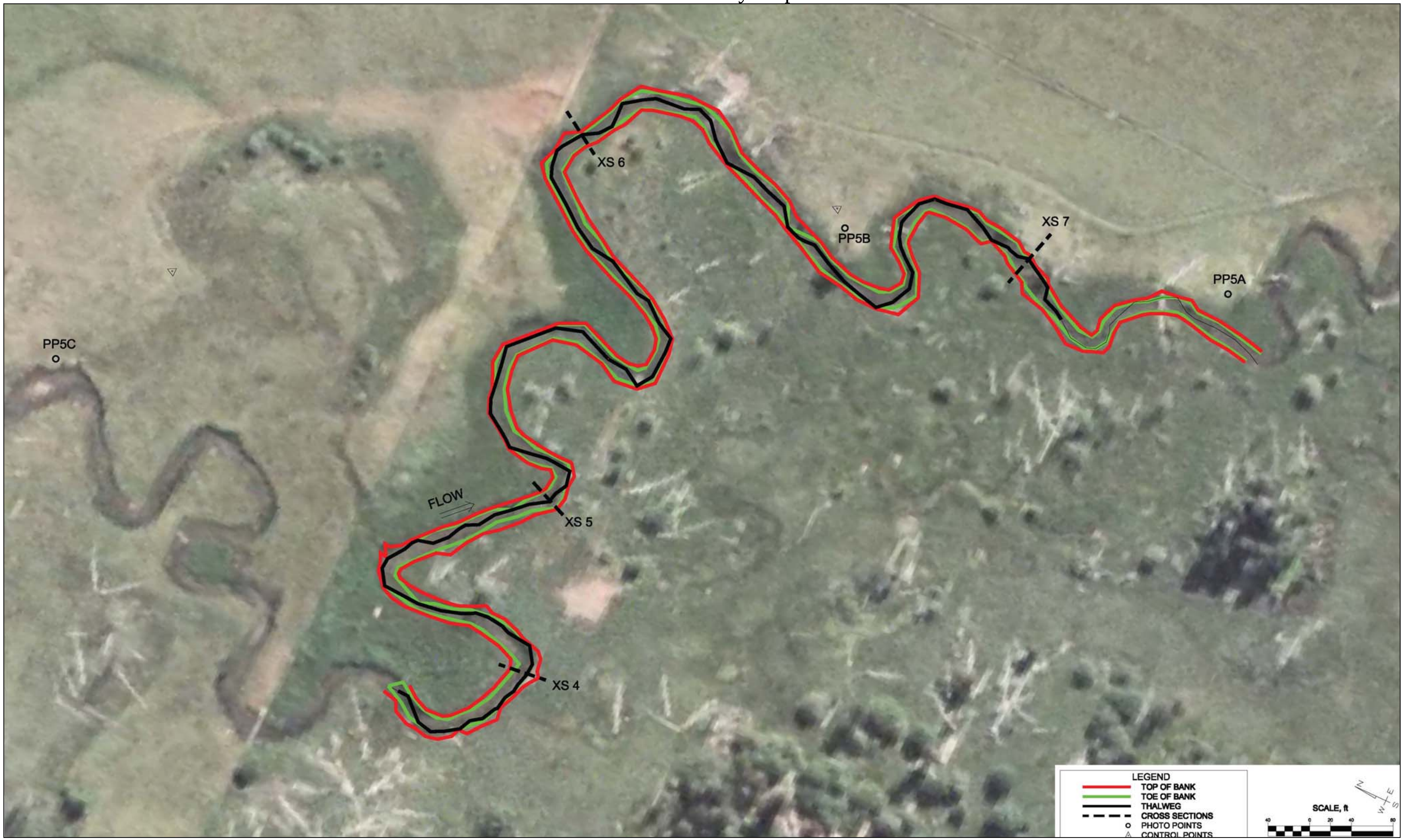
SEVENMILE CREEK
Reach 5 Survey Map



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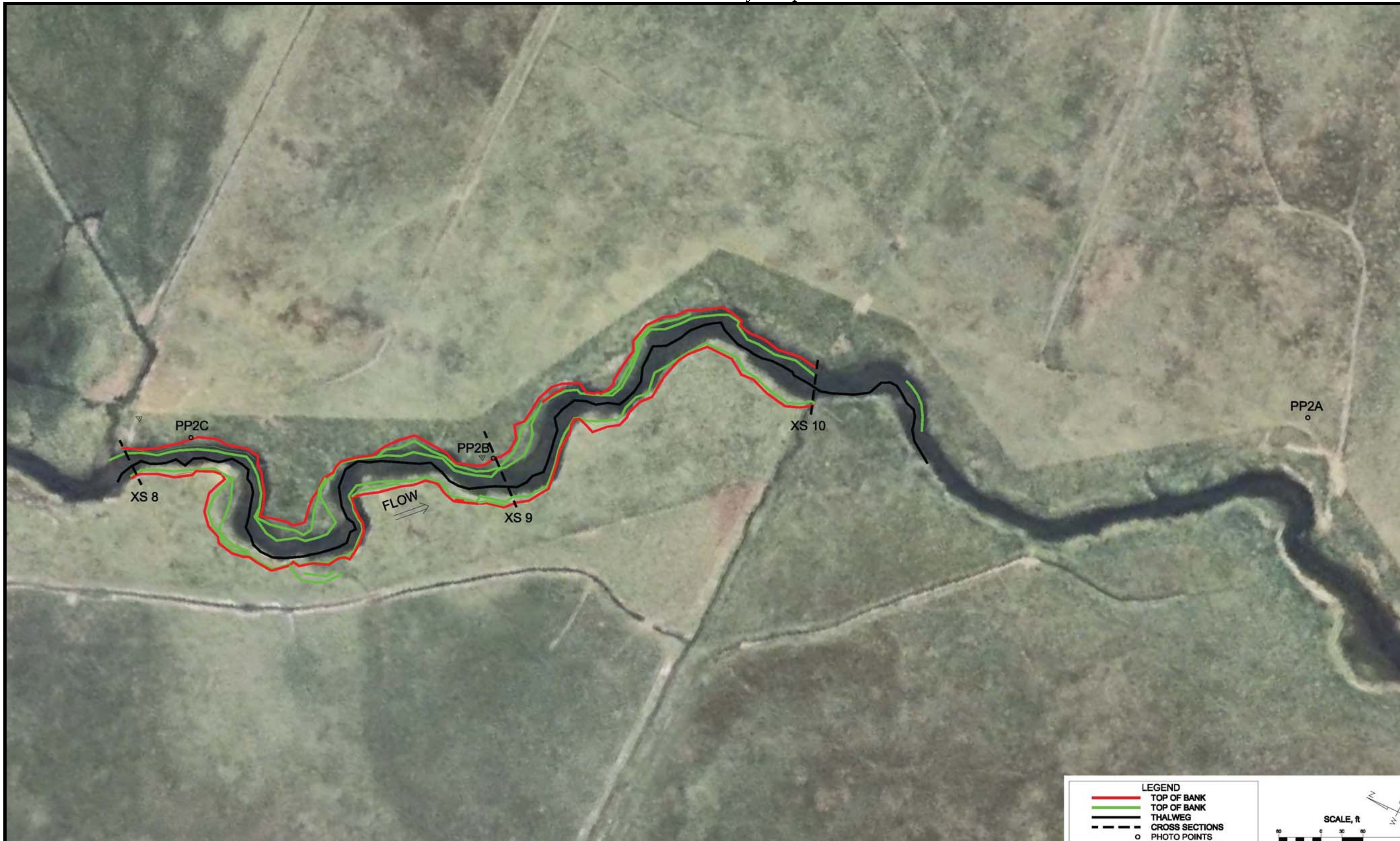
SEVENMILE CREEK

Reach 2 Survey Map



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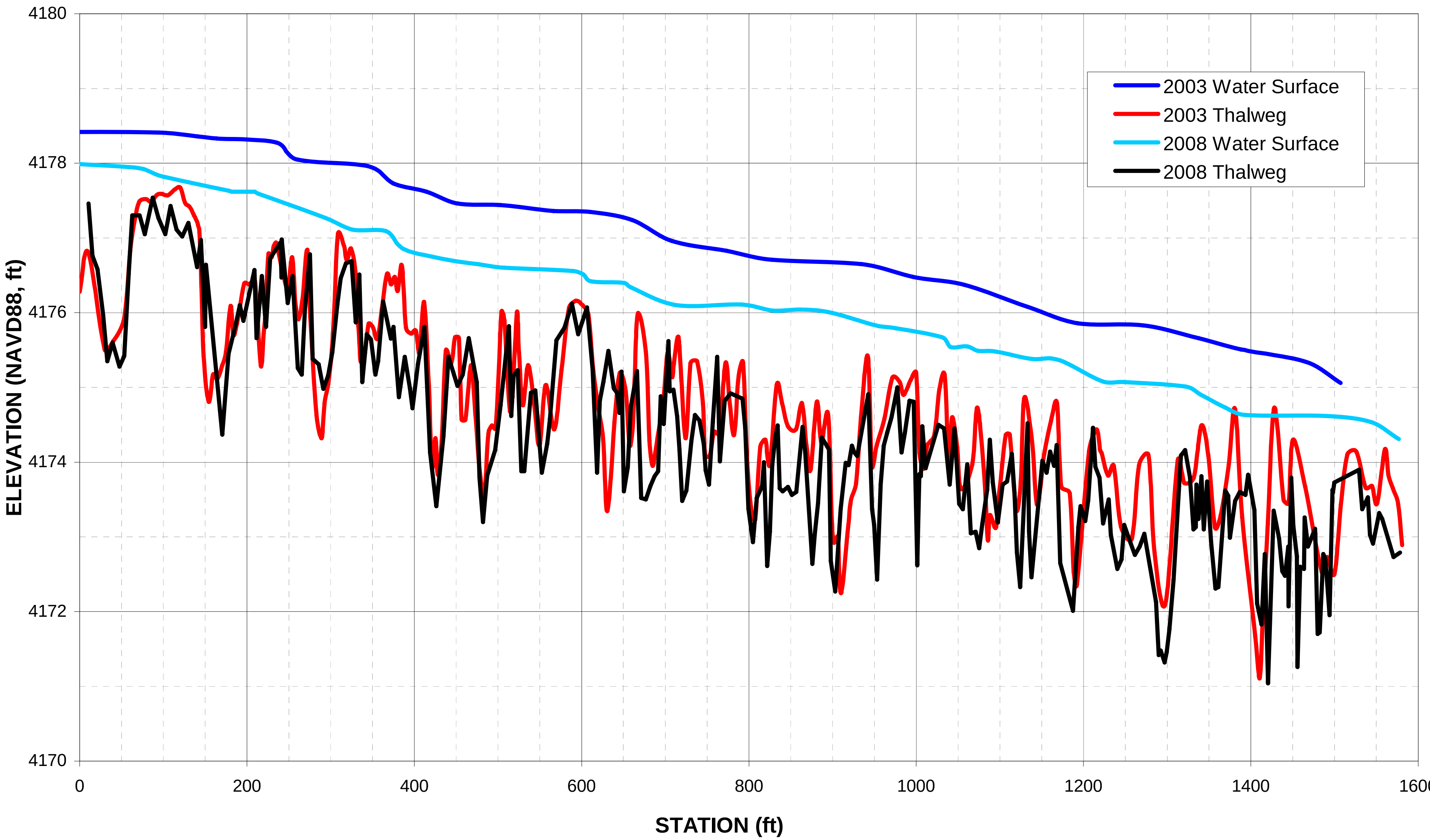
SEVENMILE CREEK

Reach 6: Longitudinal Profile, 2003 and 2008



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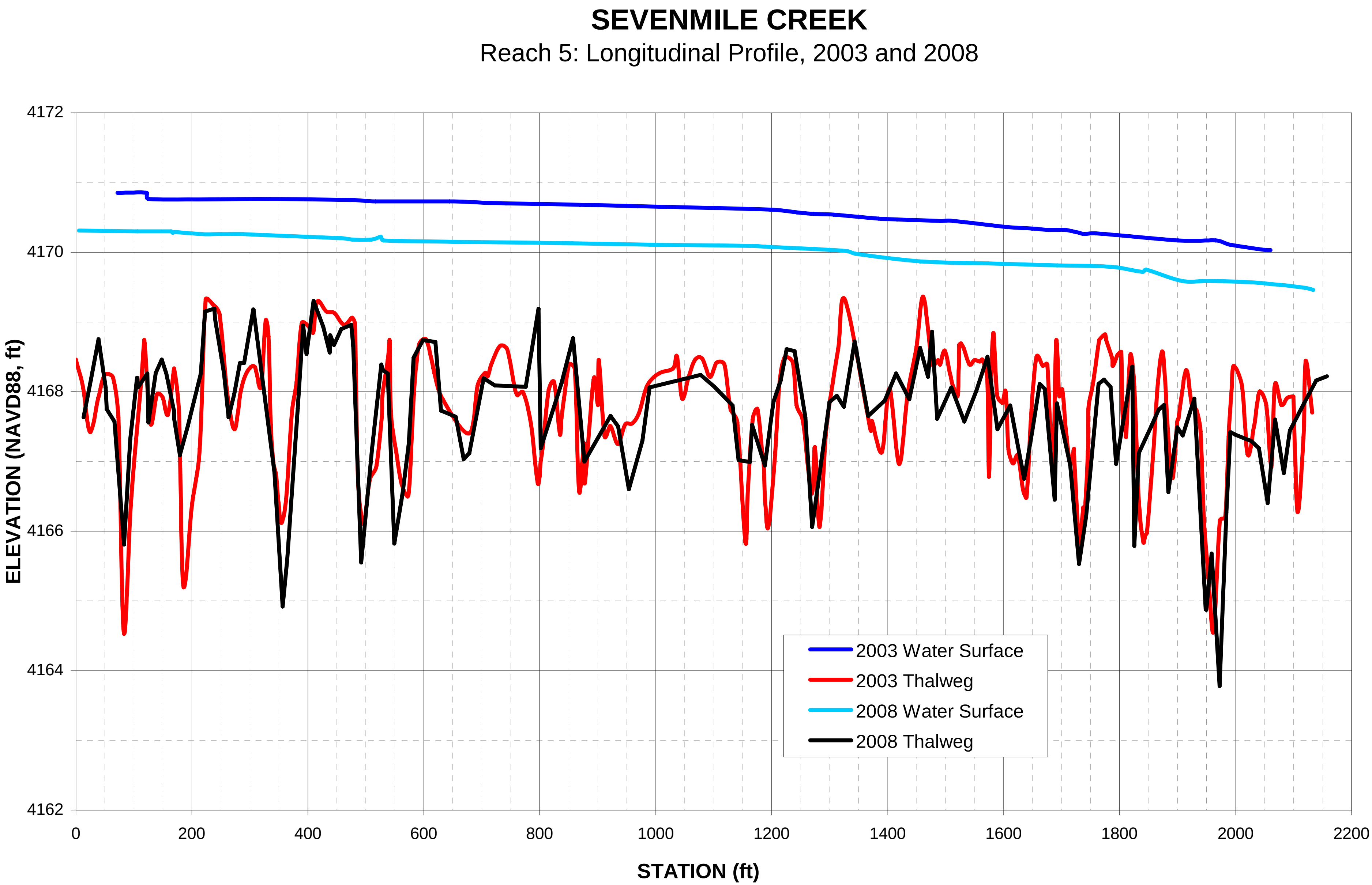

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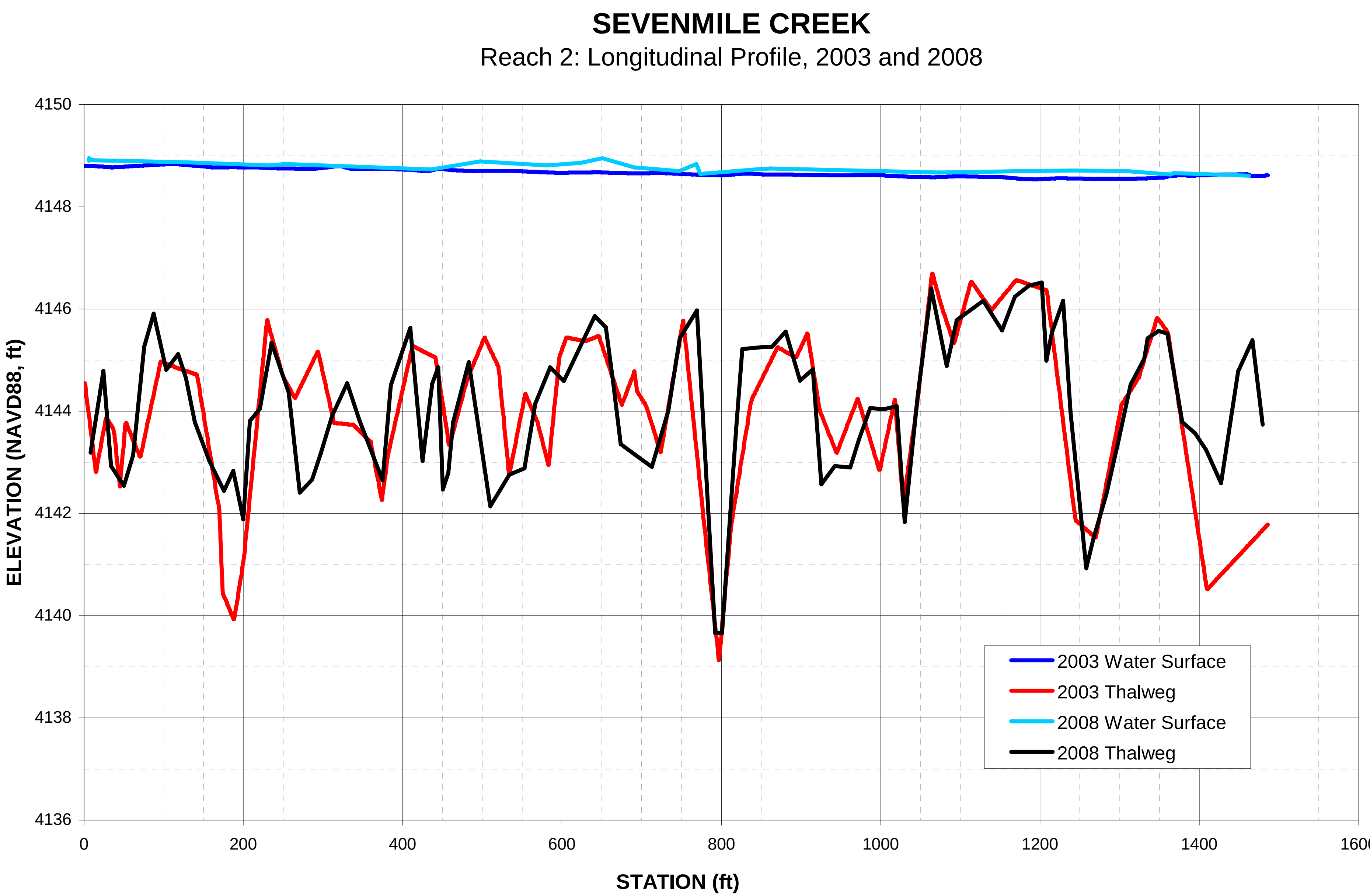

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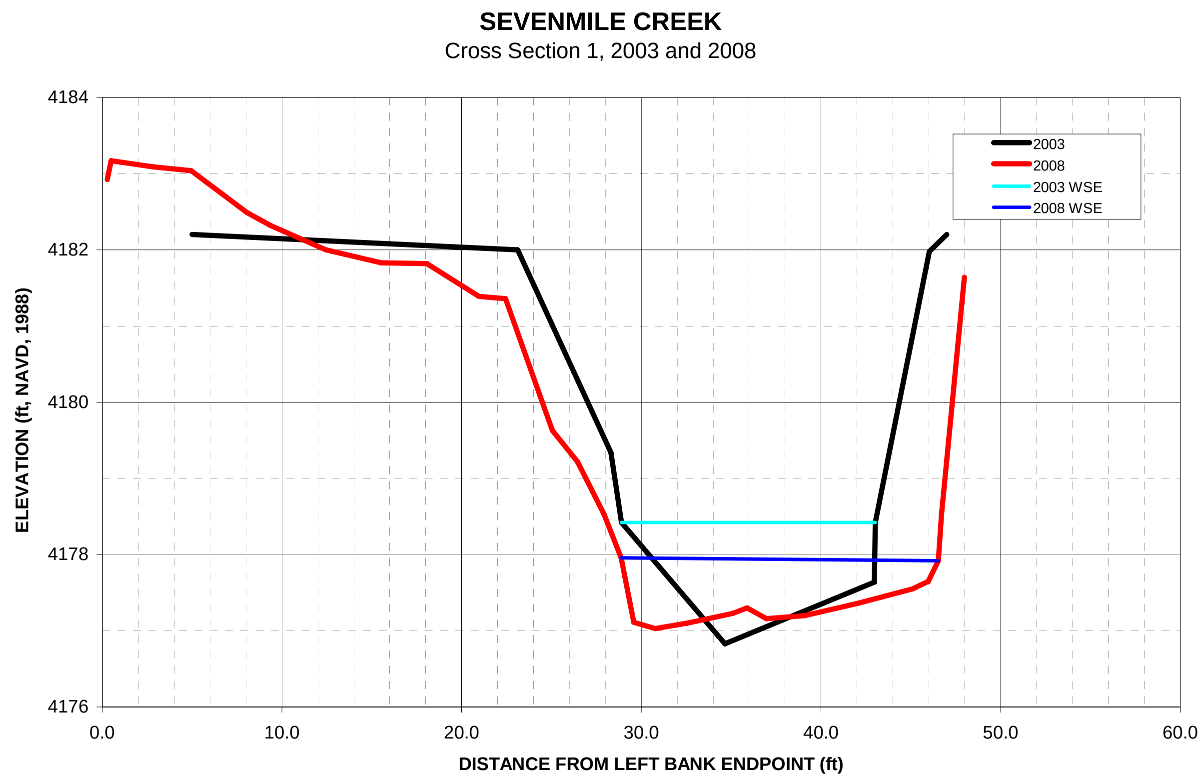
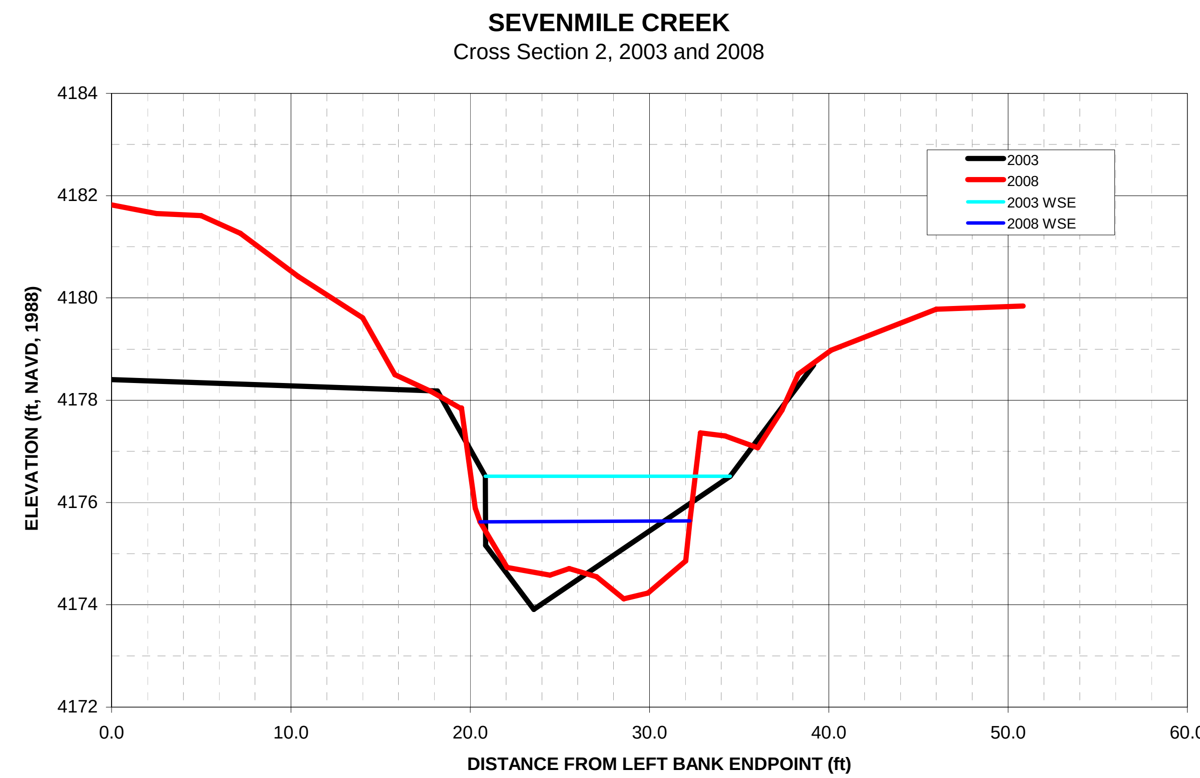
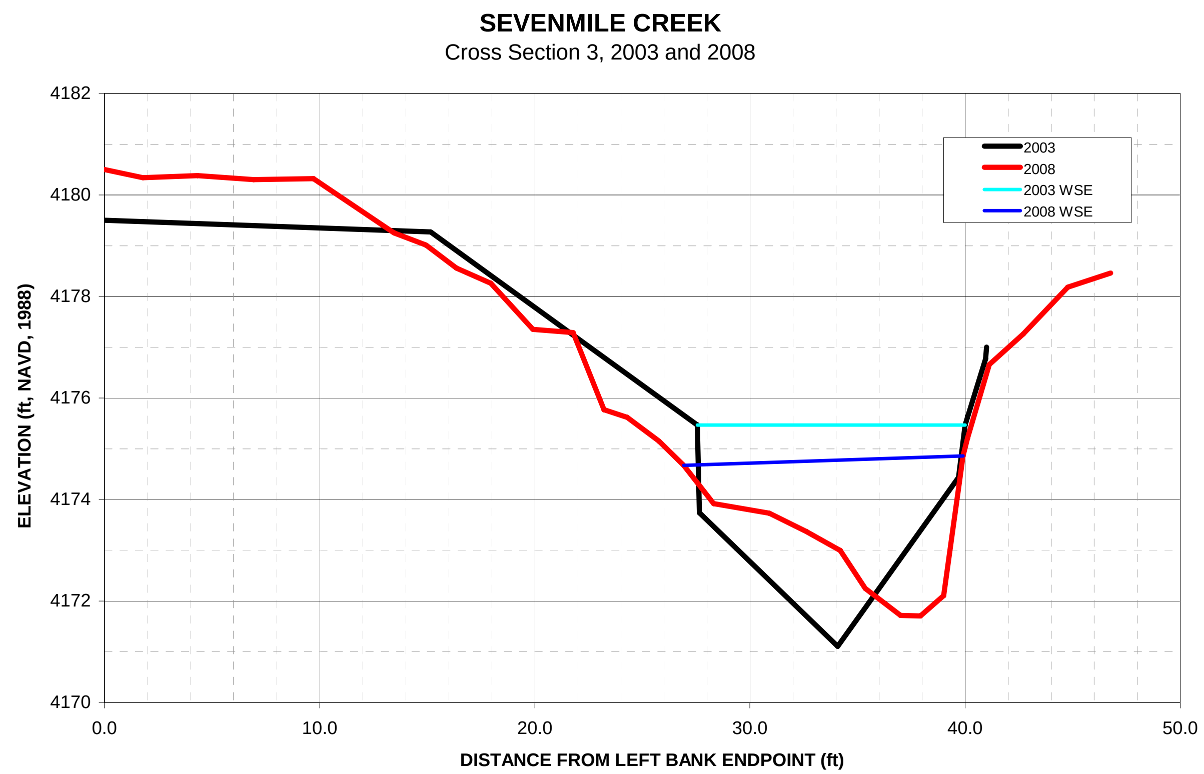
FIGURE

8

SEVENMILE CREEK, REACH 6 CROSS SECTIONS, 2003 AND 2008







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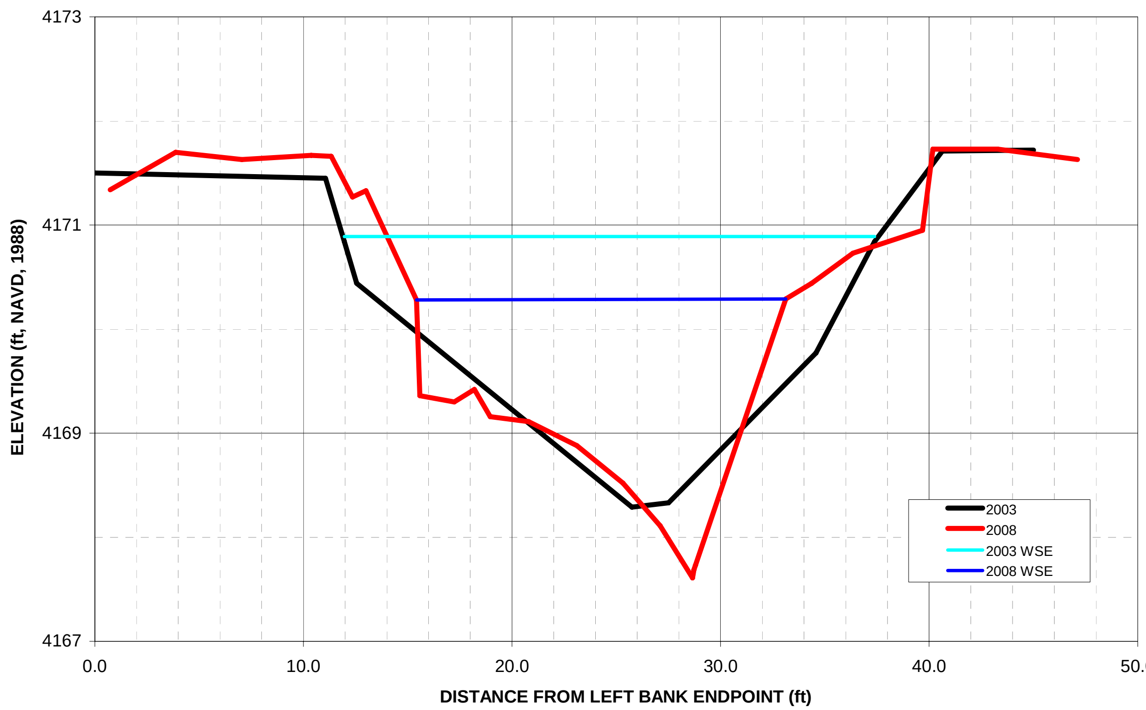
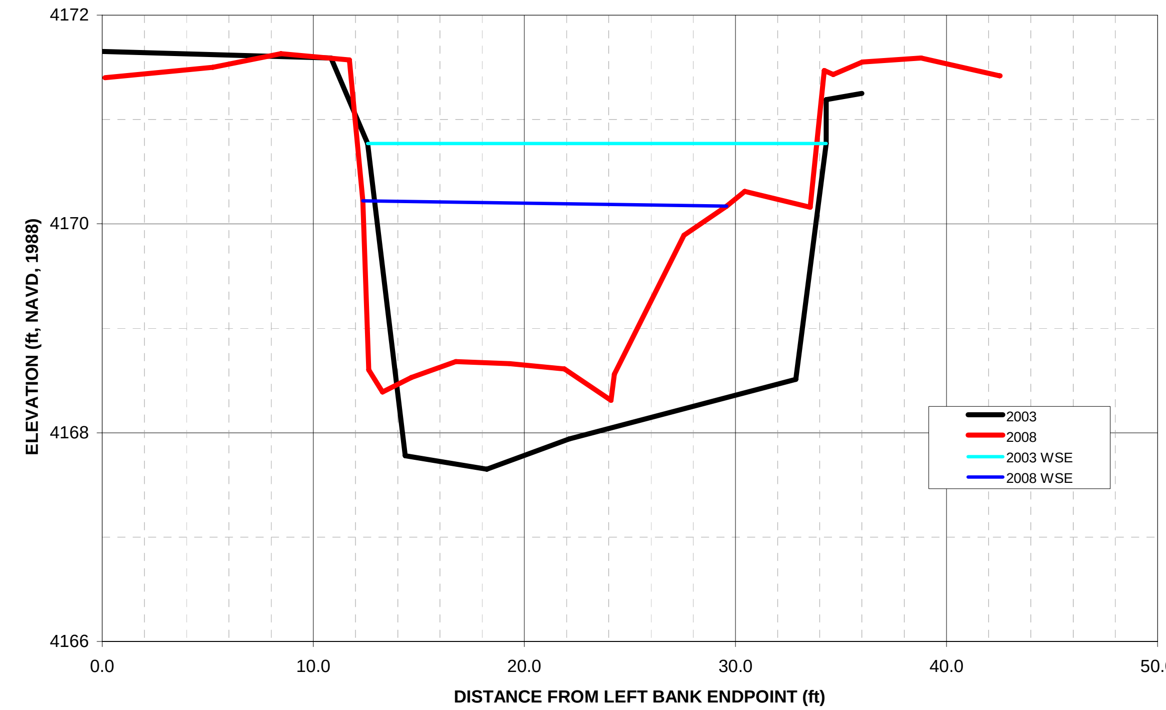
SEVENMILE CREEK, REACH 5 CROSS SECTIONS, 2003 AND 2008

Cross Section 4 (Reach 5), 2003 and 2008



Cross Section 5 (Reach 5), 2003 and 2008



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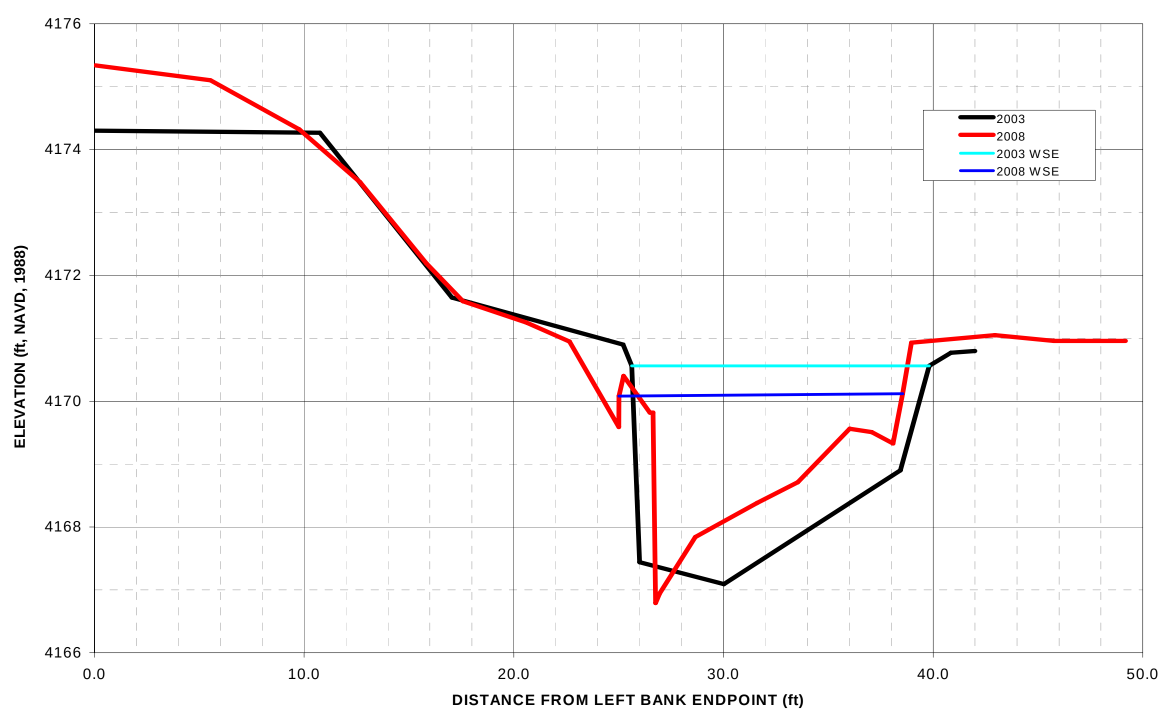
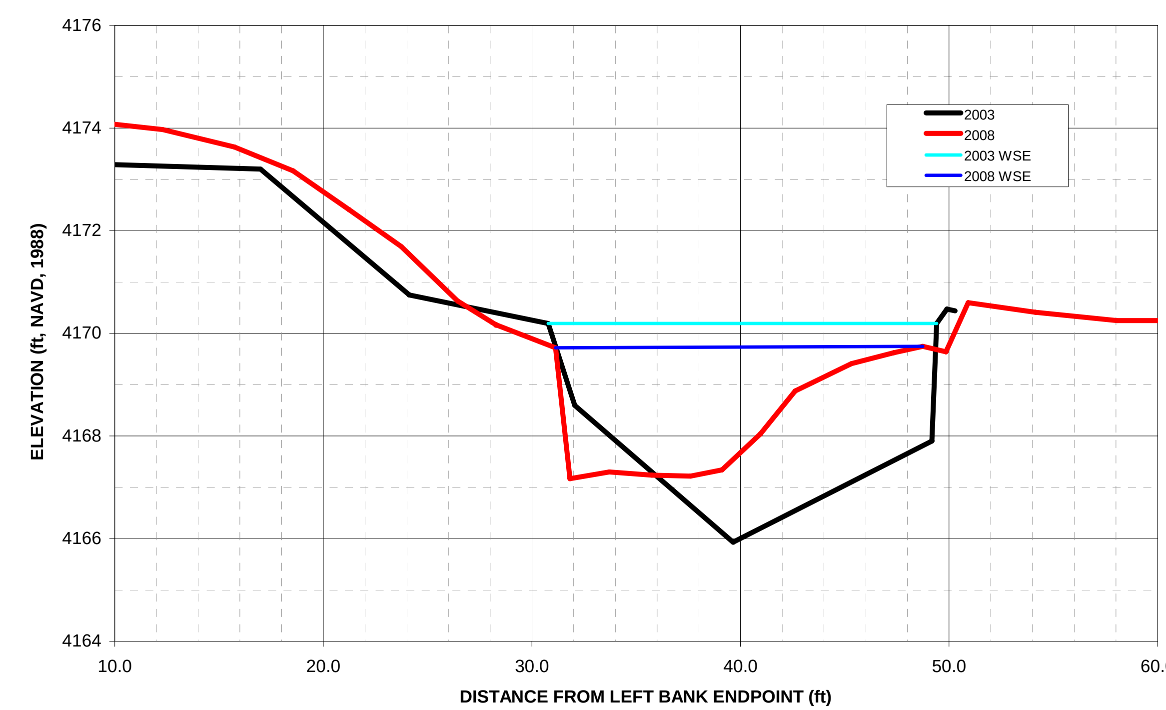


Cross Section 7 (Reach 5), 2003 and 2008



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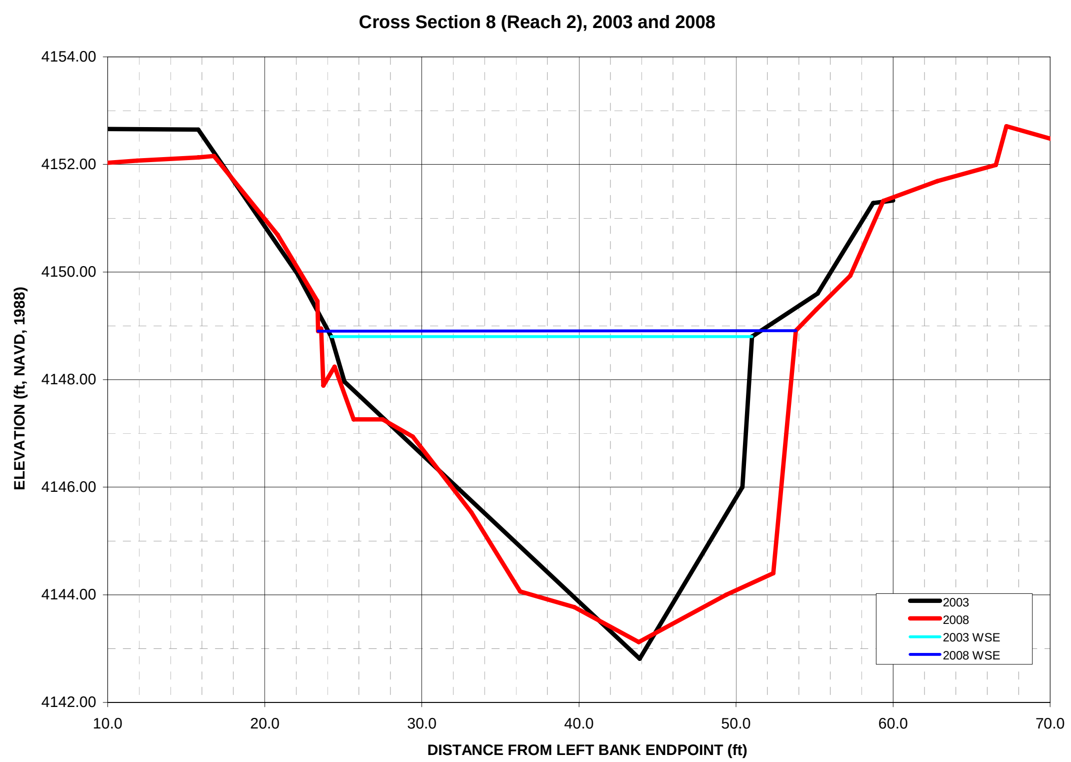
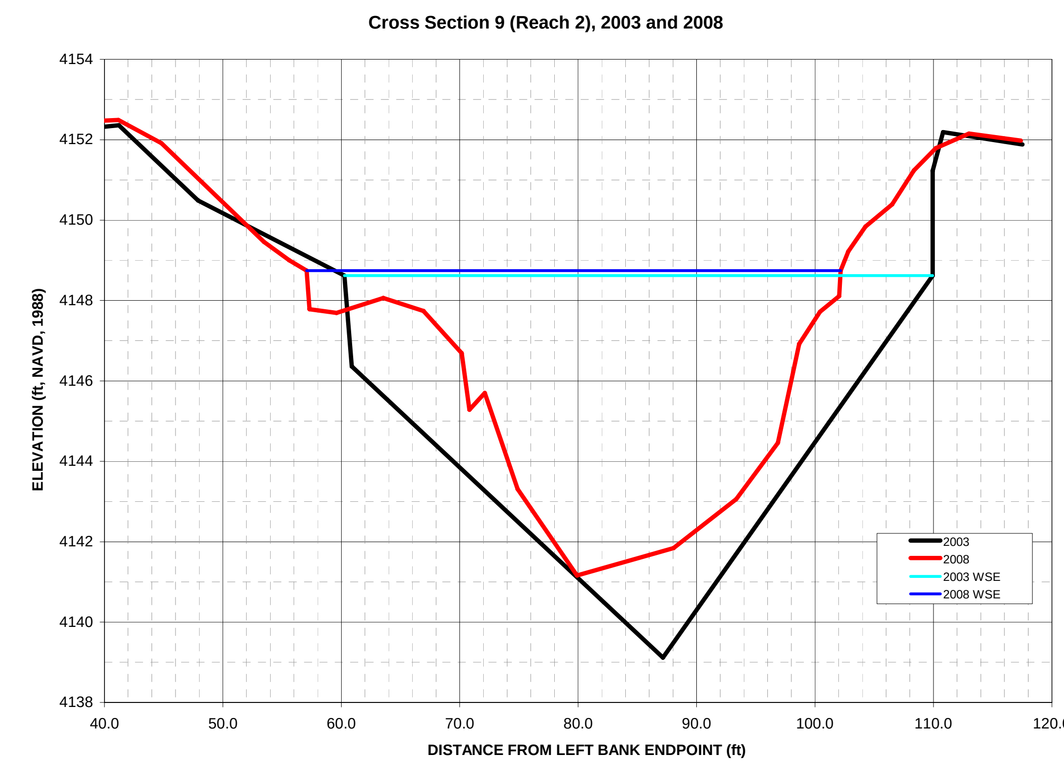
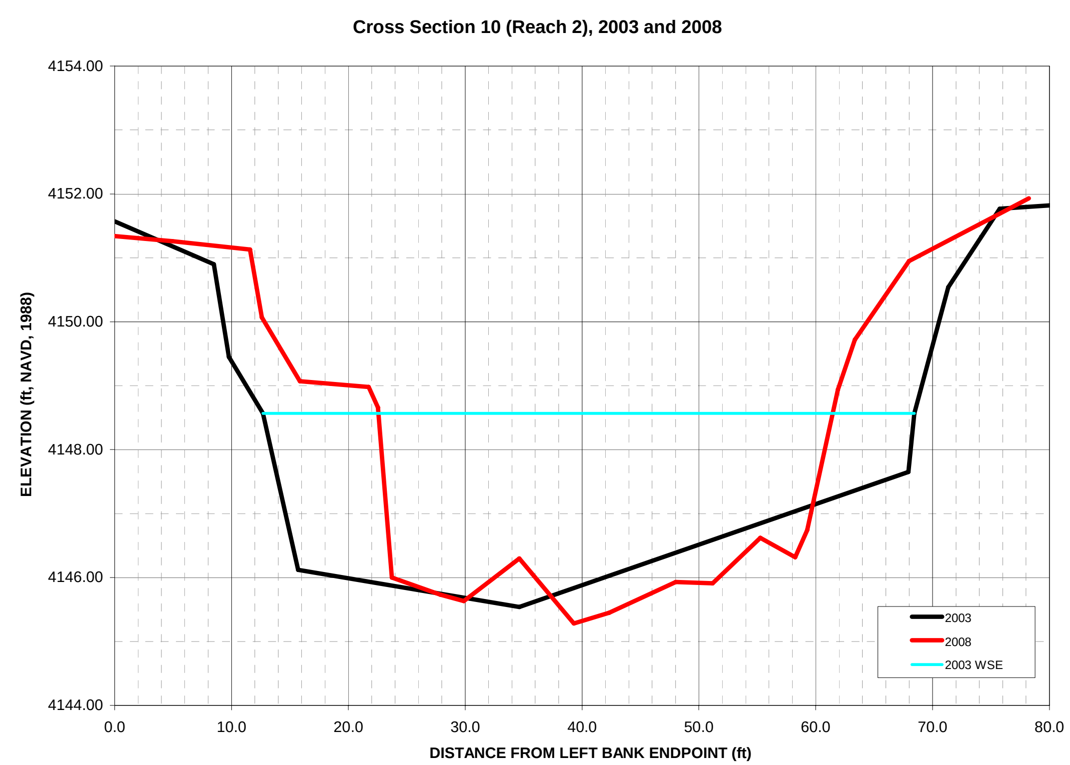
SEVENMILE CREEK, REACH 2 CROSS SECTIONS, 2003 AND 2008







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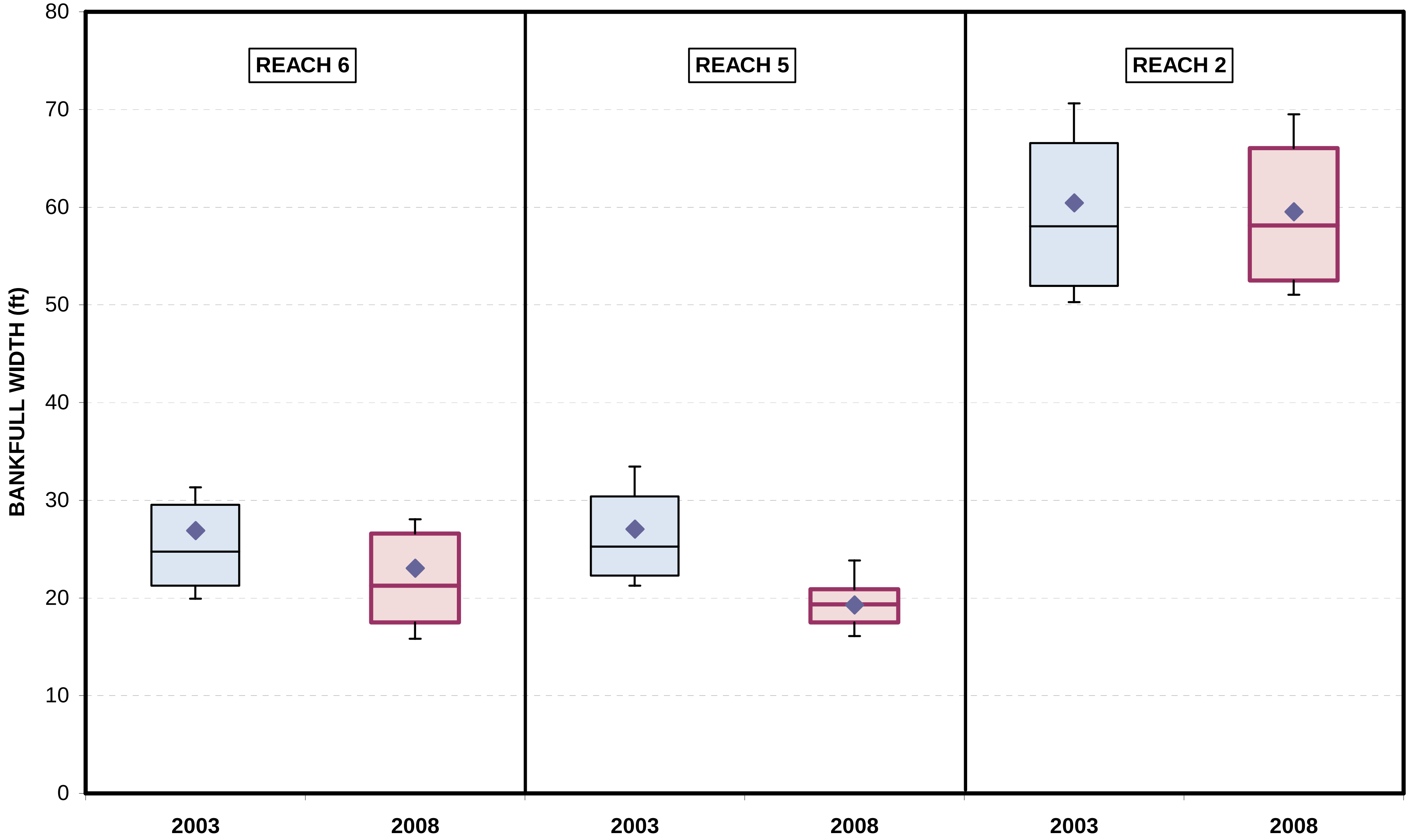
SEVENMILE CREEK

Comparison of Bankfull Channel Widths by Reach, 2003 and 2008



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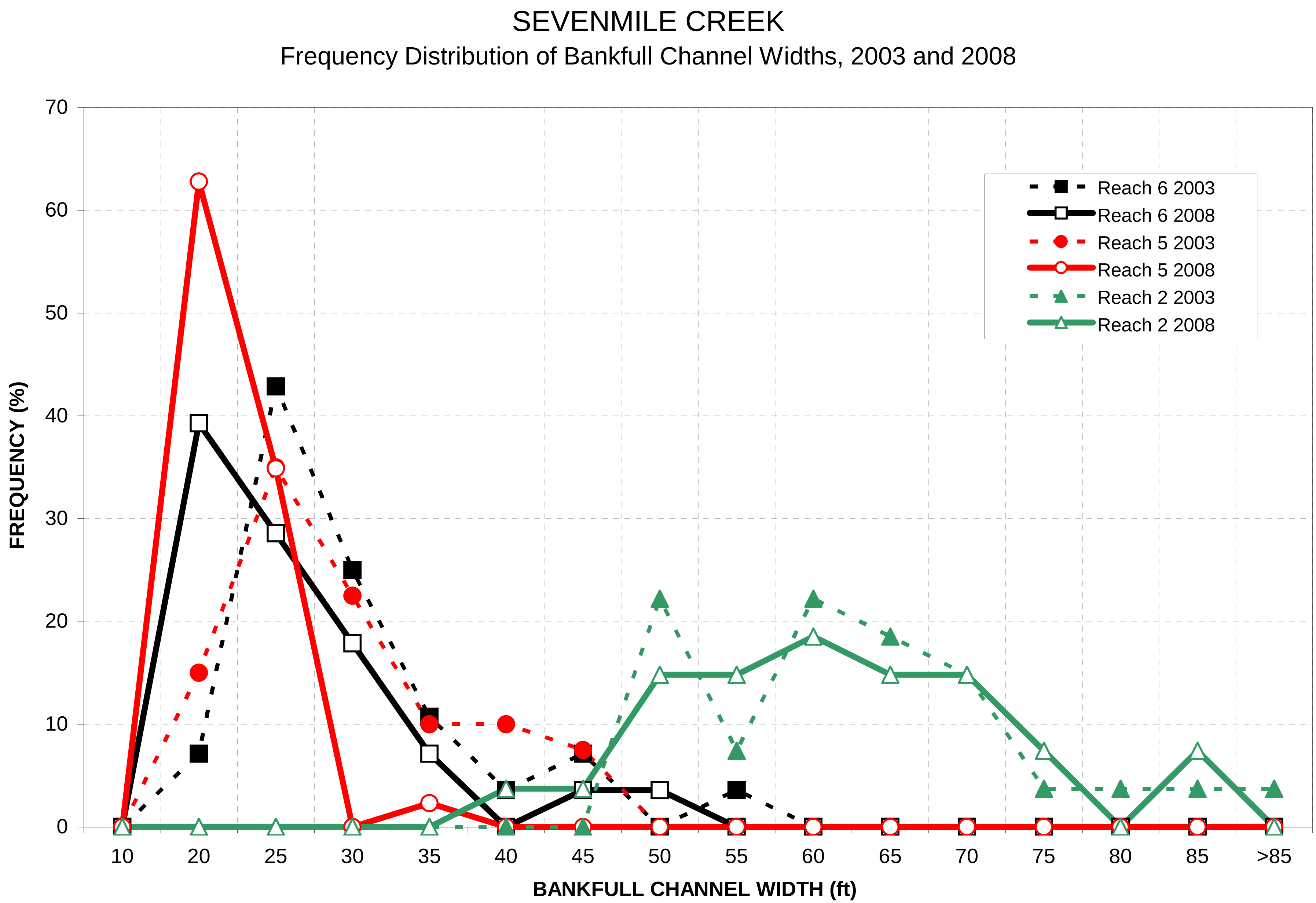

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FIGURE

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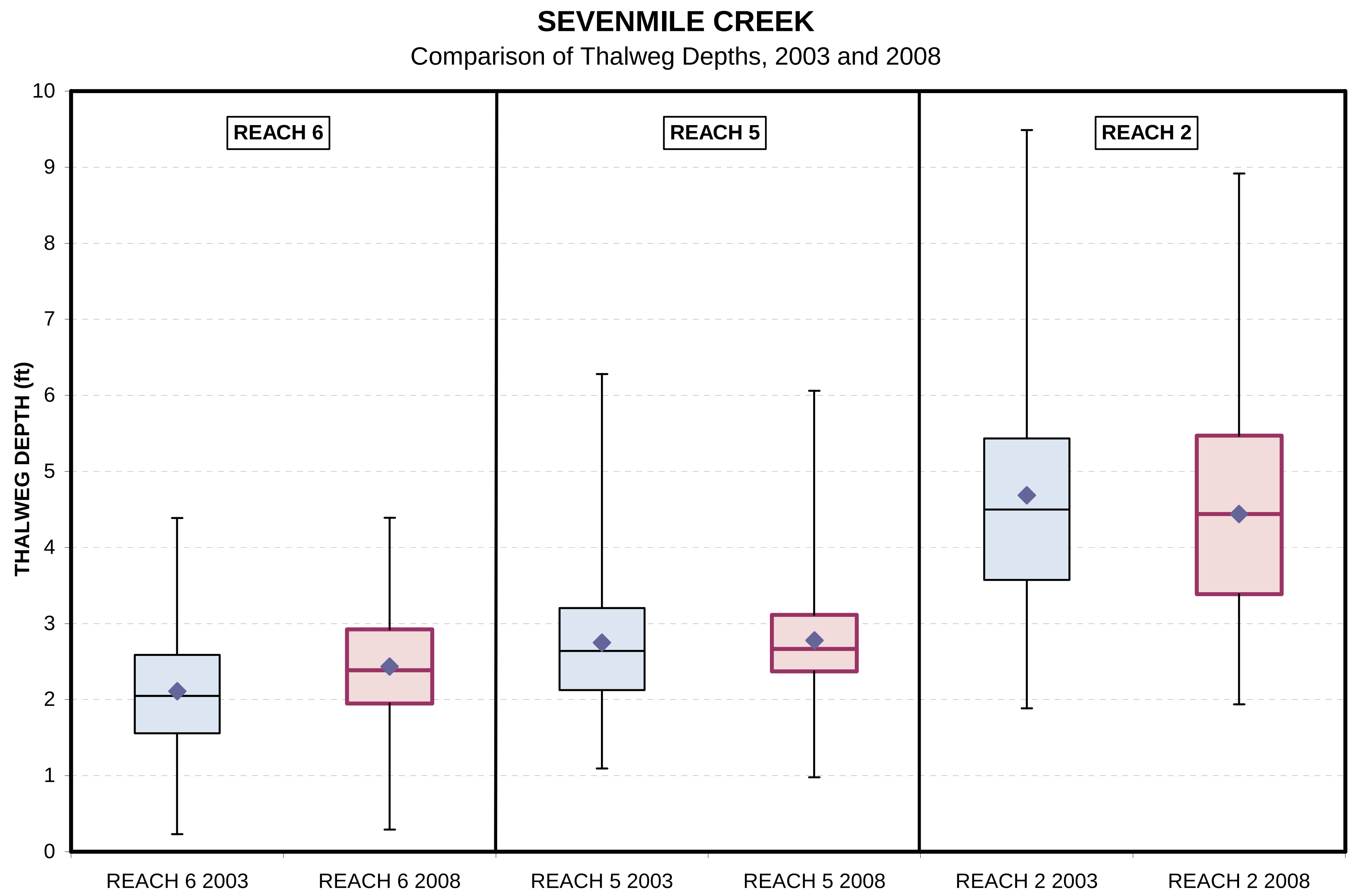

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FIGURE 12

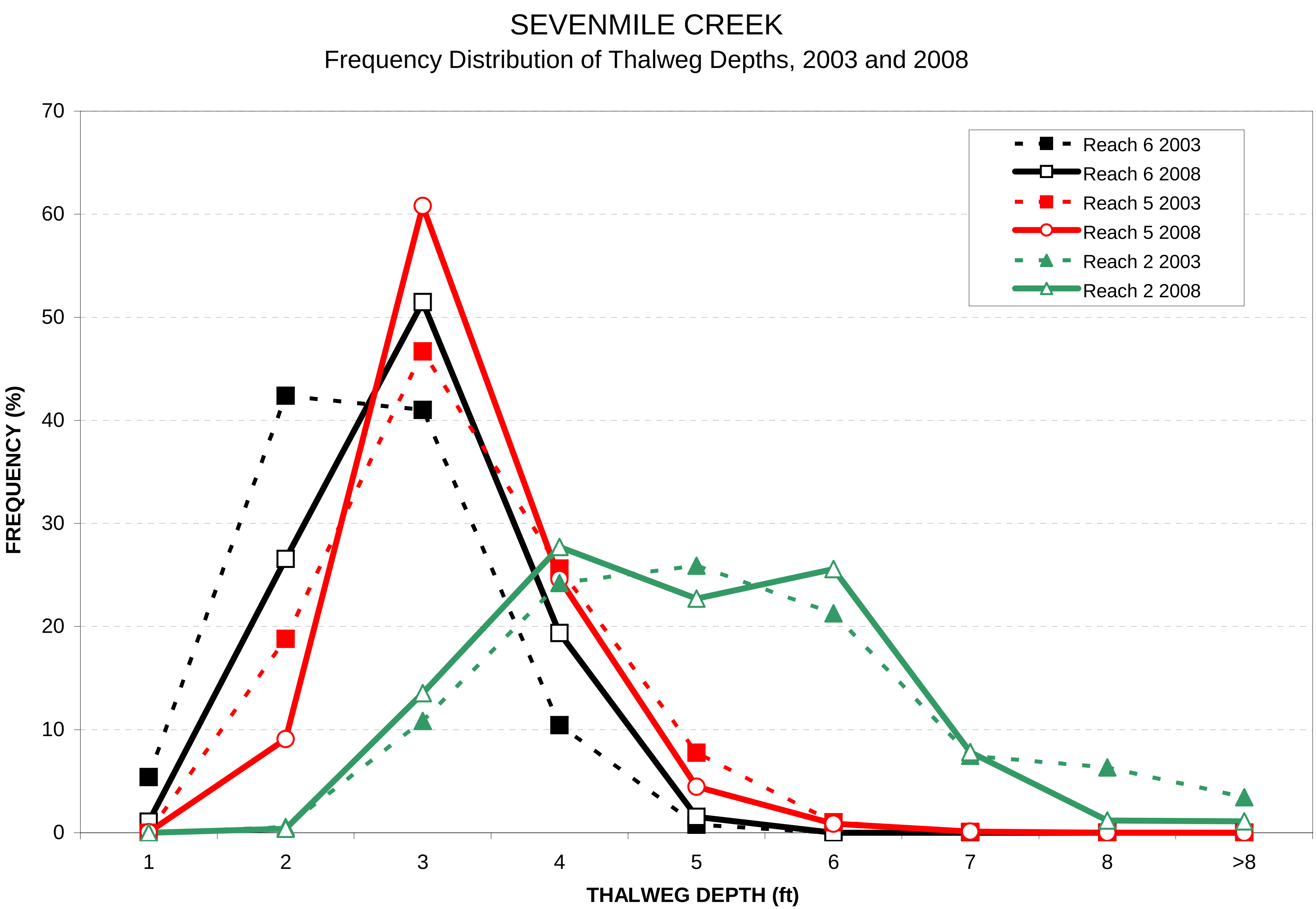

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FIGURE

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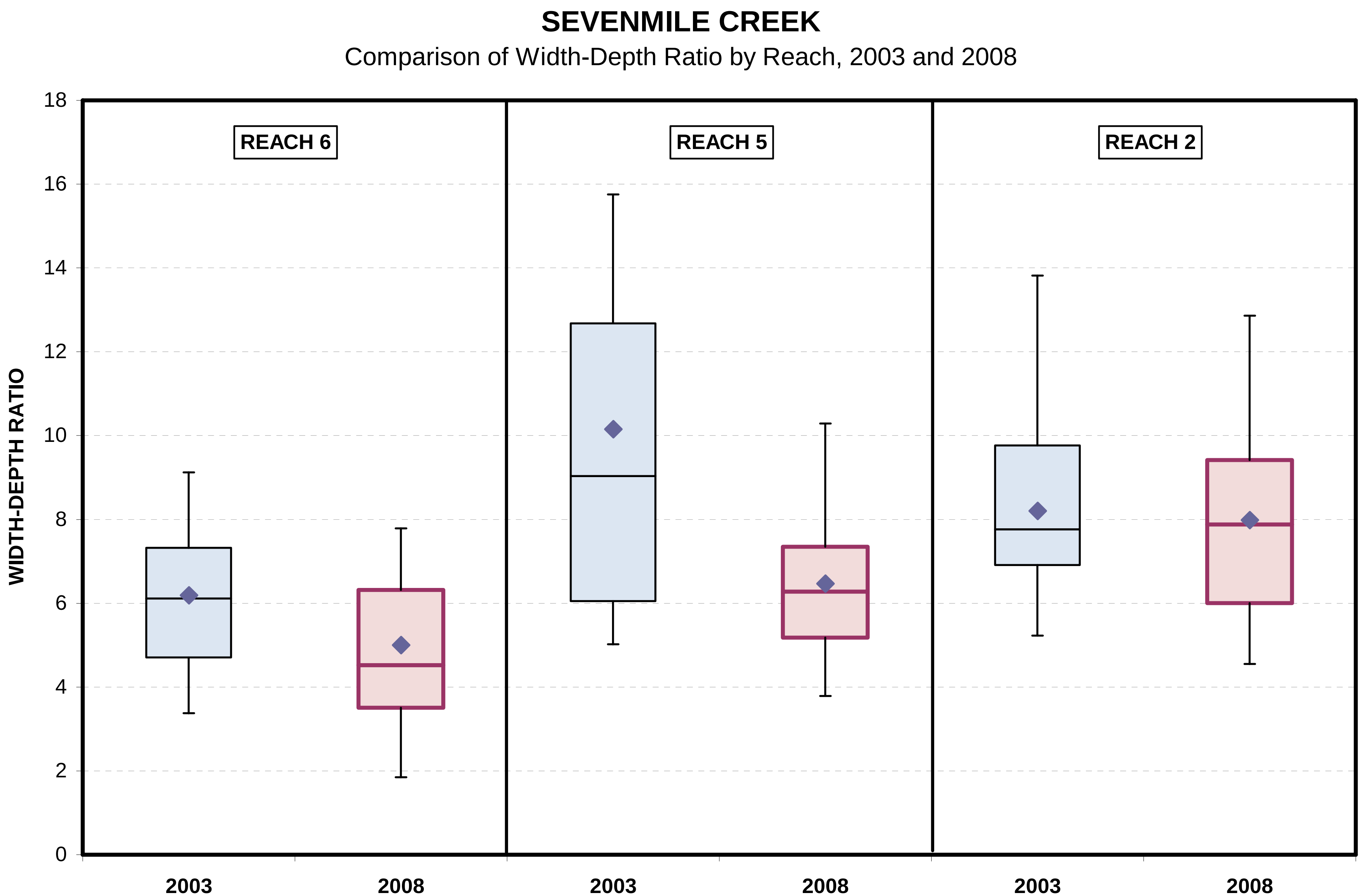

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FIGURE

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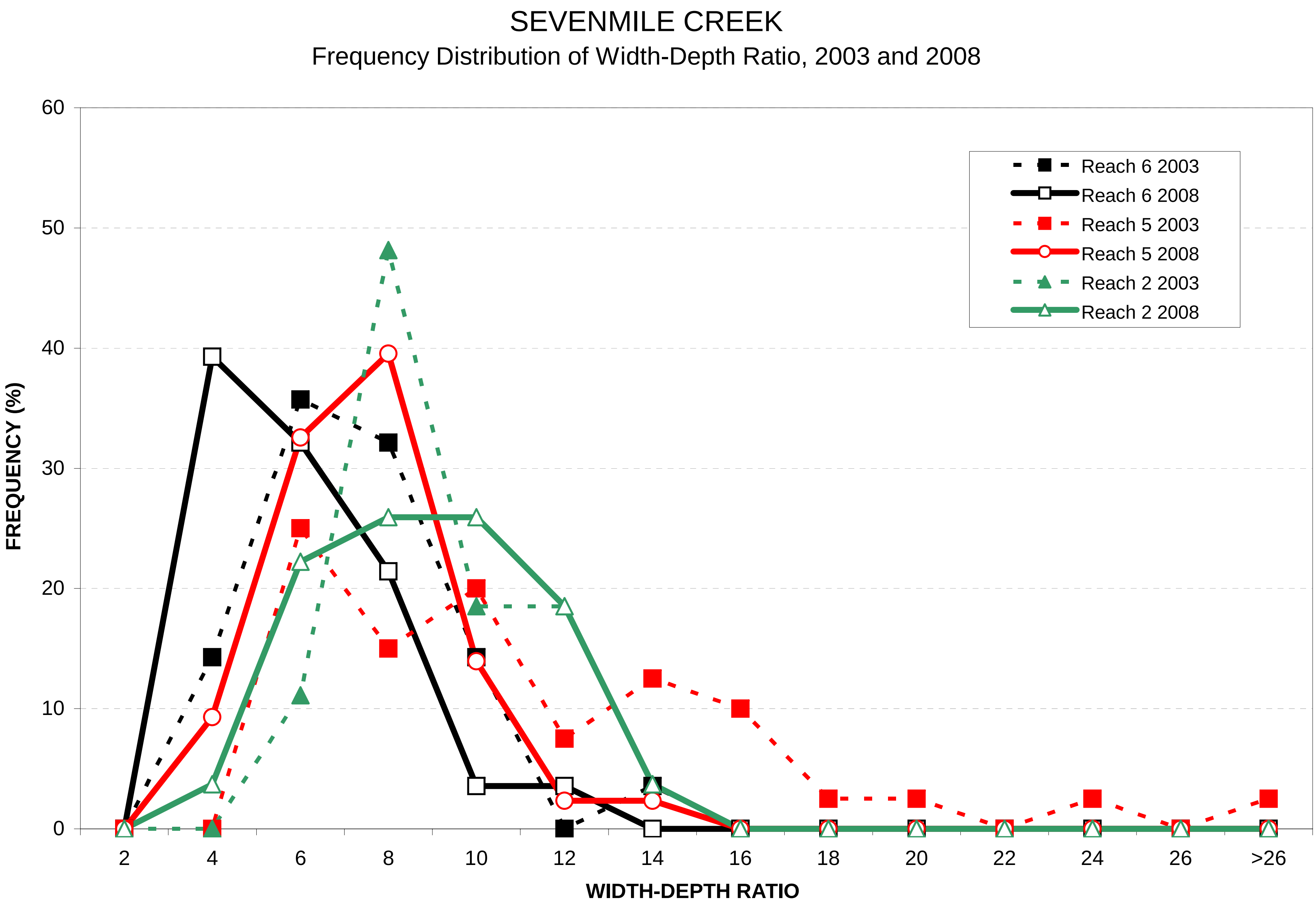

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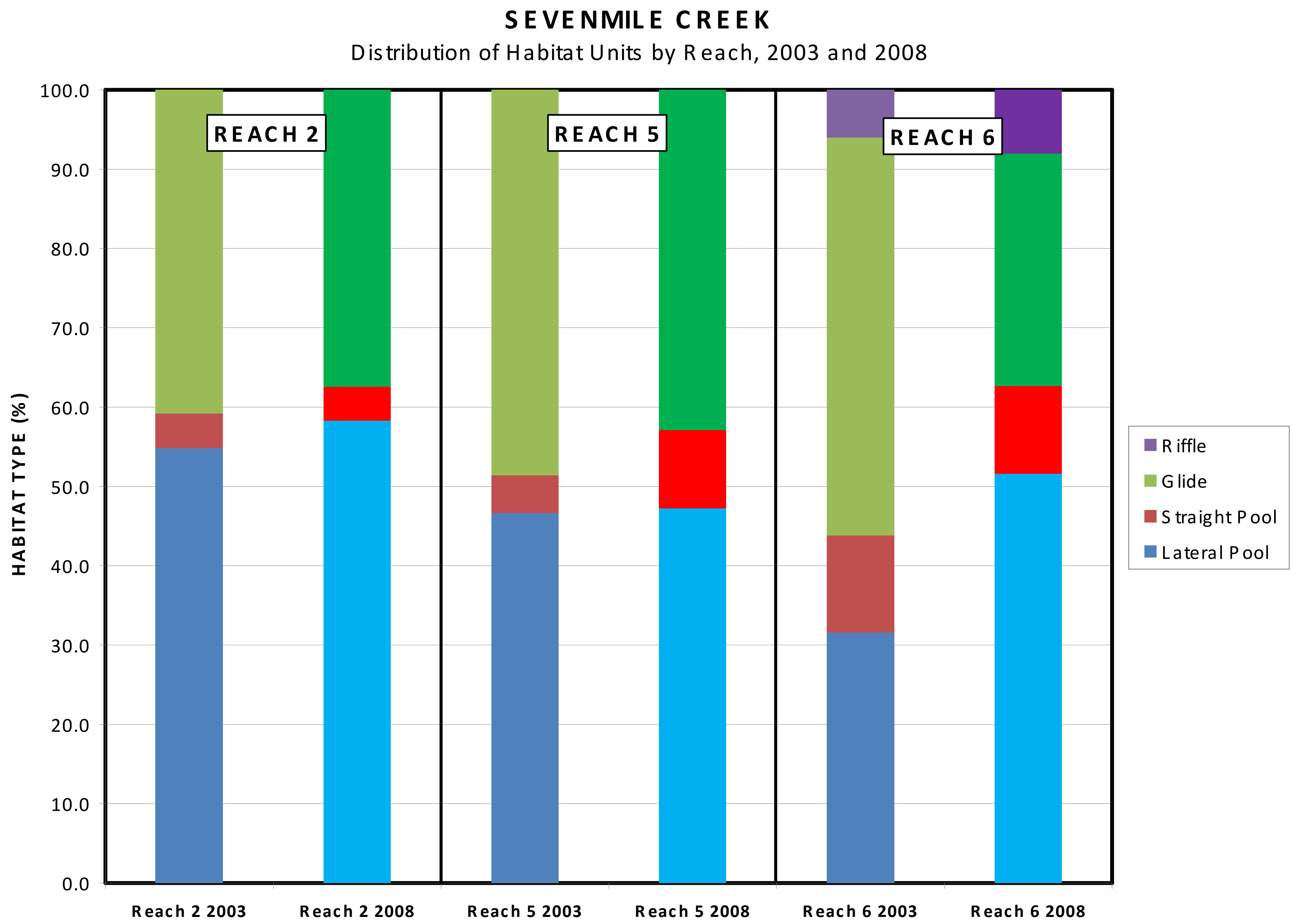

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FIGURE

16

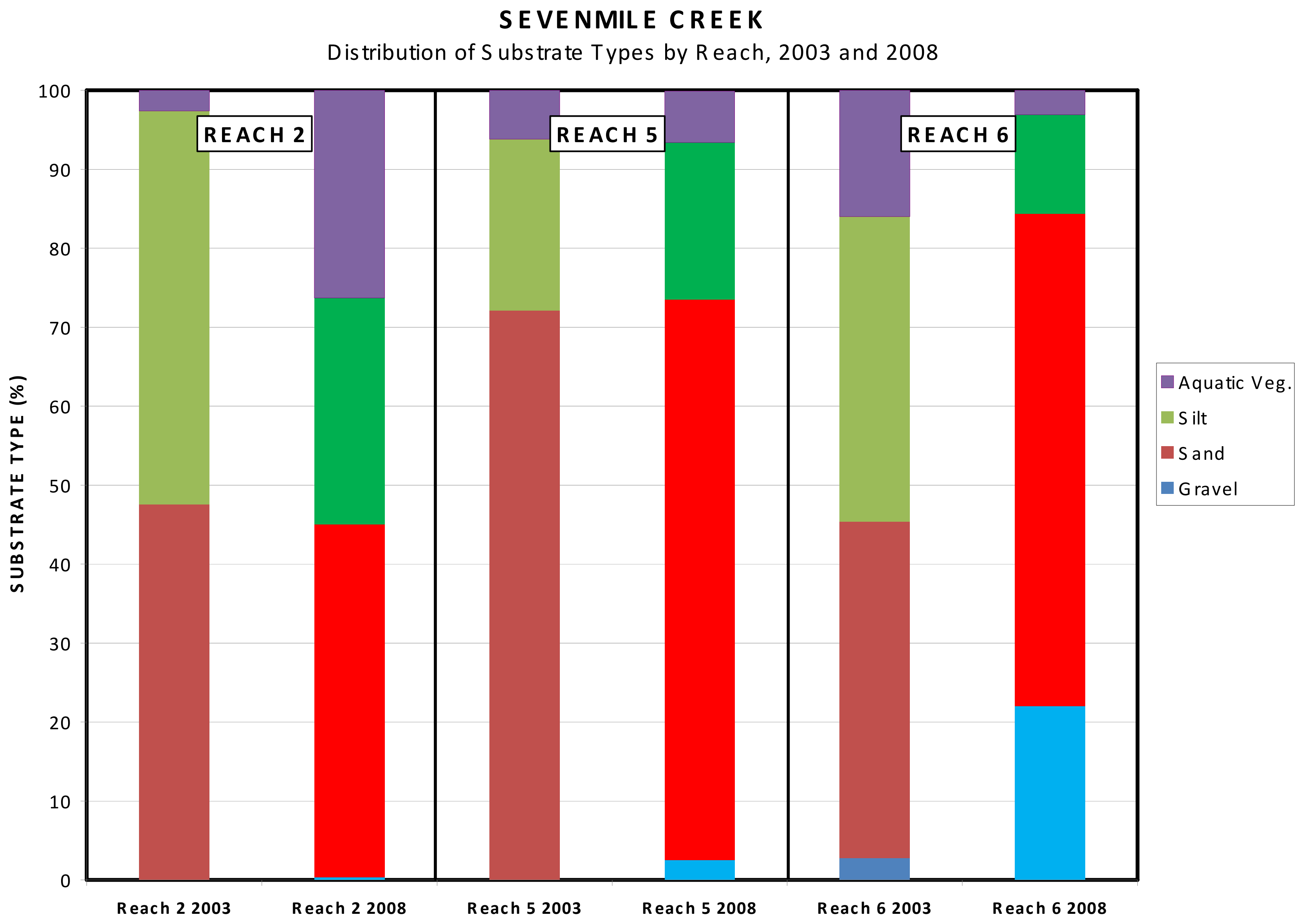

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FIGURE 17

TYPICAL SEVENMILE CREEK PHOTOPOINT COMPARISON

2003

2008

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FIGURE

18

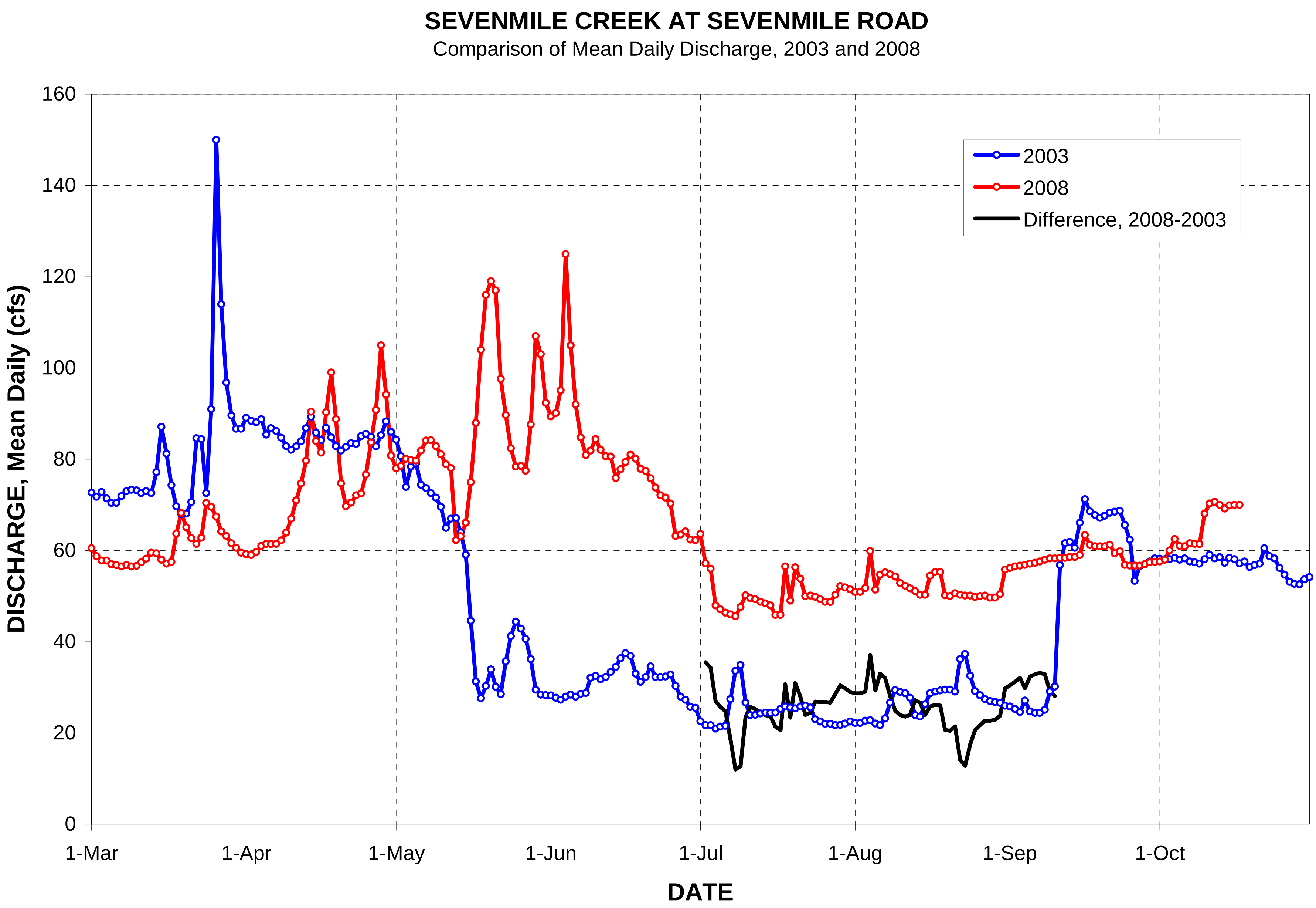

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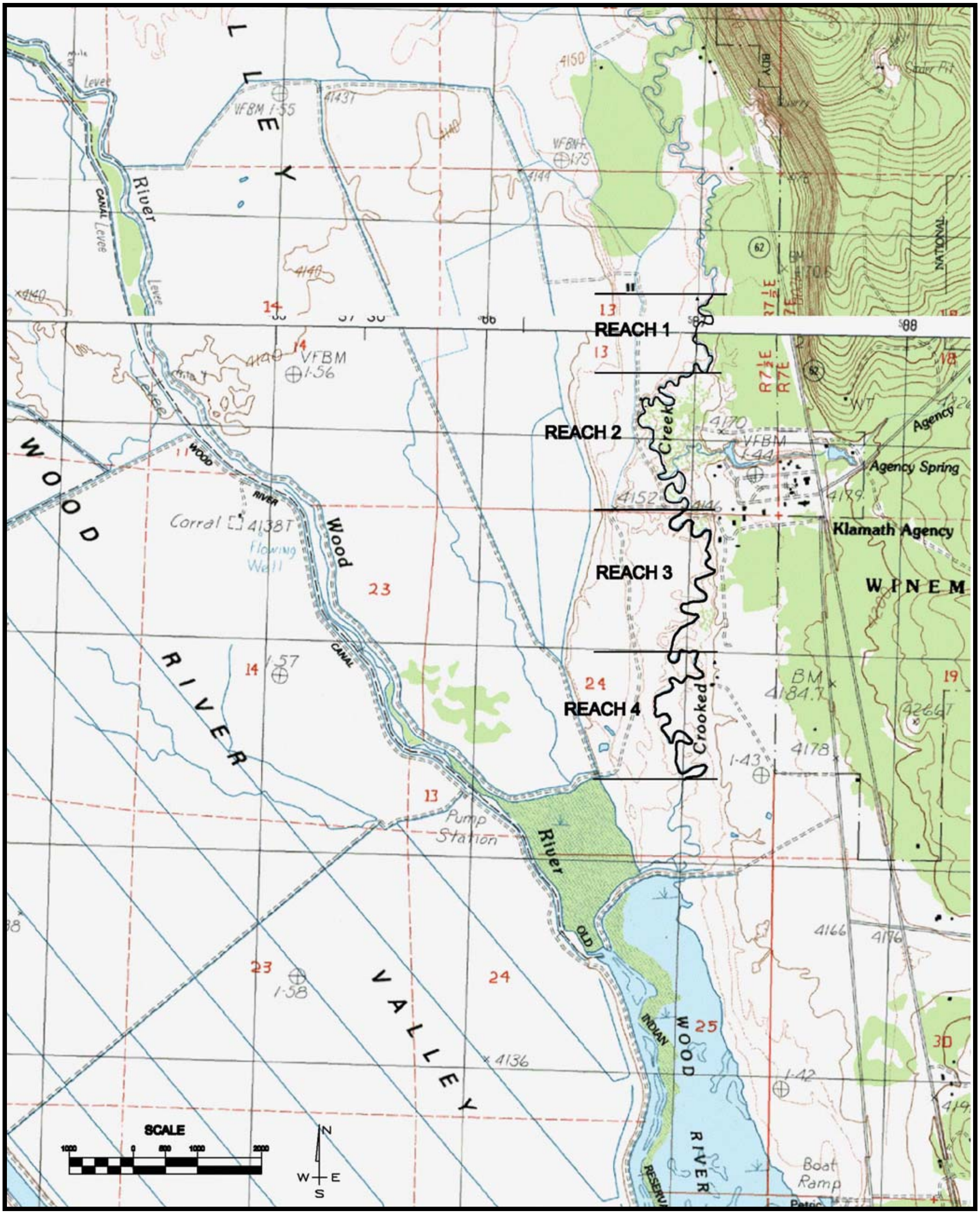
FIGURE

19

CROOKED CREEK STUDY SITES LOCATION MAP



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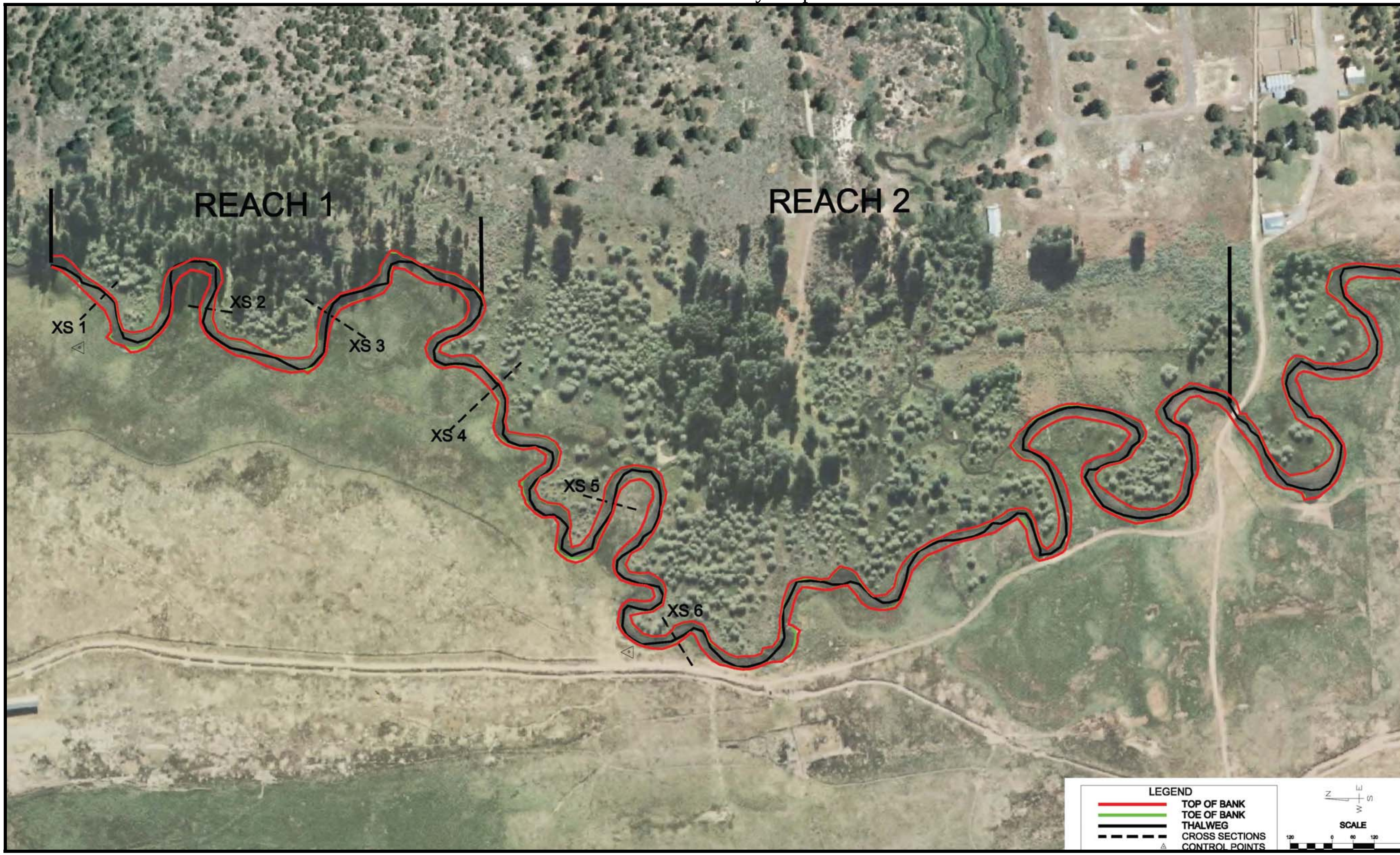
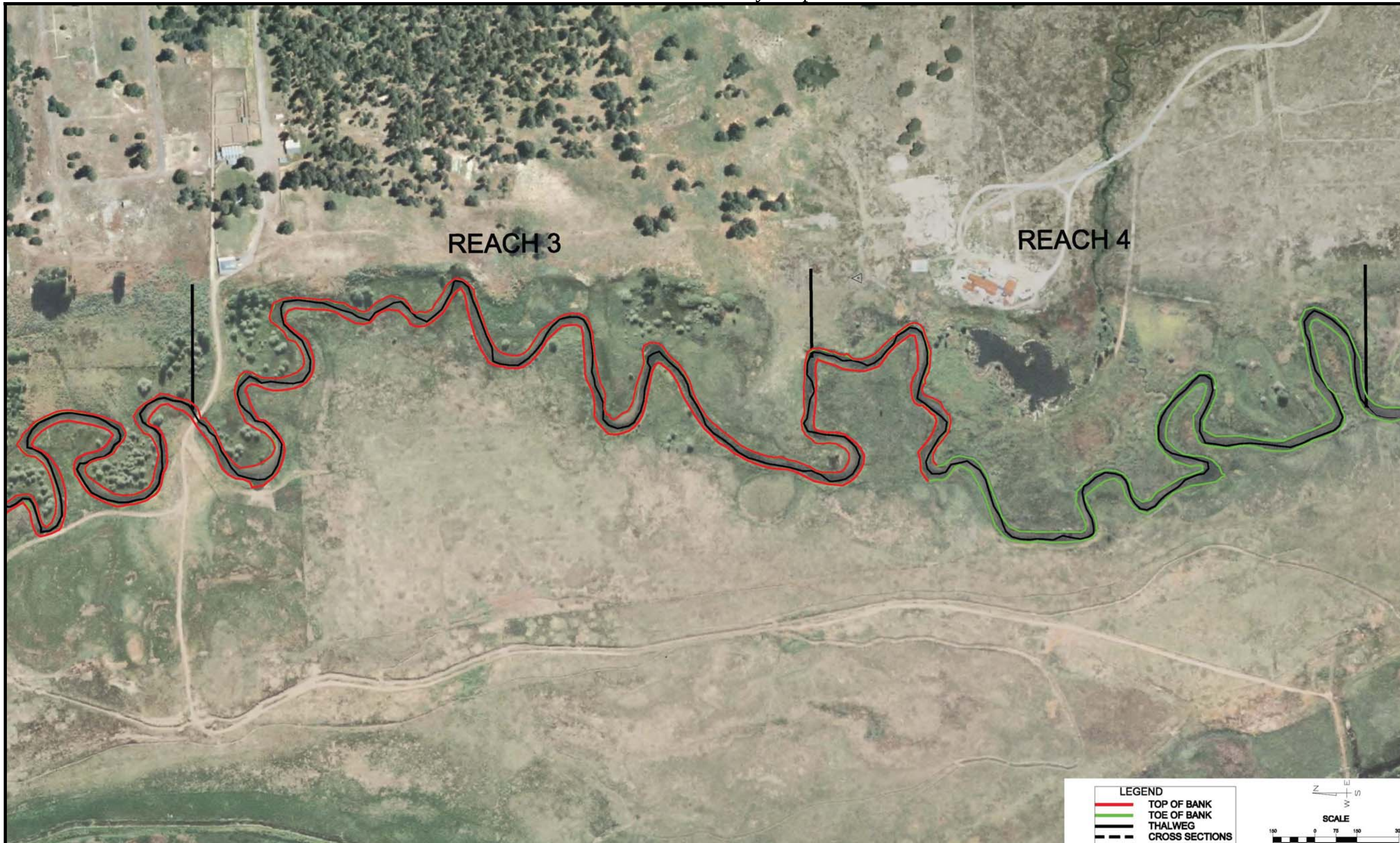
CROOKED CREEK

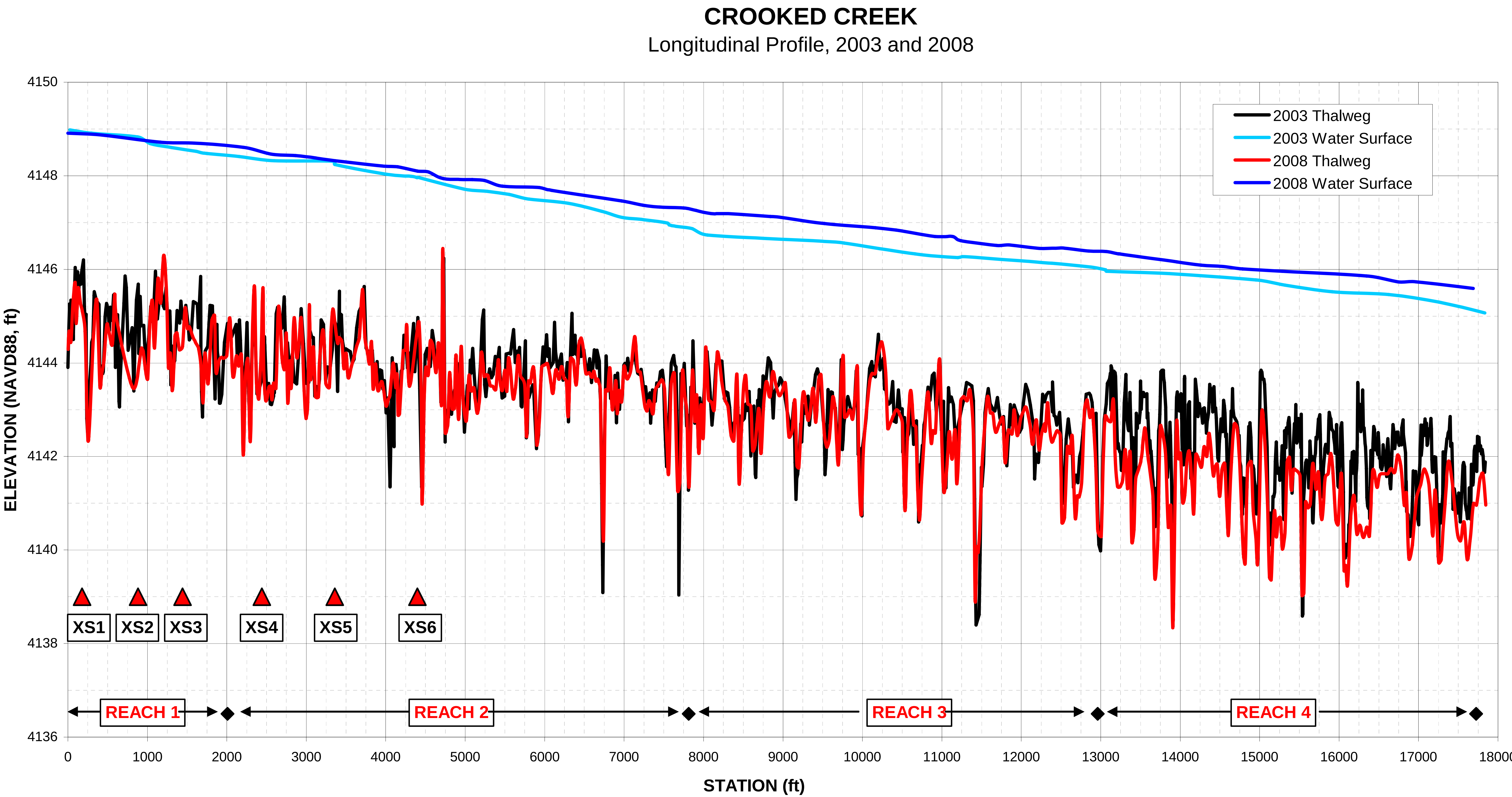
Reach 1-2 Survey Map



CROOKED CREEK

Reach 3-4 Survey Map





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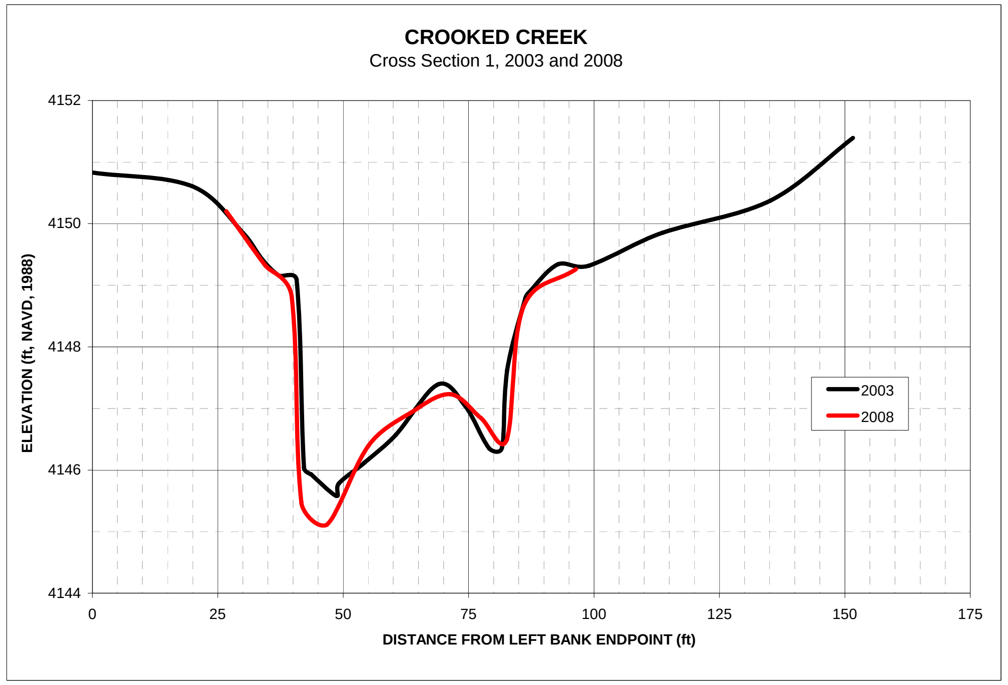
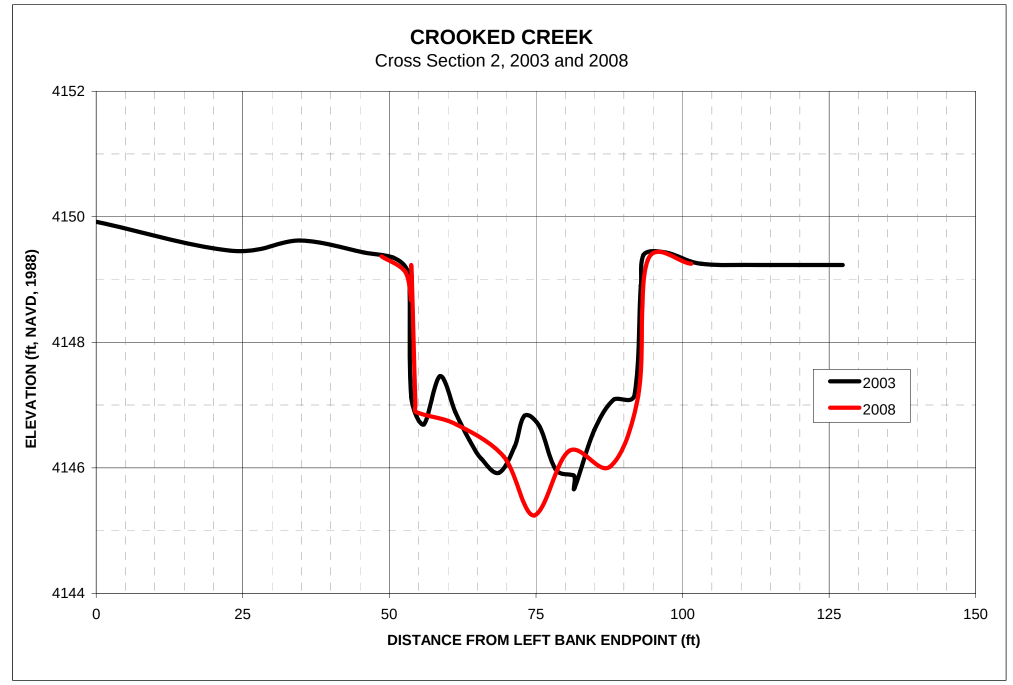
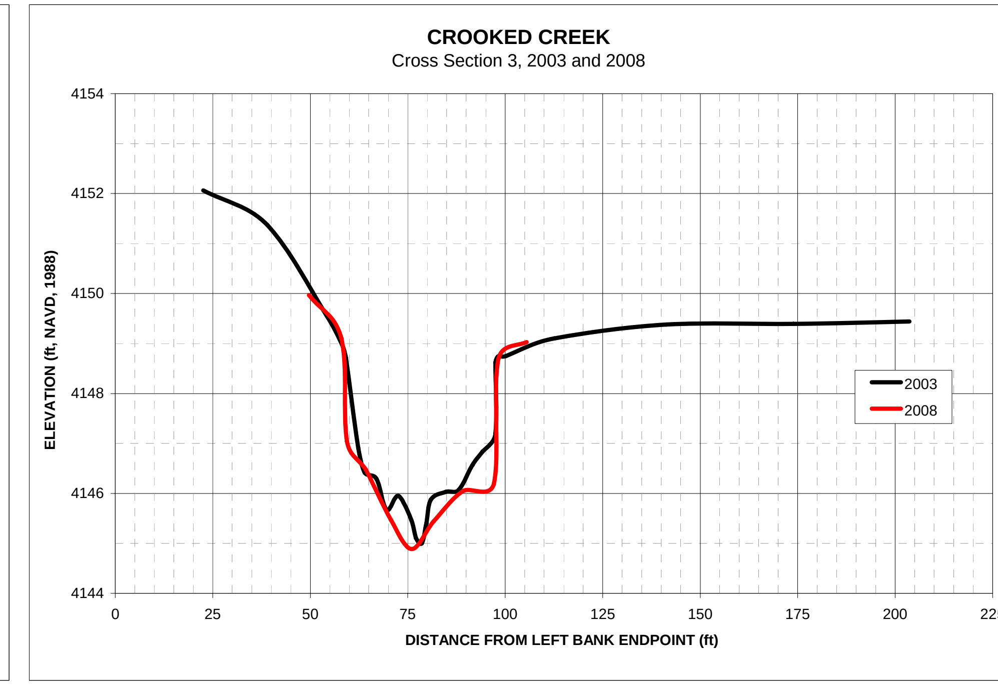
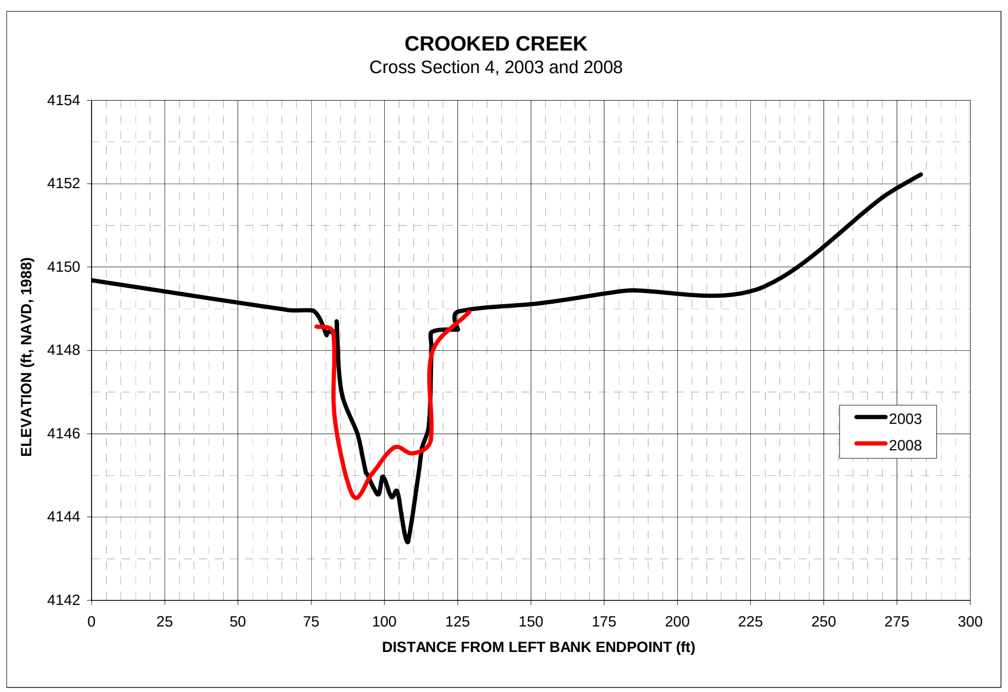
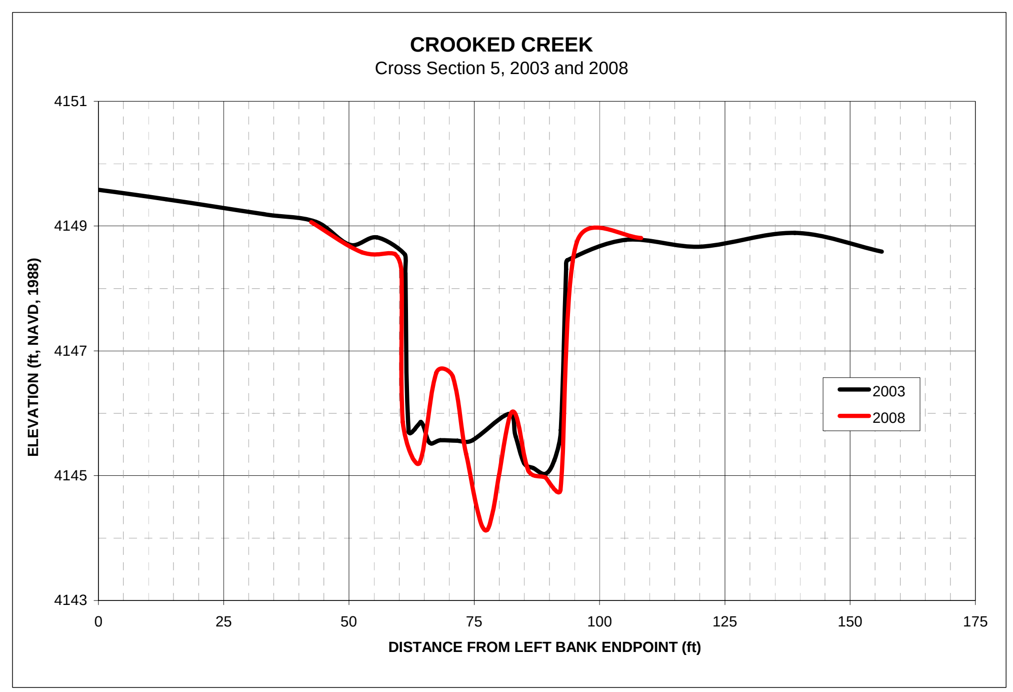
CROOKED CREEK CROSS SECTIONS, 2003 AND 2008

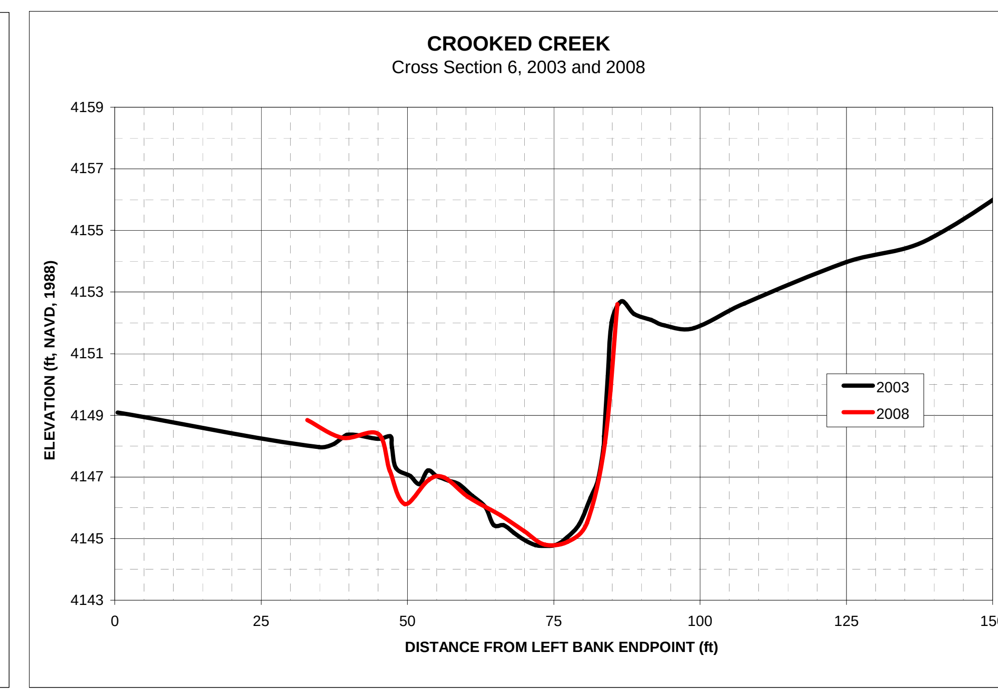












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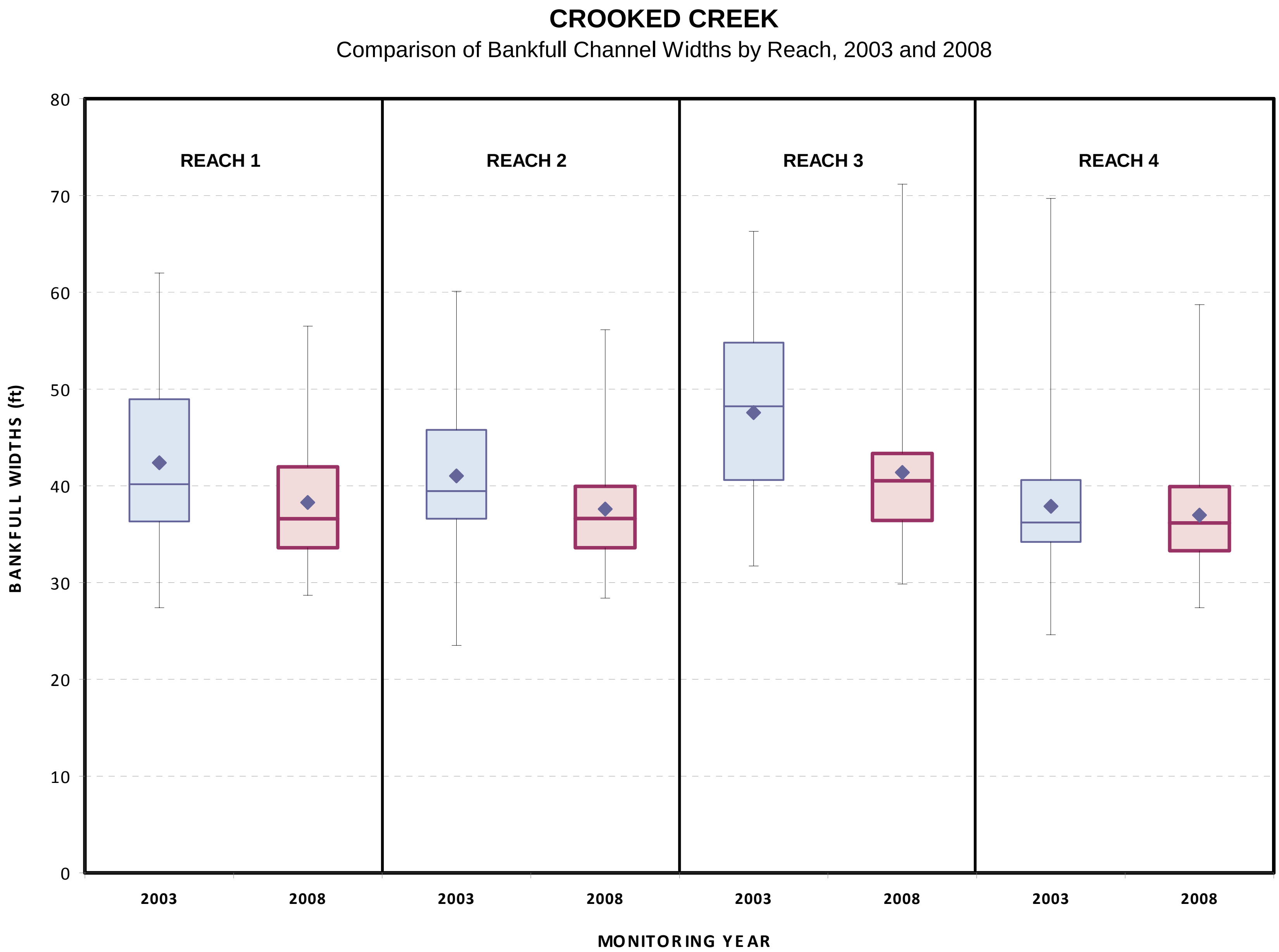

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FIGURE

25

CROOKED CREEK

Comparison of Bankfull Channel Width outside of (4A) and within (4B) Channel Restoration Area in Reach 4, 2003 and 2008

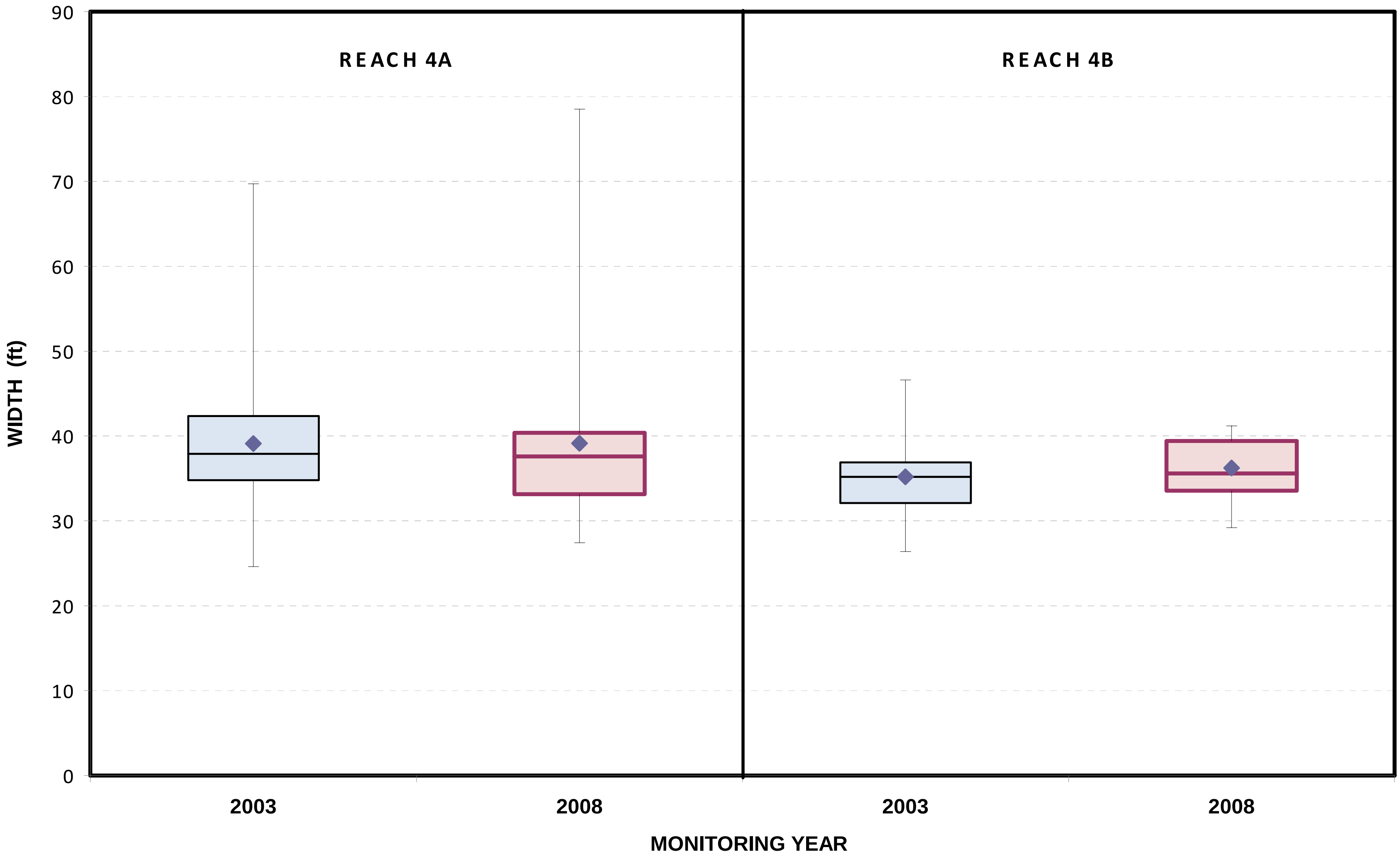

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FIGURE

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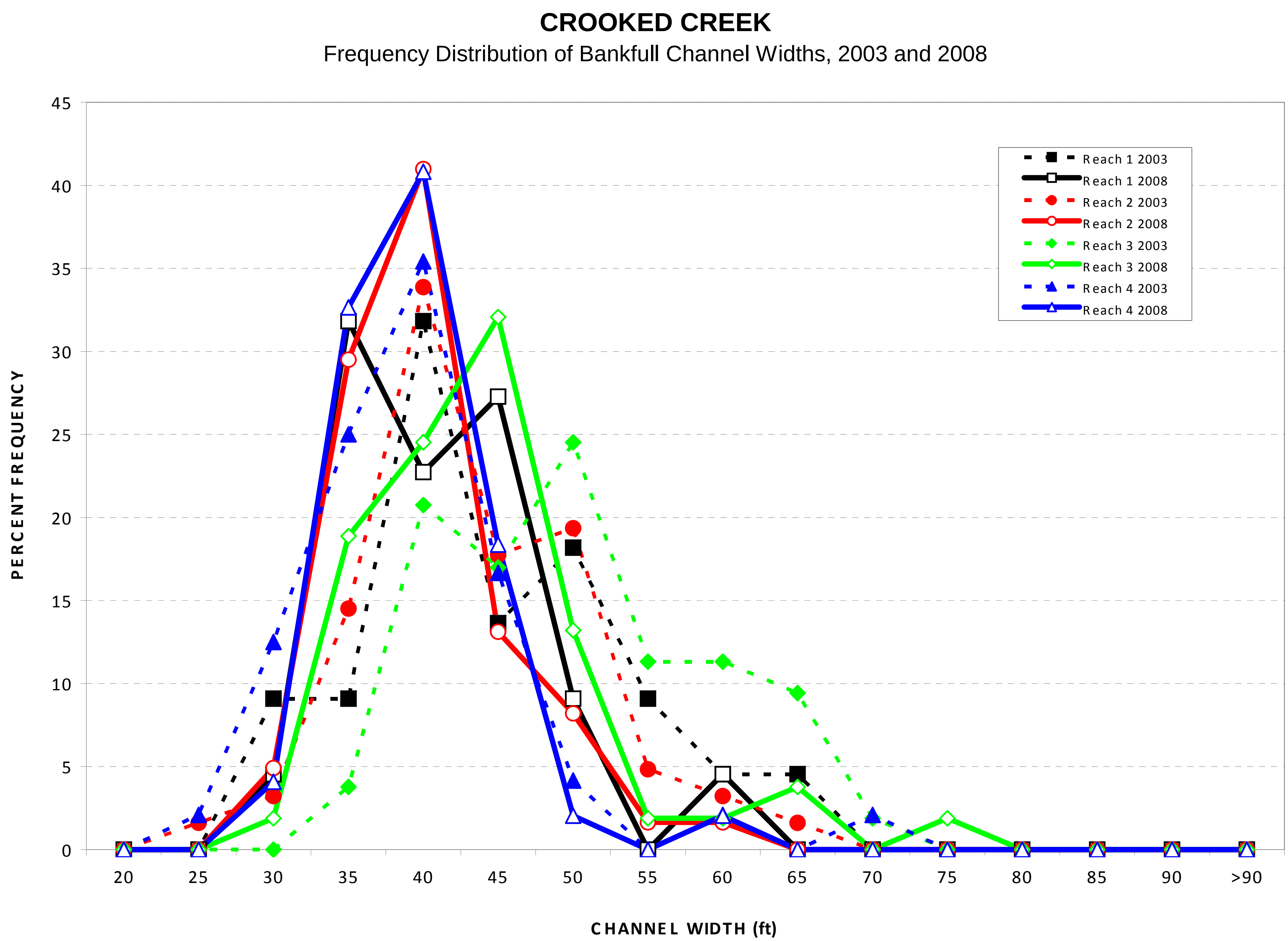

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FIGURE

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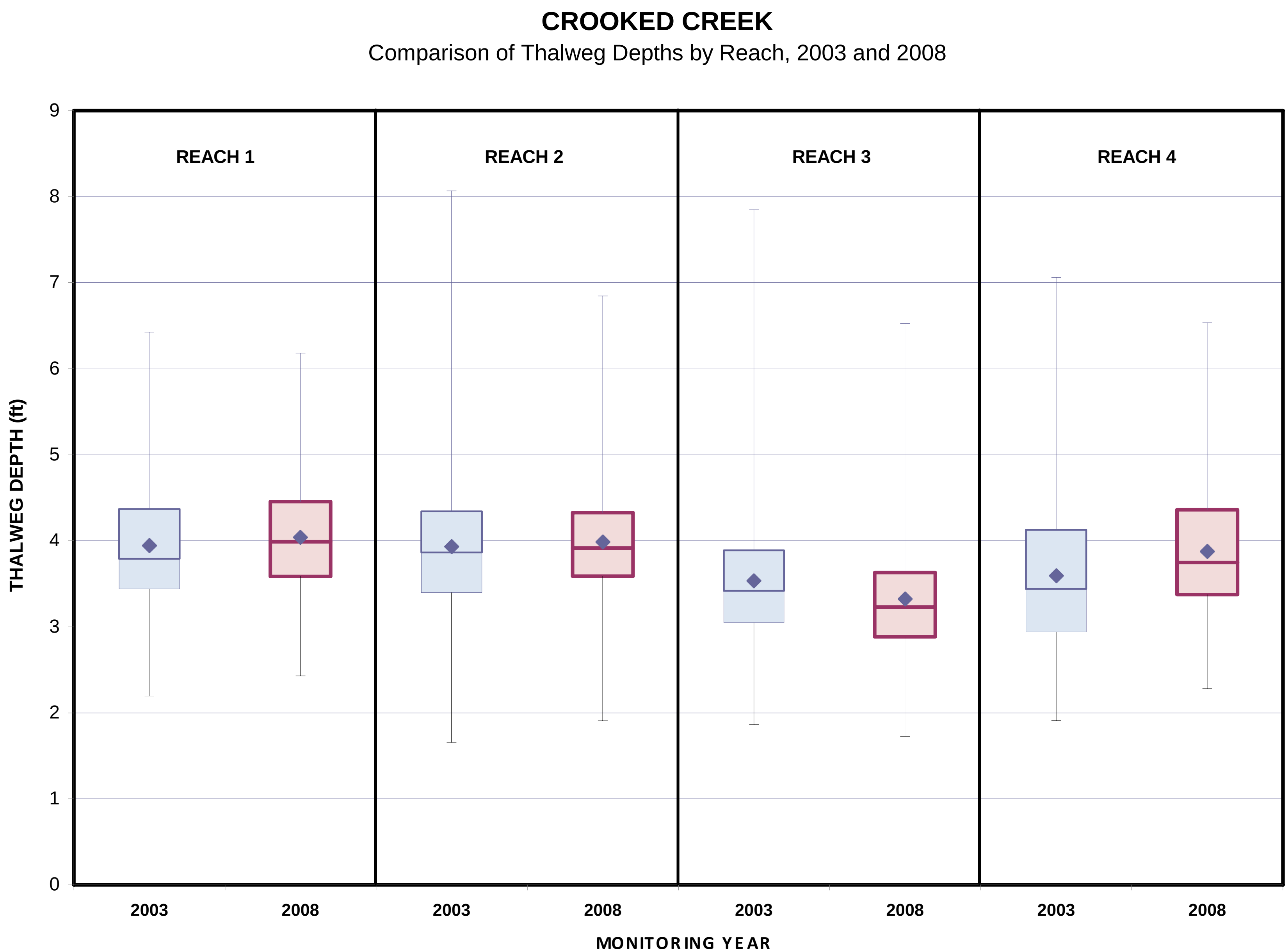

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FIGURE

28

CROOKED CREEK

Frequency Distribution of Thalweg Depths by Reach, 2003 and 2008

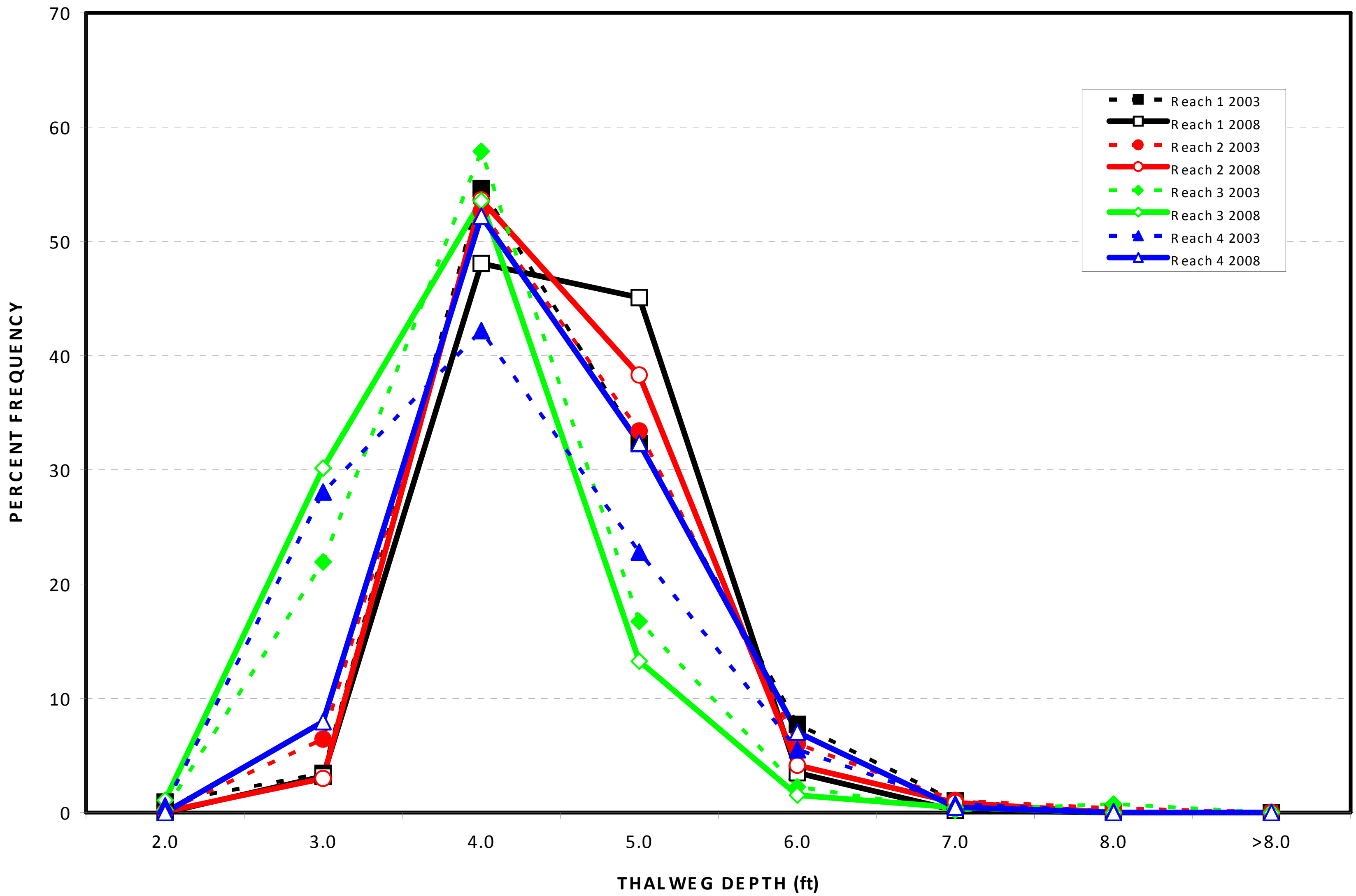

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FIGURE

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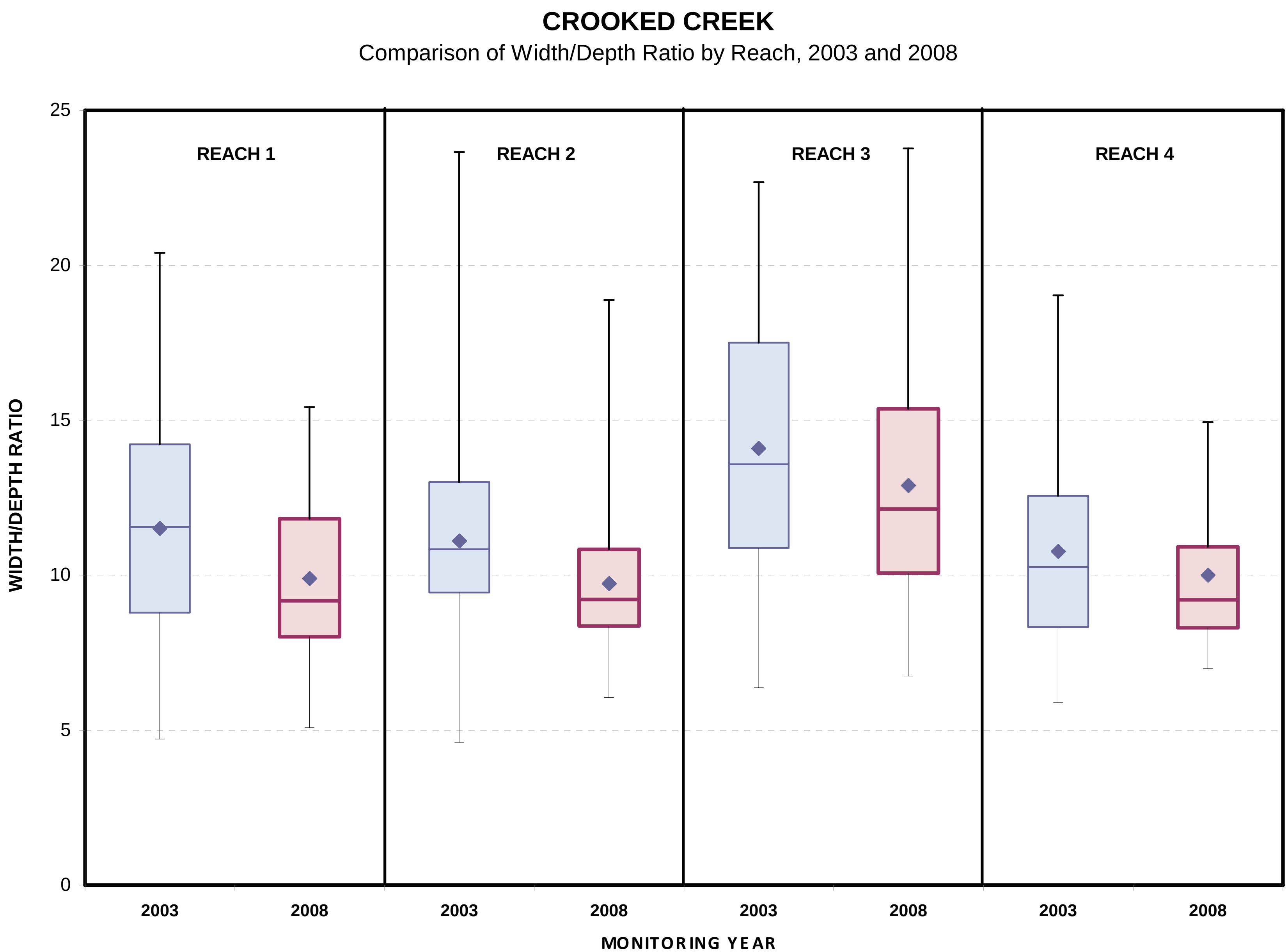

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FIGURE

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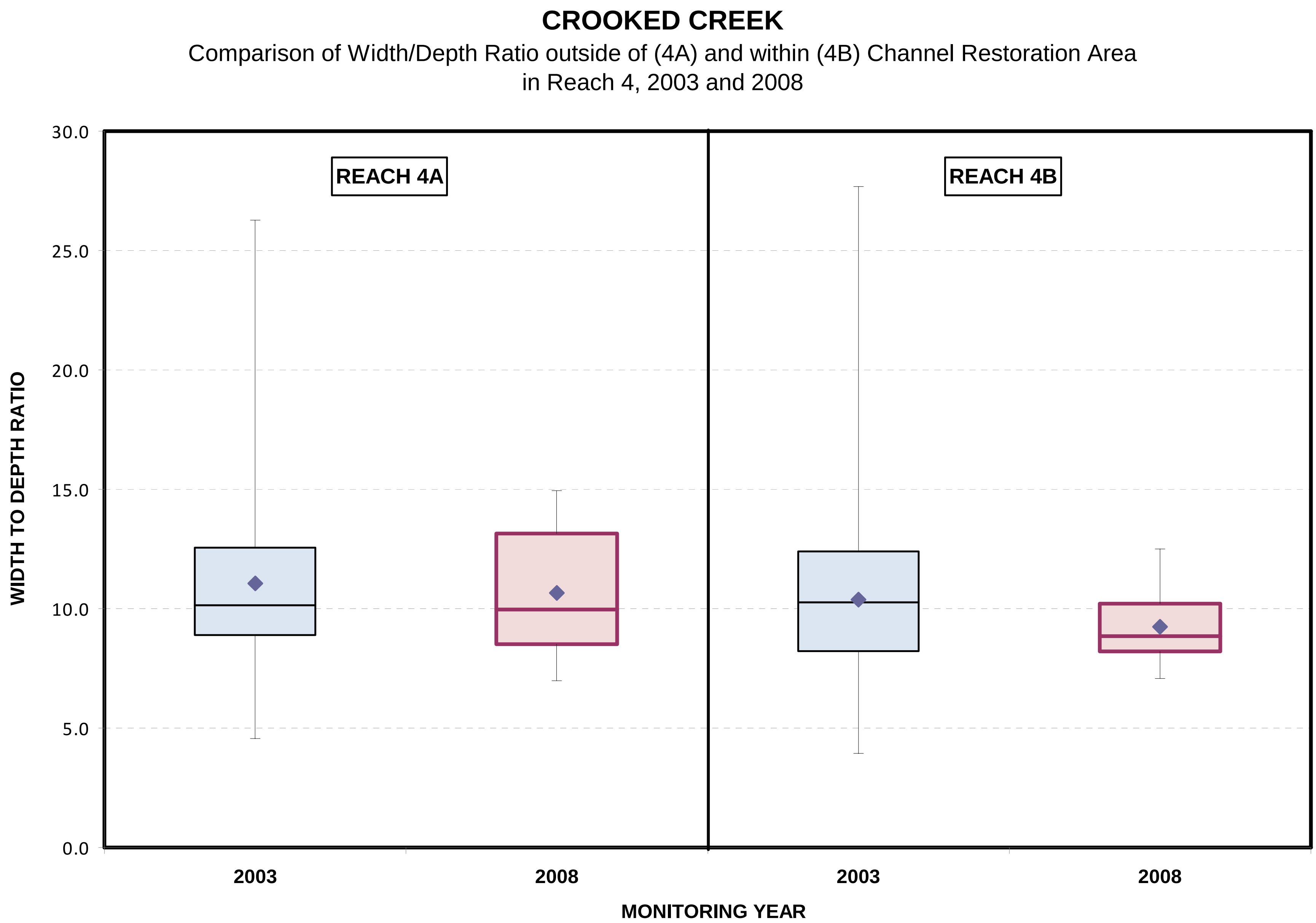

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FIGURE

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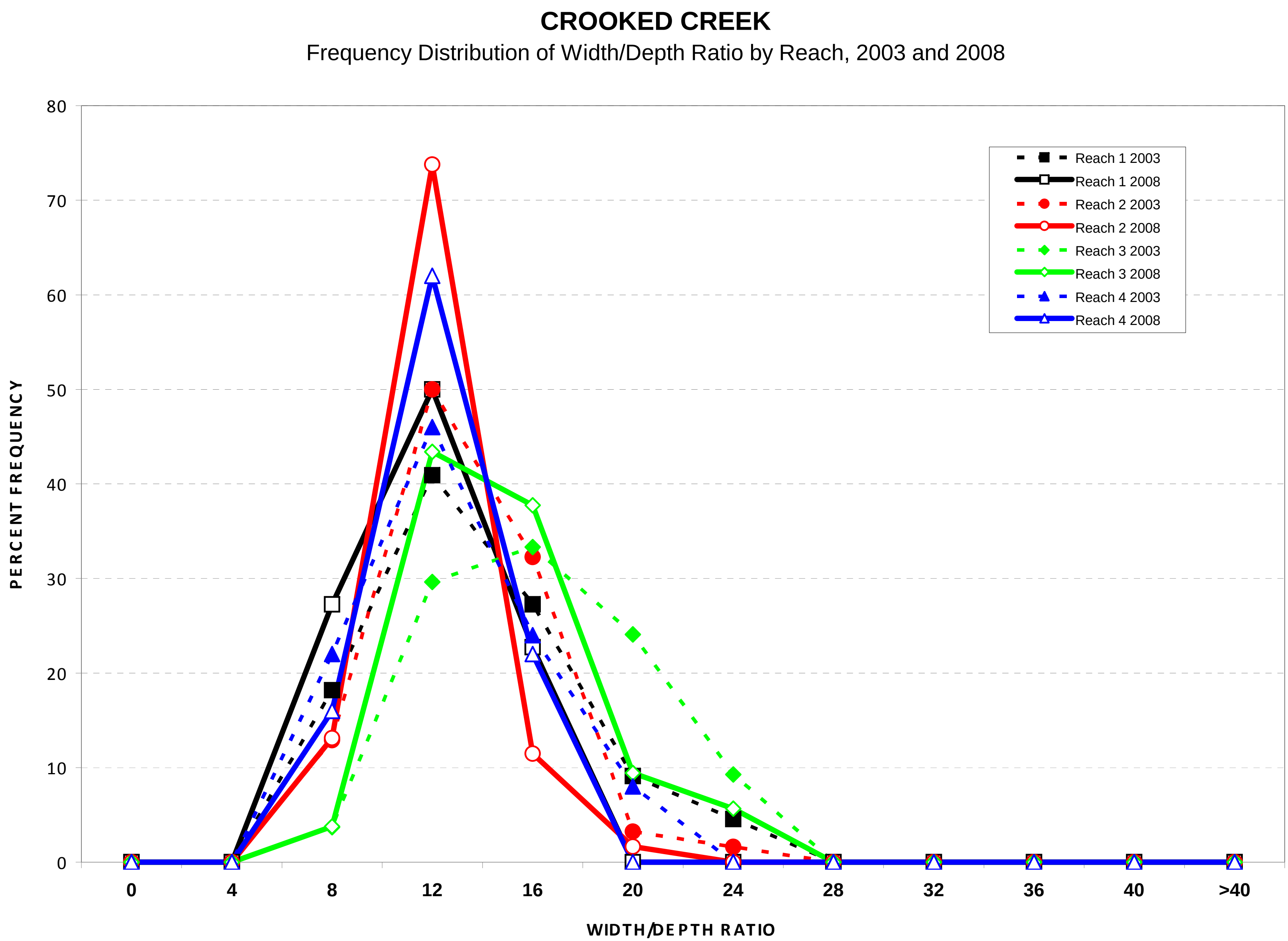

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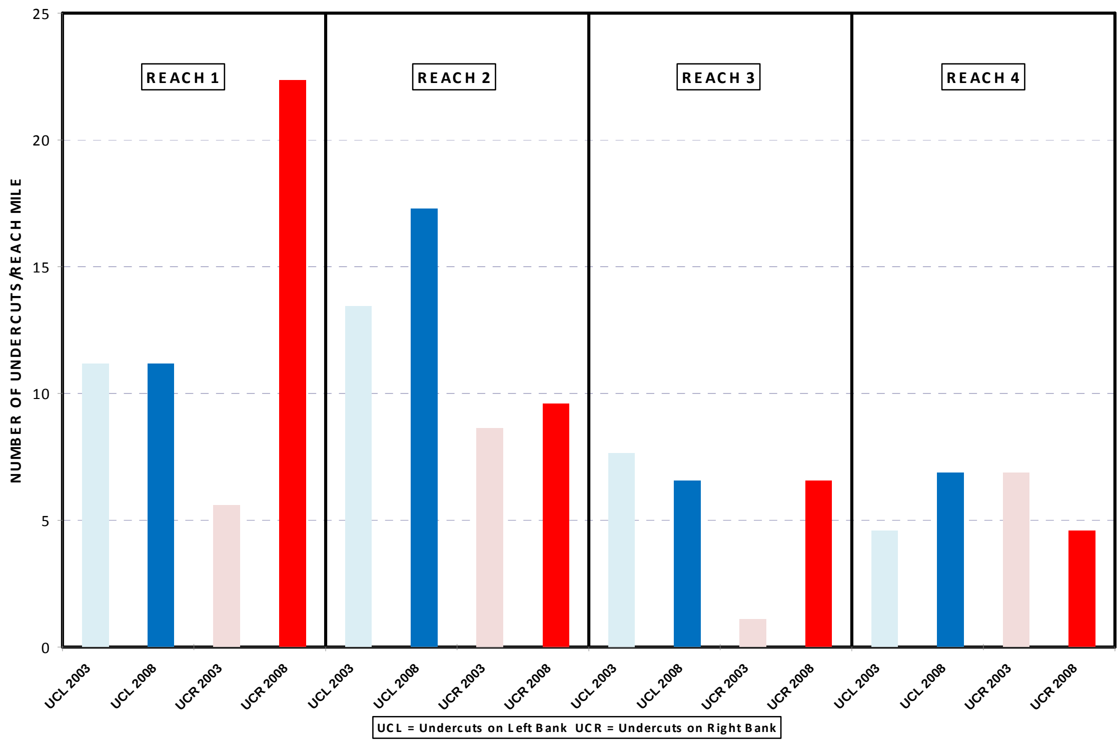
FIGURE

32

CROOKED CREEK HABITAT SURVEYS

Number of Undercuts per Reach Mile by Left/Right Bank, 2003 and 2008



Total Length of Undercuts per Reach Mile by Left/Right Bank, 2003 and 2008

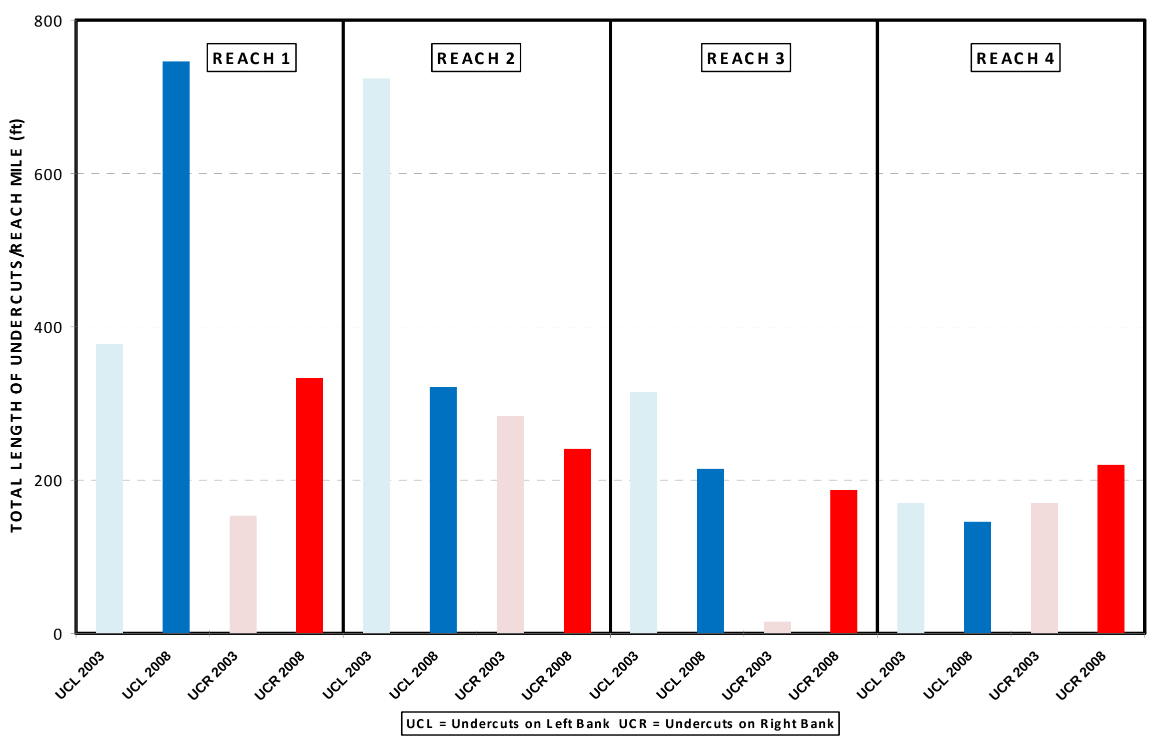


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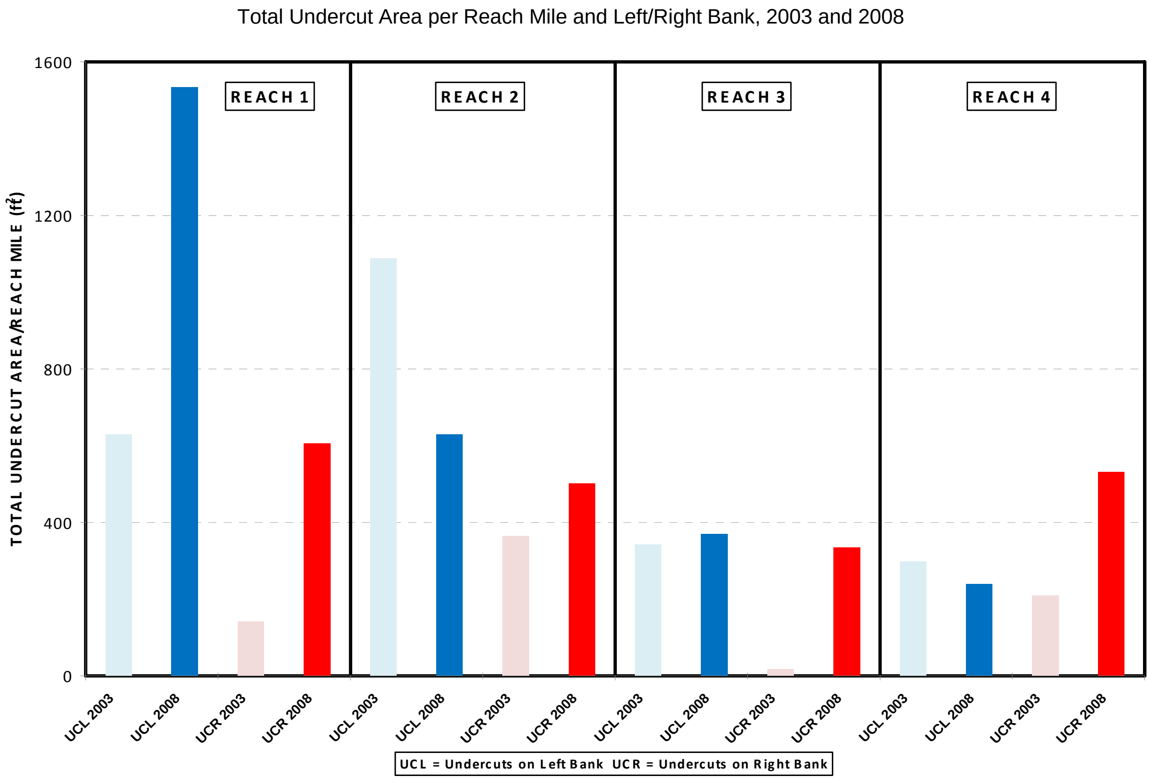
FIGURE

33

CROOKED CREEK HABITAT SURVEYS



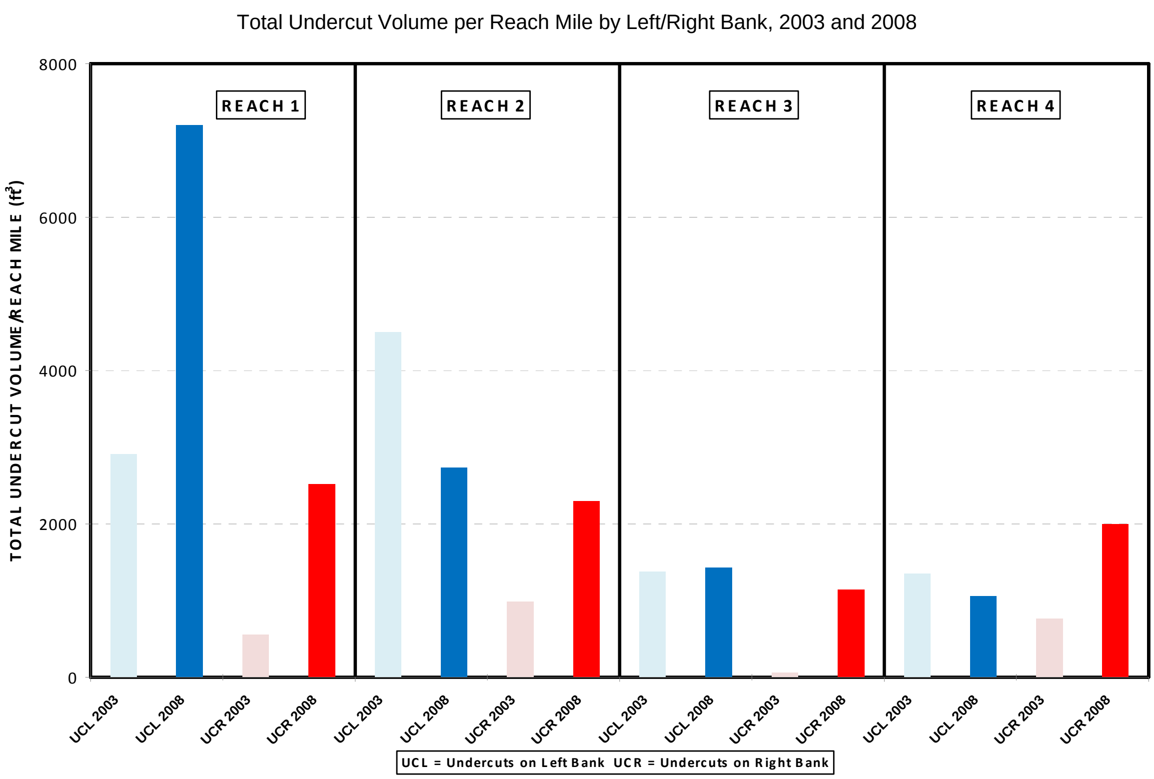


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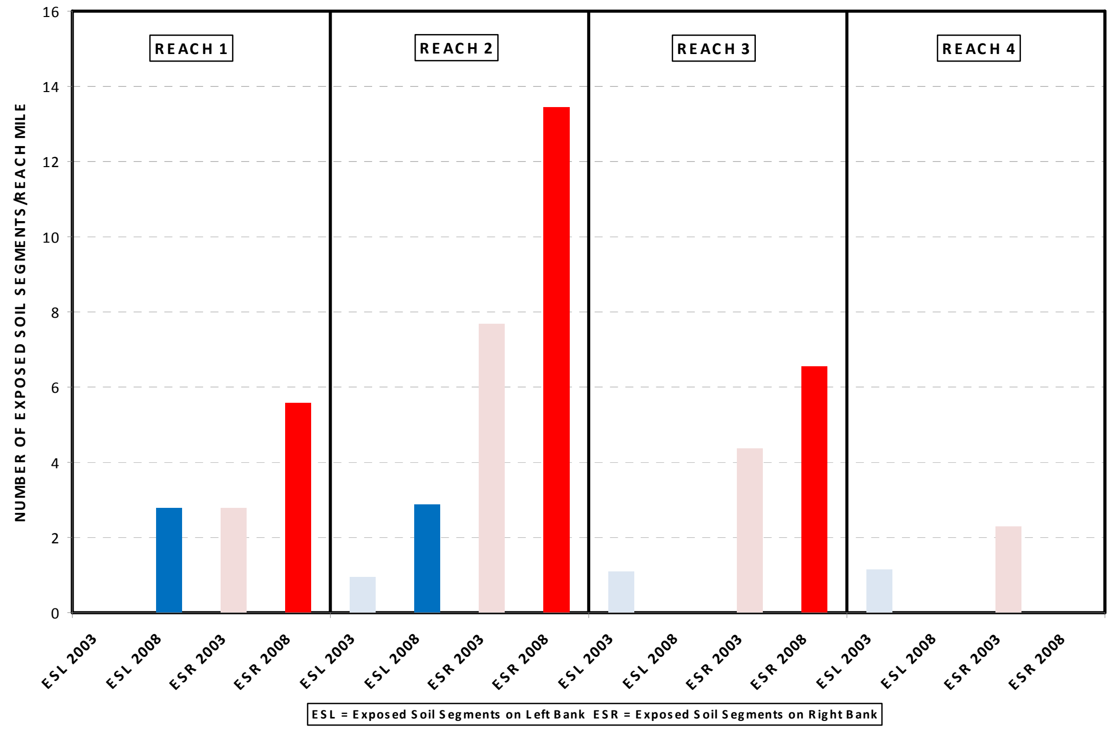
FIGURE

34

CROOKED CREEK HABITAT SURVEYS

Total Number of Exposed Soil Segments per Reach Mile by Left/Right Bank, 2003 and 2008



Total Length of Exposed Soil Segments per Reach Mile by Left/Right Bank, 2003 and 2008

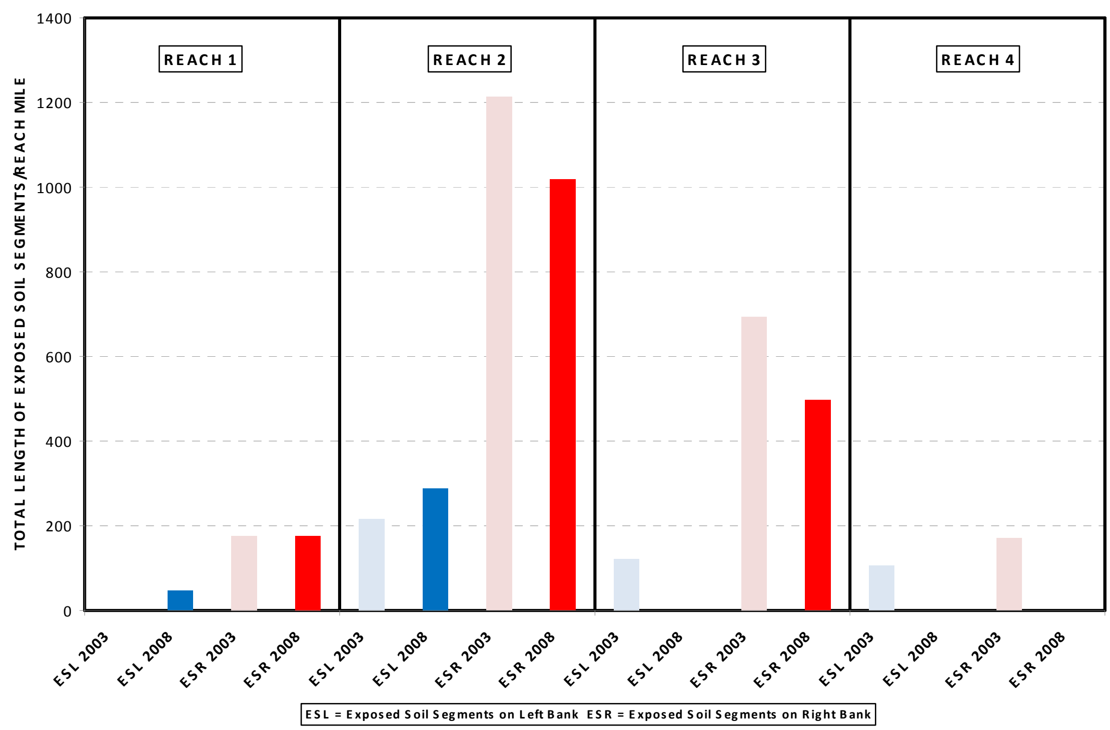


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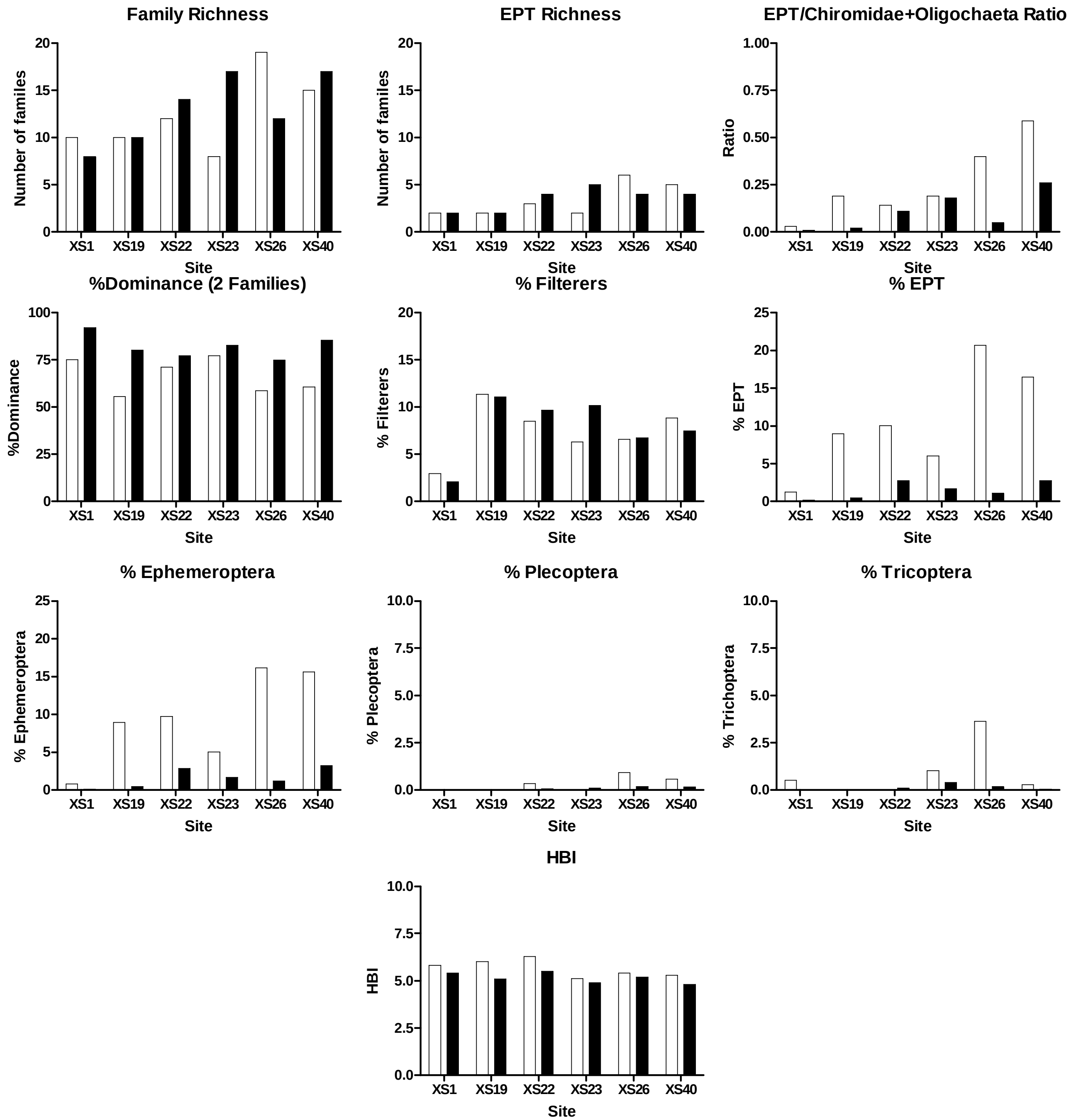
FIGURE

35

CROOKED CREEK
Macroinvertebrate Community Metrics



Metrics calculated from samples collected from six Crooked Creek sites in August 2002 (white bars) and August 2008 (black bars).

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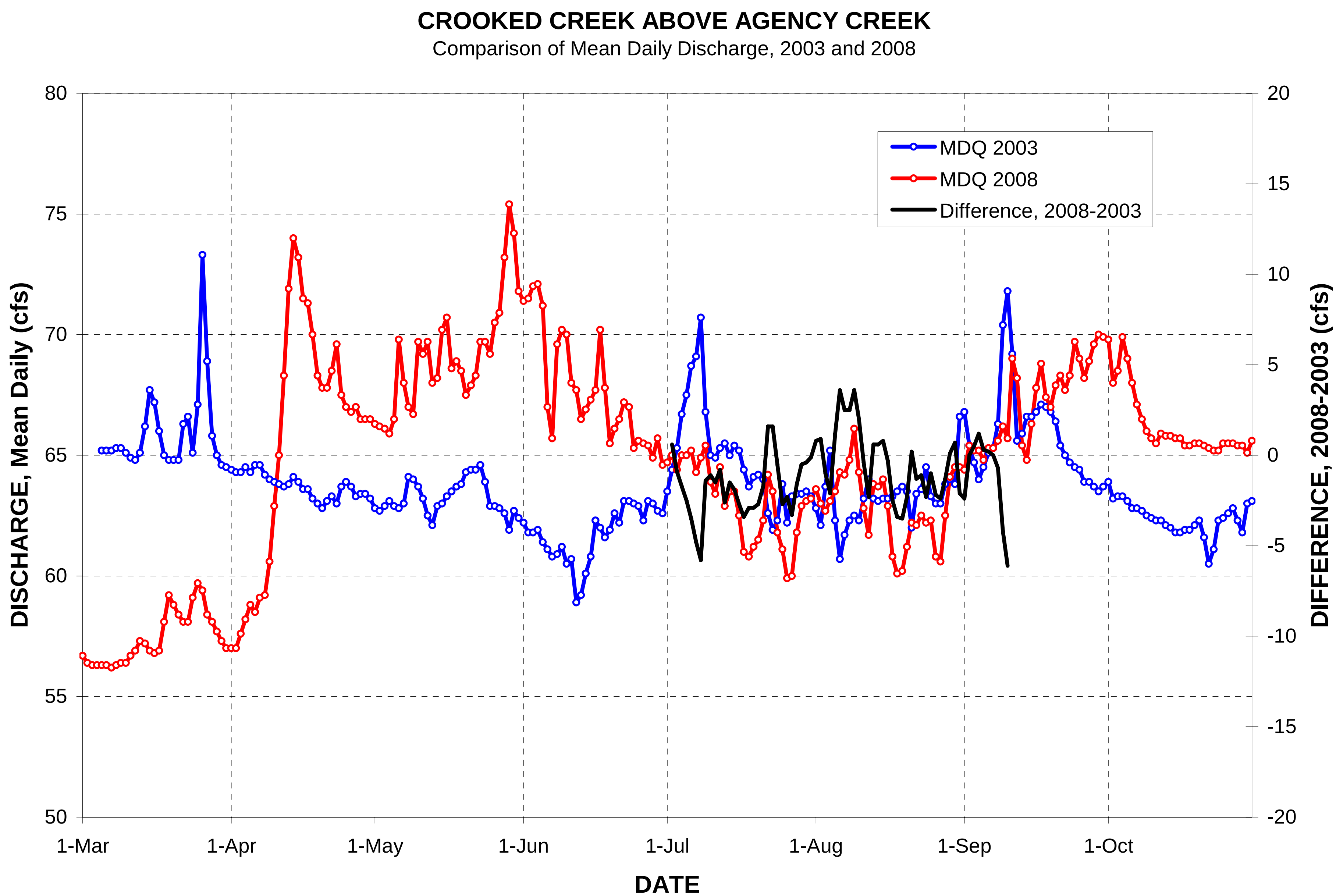

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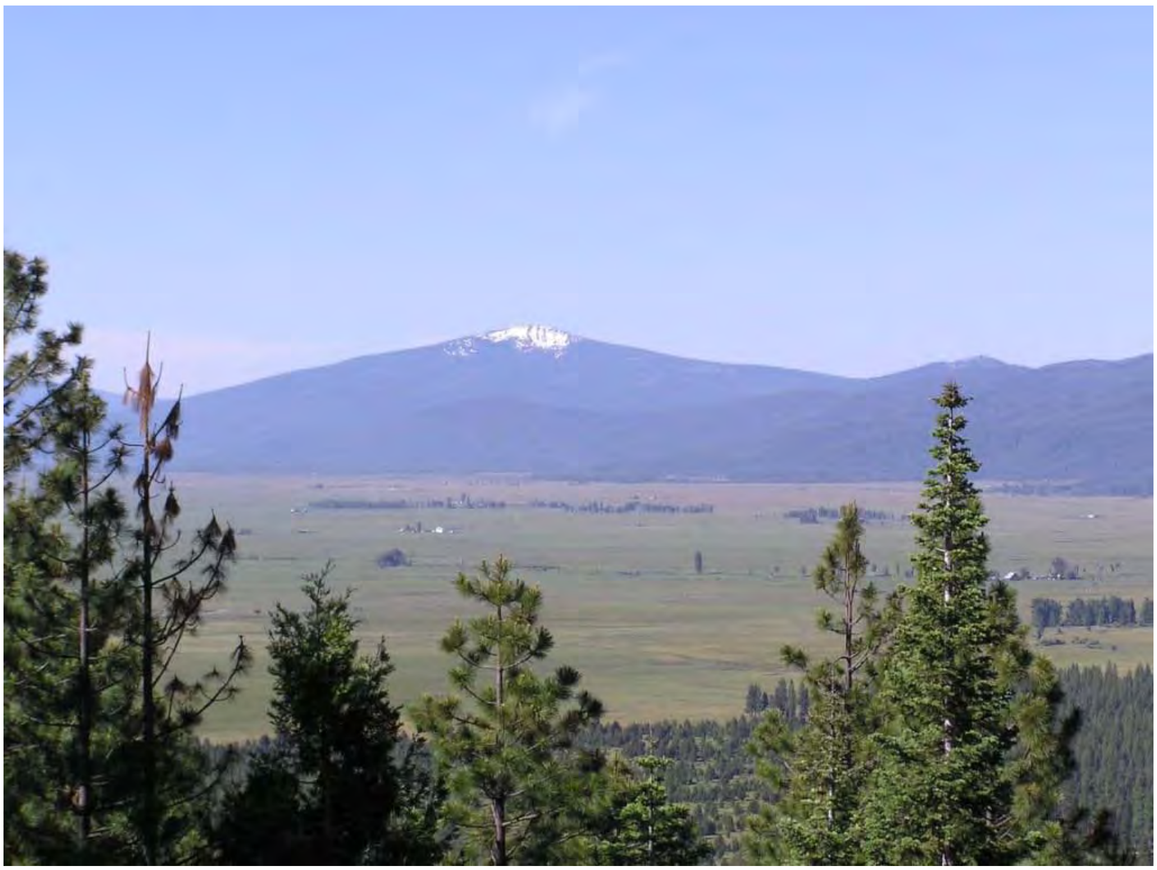
Wood River, Upper Klamath Basin, Oregon Conservation Effects Assessment Project Special Emphasis Watershed Final Report

April 2010



Overview of the Wood River Valley in Oregon

Prepared by the

Oregon Natural Resources Conservation Service

Foreword

The Wood River CEAP study was initiated as a special emphasis watershed project in 2005 by the Natural Resources Conservation Service (NRCS) through a national program known as the Conservation Effects Assessment Project (CEAP). This national program began in 2003 as a multi-agency effort to quantify the environmental benefits of conservation practices used by private landowners participating in selected United States Department of Agriculture (USDA) conservation programs. Funding from CEAP has provided a unique opportunity to address current issues in the Wood River Watershed while also providing insights into the methodologies that can be used to measure the effectiveness of conservation in similar watersheds throughout the western United States.

The Wood River Watershed, part of the Klamath Basin in south-central Oregon, was selected because it has ranching and irrigation uses common to much of the western United States that is confronting resource issues surrounding water use, water quality, and endangered species.

Executive Summary (Project Objectives and Findings)

The Wood River CEAP focused on the effects of irrigation and grazing management in a large mountain valley typical of many ranching areas in the semi arid west. Ranchers were drawn here for the productive forage furnished by the naturally sub-irrigated meadows. Irrigation was added to extend the season for the wet meadows into late summer and early fall. Over the last couple of decades competition for abundant, clean water in the Klamath Basin, as elsewhere, jeopardized the continuance of ranching as practiced in the past. Local ranchers formed the Klamath Basin Rangeland Trust (KBRT) to study and find economic and environmental solutions. USDA, USBR and other federal/state programs were utilized to test the feasibility of restoring riparian areas, withdrawing irrigation and decreasing herd size. Starting in 2002 KBRT has been monitoring the impacts from these practices on forage, wildlife habitat, and water quantity and quality. In 2005 NRCS joined KBRT in the study of effects of these practices through the Wood River CEAP.

The primary objective of the study was to determine the levels of grazing and irrigation management that could be sustained both environmentally and economically on private lands. While this study did not specifically identify an environmental and economic sustainable level, it did provide information ranchers and natural resource managers can use to make this determination. Since the study period was only two years, caution should be given to interpreting these results. It is highly recommended that further monitoring of plant, animal, soil, and water resources be conducted to determine long-term changes that can affect livestock operations in the valley.

Study findings indicate that:

Restoring riparian areas

- Improved riparian and aquatic habitat
- Increased populations of macro invertebrates and fish
- Deepened and narrowed stream channels (increased stability - closer to reference conditions)

Reducing or eliminating irrigation from grazing lands

- Encouraged a shift from wetland obligate to facultative vegetation
- Increased the percentage of bare ground
- Decreased forage production by 15 to 25 percent (depending on grazing regime)
- Maintained the nutritional value of forage (within the requirements of grazing animals)

Improving grazing management (Prescribed Grazing)

- Increased potential forage production (30 day rest versus 10 day rest or continuous grazing) or ameliorated production decreases from removing/reducing irrigation.

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1. Wood River Valley Profile

1.1 Geographic and Historic Description

The Wood River Special Emphasis Watershed is situated in the southern region of the state of Oregon in the Cascade Mountains southeast of Crater Lake in the Wood River Valley. A component of the Klamath Basin drainage system, the Wood River Valley drains 220 square miles of land extending from Crater Lake in the north to its outlet into Agency Lake in the south. Delineated as the hydrologic boundary of six sixth field hydrologic units, the watershed comprises major streams that include the Wood River, Annie Creek, Crooked Creek, Sun Creek, Sevenmile Creek and Fourmile Creek (see Figure 1 below).

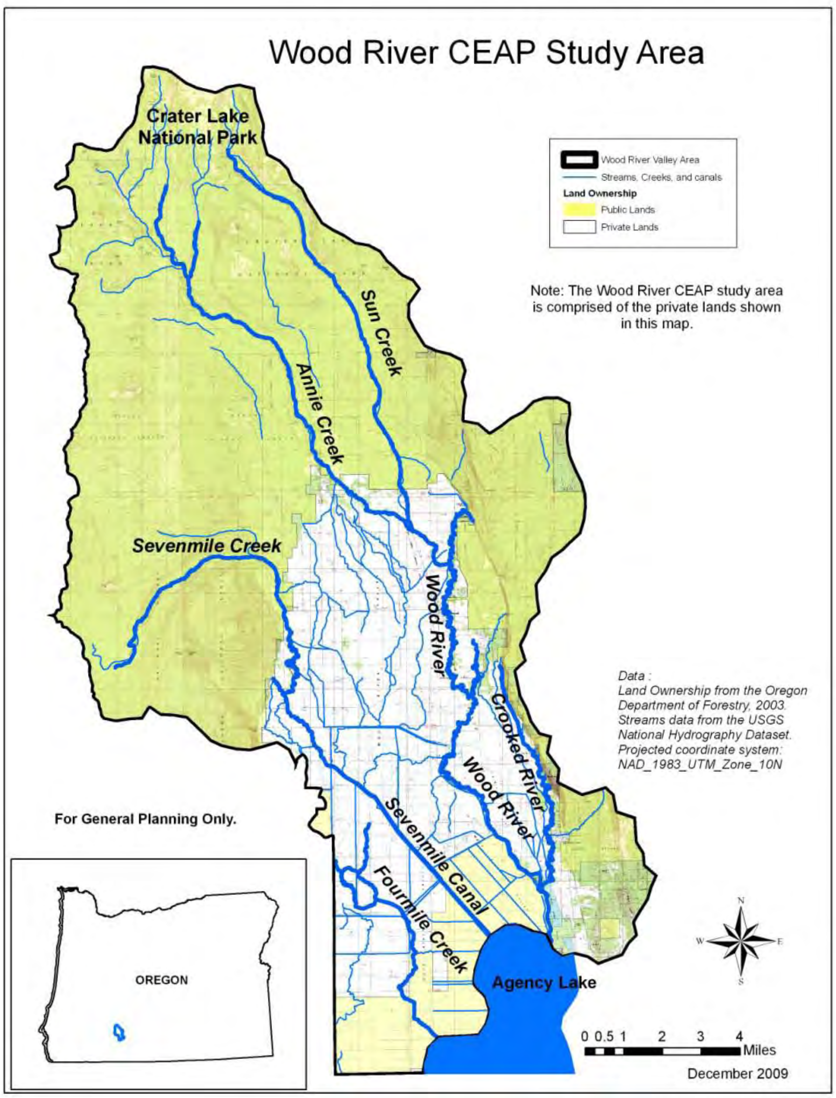

Figure 1: General Location Map of the Wood River Valley.

The study area for this project focused on the 39,000 acres of private, irrigated grazing lands in the Wood River Valley. Some estimates indicate 35,000 to 45,000 head of cattle are brought in each year. The area is noted for supporting a high rate of weight gain (2 or more pounds per day) in grazed livestock. Individual pastures are large, often in excess of 300 acres. Pasture condition is generally considered fair, with a mix of early seral stage plants.

Most livestock obtain water from streams and ditches. Portions of the Wood River and Crooked River have been fenced and livestock excluded. Sixty to 70 percent of the riparian areas within pastures, however, are not fenced and have little to no riparian vegetation.

The watershed receives an average annual precipitation of 35 inches ranging from a high of 71 inches along the Cascade Crest to a low of 13 inches along the eastern shore of Upper Klamath Lake.

The irrigated land in the Wood River Valley consists primarily of Kirk-Chock soils that were formed from alluvial deposits of ash and cinders. A top surface layer of loam lies above loamy sands and gravel. These soils, characterized by moderate permeability, seasonally high water tables, and moderately high water holding capacity, are suited to surface and sub irrigation methods. The permeable subsoils promote subsurface return flows to area ditches and streams. The Lather muck soil type is found in the lower-lying areas around Agency Lake and Upper Klamath Lake.

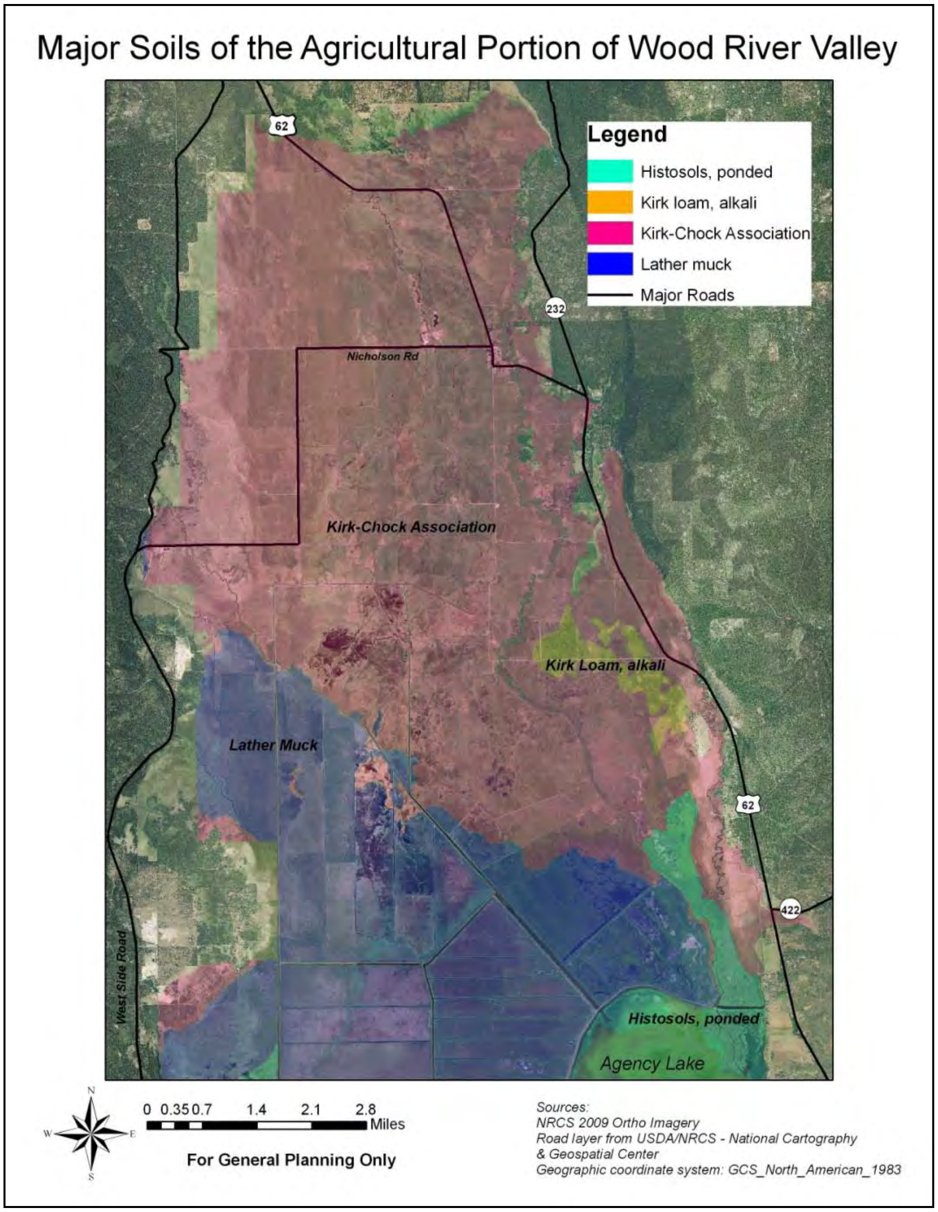

Figure 2. Major soils of the agricultural portion of the Wood River Valley.

Livestock ranching in the Klamath Basin dates from the 1870s, and irrigation was a normal practice, as well as drainage of wetlands, which began as early as 1868 along the Lost River. The earliest irrigation projects were privately initiated, and by the 1880s several thousand acres were under private irrigation. The Reclamation Act of 1902 marked the beginning of federal involvement in local reclamation efforts. In 1905, the Klamath Basin became the twelfth in the nation –and the largest to that point – to receive funding from the Reclamation Act of 1902 (Doremus and Tarlock, 2008). Since 2002 however, a small number of ranchers have begun experimenting with dry land grazing (see Section 1.3, Conservation).

Historically, the Klamath Basin was the third most productive salmon river system on the West Coast, producing between 660,000 and 1.1 million adult salmon escapement annually (Chinook, Coho, pinks, chum, steelhead). A cascade of developments in the 20th century resulted in the present fragmentation and deterioration of the salmon habitat of the Upper Klamath Basin[1]. These included intensification of human activities with attendant increases in water demand; the arrival of the Bureau of Reclamation into the Upper Klamath Basin area in 1907, with the resulting conversion of over 79 percent of the Upper Basin's wetlands into agricultural lands. The area's natural water storage capacity was reduced. The ability of wetlands to act as a natural filter for breaking down pollutants carried by agricultural runoff was diminished, and the salmon habitat was compromised (Grader and Spain, 2001).

A highly valued "take and release" sport fishery is situated on the Wood River and several of its tributaries. Locally, there is significant interest in maintaining and restoring riparian habitat along these streams to protect and promote these fisheries while protecting agricultural operations.

1.2 Resource Concerns

A variety of interests compete for water from the Wood River Watershed. These diverse interests have precipitated frequent conflicts over the determination of how water is to be distributed for farming, ranching, tribal trust obligations, conservation, commercial fishing, and recreation. Certain grazing management practices have contributed to the deterioration of water quality, the rise in stream temperatures, and compromised habitat for sensitive or endangered aquatic, avian, or terrestrial species. The drought of 2001 provided a critical impetus for seeking solutions to water issues that would enable all interests to improve and sustain the diverse activities without compromising the quality and sustainability of the habitat and the environment.

One impact of the 2001 water shut off has been an interest in reducing water use throughout the upper Klamath basin. One area where the interest in reducing water use by agriculture has moved into action has been the Wood River Valley. Some of the ranchers in the Wood River Valley have moved to non-irrigation and dryland grazing practices. The Klamath Basin Rangeland Trust

[1] At present, all anadromous runs of salmon and steelhead, once abundant in the upper basin of the Klamath River, are extinct above Iron Gate Dam. Because no fish passages were constructed, over 350 miles of historic salmon habitat is unreachable by fish. In all, there are six dams on the main stem of the Klamath River: Iron Gate (1962), Copco I and Copco II (1918, 1925), J.C. Boyle (1958), Keno, and Link River. ("Bring the Salmon Home. The Karuk Tribe's Effort to Remove Klamath Dams," p. 1). www.nijc.org/pdfs/Subject%20Matter%20Articles/Environment/Bring%20the%20Salmon%20Home.pdf.

(KBRT) has worked with these ranchers since 2002 to implement and monitor the impacts of shifting grazed pastures to non-irrigation and dryland grazing practices.

A field reconnaissance and aerial photo survey conducted for the NRCS's 2004 Upper Klamath Sub basin Assessment identified 70 miles of riparian areas along streams on private lands in the Wood River Valley. Twenty-one miles are in good riparian condition and another 12 miles are being restored through U.S. Fish and Wildlife and other programs. Subsequent to the 2004 Upper Klamath Sub Basin Assessment, the Klamath Basin Rangeland Trust has been working with the private landowners along Sevenmile Creek to fence additional areas. There remains approximately 35 miles of stream that might benefit from a restoration intervention involving fencing off the area; or that might be converted to riparian pasture with temporary fencing (cross fence running across the pasture) for time-controlled grazing.

While no streams or lakes in the Wood River Valley are listed on the 2004/2006 Oregon 303d list of water quality-limited water bodies, the Oregon Department of Environmental Quality has completed a Total Maximum Daily Load (TMDL) for Upper Klamath Lake[2]. The water quality of Upper Klamath/Agency Lake has been identified as impaired due to low dissolved oxygen, high pH, and excessive algal growth, all of which are parameters affecting fish survival. Phosphorus loading has been implicated as the primary mechanism triggering hypereutrophic conditions in the lake. Implementation of the TMDL, however, depends on reducing anthropogenic sources of phosphorus.

Both the Lost River sucker (*Deltistes luxatus*) and the Shortnose sucker (*Chasmistes brevirostris*) were listed as endangered under the Endangered Species Act in 1988 (USFWS, 1988). The Wood River, Sevenmile Creek and their tributaries also support populations of Bull Trout (*Salvelinus confluentus*) and Interior Redband Trout (*Oncorhynchus mykiss gairdneri*). Bull Trout have been designated under the Endangered Species Act as threatened since 2005 (ODFW, 2010).

1.3 Conservation

Agricultural producers, land managers, tribal groups, and natural resources agencies have been active in overseeing the stewardship of the Wood River Valley and seeking to improve ecological conditions across the landscape. Since 2002, the Wood River Valley ranchers have had an interest in finding new ways to enhance the valley's natural resources. Their efforts to conserve resources and increase the economic productivity of their watershed have increased dramatically. In addition to the ranchers, land owners, and operators' efforts, a variety of organizations and agencies, including the Klamath Basin Rangeland Trust and the NRCS, have provided technical and financial assistance to support conservation work in the valley.

Ongoing conservation work has involved the use of regular Environmental Quality Incentive Program (EQIP) and Klamath EQIP to implement 21,000 acres of prescribed grazing in the Wood River Watershed (mainly in the form of reduced numbers of cattle). In fiscal year 2006 about a dozen landowners in the Wood River Valley were enrolled in the Conservation Security

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[2] For the 2004/2006 report, see: http://www.deq.state.or.us/wq/assessment/assessment.htm.

Program, to begin working on enhancement conservation measures through 2009[3]. By fiscal year 2008, 23 land managers in the Upper Klamath Watershed had committed to conservation on 15,896 acres through the Conservation Security Program (CSP), supported with more than $5.7 million in funding through the life of the CSP contracts (USDA NRCS, 2008). See Section 3.3.5, Landowners, for additional information on conservation funding in the Wood River Valley.

With joint funding by the US Bureau of Reclamation and the NRCS, the KBRT helped landowners enroll 12,000 acres of private grazing land in irrigation and grazing forbearance programs that paid ranchers to not irrigate, to reduce herd size, and to assist them in transitioning from flood irrigation to dry land grazing. The KBRT has been an active partner in working with landowners in the Wood River Valley and helping to increase acreage enrollment in NRCS programs, so as to assure a full transition from flood irrigation to more permanent dry land management scenarios. Since 2002, KBRT has been carrying out ecological monitoring to assess the impacts of the management changes and partnered with the CEAP study.

In addition, the Oregon Department of Fish &Wildlife (ODFW) and Oregon Watershed Enhancement Board (OWEB) are contributing additional funding to assist ranchers in their efforts to improve their riparian areas and address fish passage issues. Of the 70 miles of streams in the study area, approximately 40 to 50 percent has been fenced either to totally exclude cattle or to create riparian pastures with time controlled grazing.

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[3] In 2002 the Conservation Security Program (CSP) — which would provide $20,000 to $45,000 per year to producers for "implementing conservation practices that enhance environmental quality, long-term sustainability, and improve profitability" was announced. Guidelines included the following outline of eligible practices: “Examples of practices that producers can initiate under the CSP program include: (A) nutrient management; (B) integrated pest management; (C) water conservation (including through irrigation) and water quality management; (D) grazing, pasture, and grazing land management; (E) soil conservation, quality, and residue management; (F) invasive species management; (G) fish and wildlife habitat conservation, restoration, and management; (H) air quality management; (I) energy conservation measures; (J) biological resource conservation and regeneration; (K) contour farming; (L) strip cropping; (M) cover cropping; (N) controlled rotational grazing; (O) resource-conserving crop rotation; (P) conversion of portions of cropland from a soil-depleting use to a soil-conserving use, including production of cover crops; (Q) partial field conservation practices; (R) native grassland and prairie protection and restoration; and (S) any other conservation practices that the Secretary determines to be appropriate and comparable to other conservation practices. http://www.oda.state.or.us/information/AQ/AQSummer2002/index.html. According to the USDA/NRCS Klamath Basin Conservation Partnership Accomplishments Document, Jan. 2007, between 2002 and 2006 the conservation partnership claimed, among its accomplishments, planning conservation systems on 256,273 acres; helping 23 land managers support ongoing conservation on 15, 896 acres; conserved irrigation water on 54,503 acres; developed habitat for fish and other aquatic species on 2,805 acres; improved wildlife habitat on over 19,113 acres; improved the quality and production of forage on 74,923 acres of pasture. http://www.klamathbasincrisis.org/conservation/summarykwuaJuly2007.htm.

2. Goals and Objectives

2.1 Introduction

The Wood River CEAP project was initiated in 2005 by the NRCS after an unsolicited proposal was received from the Klamath Basin Rangeland Trust (KBRT) describing an extensive monitoring program the Trust had been implementing since 2002 in the Wood River Valley. The KBRT monitoring program captured information on groundwater levels, stream flows, evapotranspiration, soil moisture, water quality, vegetation, and habitat on ranches that had adopted rotational grazing, riparian area management, and conversion from flood irrigation to dry land practices. This database, along with the potential to supplement past monitoring efforts, presented a unique opportunity to evaluate the effects of grazing and riparian management conservation activities.

2.2 Project Goals and Objectives

The purpose of the Wood River Special Emphasis Watershed CEAP is to determine the effects of changes in grazing management and irrigation management on forage production, animal health, stream/riparian conditions, fish habitat, and economic agricultural viability on grazing lands of the Wood River Valley. It proposed to do this by evaluating reductions in irrigation and grazing that has taken place in the study area over the last several years by comparing hydrologic, vegetative (riparian and grazing land), aquatic, and economic profiles.

The primary goal of this CEAP study was to determine the optimum level of grazing and irrigation management that could be sustained both environmentally and economically on private lands.

Individual objectives under this goal were to investigate:

- Changes in the vegetative component of grazing lands and riparian areas as irrigation water is withdrawn, including changes in vegetative structure, composition, annual biomass production, amount of bare ground, plant density, and increases in the number or populations of invasive plant species.
- Effects of reduced stocking rates when combined with changes in irrigation water management.
- Changes in the base nutritional plane of the range vegetation associated with the change from irrigated to dry land practices. Changes in the condition of livestock between irrigated and non-irrigated sites.
- Impacts of alternative levels of irrigation water and grazing management on forage production.
- Economic impact from alternative levels of irrigation water and grazing management on the local ranching community.

A secondary goal of the study was to determine the effectiveness of riparian pasture systems and cattle exclusion on the recovery of riparian and aquatic habitats.

Individual objectives under this goal were to investigate:

- Effects of different grazing management prescriptions on key stream/riparian habitat variables (vegetation, in-stream morphology, stream condition) and selected species (e.g. macro invertebrates and fish).

This study did not evaluate the effects of conservation practices on water quality and availability for downstream usage. Concurrent studies conducted by the Klamath Basin Rangeland Trust, United States Geological Survey (USGS), and the United States Bureau of Reclamation (USBR) on the effects of water banking and other water saving practices will, however, be reported separately from the current study. Pieces of these other studies and monitoring efforts have contributed to our understanding of the Wood River Valley ecological systems and are referenced where appropriate.

To meet the study goals and objectives described above various study components were developed, including pasture vegetation monitoring that included pasture and vegetation monitoring (vegetation community composition, structure, and production; forage quality; soil bulk density, etc.), crop production and irrigation modeling, riparian area monitoring, and aquatic habitat monitoring.

3. Wood River Study Hypotheses, Components, and Partners

3.1 Overview of Research Methodology Approach

Current scientific methods were used to monitor groundwater, surface flows, soil moisture and evapotranspiration rates as they pertain to vegetation and water quality responses to grazing and riparian management practices. The monitoring and research conducted by the KBRT between 2002 and 2008 provided base-line data pertaining to stream flow, water table and soil moisture levels, water quality, and other parameters. Additionally, selective pre-treatment monitoring was conducted by the United States Fish and Wildlife Service (USFWS) and the Klamath Tribes, and the limited data from their study sites was used in the base-line comparison profiles.

The study was designed to include the following components:

- Field Monitoring:
    - Pasture vegetation, including condition, trend, and productivity.
    - Livestock nutrition and health.
    - Riparian and aquatic habitat, using vegetation characteristics, channel morphology, fish biomass, and other parameters.
    - Soil moisture, water table levels, and evapotranspiration rates.
- Statistical Analysis:
    - Bovine fecal samples using the Nutritional Balance Analyzer (NUTBAL) Computerized Assessment Tool.
    - Multivariate analysis of pasture production, vegetation diversity, and abundance.
    - Wet chemistry analysis of forage quality.
    - Correlation of riparian habitat conservation implementation to recovery time.
- Computer Simulation Models:
    - Danish Hydrologic Institute (DHI) MIKE SHE hydrologic and DAISY models to simulate the effects, and study variations in soil moisture, water table levels, evapotranspiration rates, and crop growth associated with alternative levels of irrigation and grazing management.
- Economic Analysis:
    - Evaluation of the impact of grazing and irrigation management practices, pre- and post-irrigation and grazing reductions, on the economic viability of conservation strategies.

The study approach incorporated an extensive post-treatment design using data collected at paired sites representing a variety of management level combinations. These are detailed in appropriate segments of the report, below.

With the assistance of the Klamath Basin Rangeland Trust (see Chapter 3, section 3.3.2) some of the landowners in the Wood River Valley reduced grazing levels and ceased irrigation on their pastures beginning in 2002. Some of these landowners agreed to participate in this study effort.

Other landowners in the valley who had not shifted management after 2002 agreed to participate to help provide a basis for comparisons between irrigated and non-irrigated pastures.

For analytical purposes six irrigated and six non-irrigated groups of monitoring sites were established around the Wood River Valley (see Figure 3 below). Within each group several vegetation monitoring transects were established. Each group also included at least one small exclosure that protected the vegetation from grazing and provided a place to install shallow groundwater monitoring equipment. The group and sites described in detail in the various component reports included in the Appendices refer to the locations shown in Figure 3.

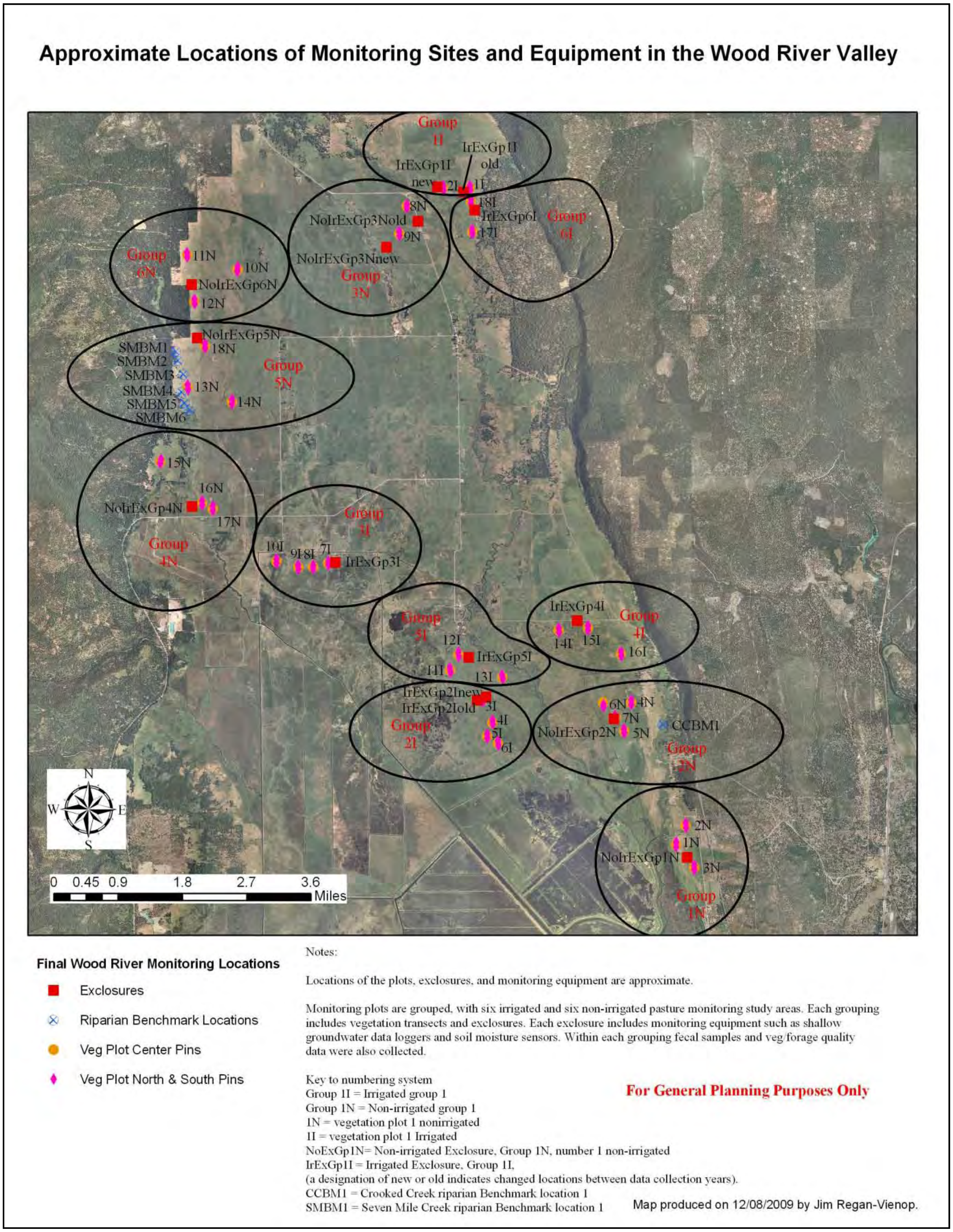

Figure 3. Approximate locations of the monitoring groups and sites.

3.3 Project Partners

The Wood River CEAP forged a partnership effort to study the effects of conservation practices applied or considered by landowners in the watershed. While many organizations participated in these studies, the principal partners in the undertaking are described below.

3.3.1 NRCS

- The West National Technical Support Center (WNTSC) provided technical expertise to develop and guide the technical aspects of the study. Jeff Repp, Rangeland Management Specialist at the WNTSC, assisted with the experimental design of the vegetative study and also contributed reports summarizing the data, analyses, and results submitted by the OSU teams (see Appendix 1).
- Oregon Water Resources Planning Team provided overall coordination of the project, data collection assistance, and landowner coordination.
- The Oregon NRCS Biological Sciences and Soils teams also contributed technical expertise and assistance in the data collection and analysis processes.

3.3.2 Klamath Basin Rangeland Trust

Founded in 2002, the KBRT is a 501(c)3 multi-constituent organization established in response to the "2001 Water Crisis" in the Upper Klamath Basin. A multi-constituent organization, KBRT is dedicated to conservation, education, and restoration in the Klamath Basin and to promoting sound stewardship values, principles and practices[4]. KBRT coordinates landowners with ongoing projects within existing programs that encourage sustainable land and water management practices, and works closely with landowners to implement permanent changes on their land that will result in improved surface water flows, and quality and habitat improvements in the Wood River Valley.

The KBRT contributed to the study in three general areas: Assisting with development of the grazing and monitoring protocols; recruiting, screening, and supervising landowner participants and compliance; and data sharing.

- Grazing and monitoring protocols – starting in 2002 KBRT helped with developing and implementing grazing plans for livestock reductions in the Wood River Valley. They also helped in designing and implementing supplemental vegetation/soil moisture monitoring and in formulating growth curves for vegetative responses under time-controlled grazing.

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[4] Klamath Basin Rangeland Trust Mission Statement: "The mission of the Klamath Basin Rangeland Trust is to restore and conserve the quality and quantity of water in Oregon's Wood River Valley and the upper Klamath Basin to enhance the natural ecosystem and supply needed water for downstream agriculture, ranching, native fish and wildlife populations. More specifically, the Klamath Basin Rangeland Trust seeks to strengthen its cooperative partnership with private property owners and government agencies to achieve the following objectives: *To address the over-commitment of water resources in the Klamath Basin by equitably forbearing water use in the Wood River Valley and reducing cattle grazing to levels that can be sustained without irrigation. *To increase the flow of water to Upper Klamath Lake for the downstream benefit of fish, wildlife, ranching and agriculture. *To manage cattle grazing in ways that improves water quality in rivers and lakes. *To reestablish wetlands adjacent to Agency Lake to increase water storage capacity and produce wetland-related environmental benefits. *To secure employment opportunities for the people of the Klamath Basin to implement the mission of the Klamath Basin Rangeland Trust." http://www.kbrt.org/Index.asp.

- Recruiting, screening, and supervising landowner participants – starting in 2002 KBRT developed contractual agreements with landowners to ensure irrigation forbearance and compliance for grazing management. KBRT also coordinated with NRCS to ensure program eligibility of individual participants. Additionally, KBRT assisted NRCS with landowner interactions and activities in the Wood River Valley, including as part of this study.
- Data sharing – KBRT shared data from its collection and analysis of field monitoring undertaken since 2002 (USDA NRCS, 2007), including data from their water quality, ground and surface water, aquatic, riparian, and vegetation monitoring efforts. In addition KBRT assisted in the field monitoring and analysis of this study.

3.3.3 Oregon State University (OSU)

Much of the fieldwork and analyses were carried out by OSU through cooperative agreements with the NRCS. Pasture and riparian vegetation data collection was carried out during the 2007-2008 field seasons and final reports were completed in December 2008. Dr. Tamzen Stringham of the Dept. of Rangeland Ecology & Management at OSU (now at the University of Nevada, Reno) led the OSU team investigating the vegetation and riparian portions of the study. Dr. Stringham's team included Sarah Quistberg and Holly Craig. This team provided the NRCS with the Wood River Valley Vegetation Monitoring Summary 2007-2008 report (see Appendix 2) and the Sevenmile and Crooked Creek (Riparian) Monitoring Summary 2008 report (see Appendix 3). In addition, Dr. Chanda Engle of OSU Extension, in cooperation with Dr. Stringham, contributed data collection and analyses of pasture Forage Dry Matter Percentage and Yield (2008) and a summary of the Wet Chemistry Forage Quality data (2008, see Appendix 4).

The NRCS also had a cooperative agreement with the OSU Department of Biological and Ecological Engineering Hydrologic Science Team to provide MIKE SHE and DAISY plant production simulation modeling assistance. Dr. Richard Cuenca led the modeling team, which included Dr. Yutaka Hagimoto and Joshua Owens. This team's modeling report on Crop Production and Irrigation was completed in November 2009 and is included in Appendix 5.

3.3.4 Graham Matthews & Associates, Inc

Graham Matthews & Associates (GMA), a consulting firm specializing in hydrology, fluvial geomorphology, and stream restoration design and construction, was contracted to do the Wood River Valley aquatic habitat study[5]. GMA had conducted a similar study for the KBRT in 2002/2003 and was asked by NRCS to re-create the original study for comparative purposes. The Aquatic Habitat Study of December 2008 is included in Appendix 6.

3.3.5 Landowners

The most important cooperators in the project were the landowners. Landowners provided access to their land, shared appropriate management information, and provided occasional support to

[5] Graham Matthews & Associates, P.O. Box 1516/Weaverville, CA 96093. http://www.gmahydrology.com/.

field operations. These cooperators provided access to 6,000 irrigated acres on three different ranch operations and 6,800 non-irrigated acres on five ranch operations. More importantly, many of these landowners are undertaking conservation work on their lands, both with and without outside financial assistance programs.

There are several financial assistance programs that have helped the landowners and local partnerships implement conservation in the area. These funding sources did not directly contribute to the CEAP study. However, landowners in the area have participated in conservation programs from various sources, including the following:

- U.S. Bureau of Reclamation, Water Bank Program
- Environmental Quality Incentive Program (EQIP), Klamath EQIP, Conservation Security Program, and Wetland Reserve Program
- Conservation Reserve Enhancement Program
- Oregon Department of Fish & Wildlife (ODFW) grants
- Oregon Watershed Enhancement Board (OWEB) grants

3.4 Introduction to the Monitoring and Analysis Summaries

The following chapters of the report describe the purpose, methods, and findings of the various study components of the Wood River CEAP. The discussions contained in many of the following chapters are summarizations from the many reports submitted by the different study teams. Chapter 11 of this report takes the information from the many investigative components of the study and attempts to synthesize and integrated the information into a coherent set of recommendations that are presented in Chapter 12.

4. Riparian Monitoring Summary

4.1 Background and Purpose

The Klamath Rapid Subbasin Assessment report as well as the Klamath Basin Rangeland Trust (KBRT) both identified restoration of riparian/aquatic habitats within the Wood River watershed as a significant resource concern. Restoring riparian habitats should help improve aquatic habitat conditions for ESA listed fish species as well as improve water quality. KBRT and others have used passive and active restoration techniques on approximately 21 miles of the 70 miles of streams in the study area. These areas have been fenced either to totally exclude cattle or to create a riparian pasture with short duration grazing. Most sites lie along Sevenmile Creek on the west side of the valley or Crooked Creek along the east side.

The riparian monitoring component of this study, in conjunction with the aquatic study, was initiated to allow for the evaluation of trends in riparian and aquatic habitats since ranchers in the area initiated restoration and conservation actions in the Wood River Valley in the late 1990s.

Many of these efforts center upon changing management of the riparian corridor along the mainstem of the Wood River and the tributaries of Crooked Creek and Sevenmile Creek (see Figure 1). In low-gradient systems like the Wood River, roots of riparian vegetation maintain the integrity of banks and bank-building processes, and thus regulate the shape (width, depth, cross-sectional and plan-form morphology) of the river channel. Channel shape, water temperature, and nutrients regulate the conditions for fish and other important aquatic resources. Integrity of the river channel also can affect floodplain groundwater levels, which in turn effect plant community composition and production and channel baseflows.

A number of different projects have been initiated on the Wood River system over the last ten years including reduction in irrigation withdrawals, riparian corridor and riparian pasture fencing along with changes in grazing practices. Given these private and institutional efforts directed towards innovative approaches to simultaneously improve riparian communities and channel conditions for the benefit of landowners and the aquatic ecosystems in the Wood River Valley, KBRT initiated riparian and aquatic habitat surveys starting around 2002/2003. However, when the CEAP proposal for the Wood River was written it was envisioned that a comparison of pre and post treatment results would provide information on riparian and aquatic habitat recovery rates.

Unfortunately, after a review, KBRT's attempts to monitor riparian habitat was limited and did not follow repeatable protocols that could be used with post treatment surveys. A second option examined was to compare current riparian conditions to representative plant communities. This option also proved unworkable. Researchers from Oregon State University identified three distinct riparian plant communities in the Wood River Valley but no truly representative sites that could be used for comparative purposes. Consequently, riparian efforts focused more on establishing detailed baseline vegetation and stream channel data following proven scientific methods so that future monitoring could be used to document changes. Appendix 3 contains a detailed report on the riparian monitoring conducted for this CEAP study. Monitoring work for both the Riparian and Aquatics portions of this CEAP study were focused on Sevenmile and Crooked Creeks.

As a complement to, and interrelated with, the riparian monitoring this CEAP study included an aquatics monitoring component. The aquatics monitoring, conducted by Graham Matthews Associates, Inc., was closely coupled with the Riparian monitoring portion of the study. The aquatics monitoring component of the study is described in Chapter 5 the Aquatic Study Summary.

4.2 Riparian Monitoring Objectives

After determining that a pre and post treatment comparison and analysis was not feasible, new objectives were developed for this portion of the study. These new objectives described the design and installation of a riparian monitoring framework that could be repeated in future monitoring efforts. The objectives included:

- Develop a riparian community type classification for the Wood River stream system located in the upper Klamath Basin of southern Oregon.
- Describe the general physiographic, edaphic, and floristic features of each community type.
- Describe the fluvial landform and stream channel type associated with the community type.
- Establish permanent channel cross-section monitoring sites on Sevenmile Creek and Crooked Creek.
- Utilize the community type information for the establishment of a network of vegetation and cross section monitoring.

No specific effects analysis was developed for the revised riparian portion of the study. Instead work involved setting up a framework to allow for more scientifically rigorous future evaluations of Sevenmile and Crooked Creeks.

4.3 Methods Overview

4.3.1 Community Type Development

Plant communities are an assemblage of plants living and interacting in the same location. Plant communities have no specific successional status (Crowe et al., 2004). A plant community type is a set of plant communities that have similar species structure and composition. A plant community type represents repeated occurrences of similar plant communities, but do not form a plant association or the plant community is not a climax community type (Crowe et al., 2004). Many of the plant communities on Sevenmile Creek would not be considered climax communities because of human disturbances, including grazing, channelization, removal of tree canopy, and irrigation withdrawal. Riparian classifications have been performed in Oregon; however these classifications are based on relatively undisturbed plant communities and the plant communities generally include the adjacent floodplain and not just the greenline plant community. There was a need to identify the plant communities currently on Sevenmile Creek, specifically on the greenline.

Sites were determined through utilization of the geomorphic information provided by the Klamath Tribes and through field reconnaissance in the summer of 2007. Consideration was also given to the Aquatic monitoring sites surveyed in 2003 and to be re-surveyed in 2008. Late seral and transitional riparian communities were identified and GPS located. Cross-sectional sketches showing the location of fluvial surfaces and both wetland/ transitional riparian and adjacent upland plant associations were created. Each fluvial surface with its corresponding plant association represented a vegetation plot. There were a total of 20 vegetation plots sampled at the various sites (see Figure 4 below).

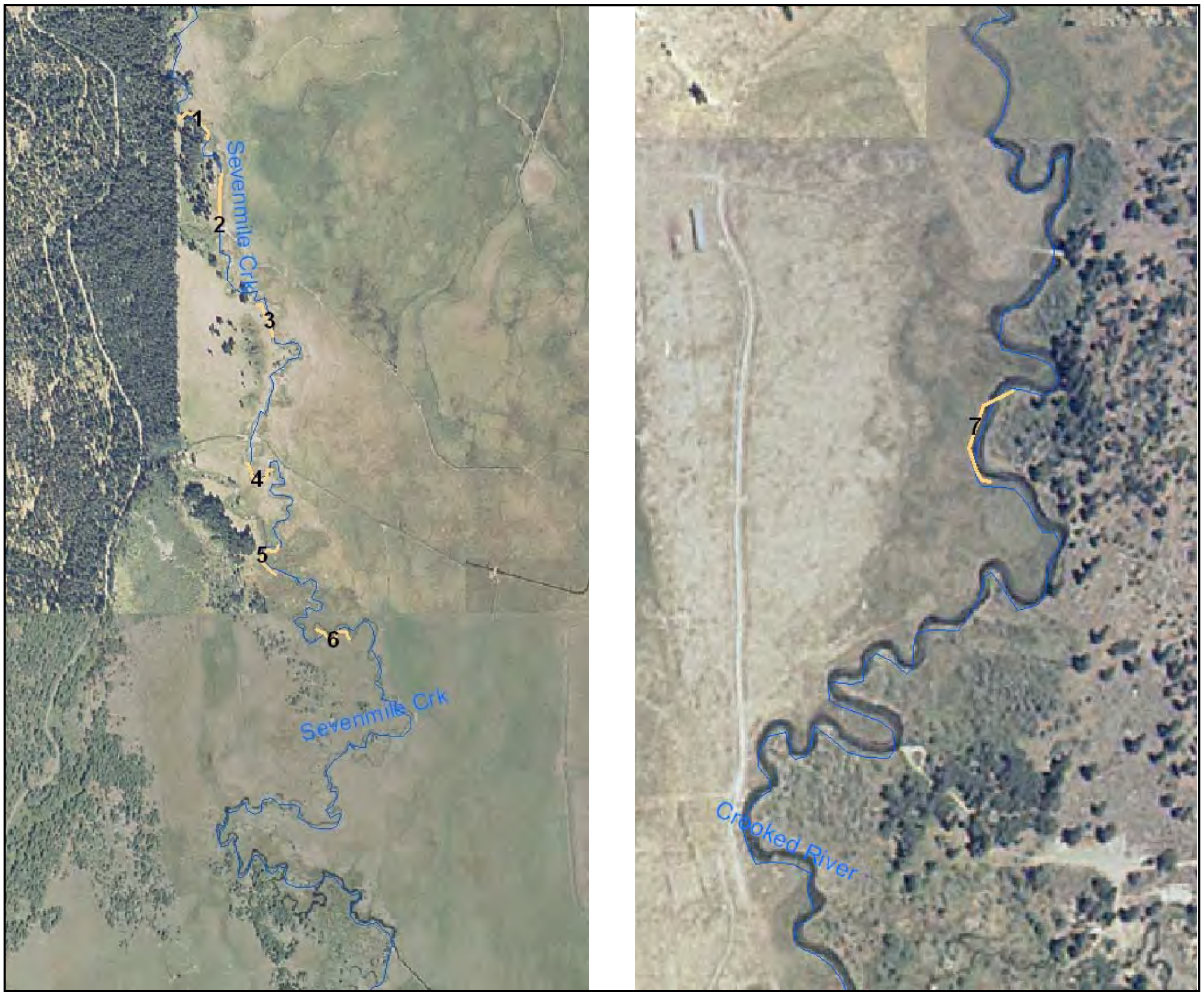


Figure 4. Riparian Study locations at Sevenmile Creek and Crooked River. Site locations are indicated in yellow.

For the vegetation sampling, the following considerations were used:

- Each community type chosen for sampling was at least twice as large as the plot in order to avoid sampling ecotones.

- A minimum sample size of 18 frames per site within homogenous plant community was chosen to insure sampling veracity. Plots were sampled using “Daubenmire” frames (30 cm by 60 cm).
- Canopy cover of dominant plants was recorded. Ocular estimates of canopy cover for each of the indicator species within a plot were made to the nearest percent up to 10 percent and to the nearest 5 percent thereafter.
- Soil was described by morphological features including: current depth of the water table; depth to which 90 percent of the vascular plant roots reach; depth to and description of redoximorphic features; depth of the surface organic horizon (if present); thickness of the epipedon (surface horizon); depth to the buried stream bed; and parent material.
- Soil horizon description included: thickness; moist color, percentage and coloring of redoximorphic concentrations and depletions; texture; current moisture status (dry, moist, wet or saturated); percentage and size class of coarse fragments, if present; and amount and diameter classes of roots.
- Rosgen stream type (Rosgen, 1996; Rosgen, 2006) was visually determined from the geomorphic information provided and recorded for each plot location.
- Valley landform descriptors (valley shape, gradient, width, side slope gradient and aspect) were recorded at each plot.

4.3.2 Riparian Monitoring Methods

The methods used for riparian monitoring in the Wood River Valley can be found in, “Monitoring the vegetation resources in riparian areas” (Winward, 2000). The only modification made for these sites were in the number of valley cross sections. Winward (2000) suggests using five transects and only three were used because of the similarity in valley/floodplain vegetation along each stream.

The monitoring sites were selected based on the vegetation community type work performed the previous season. That initial reconnaissance and intensive sampling provided the necessary information to establish permanent monitoring sites. The sites were selected based on vegetation community composition and potential for change with management.

4.3.2.1 Greenline

The Greenline was the method used to quantify riparian vegetation along the stream edge. Greenline has been defined as the first perennial vegetation that forms a patch or line (6 by 28 inches) that is at least 25 percent foliar cover of vegetation that is on or near the water’s edge (Cowley et al., 2008; Winward, 2000). Sampling the greenline can provide information about the ability of the channel to maintain bank stability and buffer the forces of water at high flow. Measurement of the greenline in a specific area over time can provide an indication of the long-term trend for the riparian area.

- The starting point of each greenline was permanently marked with rebar and a cap on the right bank of the channel, looking downstream.

- Community types or dominance/sub dominance of the vegetation along the greenline was recorded using a step transect approach (Winward, 2000) with enough steps to total a minimum of 363 feet on each side of the channel.

4.3.2.2 Valley Cross Section

This method quantifies the percent of each community type/species dominance perpendicular to the stream valley (Winward, 2000). Measurements taken in future monitoring efforts taken on the same site will provide information on the long-term changes and trend of the species within the site.

- Three transect locations were chosen based on distance downstream from the beginning of the greenline (each transect is not permanently marked).
- Each transect was paced instead of using a measuring tape.
- The first transect was located at the beginning of the greenline with the second transect 180 feet downstream from the first and the third transect another 180 feet downstream from the second transect.
- Each transect is perpendicular to the valley and at 60 and 240 degrees from magnetic north.
- Each transect was paced from the stream either to a fence line on the east side of the channel or to the conifer trees on the west side of the channel (see Figure 3 in Appendix 3).

4.3.2.3 Woody Species Regeneration

Woody species regeneration was measured using a 6-foot wide belt along the same transect used for the greenline.

- The sampler walked along the greenline with the center of a six-foot long pole over the inside edge of the greenline (that is, parallel to the edge of the stream).
- Woody species were recorded as they were encountered within the 6-foot belt transect along with the age class of the species (see Table 4 in Appendix 3).

4.3.2.4 Stream Cross Section

The stream cross sectional surveys included the following:

- Each monitoring site was benchmarked with cement and a metal pin placed in the cement. Distances and compass bearings were taken at the benchmark to the cross section and greenline so the site can be found in subsequent years.
- The endpoints of the cross section were marked using rebar.

- A measuring tape was then stretched in between the rebar going perpendicular to the channel flow. Elevations were then taken along the tape at any significant change in slope along the tape.
- At least 20 measurements were taken along the tape to accurately characterize a stream channel.
- Each cross section was located in a straight reach between two channel meander bends.

4.3.3 Data Analysis

Three different metrics were used to describe the functionality of the site, (1) successional status, (2) streambank stability, and (3) wetland rating. Detailed descriptions of successional status and streambank stability can be found in Winward (2000) and wetland rating in Burton et al. (2007). The following is a summarization of these metrics.

- Successional status was weighted by the percent of plants by successional status along the greenline.
- Streambank stability was based on the ability of a plant species to withstand the erosive forces of water. The data was summarized by weighted average for the greenline transect. Bank stability of over "7" was generally considered adequate to protect the streambank and allow them to function correctly.
- Wetland rating was a weighted average based on the wetland indicator status. The wetland indicator status was the frequency with which an individual plant species occurs in saturated soil. This was used for descriptive purposes.

4.4 Results/Findings

The predominant species found on the greenline were *Scirpus microcarpus, Poa pratensis, Carex nebrascensis, Carex aquatilis* and *Carex utriculata* (see Table 2 in Appendix 3). All the species but *Poa pratensis* are typically found only in riparian areas. They are rhizomatous and can form dense patches of vegetation along stream banks providing good bank stability. *Poa pratensis* is generally found in less saturated conditions than the other dominant riparian species. It is rhizomatous, but not as deep rooting therefore it does not provide the bank stability generally associated with these types of obligate wetland rhizomatous species. Generally, the dominant species at sites 1, 2, 5, and 6 (see Figure 4 above) are wetland plants that should continue to hold the banks together as long as water remains in the channel year round (see Tables 5 and 6 in Appendix 3). Sites 3 and 4 have plant species that are found in drier conditions that do not have the root/rhizome structure to hold the streambanks together as well as sedges and shrubs found at other sites. Reed canarygrass is present along much of Sevenmile Creek and the growth of the patches should be monitored.

Over time if sites 3 and 4 continue to develop and progress towards wetter riparian conditions, the sub-dominant species may begin to increase in cover. It will be important to monitor the sites again in 3 to 5 years to assess the trend over time. Baseline monitoring only gives a point in time snapshot of the site and observing how it develops over the course of a few years will be important in establishing a positive or negative trend (see Table 7 in Appendix 3).

The sites with young willows and bulrush were given an early ecological status because the willows are still developing. With the many young willows at the site, the numbers of willows will drop as they mature and the ecological status will probably change as they mature. Site 2 may experience the most change over time because the vegetation is still developing although the sites that have the most potential for improvement are sites 3 and 4.

Shrubs would naturally be present in patches along both Sevenmile Creek and Crooked Creek. Willows are fairly well developed in the floodplain of Crooked Creek and they are establishing in the greenline in some sites along Sevenmile Creek (see Table 9 in Appendix 3). The shrubs developing along Sevenmile Creek are mainly in the greenline because that is the area that has experienced the most change in recent years. The age class of the woody species should shift upwards as the plants mature and the number of woody plants in the youngest age classes may decrease at some sites as they mature.

The cross sections show that in the downstream section of Sevenmile during high flows, it should have access to the floodplain (see Appendix 3 [appendix 1.d; table 8]). This can also be seen in the vegetation composition on the greenline. The downstream portions of the stream have a higher composition of obligate wetland plants than do the upstream sections and the area directly influenced by the channel outside of the greenline also has the potential for a higher composition of obligate/facultative wet plants. Crooked Creek does not have the same flood generation capability as Sevenmile because it is a spring fed system that experiences limited snowmelt influence, however, the water remains near bank full year round, allowing obligate wetland plants to establish along the greenline and floodplain on the left side of the stream.

In addition to the results described here, the reader should refer to the Aquatics study results and findings in Chapter 5. The researchers involved in this CEAP study attempted to overlap reaches for the riparian and aquatics surveys where feasible so that changes in riparian habitat could be compared to changes in adjacent aquatic habitat.

5. Aquatic Study Summary

5.1 Background and Purpose

As described in the Purpose and Background section of the Riparian Monitoring Summary, in 2002, the Klamath Basin Rangeland Trust (KBRT) began a pilot project to evaluate the feasibility and effectiveness of conservation actions being undertaken in the Wood River Valley. The goal of the program was to increase the quantity and quality of water in the Klamath Basin by conserving irrigation water in the Wood River Valley, while restoring pastures and wetlands to maximize ecological value. The primary means to accomplish this goal was eliminating irrigation diversions for project lands, thus leaving this water in-stream, providing important ecological benefits and increased flows for downstream use. Other actions include various cattle management strategies, including substantial reductions in cattle numbers, riparian fencing, and active stream restoration.

Extensive monitoring of the projects promoted by KBRT was begun in 2002, including surface water, water quality, fish habitat, and stream conditions. Initial thoughts in 2002 on the potential timeframe until changes caused by KBRT management might be detectable centered on a 5-10 year period. Five years had passed since the 2002 initiation of the KBRT conservation program and it was deemed an appropriate time to evaluate potential changes to the aquatic systems.

In 2002/2003 KBRT hired a consulting firm to conduct aquatic and riparian monitoring. The 2002/2003 aquatic, pre treatment habitat monitoring was conducted following repeatable protocols. Thus, NRCS, working with KBRT, was able to hire the same consultants to conduct post treatment surveys for this study. The aquatic monitoring conducted in 2008 re-surveyed the aquatic environment and a comparison to the 2002/2003 data was undertaken. The consultants also established photo points during their 2002-03 survey which allowed a qualitative comparison of pre and post treatment riparian conditions.

The purpose of this portion of the Wood River CEAP study was to determine whether measurable impacts to the aquatic system could be shown to result from the various changes in land management initiated over the last ten years or so.

5.2 Hypotheses and Objectives

The primary objective of the aquatic monitoring portion of this Wood River CEAP study was to measure changes in fish habitat and fish numbers on Crooked Creek and fish habitat on Sevenmile Creek after five years of the KBRT sponsored land use management changes. The aquatic monitoring efforts included repeating surveys of geomorphic conditions, fish habitat, and fish abundance.

5.3 Methods Overview

Baseline conditions were established in 2002 and 2003 (Pacific Groundwater Group et al., 2003; Kann and Reedy, 2004) for fish habitat and geomorphic conditions of Crooked Creek and Sevenmile Creek (see Appendix 6, figure 1), two streams affected by management actions of KBRT. Additional monitoring work has occurred on Crooked Creek since the late 1990s, primarily associated with the planning and implementation of a specific stream restoration project.

The full report in Appendix 6 describes the monitoring objectives, methods, results, and analyses used for the aquatic monitoring portion of the Wood River CEAP study. Most of the methods were established and reported in the 2003 Fisheries Habitat Monitoring Report (Kann and Reedy 2004) and the basics are not reiterated here unless methods were altered or new methods added. The results were compared to those from 2003 to evaluate general trends for predictive purposes.

The Wood River Valley Aquatic Habitat monitoring was conducted by Graham Matthews & Associates in 2003 for KBRT. Graham Matthews & Associates was re-hired in 2008 for the Wood River CEAP study to increase confidence in having the original surveys redone at the correct locations, using the same methodologies, having similar sampling effort, etc.

The Sevenmile Creek and Crooked Creek areas were surveyed according to the following five metrics:

- Geomorphic Field Surveys: Geomorphic surveys of the channel banks and the thalweg (deepest part of the channel) were done using survey grade RTK-GPS equipment and data reduction.
- Habitat Surveys: Habitat units were delineated by measuring cover, depth, pool quality, wood and substrate parameters, and collecting photo point data. Habitat unit boundaries were defined using survey grade RTK-GPS equipment.
- Fish Surveys (Crooked River only): A snorkel survey of the creek was done to count fish.
- Macroinvertebrate Surveys (Crooked River only): Macroinvertebrate samples were collected and the samples were sent to a lab for analysis.
- Photo points: The photo point monitoring sites used in 2003 were re-located, where possible, and photos were taken in 2008 using the same orientations (upstream, downstream, and across) to provide a basis for visual comparisons with the 2003 images.

Both Sevenmile and Crooked Creeks were divided into segments for the monitoring work to differentiate hydrologic and morphological features and to facilitate the assessment and reporting process (See figures 5 and 6 below).

As described in the Riparian monitoring discussion above, the Aquatic monitoring and Riparian monitoring were geographically coordinated as much as feasible given the different needs of the study methodologies. Appendix 6 contains a more detailed description of the methodologies used in the Aquatics monitoring.

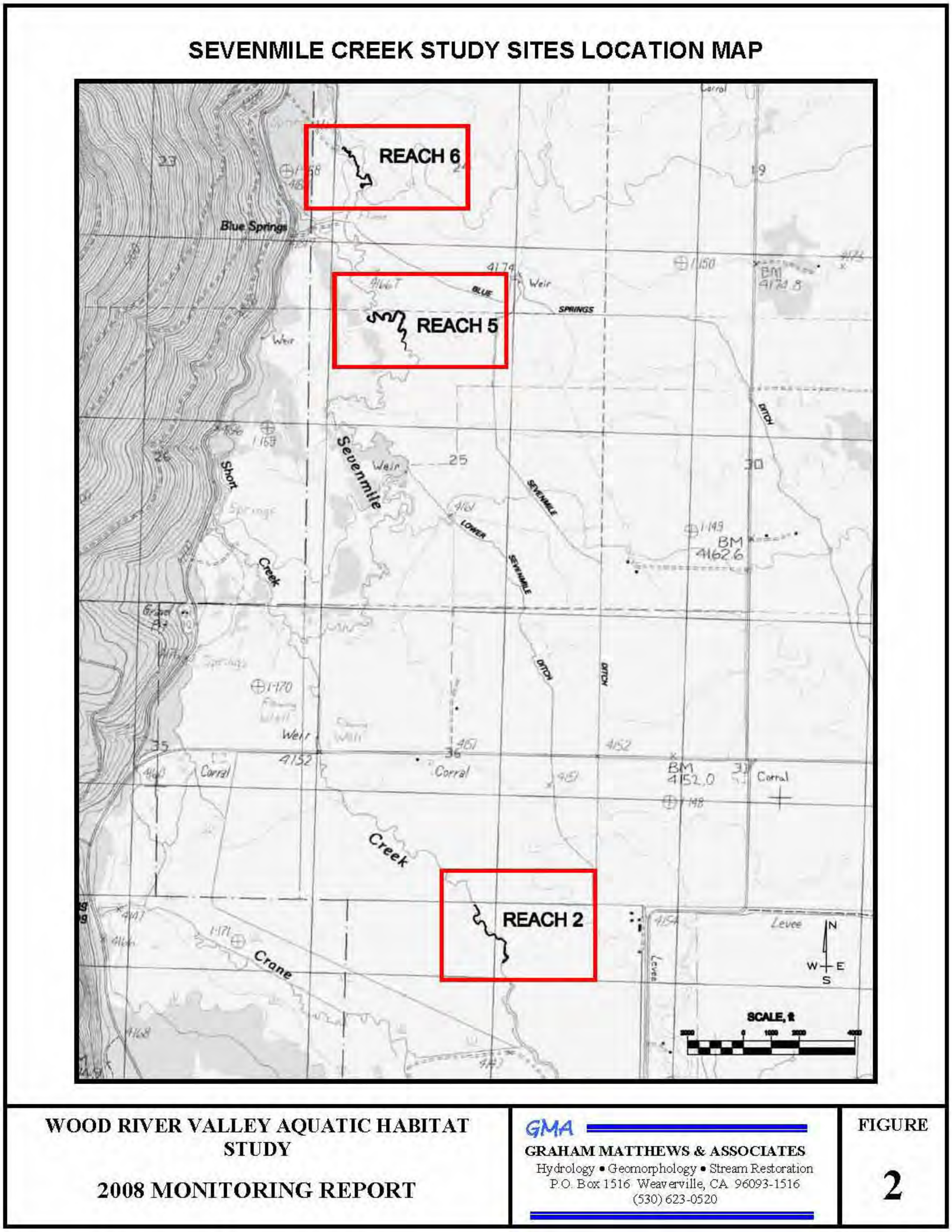


Figure 5. Sevenmile study sites.

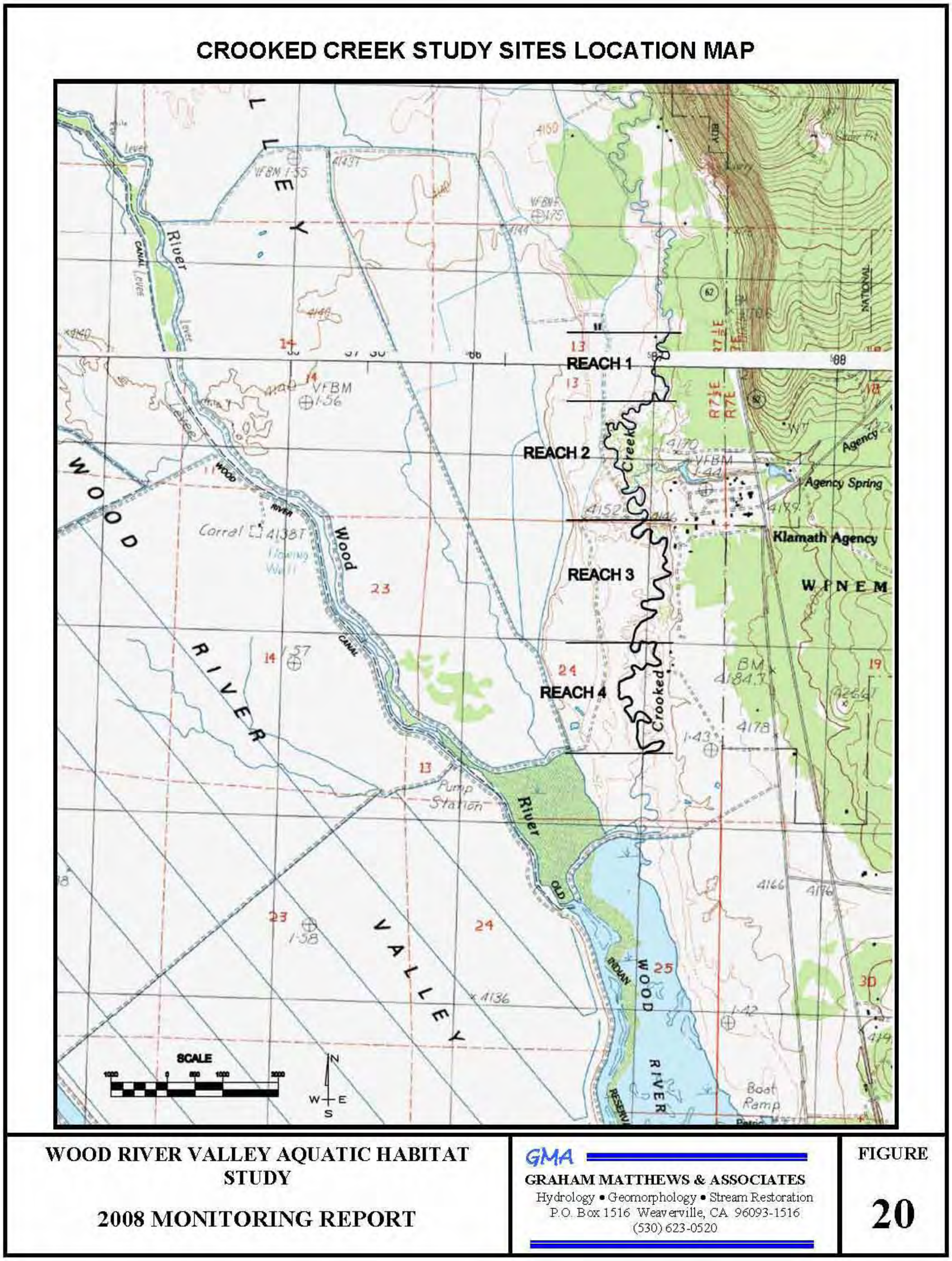


Figure 6. Crooked Creek study sites.

5.4 Results/Findings

Appendix 6 contains the full Aquatic habitat monitoring report. The following are a few of the more notable results.

On Sevenmile Creek, decreased grazing pressure has had the most impact on Aquatic Reaches 5 and 6 by allowing riparian vegetation to grow and stabilize banks thereby reducing erosion, narrowing and deepening the channel, and reducing the width to depth ratio.

Aquatic Reach 6 has experienced the most dramatic changes resulting from the KBRT sponsored land management changes, which directly affected water diversions and grazing practices. Fish habitat greatly improved as shown by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Aquatic Reach 6 clearly demonstrates the possible improvements in channel and riparian conditions over a 5 year period with new management prescriptions. Graham Matthews and Associates report that Aquatic Reach 6 saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches, (2) it has a much steeper gradient than the other reaches (4-5 times steeper) thus providing considerably more energy with the increased stream flows to scour the bed, and (3) it likely saw the highest percentage increase in base flow, as prior to the management changes, it was essentially dewatered much of the summer.

Aquatic Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This is likely due to the very low gradient of this reach. With less energy available to promote change, change will take a much longer period of time. Although the mean depth and large woody debris decreased in Aquatic Reach 2, there was an increase in pool quality, partly due to an increase in percentage of undercut banks. Being the most downstream reach (and lowest gradient), one would expect Aquatic Reach 2 to improve the slowest, both due to low energy available and that much of the sediment released from upstream as those reaches recover will move through the downstream reaches.

A significant increase in amount of habitat available, although not directly measured, is suggested by the increase of base stream flow during the critical summer months as shown in Figure 19 of Appendix 6. To evaluate such changes this directly, habitat would need to be measured at the same time of year (not the case for the 2003 and 2008 surveys), then, not only would the physical changes be apparent, but the available habitat (not just physically based but also dependent on the base flow amount) during critical periods could also be determined.

On Crooked Creek decreased grazing pressure has caused channel narrowing and a decrease in width to depth ratio throughout the monitoring reaches. There is a current effort to increase the cattle exclusion area along the right bank through most of Aquatic Reaches 3 and 4 which should further reduce bank erosion and increase bank undercuts.

Overall, channel widths and width to depth ratios decreased as bank erosion has decreased. Undercut banks have not increased as much as one would expect except in Aquatic Reach 1 where the difference is significant.

The most dramatic change between 2003 and 2008 has been with the distribution of adult trout in the four reaches. Although the number of fish was lower than in 2003, a much higher percentage of the fish counted were in the index section of Aquatic Reach 4. It is likely that the increase in depth and decrease in width and, even more so, the increase in large woody debris incorporated with the channel narrowing projects have improved the fish habitat and encouraged fish use.

6. Synthesis of Riparian and Aquatic Findings

6.1 Purpose

The following table and accompanying map describe basic information about the reaches surveyed for riparian and aquatic habitat. Researchers attempted to overlap reaches for the two surveys where possible so that changes in riparian habitat could be compared to changes in adjacent aquatic habitat. Figure 7 and Table 1 below show where the Riparian and Aquatic monitoring surveys overlapped on Sevenmile Creek.

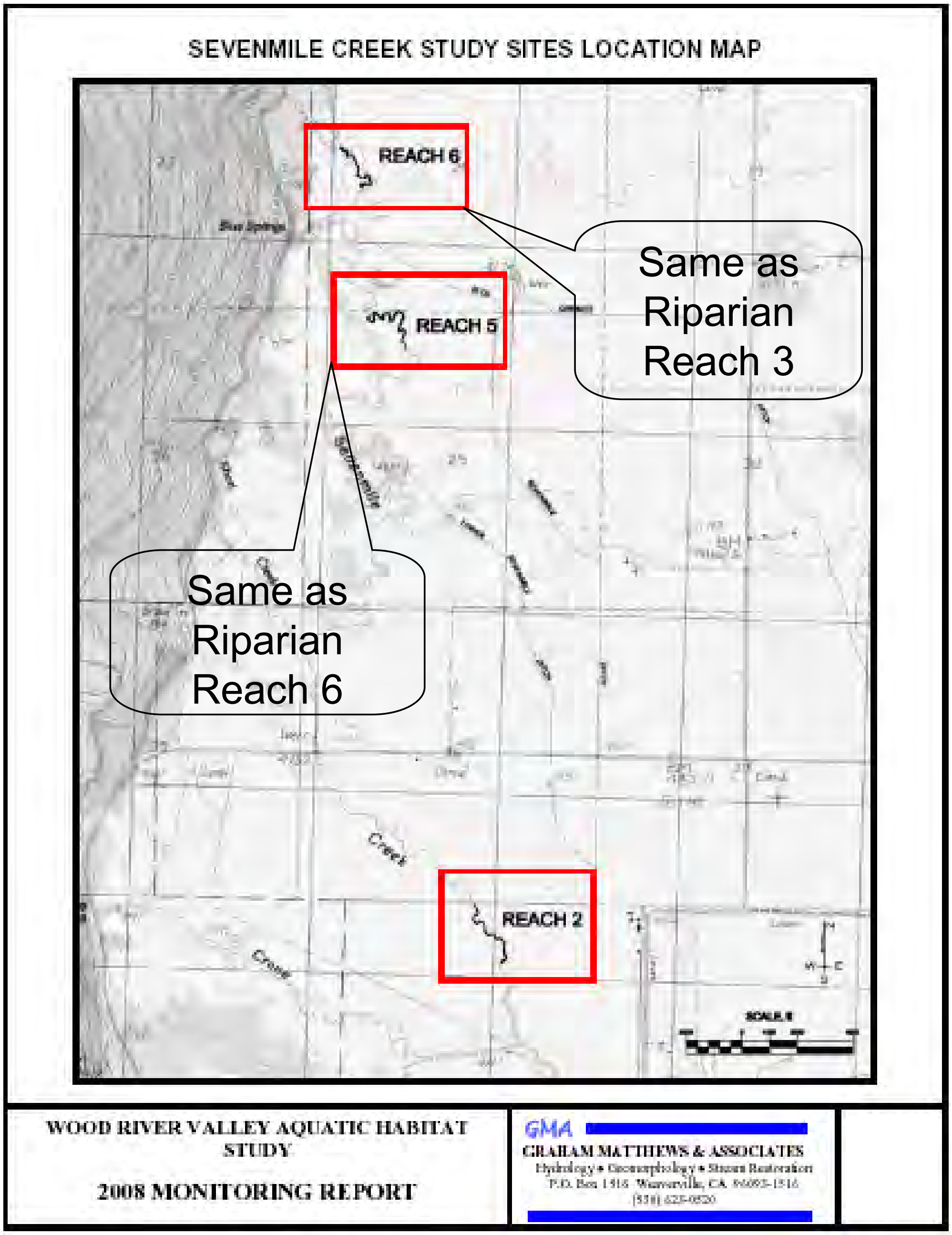


Figure 7. Sevenmile Creek study reaches.

Table 1. Riparian and Aquatic Habitat Surveyed Reaches.								
Creek	Riparian Reach	Riparian Reach Length (ft)	Aquatic Reach	Aquatic Reach Length (ft)	Treat-ment Year	Treat-ment Type	Treatment Description	Post Treatment Grazing
Seven mile	1	444			2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	2	432			2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	3	328	6	1,247	2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	4	380			2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	5	409			2004	Passive	Riparian fencing & managed grazing	limited
Seven mile	6	413	5	1,557	2006	Passive	Riparian fencing & managed grazing	none
Seven mile			2	1,490	2005	Passive	Riparian fencing & managed grazing	limited
Crooked	7	429	1	1,931	2002 – limited grazing; 2008 – fenced	Passive	Riparian fencing & managed grazing	East side – none; West side – limited
Crooked			2	5,708	2001	Passive	Riparian fencing & managed grazing	East side – none; West side – limited
Crooked			3	4,787	2001	Passive	Riparian fencing & managed grazing	East side – none; West side – horses
Crooked			4	4,695	1997	Passive & Active	Riparian fencing, channel shaping, riparian plantings & managed grazing	None
Rows with yellow highlighting indicate overlap of Riparian and Aquatic monitoring river segments.								

As discussed in the Aquatic Study chapter of the report, on Sevenmile Creek the decreased grazing pressure had substantial impact on Aquatic Reaches 5 and 6. It was suggested that changes in management allowed the riparian vegetation to grow and stabilize banks thereby reducing erosion, narrowing and deepening the channel, and reducing the width to depth ratio. These parameters were measured as well as documented with photo-point monitoring. Figures 8, 9, and 10 are representative examples that illustrate the changes documented in the Aquatics portion of the study.

Aquatic Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This is likely due to the very low gradient of this reach. The Riparian monitoring showed that the predominate vegetation in this reach (Riparian Reach 6/Aquatic Reach 5) are riparian/wetland plants that are rhizomatous, can form dense patches, provide good bank stability, and should hold the banks together if water continues to be present year round.

Figure 8. Photo on left is from the summer of 2003 and on the right from the summer of 2008 – same location in Aquatic Reach 5, Sevenmile Creek.

Figure 9. Photo on left is from the summer of 2003 and on the right from the summer of 2008 – also Aquatic Reach 5, Sevenmile Creek.

Aquatic Reach 6 (Riparian Reach 3) experienced the most dramatic changes resulting from the land management changes, which directly affected water diversions and grazing practices. Fish habitat greatly improved as shown by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased, and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Aquatic Reach 6 (Riparian Reach 3) clearly demonstrates the possible improvements in channel and riparian conditions over a 5 year period with new management prescriptions. The Aquatic Monitoring Study found that Aquatic Reach 6 saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches, (2) it has a much steeper gradient than the other reaches (4-5 times steeper) thus providing considerably more energy with the increased streamflows to scour the bed, and (3) it likely saw the highest percentage increase in baseflow, because prior to the management changes the reach was essentially dewatered much of the summer.

Aquatic Reach 6 is the same as Riparian Reach 3. The riparian monitoring found that this reach had plant species that are found in drier conditions that do not have the root/rhizome structure to hold the streambanks together as well as sedges and shrubs found in other parts of Sevenmile Creek. The Riparian monitoring report also noted that if the reach continues to progress towards more of a wetter riparian site over time the sub-dominant species may begin to increase in cover and provide more bank stability through a more extensive rhizomatous/root system.

Figure 10. Photo on left is from the summer of 2003 and on the right from the summer of 2008 – Aquatic Reach 6, Sevenmile Creek.

6.2 Results/Findings

Appendix 6 contains more detailed results and findings than are summarized here. What appears clear from the Aquatic and Riparian monitoring work is that the changes in irrigation and grazing management through the KBRT sponsored program have had several positive effects on the channel morphology and fish habitat for Sevenmile Creek and Crooked Creek. Table 2 shows that on Sevenmile Creek, Aquatic Reach 6 (the uppermost section studied) showed the most improvement in fish habitat with increases in pool numbers, depth, large woody debris, and a decrease in fine sediment. Aquatic Reaches 5 and 6 both have more stable banks and narrower, deeper channels.

Table 2: Comparison of Riparian and Aquatic Reaches on Sevenmile Creek.

Riparian Reach Number			3	6
Aquatic Reach Number			6	5
Riparian Vegetation Condition 2008		Stability Rating	Moderate	Excellent
		Ecological Status	Mid	PNC
		Wetland Status	Good	Very Good
Aquatic Habitat Condition 2003 and 2008	Habitat Units	2003	37	35
		2008	50	38
	Mean Depth (ft)	2003	2.1	2.8
		2008	2.4	2.8
	Mean Width (ft)	2003	26.9	27.0
		2008	23.1	19.3
	Eroding Banks (%)	2003	16.1	0.3
		2008	6.8	0.0

The effects of the new management were somewhat less but still substantial for the Crooked Creek study reaches. Channel width and width to depth ratios decreased and bank erosion decreased. The areas of Crooked Creek Aquatic Reach 4 that have undergone restoration in the form of channel narrowing and large woody debris enhancement showed an increase in adult trout usage.

The rate of recovery for channels affected by grazing appears to be strongly influenced by the flow and sediment regime available to initiate change. Sevenmile Creek has a more extensive watershed and higher winter storm and spring snowmelt runoff compared to the spring-dominated Crooked Creek. In addition, upstream areas have higher gradients, providing more energy to scour the bed, creating deeper pools and improving substrate by selectively flushing fine sediments. As a result, lower gradient reaches will take longer to recover.

7. Grazing Land Vegetation Monitoring Summary

7.1 Purpose

The main purpose of this study was to determine the effects of changing irrigation and grazing management in the Wood River Valley. The grazing land vegetation monitoring specifically addressed five questions:

How does “no” or “reduced” irrigation versus full irrigation affect:

- Total annual above-ground and available forage production (monthly and annual)?
- Vegetation species diversity and abundance?
- Amount of bare ground and perennial plant basal gaps?
- Forage quality (protein and energy) for use by domestic livestock?

Several additional questions link the four questions above with the researchers’ confidence in the findings to state what the long term implications may be. That is:

- Will plant community composition continue to change?
- Will percent bare ground and basal gaps continue to increase?
- Will production continue to decline?
- Will forage quality increase or decrease?

Three interconnected studies were undertaken to answer these questions. The reports prepared by the researchers include:

- 2007-2008 NIRS Forage Quality Assessment, Wood River Special Emphasis CEAP Watershed, Upper Klamath Basin, Oregon, Jeff Repp, USDA-NRCS, West National Technical Support Center, Portland, Oregon, January 2009 (included as part of Appendix 1).
- Wood River Valley Vegetation Monitoring Summary 2007-2008, Tamzen K. Stringham and Sarah E. Quistberg, Rangeland Ecology and Management, Oregon State University, December 2008 (included as Appendix 2).
- Summary of Wood River CEAP Wet Chemistry Forage Quality Data, for both Inside (ungrazed) and Outside (grazed) the exclosures, for the Year 2008, Chanda L. Engel, OSU Klamath Basin Research and Extension Center, Klamath Falls, Oregon, February 2009 (included as Appendix 4).
- 2007-2008 Exclosure Clipping Study Results, Wood River Special Emphasis CEAP Watershed, Upper Klamath Basin, Oregon, Jeff Repp, USDA-NRCS, West National Technical Support Center, Portland, Oregon, January 2009 (included as part of Appendix 1).

Each study contains more information on methods and results than are summarized in this report. Information summarized here represents those components the researchers considered most significant or useful in answering the questions posed at the outset of the study process. The researchers for the individual component studies also provided NRCS with the raw data collected in the field. In addition, information and data from studies and monitoring done by other agencies and organizations have been consulted, referenced, and incorporated as appropriate in this discussion.

7.2 Objectives

The objectives of this component of the study were to:

- Determine vegetative production, composition, structure, and forage quality on irrigated vs. non-irrigated sites.
- Compare soil compaction as measured by a relative penetronmeter and bulk density within irrigated and non-irrigated sites.
- Evaluate the base nutritional plane of the vegetative component of the biological communities or animal performance between irrigated and non-irrigated pastures.

7.3 Methods Overview

7.3.1 Field Sites

A total of 12 field groups were selected, consisting of 6 irrigated groups (1I, 2I, 3I, 4I, 5I, and 6I) and 6 non-irrigated groups (1N, 2N, 3N, 4N, 5N, and 6N) distributed throughout the Wood River Valley. All irrigated sites were fully irrigated; there were no sites with reduced irrigation levels. Three vegetation transects and one vegetation exclosure were established at each site. Water table and soil moisture sensors connected to data loggers were placed within the exclosures. Fecal and forage quality data were also taken within each grouping. A digital elevation model (DEM) of the Wood River Valley with 1-m horizontal cell resolution was obtained via LiDAR (Light Detection and Ranging data) supplied by the Klamath Basin Rangeland Trust.

7.3.2 Data Collection

7.3.2.1 Plant Production and Composition (Stringham and Quistberg)

Annual above-ground, air-dry reconstructed plant production and composition by foliar cover were measured at each of the 18 non-irrigated and 18 irrigated plots and at exclosures. Three transects and one exclosure were established for each field group. Transects were 150 feet (45.72 meters) long and oriented North-South (two per plot for 300 feet total length). Vertical point samples were collected every 2 feet (0.61 meters) along transects once a month from April to October to determine foliar cover of plant species and soil cover (150 points). Ten subplots were estimated and clipped (10 estimated and two clipped) by species along transects in 2007 to determine total annual air-dry reconstructed production (double sampling). Exclosure samples were taken concurrently. The exclosures were 64 square feet (5.94 square meters). For each sampling location the following data/observations were taken:

- Double Sampling: Annual air-dry above-ground reconstructed production (2007 only).
- Basal Gaps: Distance between rooted perennial plants.

- Line Point Intercept: Species composition by percentage of foliar cover and percent of bare ground.
- Belt Transect: Presence of invasive species by plants per area (density), especially bull thistle.
- Exclosure Clipping: Monthly air-dry production via subplot clipping and re-growth clipping. [Exclosures were placed as close as possible to fixed plots but were spatially removed from plot locations to reduce impacts to grazing animals.]

7.3.2.2 Forage Quality (Plant and Fecal Sampling)

7.3.2.2.1 Plant Sampling (Engel)

Each month during the 2008 growing season six forage samples from each field group were taken and analyzed using wet chemistry techniques for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro dry matter digestibility (IVDMD), and in vitro neutral detergent fiber digestibility (IVNDFD). These analyses were designed to estimate total and digestible fiber present in the forage so that a nutrition balance of the livestock could be made.

7.3.2.2.2 NIRS Analysis of Fecal Samples (Repp)

In 2007 and 2008, fecal samples were collected from animals in each grouping each month, May through October. When animals were not present on pastures within a group, no fecal sample was collected. Fecal samples were analyzed with near infrared reflectance spectroscopy (NIRS) for percent crude protein (CP), digestible organic matter (DOM), percent fecal Phosphorus and percent fecal Nitrogen. NIRS samples are easier and cheaper to collect and analyze than the wet chemistry samples and have been validated thoroughly for cool-season forages (Texas A&M University Grazingland Animal Nutrition (GAN) Lab). NIRS is also advantageous in that it directly samples what the animal ingested and the sampler does not have to attempt to clip forage in the same proportions that an animal would graze. Stubble height was also recorded when collecting plant and fecal samples.

7.3.2.3 Grazing Management

Visits to the field groups were made each month from April to October to estimate grazing characteristics. Observations were made for animal breed, average weight, body condition score (BCS), average age, and metabolic activity (lactating, dry, growing animal, etc.). Estimates of the amount of remaining forage and rate of plant re-growth were made visually. These observations were confirmed with the landowner when possible. The typical grazing system practiced in the Wood River Valley was continuous season-long grazing. Cattle were kept in large pastures and grazed freely throughout the growing season.

7.4 Results/Findings

7.4.1 Plant Production and Composition (Stringham and Quistberg)

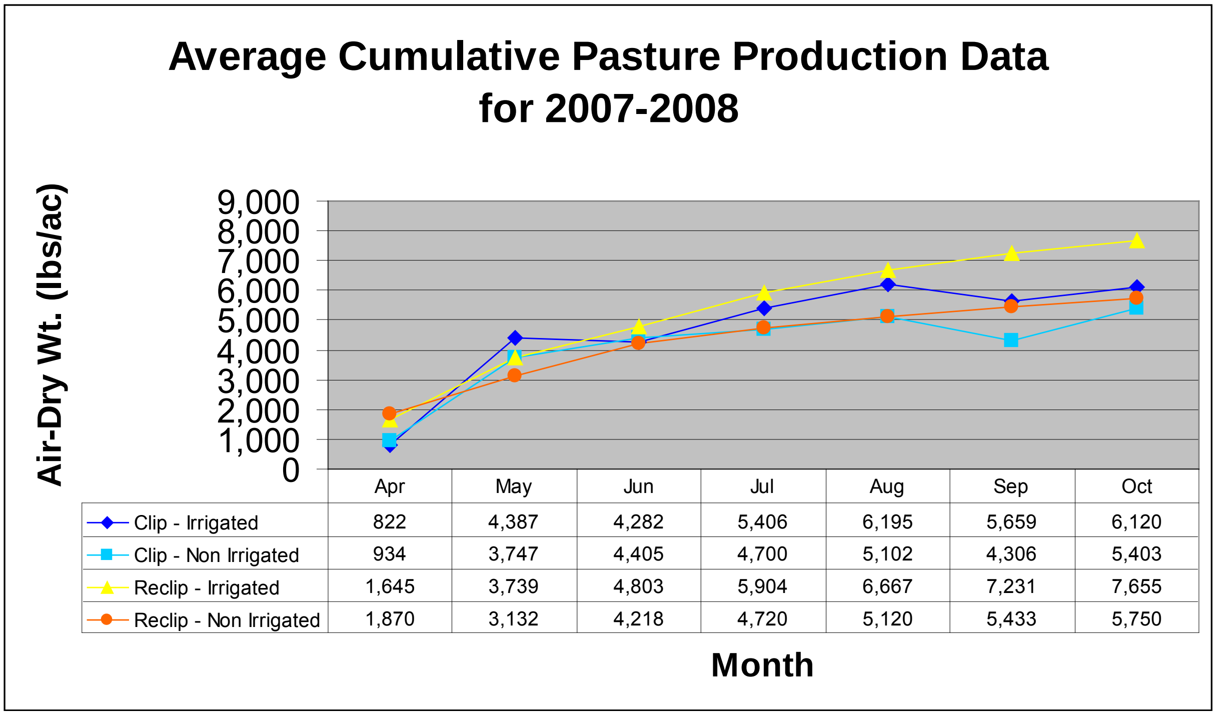
7.4.1.1 Plant Production

Double sampling for reconstructed annual air-dry above-ground production was conducted on each of the 36 plots in 2007. The method is described in Herrick et al. (2005) and has been part of the National Resource Inventory Range Study since its inception in 2003. This data provides a baseline for annual above ground air-dry production during a single year regardless of accessibility or palatability to grazing animals. Production data was not collected at the plots in 2008 so comparisons between years is not possible. The 2007 data was used to validate the production data collected by monthly cumulative and re-growth clipping in the exclosures (see Appendix 1.

Production sampled from exclosures included cumulative monthly clipping and clipping of re-growth. Each month a subplot was clipped within a new 1.92 square foot hoop thereby representing cumulative growth over each growing season (each month's growth would include the previous month's growth as well). This approximated the amount of production with no impact from grazing. Also each month each subplot clipped the previous month was re-clipped.

Samples were weighed green, air-dried (about 72 hours) and re-weighed to determine percent air-dry at time of clipping (used in reconstruction factors). The re-clip data represents re-growth since the last clipping. Consequently, re-growth clipping represents production assuming a monthly harvest or a 30-day rest period between harvests. Combining monthly accumulated clipping and re-growth clipping give a more accurate estimate of total productivity.

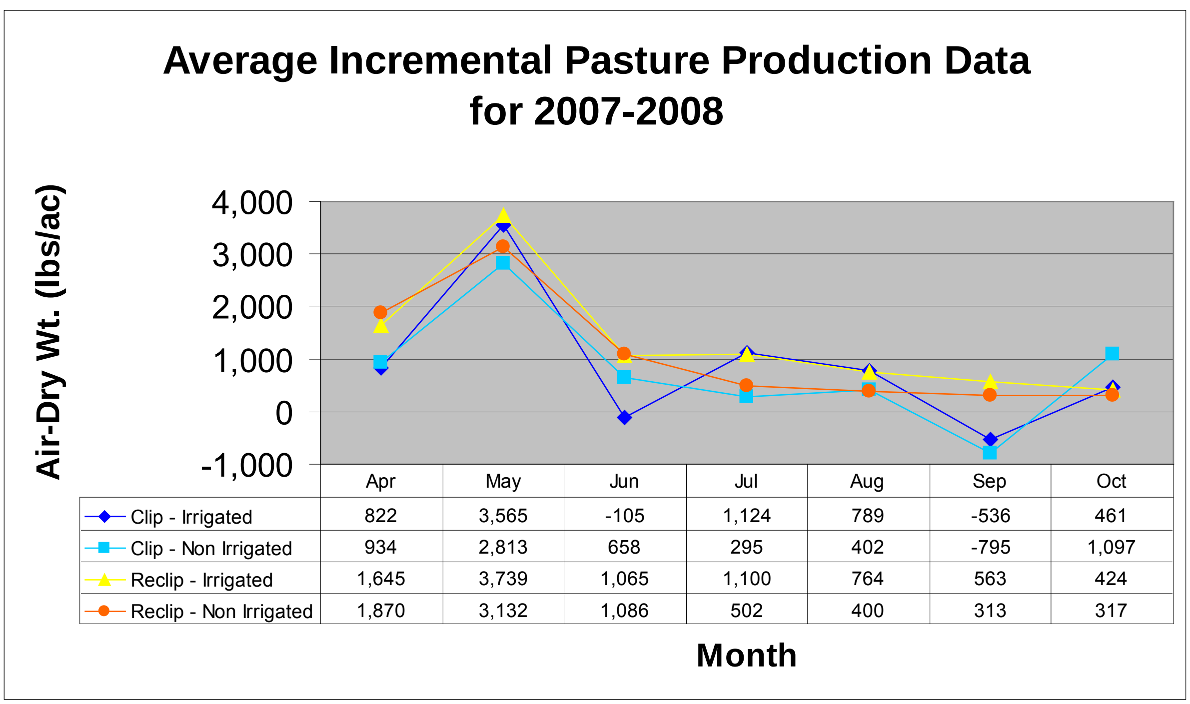
Figure 11 compares cumulative monthly plant production averaged over the two years of data collection for both clip and re-clip samples from six irrigated and six non-irrigated sites. Both clip and re-clip accumulative totals are similar (6,120 and 7,755 for irrigated sites and 5,403 and 5,750 lbs/acre for non-irrigated sites). Re-clip data totals are slightly higher than clip totals. Periodic harvesting or grazing can encourage new tiller or shoot growth sometimes referred to as compensatory growth. Production on irrigated sites is higher than non-irrigated (13 percent higher on clip sites versus 33percent higher on re-clip sites).



	Apr	May	Jun	Jul	Aug	Sep	Oct
Clip - Irrigated	822	4,387	4,282	5,406	6,195	5,659	6,120
Clip - Non Irrigated	934	3,747	4,405	4,700	5,102	4,306	5,403
Reclip - Irrigated	1,645	3,739	4,803	5,904	6,667	7,231	7,655
Reclip - Non Irrigated	1,870	3,132	4,218	4,720	5,120	5,433	5,750

Figure 11. Average Cumulative Pasture Production.

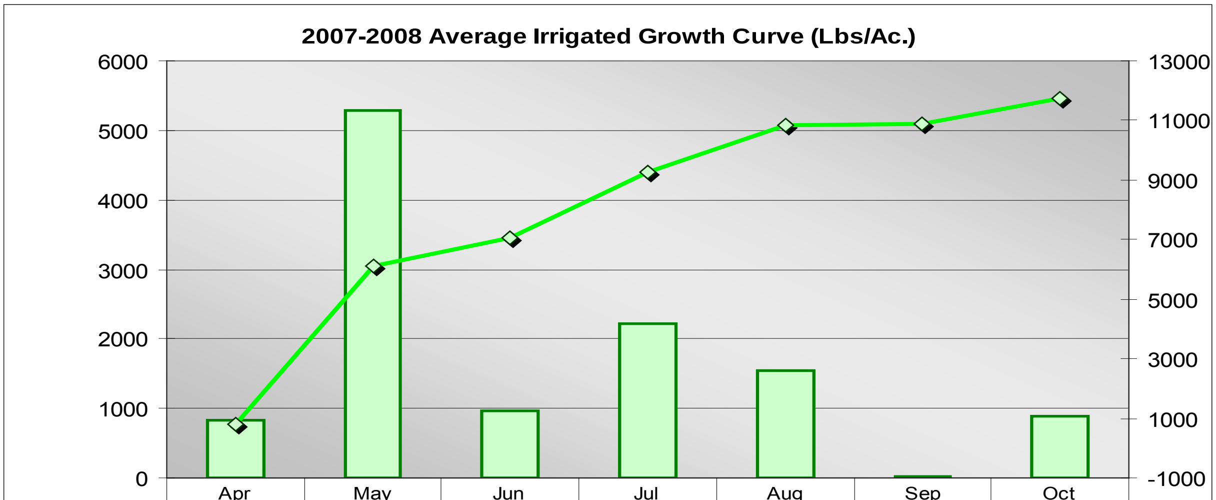
Examining the incremental monthly growth (Figure 12) shows the greatest growth occurs early in the season and tapering off into late summer and fall. This occurs both at irrigated and non-irrigated sites. Possible reasons include plant senescence following hot, dry summer weather, insect and small mammal foraging, and possibly nutrient availability.



	Apr	May	Jun	Jul	Aug	Sep	Oct
Clip - Irrigated	822	3,565	-105	1,124	789	-536	461
Clip - Non Irrigated	934	2,813	658	295	402	-795	1,097
Reclip - Irrigated	1,645	3,739	1,065	1,100	764	563	424
Reclip - Non Irrigated	1,870	3,132	1,086	502	400	313	317

Figure 12. Average Incremental Pasture Production for 2007 – 2008.

The following figures (Figures 13 and 14) show the total monthly and annual accumulation of air-dry above-ground production from irrigated and non-irrigated sites (based on exclosure clipping: monthly and re-growth added together) and represent the average of all growth in all exclosures for both years. The bars represent the monthly growth (left Y axis) and the line represents the accumulation of growth over the growing season (right Y axis). The amount of forage available to grazing animals is a percentage of these amounts but it will still accrue according to the growth curve.



	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly	821.7	5277.9	959.6	2224.0	1552.4	27.5	885.3
Cumulative	821.7	6099.6	7059.2	9283.2	10835.6	10863.1	11748.4

Figure 13. Average Irrigated Exclosure Growth Curve for 2007-2008.

The low (or negative for non-irrigated) amounts of growth in September are most likely due to drier conditions and consumption by rodents and other creatures that had access to the exclosures. Observations indicate that there is still growth accruing in September, although at a lowered rate. Most annual growth on both types of sites occurs in May when soil water and temperatures are optimum. Irrigated sites during this period (2007-2008) were capable of producing on average, almost 12,000 pounds per acre of biomass. Non-irrigated sites produced on average, about 20 percent less or 9,650 pounds per acre of biomass.

The average irrigated exclosure growth curve for 2007-2008 was constructed from peak standing crop data along with re-growth data from monthly clippings. The curve reflects rapid growth before June, sustained growth through August, senescence in September, and fall growth (in October) before freeze-up in November. The irrigation influence can be plainly seen in the growth numbers of June through August when compared with the non-irrigated growth curve below.

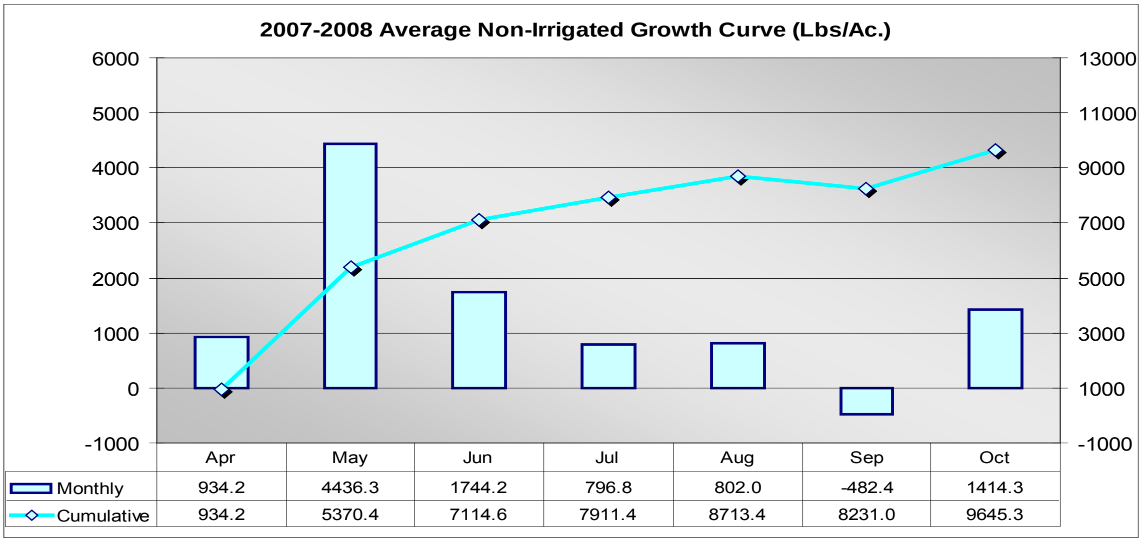


Figure 14. Average non-irrigated exclosure growth curve for 2007-2008.

The average non-irrigated exclosure growth curve for 2007-2008 was constructed from peak standing crop data along with re-growth data from monthly clippings. The curve reflects rapid growth before June, sustained growth through August, increased senescence (and probably rodent and insect harvest) in September, and fall growth (in October) before freeze-up in November. Overall productivity is less than in the irrigated exclosures (about 20 percent less).

7.4.1.2 Vegetation Species Diversity and Abundance

Vegetative foliar cover was determined from each of the 36 plots in 2007 and 2008 using the line-point intercept method. The method is described in Herrick et al. (2005) and has been part of the National Resource Inventory Range Study since its inception in 2003. Foliar cover is measured at a point, and differs from canopy cover which measures the cover of individual plants. The line-point intercept method quickly and accurately measures percent foliar cover, percent bare ground, and percent basal cover when an adequate number of points are sampled.

Vegetative data was collected along three transects for each of the six irrigated and six non-irrigated groups in 2007 and 2008 and showed that:

- Non-irrigated sites had a higher ratio of native to non-native species than did irrigated sites.
- Non-irrigated sites had more grass species and less obligate and facultative wet species (Sedges) than irrigated sites.
- Grass species and native species on non-irrigated sites increased in abundance from 2007 to 2008.

More deeply rooted grass species should positively impact production and forage quality on non-irrigated sites. Nebraska sedge is a desirable facultative wet species that appears to decline in abundance on non-irrigated sites (see Figure 15). From this data alone it's difficult to predict what the long term impact of species change in diversity and abundance might have on forage production and quality.

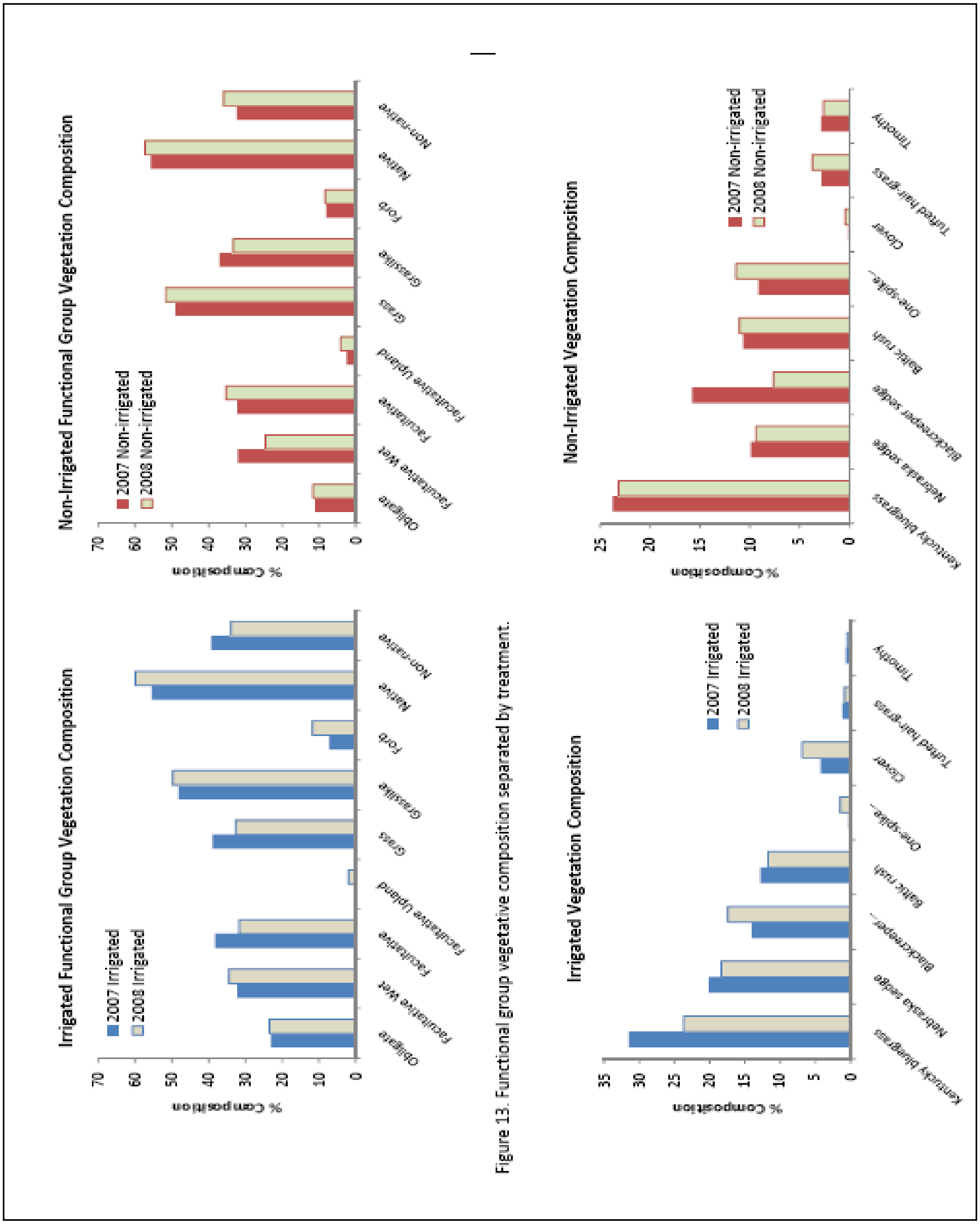


Figure 15. Vegetation Composition in Irrigated and Non-irrigated groups.

7.4.1.2 Amount of Bare Ground and Basal Gap

The amount (percent) of bare ground and basal gaps (physical space between plants) are further sources of information demonstrating resistance, resilience, and capability of a site to produce forage, protect soils, and to store moisture. Percent bare ground is an especially sensitive marker of plant community change because it shows initial changes in the plant community and it can be quickly and accurately measured. As sites respond to the reduction or removal of irrigation water, individual plants perish leaving less soil cover and protection. Basal gaps represent changes in soil protection: increase in the size of basal gaps indicates increased susceptibility to water and wind erosion. As water tables and soil moisture levels drop, fewer plants can be supported per unit area and, along with associated composition changes (plant species replacement), potential risks to soil and water resources are increased.

The average lengths of plant basal gaps for irrigated and non-irrigated groups are 139.7 cm and 196.6 cm, respectively.

A plot of the percent bare ground by years since irrigation measured along 18 transects show a slight increase over time.

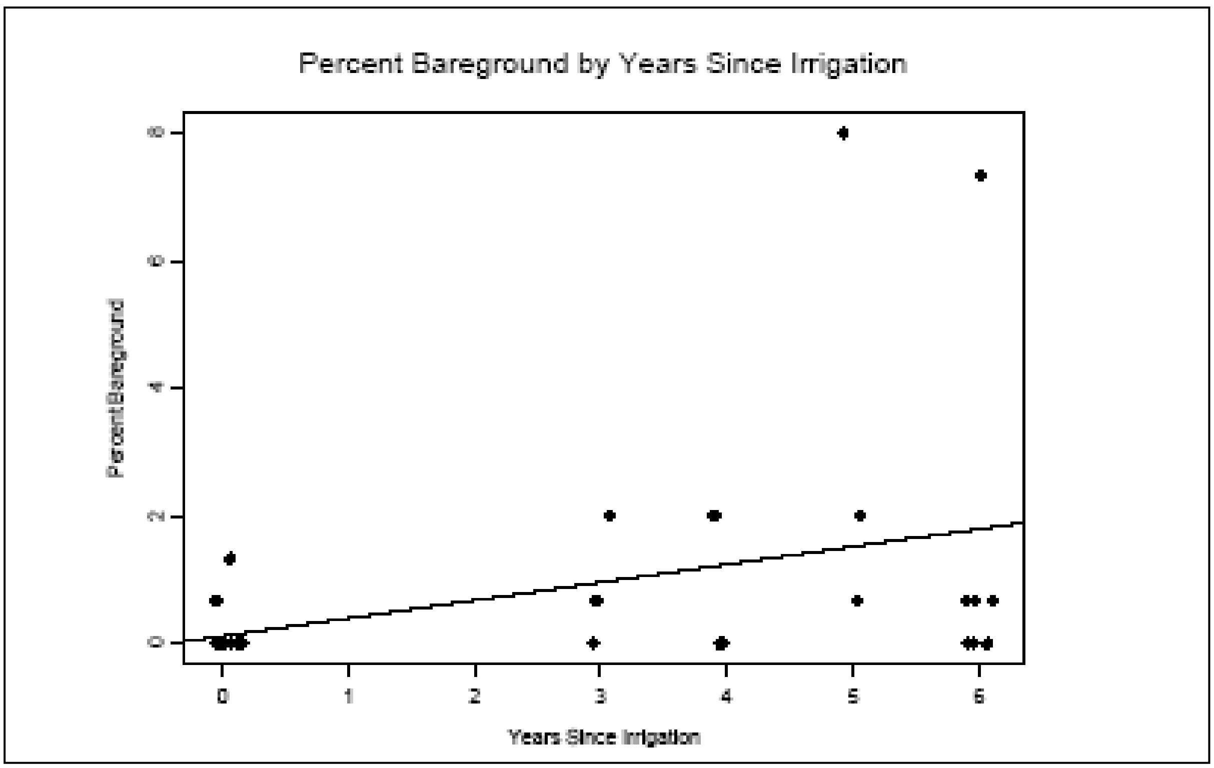


Figure 16. Percent Bare Ground by Year Since Irrigation.

7.4.1.3 Forage Quality for Use by Domestic Livestock

The feasibility of sustaining ranching in the Wood River Valley depends not only on the amount of forage produced but also its quality. It must provide adequate nutrition to enable grazing livestock to have reasonable gains in weight and maintain their health and body condition.

Some general rules on forage quality to maintain rates of gain and body condition are:

- Crude protein (CP) levels over 7 percent
- Digestible Organic Matter (DOM) - a DOM:CP ratio between 4.0 and 8.0 is considered acceptable with 4 being optimal.

Table 3 presents the finding from analysis of fecal samples (2007-2008) and wet chemistry of plants sampled (2008). Digestible organic matter (DOM) and Total Digestible Nutrients (TDN) are used here as interchangeable terms.

Table 3. Pasture Forage Quality.						
Average Irrigated Pasture Forage Quality - Fecal Samples - 2007-2008.						
	May	Jun	Jul	Aug	Sep	Oct
CP%	14.1	11.7	10.3	11.0	11.8	8.9
DOM%	65.7	64.3	63.0	62.8	64.3	61.5
DOM:CP	4.7	5.5	6.1	5.7	5.4	6.9
Average Non-irrigated Pasture Forage Quality - Fecal Samples - 2007-2008						
	May	Jun	Jul	Aug	Sep	Oct
CP%	15.2	12.7	11.0	10.5	10.2	8.4
DOM%	67.6	65.9	63.1	61.8	61.2	60.5
DOM:CP	4.5	5.2	5.7	5.9	6.0	7.2
Irrigated Pasture Forage Quality - Wet Forage Chemistry - 2008						
	May	Jun	Jul	Aug	Sep	Oct
CP%	13.5	10.9	9.6	9.8	9.8	8.7
TDN%	62.5	62.1	60.3	59.9	60.0	58.7
TDN:CP	4.6	5.7	6.3	6.1	6.1	6.7
Non-irrigated Pasture Forage Quality - Wet Forage Chemistry - 2008						
	May	Jun	Jul	Aug	Sep	Oct
CP%	15.1	10.2	8.6	8.1	7.5	6.4
TDN%	64.3	63.2	61.5	59.7	59.5	57.2
TDN:CP	4.3	6.2	7.2	7.4	7.9	8.9

Forage quality based on both methodologies meets general rules for animal nutrition stated above. The exception were October wet chemistry samples from non-irrigated pastures with Crude Protein (CP) at 6.4 percent and TDN:CP ratio at 8.9.

In all cases forage quality tapers off late in the season with decreasing CP and DOM with non-irrigated pasture values dropping most.

To address more specifically the potential effects of “reduced” irrigation and “improved” grazing management, this study included a crop growth model (see Chapter 9). By using a model calibrated by the data collected, researchers simulated different levels of irrigation and grazing management to understand effects on forage production.

8. Hydrologic Monitoring Summary

8.1 Purpose and Objectives

Changes in vegetation species, diversity and production are directly related to the amount of water available for plant use (evapotranspiration). Soil hydrology data was collected as part of this study to fully understand the changes being observed and in order to predict what future changes might be under different irrigation water management regimes (see Chapter 9 on Hydrologic Modeling).

8.2 Methods Overview

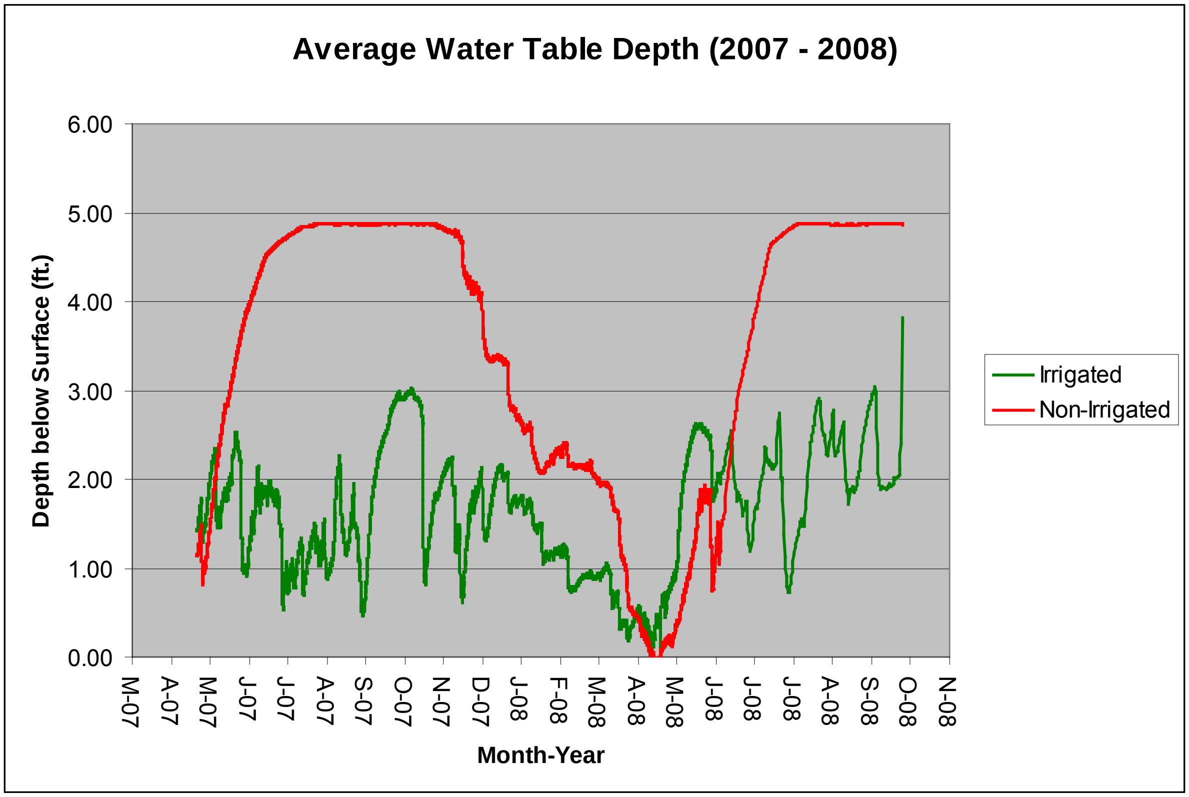
Soil hydrology data were collected within the exclosures of all of the sites. Water table elevation in the shallow aquifer was collected using pressure transducers installed between depths of 1.4 m (4.5 ft) to 2.0 m (6.5 ft). Data were collected at hourly intervals. For the non-irrigated sites the water table dropped below the pressure transducers during the summer months.

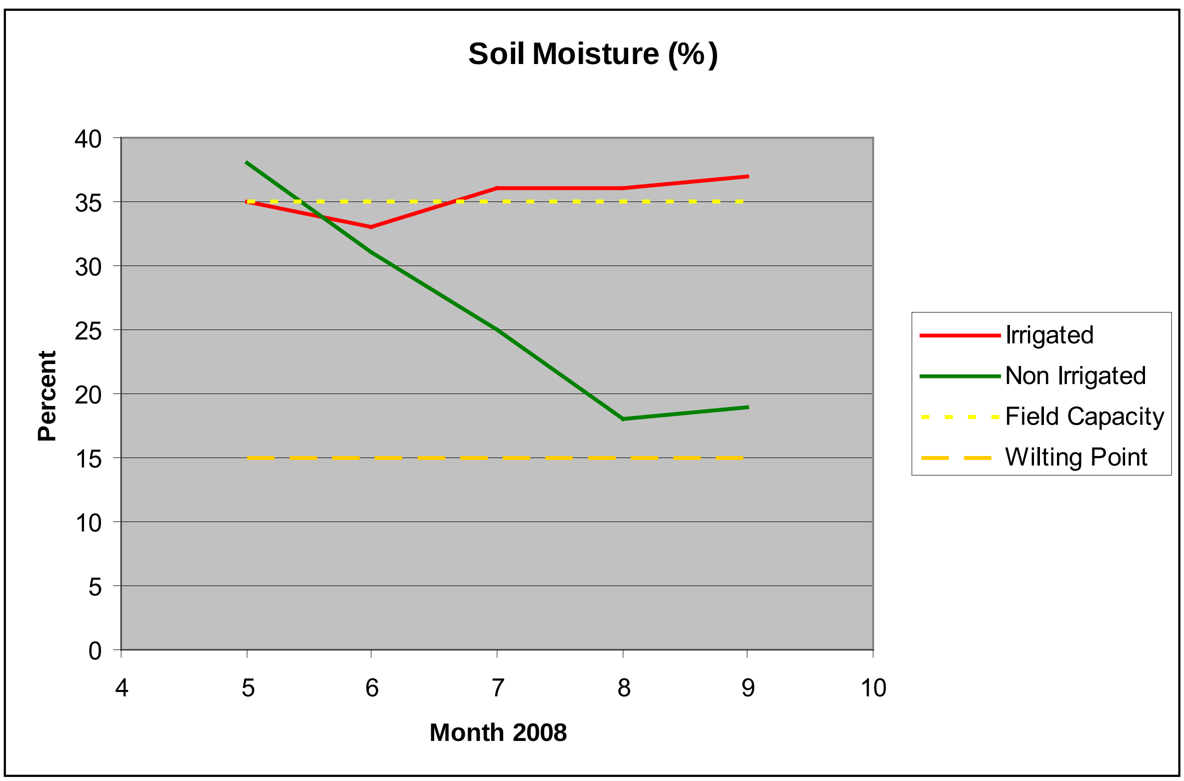
Soil water content was also collected using factory calibrated Time Domain Reflectrometry (TDR) probes. The factory calibration settings were found to be unsuitable for the volcanic andisols soils of the Wood River Valley because the soils have unique physical properties for their texture class, such as low bulk density, high porosity, and large specific surface area [Miyamoto et al., 2003]. As part of the Wood River Vegetation Monitoring study conducted by OSU, gravimetric soil moisture measurements were taken monthly during the summer of 2008 at irrigated and non-irrigated sites.

8.3 Status Assessment

The Wood River Valley is naturally sub-irrigated. Figure 17 shows that for both irrigated and non-irrigated sites water tables are at or near the surface in the spring. For non-irrigated sites water tables remain within 24 to 36 inches of the surface until June or early July. This is within the rooting depth of most deep rooted grasses. As the season progresses water tables decline to five or more feet (sensors were installed only to a depth of five feet [1.5 meters]) at non-irrigated sites while irrigation kept water tables with 12 to 36 inches of the surface.

Reliable soil moisture samples were limited in the spring – early levels were at or near field capacity in the spring and early summer for both irrigated and non-irrigated sites (see Figure 18). Irrigated sites were maintained at these levels, however soil moisture levels on non-irrigated sites declined to near the wilting point by the season’s end.





Figures 17 and 18. Plots of Average Water Table Depth and Soil Moisture.

9. Hydrologic Modeling: MIKE SHE/Daisy Models Summary

9.1 Purpose and Objectives

As previously stated, the primary objective of this CEAP study was to determine the optimum level of grazing and irrigation management that could be sustained both environmentally and economically on private lands. Observed data on forage production and hydrology only cover fully irrigated and non-irrigated scenarios with an approximate rest period of 25 to 35 days between clippings (harvests). In order to estimate production effects of other levels of irrigation and grazing management, computer simulation models were employed to simulate hydrology and crop production.

9.2 Modeling Background

Much attention in the Wood River Valley (WRV) over the last five to ten years has focused on reducing water demand by curtailing irrigation accompanied with reductions in cattle grazing intensity. Public funds have been expended to compensate ranchers for lost income through water banking and grazing forbearance programs. In 2006 the NRCS initiated this Wood River CEAP study in the Wood River Valley to determine the effects of irrigation and grazing forbearance on forage production and animal unit carrying capacity.

The models chosen to assist with the analysis were MIKE SHE a product of the Danish Hydraulics Institute (DHI) and DAISY. The European Hydrological System (SHE) was developed in the 1980s as a joint effort by the Institute of Hydrology, Societe Grenobloise d'Etudes et d'Applications Hydrauliques, and the DHI. These three groups have since developed SHE independently, and MIKE SHE is the DHI version of the model. MIKE SHE simulates the land phase of the hydrological cycle including ground water, soil moisture, overland (non-channelized) flow, precipitation and irrigation, and evapotranspiration.

MIKE SHE is a fully distributed, physically based model. It is very versatile with a modular structure that can be easily suited to project needs. The modules available in MIKE SHE include Overland Flow, Rivers and Lakes (requires MIKE 11), Unsaturated Flow, Evapotranspiration, Saturated Flow, and Advection-Dispersion for Water Quality. Each module is flexible, giving the user control over how the model is run. For example, the unsaturated flow module can be run using Richards Equation, gravity flow, and two-layer model that will be selected based on the user's requirements for accuracy and computational efficiency. Furthermore, MIKE SHE allows selection from two retention curve functions, three hydraulic conductivity functions and tabulated values for the fitting parameters. It is possible to set up very complex models but computational resources and time requirements become major factors in using MIKE SHE, especially when running 3-dimensional models over large areas or at fine spatial resolutions.

The DAISY model is a soil-vegetation-atmosphere transfer (SVAT) model used to simulate one-dimensional water balance, heat balance, solute balance and crop production in various agroecosystems. The model estimates maximum plant productivity as a function of carbohydrate production rate through photosynthesis in each development stage (e.g., germination, flowering, and maturation), then estimates actual plant productivity after accounting for stress factors (i.e. water and nitrogen deficiencies).

The DAISY model was used to simulate forage production for 8 irrigation levels and 2 grazing rest periods (total of 16 simulations). The MIKE SHE model was used to furnish time series groundwater elevations to the DAISY model for these 16 simulations.

9.3 Data and Modeling Parameters

Six irrigated and six non-irrigated pastures were selected to monitor the effects of irrigation and grazing forbearance. Grazing forbearance on non-irrigated sites has resulted in the reduction of herd sizes by 30 to 50 percent of the animal units customarily stocked on irrigated sites in the Wood River Valley. The CEAP Study monitoring work began during the 2007 growing season (April to November) and continued through the 2008 growing season. Each site (see Figure 3) had vegetation transects to measure plant composition, exclosures to measure crop growth and productivity, and continuous data loggers to measure the shallow water table elevation.

These data were used to construct and calibrate numerical models for pasture production (DAISY) and soil hydrology (MIKE SHE). These models where used to simulate intermediate levels of irrigation to develop curves describing crop production as a function of irrigation level. From these data animal unit carrying capacity can be described as a function of irrigation level. From these results an economic analysis could then be performed to determine the lost production value due to decreased irrigation, and a fair cost could be assigned to irrigation forbearance. In addition, optimal levels of grazing and irrigation may also be determined.

The full modeling report contained in Appendix 5 describes the numerical crop production and soil hydrology modeling performed by the Hydrologic Science Team at Oregon State University under the supervision of Dr. Richard Cuenca.

In addition to the hydrological modeling the OSU team undertook specifically for this CEAP study, Dr. Cuenca has been involved in measuring Evapotranspiration (ET) rates on both irrigated and non-irrigated sites in the Wood River Valley since 2003. The ET measurements Dr. Cuenca and team have reported show substantially different ET rates, which has implications for forage production and water usage/savings potential. Figure 19 below shows the data recorded in 2004. This type of data was used to help in build, calibrate, and validate the modeling process. Their work also represents the best estimates of potential water savings from reducing or eliminating irrigation. The differences in irrigated and non-irrigated ET varied from 257 mm (10.1 inches) to 320 mm (12.6 inches) for the years measured. Based on OSU's research the Klamath Basin Rangeland Trust as well as state and federal agencies have assumed approximate savings on an acre-foot of water per year in the Wood River Valley when irrigated pasture is converted to dryland management.

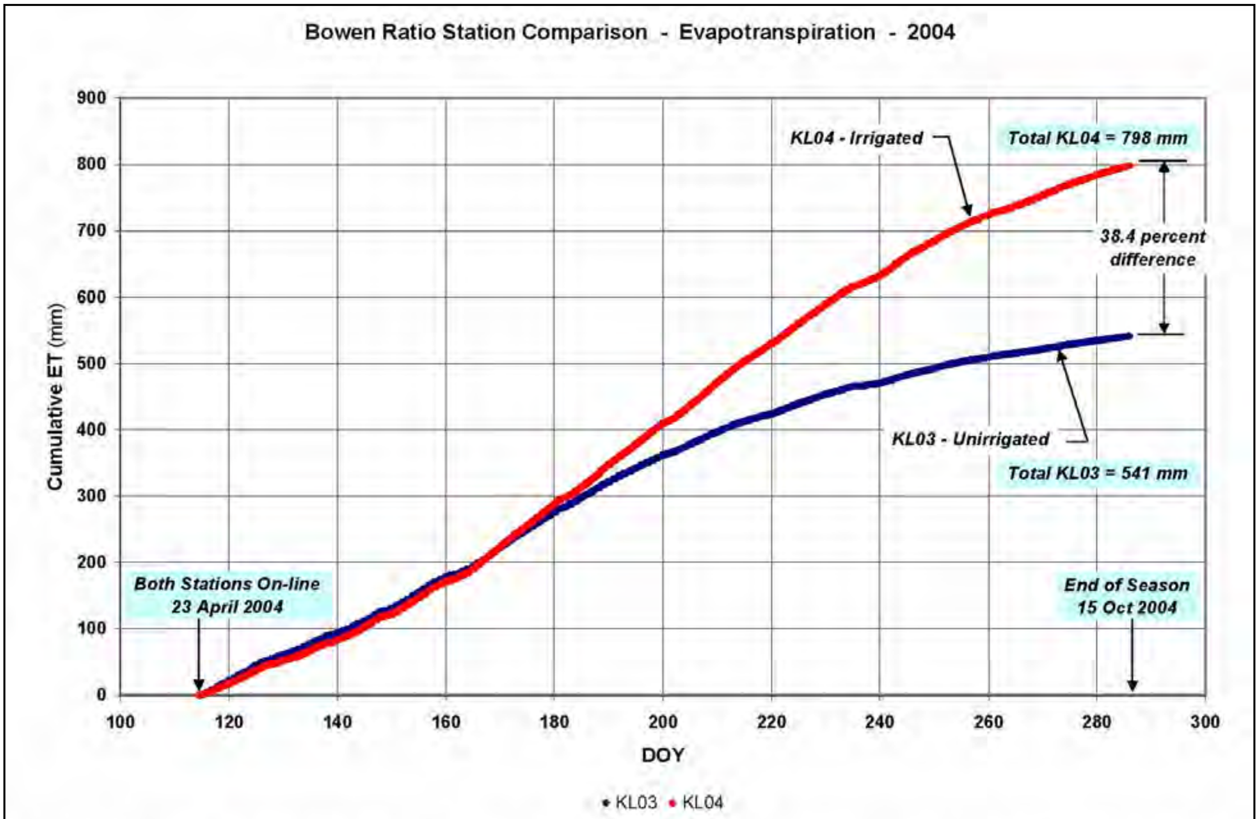


Figure 11. Bowen ratio station comparison for cumulative evapotranspiration for KL03 (unirrigated) and KL04 (irrigated) from start of measurements to end of irrigation season, DOY 114 to 289, 2004.

KBRT 2004 Monitoring Report 32 Vol.4: Evapotranspiration
Hydrologic Engineering, Inc.

Figure 19. 2004 Comparison of Evapotranspiration rates for irrigated and non-irrigated vegetation.

9.4 Methods Overview

9.4.1 Introduction

Appendix 5 contains the full modeling report detailing the methods used to model the data obtained during the field monitoring work. Much of the data used for the modeling process came from the grazing land vegetation monitoring and the hydrologic monitoring components of this CEAP study (described in Chapters 7 and 8). The following sections are a brief overview and summary of the process and methodology used for this component of the study.

9.4.2 Field Sites

As described in Chapter 7, section 7.3, a total of 12 field groups were used, consisting of 6 irrigated groups (1I, 2I, 3I, 4I, 5I, and 6I) and 6 non-irrigated groups (1N, 2N, 3N, 4N, 5N, and 6N) distributed throughout the Wood River Valley (See Figure 3). All irrigated sites were fully irrigated with no sites having reduced irrigation levels. Three vegetation transects and one vegetation exclosure were established at each site. Water table and soil moisture sensors connected to data loggers were placed within the exclosures. Fecal and forage quality data were also taken within each grouping. A digital elevation model (DEM) of the WRV with 1-m horizontal cell resolution was obtained via LiDAR supplied by the Klamath Basin Rangeland Trust.

9.4.3 Data Collection

In addition to using the plant production and composition, forage quality (plant and fecal sampling), and grazing management monitoring data previously described in Chapter 7, section 7.3, this modeling process also used data on soil hydrology, soil physical properties, meteorological conditions, and a digital elevation model.

9.4.3.1 Soil Hydrology

Soil hydrology data were collected within the exclosures of all of the sites. Water table elevation in the shallow aquifer was collected using pressure transducers installed between depths of 1.4 meters (4.5 feet) to 2.0 meters (6.5 ft). Data were collected at hourly intervals. For the non-irrigated sites the water table dropped below the pressure transducers during the summer months. Soil water content was also collected using factory calibrated Time Domain Reflectrometry (TDR) probes. The factory calibration settings were found to be unsuitable for the volcanic andisols soils of the Wood River Valley because they have unique physical properties for their texture class, such as low bulk density, high porosity, and large specific surface area.

9.4.3.2 Soil Physical Properties

Soil moisture retention curves and bulk density were obtained from NRCS National Cooperative Soil Survey (NCSS) Laboratory Characterization Data for a data sample taken near Fort Klamath (Pedon ID 67OR035013). Saturated hydraulic conductivity was obtained from an NRCS report that used an amoozemeter for in situ measurement. In addition, undisturbed soil cores were taken within field groups 3I, 4I, 6I, 2N, 4N, and 6N ranging in depth from 5 cm to 70 cm. The cores were then analyzed for soil moisture retention. Due to the length of time required to run this analysis and the suitability of the NRCS NCSS data, the soil core data were not been used in the simulations.

The soil hydraulic parameters used with MIKE SHE and DAISY were estimated based on these soil hydraulic data. Among different formulations implemented in MIKE SHE and DAISY, this study selected the van Genuchten and the Mualem equations (see Appendix 5).

9.4.3.3 Meteorological Data

Daily meteorological data used included mean daily air temperature, precipitation, global radiation, and alfalfa based reference evapotranspiration, which were obtained from the Agency Lake AgriMet Station (AGKO) located at the southern end of the Wood River Valley. MIKE

SHE and DAISY require the use of potential (grass based) evapotranspiration, which can be calculated (see Appendix 5).

9.4.3.4 Digital Elevation Model

The Klamath Basin Rangeland Trust provided a digital elevation model (DEM) of the WRV generated using LiDAR data collected from flights flown on 09/26/2004 and 09/27/2004 by Watershed Sciences, Inc. of Corvallis, OR.

9.5 Findings/Conclusions

9.5.1 Simulation Scenarios

Eight irrigation scenarios were simulated for this study. Table 4 lists these scenarios ranging from "full irrigation (Lv1-Lv4)" to "once a season (Lv5j-Lv5s)" to "no irrigation (Lv6)". Lv2 is assumed to represent the most commonly level of irrigation management currently practiced in the Wood River Valley.

Table 4. Simulation Scenarios - Irrigation timing[1].

Level	Frequency (Approx)	Application Dates
Lv1	Weekly	1, 7, 15, 22, of each month
Lv2	Twice Monthly	1, 15 of each month
Lv3	Monthly	1 of each month
Lv4	Bi-Monthly	5/1, 7/1, and 9/1
Lv5j	Once	7/1
Lv5a	Once	8/1
Lv5s	Once	9/1
Lv6	None	

[1] Irrigation timing for each level or scenario: irrigation duration is 24 hours. The irrigation season is defined as lasting from 5/1 to 9/30 in each year.

This study defines “rest period” in the model as the period between two grazing events with the grazing event taking place in one day. In continuous grazing cattle are allowed to migrate within a large pasture and will intensely graze a small area then move on, giving the area a rest period before the cattle return. Higher stocking rates will lead to increased grazing intensity and a decreased rest period. It was considered that the common grazing intensity in the Wood River Valley can be best represented by a 10-day rest period. The 8 irrigation scenarios were also run with a 30-day rest period to assess effects of the longer rest period on the pasture systems.

This analysis was done based on the results from 16 simulations (8 irrigations x 2 rest periods) during the April through October growing seasons from 2005 to 2008.

9.5.2 Model Calibration and Validation

9.5.2.1 Daisy Model Performance

Model performance for DAISY was assessed by comparing the observed vs. simulated crop production data for 2007 and 2008. Figure 20 shows a plot of simulated vs. observed values.

The results show a good fit between the model output and observed values of monthly production. The R^2 coefficient of determination for the Irrigated data is 0.96 and the R^2 for the non-irrigated data is 0.92.

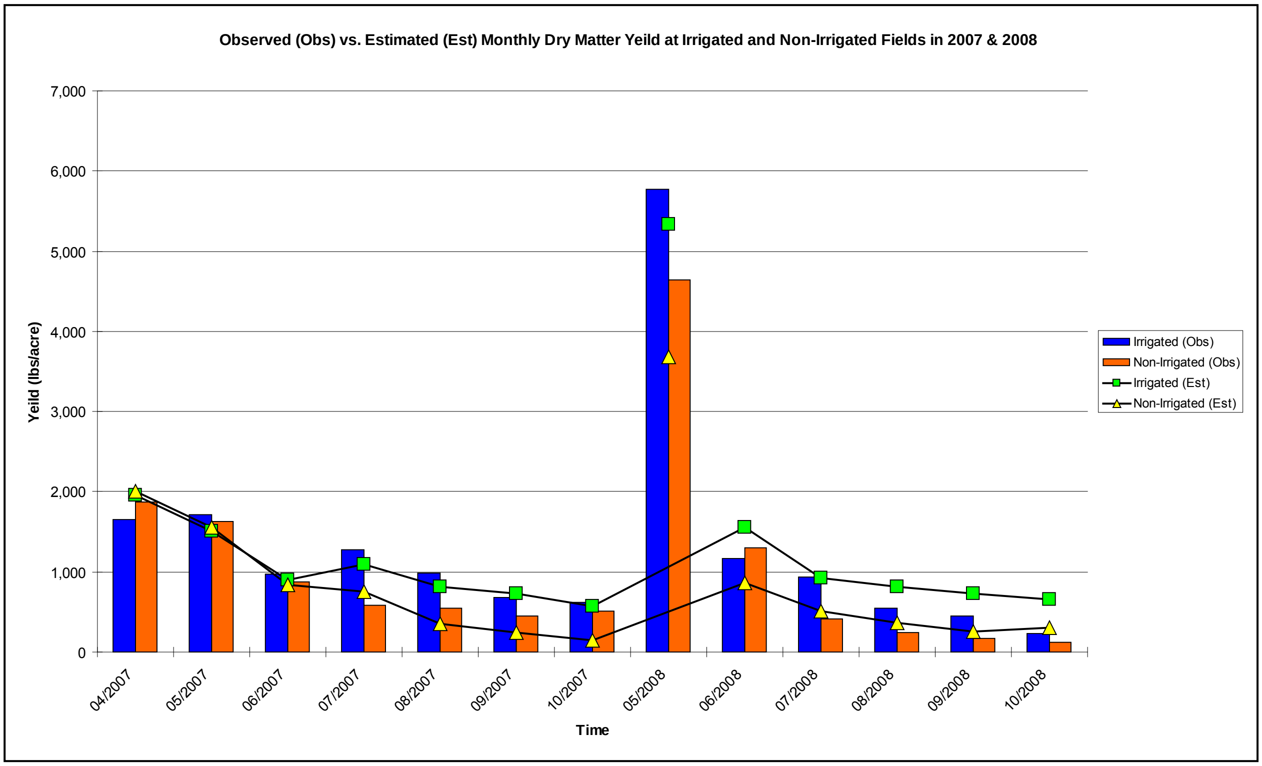


Figure 20. Simulated and Observed Crop Production for 2007 and 2008.

9.5.2.2 MIKE SHE Model Performance

Model performance for MIKE SHE was assessed by comparing observed vs. simulated water table data for site 4N which are shown as a time series in Figure 21. Table 5 displays the goodness of fit parameters for both the calibration period (2007) and validation period (2008). Both the R^2 and Nash-Sutcliffe statistics indicate a good model fit with observed data.

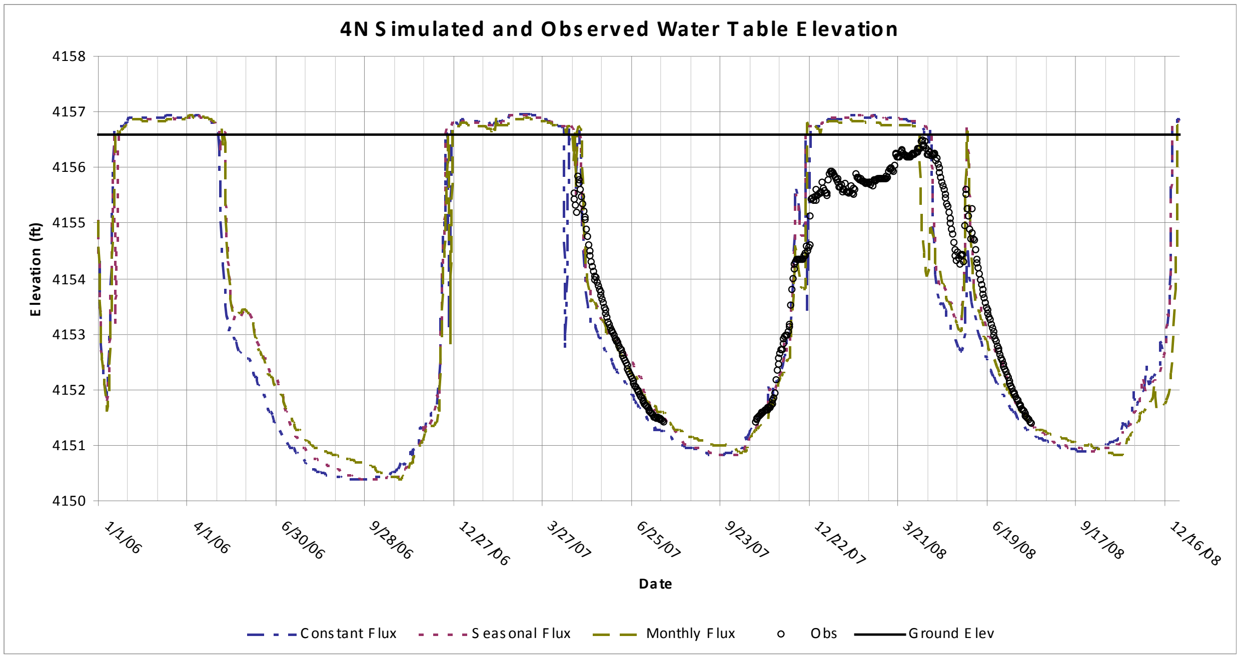


Figure 21. Simulated and Observed Water Table Elevations for Site 4N, 2006 to 2008.

Table 5. Goodness of fit parameters for the calibration period (2007) and validation period (2008).

Parameter	Constant Flux		Seasonal Flux		Monthly Flux	
	Calibration Period 2007	Validation Period 2008	Calibration Period 2007	Validation Period 2008	Calibration Period 2007	Validation Period 2008
Nash – Sutcliffe	.731	.415	.773	.573	.796	.515
Nash – Sutcliffe[1]	.763	.503	.893	.725	.887	.597
R^2	.846	.762	.871	.799	.871	.735
$R^{2\,(1)}$	.868	.779	.895	.802	.899	.769

[1] These parameters were calculated for 01 April to 31 October.

9.5.3 Results for 10-Day Grazing Rest Period

Table 6 summarizes the irrigation and plant production results from MIKE SHE and DAISY with a 10-day rest period that represents the typical grazing management in the Wood River Valley (results have been converted from metric units). In Table 6 Irr is the total water applied during the growing season including irrigation and precipitation and Prod10 is the total monthly plant production with a 10-day rest period.

Table 6. Total water applied and plant production with 10-day rest period during the growing season (May to October).

Level	2005		2006		2007		2008	
	Irr	Prod 10	Irr	Prod 10	Irr	Prod 10	Irr	Prod 10
	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)
Lv1	35.8	5,019	33.2	5,483	35.6	4,313	32.0	5,438
Lv2	36.1	4,867	32.0	5,340	33.9	4,197	32.8	5,251
Lv3	34.5	4,554	28.9	5,045	33.3	3,893	31.9	5,054
Lv4	37.3	4,224	32.7	4,760	35.7	3,679	33.8	4,679
Lv5j	13.7	4,081	15.7	4,635	19.2	3,465	17.2	4,528
Lv5a	18.4	4,072	15.7	4,617	19.2	3,438	17.2	4,510
Lv5s	18.4	3,974	15.7	4,510	19.2	3,322	17.2	4,438
Lv6	4.3	3,777	1.5	4,340	5.0	3,179	3.1	4,260

Figure 22 displays the monthly forage production simulated for each of the 8 irrigation scenarios with a 10-day rest period. Spring production is similar for each of the scenarios while late season production decreases with decreases in irrigation frequency. All production, even with full irrigation, decreases during the late summer and fall. The DAISY simulation results suggest that nitrogen availability in the pasture systems in the Wood River Valley (no external nitrogen sources) is not sufficient to support full productivity throughout the growing season (see Appendix 5 for more details).

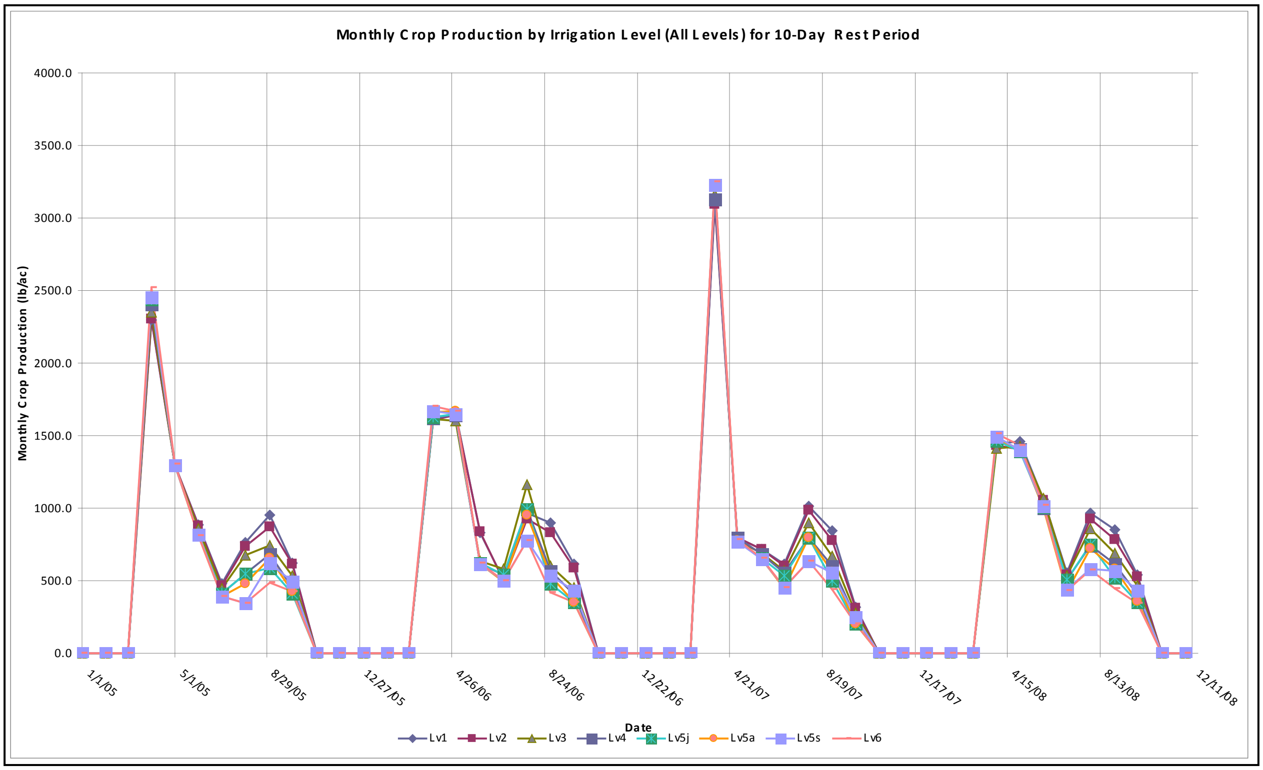


Figure 22. Four-year (2005-2008) Simulated Monthly Crop Production for a Rest Period of 10 days.

Table 7 shows the average monthly production for each irrigation scenario under a ten day rest period grazing scheme.

Table 7. Average monthly production for each irrigation group with the 10-day rest period (Prod10).

	Avg. Lv 1-4	Avg. Lv 5	Avg. Lv 6	% Change[1]	Std. Dev.[2]
	lb/ac (kg/ha)				
2005	4,660 (5,224)	4,039 (4,528)	3,772 (4,228)	-19.1	456 (511)
2006	5,152 (5,775)	4,581 (5,135)	4,335 (4,860)	-15.9	419 (470)
2007	4,017 (4,504)	3,406 (3,818)	3,176 (3,560)	-20.9	435 (488)
2008	5,101 (5,718)	4,486 (5,029)	4,251 (4,766)	-16.7	439 (492)
Average	4,733 (5,305)	4,128 (4,628)	3,883 (4,353)	-17.9	
STDEV[2]	525 (589)	536 (601)	533 (597)		

[1] percent change from Avg. Lv1-4 to Lv6.

[2] Note that the standard deviation (STDEV) between years (bottom) is larger than the Std.Dev. between irrigation groups (right).

Scenarios Lv1-4 approximate full irrigation (keep water tables elevations and soil moistures adequate for crop use). Lv5 scenarios represent supplementary irrigation. Lv6 is no irrigation other than sub-irrigation from high water tables. Percent change is the average difference between full irrigation scenarios Lv1-4 and no irrigation Lv-6. Production reduction from no irrigation ranges from 15.9 to 20.9 percent and average 17.9 percent less over the 4 years of simulations. Likewise, Lv5 scenarios produced 12.8 percent less forage than the full irrigation over the same time period.

9.5.4 Results for 30-Day Grazing Rest Period

Another set of simulations was done with a 30-day rest period using the same meteorological and field hydrological data to assess the effect of longer rest periods (shifting from continuous grazing to rotational grazing) on the pasture systems in the Wood River Valley.

Table 8 summarizes the irrigation and plant production results from MIKE SHE and DAISY with the 30-day rest period. Prod 30 is the total monthly plant production with the 30-day rest period.

Table 8. Total water applied and plant production with 30-day rest period during the growing season (May to October).

	2005		2006		2007		2008	
Level	Irr	Prod 30	Irr	Prod 30	Irr	Prod 30	Irr	Prod 30
	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)
Lv1	35.5	5,474	32.9	5,412	35.3	5,304	32.0	5,912
Lv2	35.9	5,340	31.8	5,251	33.7	5,215	32.8	5,769
Lv3	34.6	5,010	29.0	4,929	33.5	4,885	31.9	5,429
Lv4	37.6	4,724	33.0	4,697	36.0	4,653	33.8	5,188
Lv5j	13.8	4,608	15.8	4,572	19.3	4,536	17.2	5,081
Lv5a	18.5	4,608	15.8	4,617	19.3	4,483	17.2	5,019
Lv5s	18.5	4,519	15.8	4,492	19.3	4,367	17.2	4,894
Lv6	4.2	4,358	1.5	4,349	5.0	4,251	3.1	4,760

Figure 23 displays the monthly production results for each of the 8 irrigation levels with a 30 day rest period assumed between grazing. As with the 10-day rest period, early season crop production is similar for all 8, although scenarios with less frequent or no irrigations decline more dramatically later in the growing season. Table 9 shows the average monthly production for each irrigation scenario under a 30 day rest period grazing scheme.

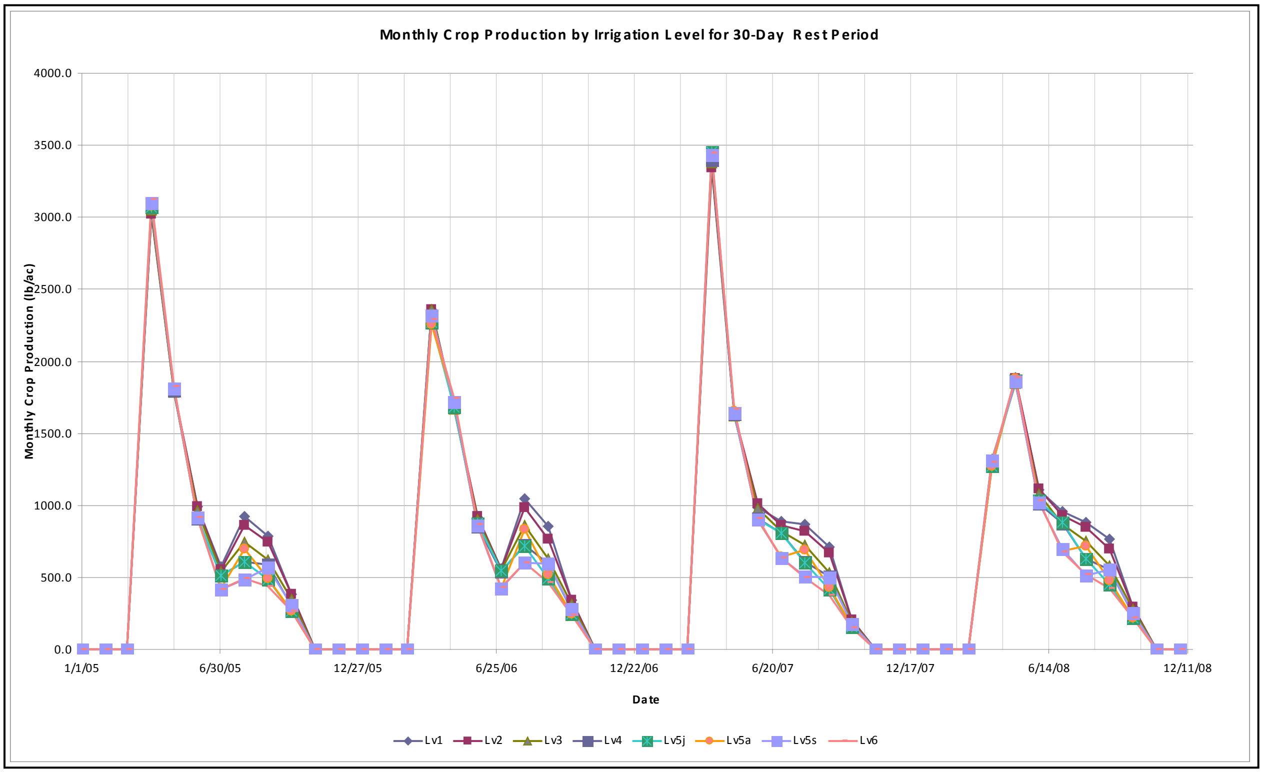


Figure 23. Four-year (2005-2008) Simulated Crop Production for a Rest Period of 30 days.

Table 9. Average monthly production for each irrigation group with the 30-day rest period (Prod10).

	Avg. Lv 1-4	Avg. Lv 5	Avg. Lv 6	% Change[1]	Std. Dev.[2]
	lb/ac (kg/ha)				
2005	5,131 (5,753)	4,573 (5,127)	4,357 (4,885)	-15.1	399 (448)
2006	5,065 (5,678)	4,555 (5,106)	4,347 (4,874)	-14.2	369 (414)
2007	5,008 (5,615)	4,459 (4,998)	4,249 (4,763)	-15.2	392 (440)
2008	5,567 (6,241)	4,993 (5,598)	4,757 (5,333)	-14.6	417 (467)
Average	5,193 (5,822)	4,645 (5,207)	4,427 (4,964)	-14.7	
STDDEV[2]	254 (285)	238 (266)	225 (252)		

[1] percent change from Avg. Lv1-4 to Lv6.

[2] Note that the standard deviation (STDEV) between years (bottom) is larger than the Std.Dev. between irrigation groups (right).

With a 30-day rest period, production reduction from no irrigation ranges from 14.2 to 15.2 percent and averages 14.7 percent less over the 4 years of simulations. Likewise, Lv5 scenarios produced 10.6 percent less forage than with full irrigation over the same time period. A reduction in forage production due to less frequent irrigation is less pronounced with a 30-day rest period between grazings than with a 10-day rest period.

9.5.5 Modeling Conclusions

This modeling study as well as the Wood River Valley Vegetation Monitoring Summary 2007-2008 report in Appendix 2 both show that there is a small, but appreciable decrease in pasture production between the irrigated and non-irrigated treatments. When considering years individually there is a consistent reduction in productivity in the non-irrigated sites (average 17.9 percent with a 10-day rest period, 14.7 percent with 30 day rest period).

DAISY simulation results suggest that nitrogen availability in the pasture systems in the Wood River Valley (no external nitrogen sources) is not sufficient to support full productivity throughout the growing season.

For better appreciation of the effect of irrigation management on pasture productivity, an additional comprehensive nutrient study is recommended.

The pasture productivity for the 30-day rest period is higher than that of the 10-day rest period as seen in Figures 22 and 23.

Another key feature of the 30-day rest period is that the year to year variation is much lower, which indicates using a 30-day rest period in grazing management enables a more consistent productivity from year to year to mitigate environmental factors that would cause productivity to drop for a given year.

One possible affect of the current patchwork of irrigated and non-irrigated fields in the WRV is that the irrigated fields may contribute to maintaining a higher water table across the WRV making sub-irrigation from the shallow aquifer to the non-irrigated sites possible. If more landowners forgo irrigation, resulting in significant amounts of land being taken out of irrigation, there may be basin-wide implications due to a lower water table.

Finally, the analysis seems to suggest that a single irrigation in July along with an increase in grazing rest period to 30 days could produce up to about 95 percent of the forage as the current, fully irrigated (every 14 days), continuous grazing scenario. This possibility suggests that in the Wood River Valley some ranches could use less water and still maintain a fairly high level of forage production. Whether any ranches chose to move towards this type of management will depend on their own specific economic considerations and situation.

10. Economic Analysis Summary

10.1 Purpose

As indicated in the Chapter 1, Wood River Valley Profile, livestock grazing is the dominant form of land use on the nearly 40,000 acres of private lands in the Wood River Valley. Grazing is an important economic activity in the valley that is and has been impacted by the water and fisheries resource concerns of the Upper Klamath Basin.

The semi-arid, western United States' grazing lands, including the irrigated/sub-irrigated Wood River Valley, require effective and efficient stewardship of water resources to maintain environmental and economic health. The need for this attentiveness became especially evident during the drought of 2001, which brought the Upper Klamath Basin to the attention of the national media. In 2002, the Klamath Basin Rangeland Trust teamed up with some of the Wood River Valley ranchers to begin searching for different ways of managing their businesses that would allow them to be more effective and efficient with their water supplies (e.g. irrigation), to provide for healthy biotic systems (e.g. riparian restoration), and to remain economically viable and sustainable (e.g. grazing).

For example, a concerted effort has been made since 2002 to restore riparian habitat both to protect endangered fish (with economic implications for Tribal groups; the recreational "catch-and-release" program and commercial fishing) and to improve water quality. Similarly, the various partners in the valley have found ways to shift to dryland grazing and water banking (non-irrigation) to conserve water and to shift grazing techniques by reducing herd sizes, fencing riparian areas, and implementing rotational and intensive grazing management practices.

In spite of these shifts many questions were being raised about the long-term feasibility or sustainability of these shifts in grazing management and irrigation practices. This study was initiated to try to answer some of the more pressing concerns related to the changes in irrigation and grazing practices being implemented since 2002.

10.2 Objectives

A primary objective of the economic analysis was to determine the optimum levels of grazing and irrigation water management that could be sustained economically and environmentally in the Wood River Valley without public financial assistance.

10.3 Methods Overview

Several ranches in the Wood River Valley have participated in financial assistance programs that have allowed them to not irrigate their pasture land in exchange for compensation for the value of the forgone forage. Through these programs the ranchers received compensation for allowing their water rights allocations be used for downstream uses (e.g. sucker and salmon needs, downstream irrigation on Bureau of Reclamation project lands) and for reducing their herd sizes as a result of the expected decreases in forage production from not irrigating their pastures. The ranches ranged in size from 400 to 3,000 acres, with the typical ranch encompassing about 1,000 acres of grazing land.

Interviews and surveys were designed and used to collect data on the impacts to the ranchers from management changes. Data was collected to begin examining the benefits and costs of management changes to:

- stocking density
- grazing lease payments
- changes in veterinarian and herding costs
- insect and weed population changes (inasmuch as these have implications for increased or decreased use of insecticides/herbicides)
- livestock weight changes
- reduced irrigation costs
- changes in supplemental feed costs
- fence and canal maintenance
- forage utilization

Eight ranchers/managers/operators in the valley were interviewed between October 15 and 17, 2008. Due to differences in how the various ranchers operate in the valley (e.g. the varied lease arrangements, different levels of detail in management records, different levels of willingness or ability to provide detailed information, etc.) a detailed economic analysis was not possible. However, from the information that was collected, along with the results from forage production modeling, a generalized comparison was made of likely shifts in benefits, costs, and unaffected items.

10.4 Results/Findings

10.4.1 Management Scenarios

Chapter 9 contains the results of the MIKE SHE/Daisy model simulations of forage production under different management scenarios. This simplified economic analysis compared three scenarios: typical irrigation and grazing (LV2 with 10 day rest), reduced irrigation with improved grazing (LV5 average with 30 day rest) and no irrigation and improved grazing (LV6 with 30 day rest). These combinations most closely approximate the levels of irrigation and grazing intensity currently practiced with scenarios that conservationists might recommend to maximize both ranching and environmental benefits.

Table 10 below summarizes results from Chapter 9 for these three scenarios.

Table 10. Management Scenarios.				
	Average Production		Average Value per acre	Average Gross Revenue for 1,000 acre Ranch
Management Scenario	lbs/acre	% of Lv2	Dollars/ acre	Dollars/ 1,000 acres
Typical Irrigation and Grazing (Lv2 with10 day rest)	4,914	100.0%	$270	$270,300
Reduced Irrigation and Improved Grazing (Lv5 Avg with 30 day rest)	4,645	94.5%	$255	$255,500
No Irrigation and Improved Grazing(Lv6 with 30 day rest)	4,427	90.1%	$243	$243,500

Most landowners in the Wood River Valley lease their lands to ranchers from out of the region who bring their cattle to the Wood River Valley to graze each season. The basis of payment to Wood River landowners varies. Payment can be based on a per acre basis, weight gain of cattle for the season or for the number of animal unit months of grazing provided. Each landowner/ rancher should evaluate the information contained in this report to determine their own ranch economics. However in order to provide some reference as to the potential impacts of these three scenarios, this analysis will value forage as if it were grass hay. According to USDA Market News as of January 2010 the average "freight on board" price for good quality alfalfa hay was $110 per ton or $.055 per pound (USDA, 2010). Using this value for the forage produced in the Wood River Valley along with the forage production simulation results would indicate for the average 1,000 acre ranch a $22,200 decrease in revenue for reduced irrigation and improved grazing (Lv5 with 30 day rest) up to a $40,180 decrease with no irrigation and improved grazing (Lv6 with 30 day rest). In order to break with typical irrigation and grazing practices (Lv2 with 10 day rest), landowner must find other ways to increase revenues and reduce costs. Table 11 (at the end of this chapter) summarizes potential revenue and cost categories which were mentioned in landowner interviews as potential sources to offset revenue losses.

10.4.2 Benefits

10.4.2.1 Increased Revenues

Interviewees indicated that the forage in the non-irrigated pastures is stronger, better quality and more vigorous, which may partially offset some of the stocking level reductions. Some ranchers indicated cattle on dryland seemed to experience a faster rate of gain although this could not be substantiated with measured observations or from estimates of rate of gain obtained from fecal sample analyses.

10.4.2.2 Reduced Costs

Typically ranches in the Wood River Valley are irrigated from 10 to 15 times per season or approximately once every other week. The reduced irrigation scenario assumes that only one irrigation would occur late in the season – August or later. Pumping costs may or may not have changed. Most ranches in the valley use (or formerly used) flood irrigation methods which incur little in the way of pumping costs for irrigation. Much of the pumping done in the Wood River Valley is during the spring and is done to pump water off the fields. Where draining the fields occurred there was no change in pumping costs. However, for those ranches that used irrigation pumps prior to switching to non-irrigation there was a reduction in energy/ power costs. For those ranchers who switched to dryland management practices, many experienced reduced ditch maintenance costs. They were able to eliminate some lateral ditches using a scraper blade or ditch plow (once every three years). However, some ranchers did not experience a change in ditch maintenance due to the need to water cattle. Time to open and close irrigation gates/dams would be substantially reduced with either reduced or no irrigation scenarios.

In some cases, the cessation of irrigation has led to a reported decrease in pests. Removing irrigation water decreased the mosquito population and associated risk of illness. This may have resulted in potential increases livestock weight gain. The ranchers also reported experiencing a reduction in plant pests either due to the lack of water or the reduction in stream/ditch bank erosion.

Some ranchers reported a decrease in veterinarian bills. Ceasing irrigation may reduce foot rot, cut respiratory illness and phenomena, decrease eye problems, and reduce Coccidiosis[6]. In addition, it appears the cattle seem to recover faster from illnesses when not left in standing water.

Fence maintenance seemed to be a mixed bag as to whether there were increases or decreases experienced with a change in management. Some ranchers reported no significant change while others increased fencing and maintenance costs. Many ranchers added additional cross fencing for cattle rotations and to protect riparian areas.

10.4.3 Costs

10.4.3.1 Reduced Revenues

As reported above there is a potential loss in revenue from switching to less frequent irrigation from $15,000 to $27,000 for a 1,000 acre ranch.

[6] Coccidiosis is a parasitic disease of the intestinal tract of animals, caused by coccidian protozoa. The disease spreads from one animal to another by contact with infected feces or ingestion of infected tissue.

10.4.3.2 Increased Costs

Converting pastures from a continuous grazing system where cattle have season long access (simulated as 10 day rest period) to one that mandates a 30 day rest period would increase herding costs. These grazing systems typically involved four or more pastures that were grazed at least once per season, with cattle moved one to six times per month, and required two people per rotation and one day to complete.

Anecdotally, some ranchers indicated they saw the removal of irrigation water as resulting in increases in the grasshopper population with an attendant risk of reduced forage production. However, there are others who believe that there are natural cycles in pest populations and that the outbreak of grasshoppers observed the first year of non irrigation was a natural phenomenon. Subsequent to that first year the grasshopper population has not been a major problem. Whether the reduced irrigation caused or contributed to a grasshopper population explosion remains an unresolved issue. However, there were increased costs to ranchers in the valley for treatment of the grasshopper outbreak.

10.4.4 Unchanged, Uncertain, or Undocumented Impacts

Ranchers report having seen significant changes in the wildlife with the switch to dryland management. Anecdotally, the ranchers report that there has been a significant increase in bird populations, including migratory, water fowl, and raptors. Similarly, ranchers in the valley reported that they have seen the fish populations, including special status species increase greatly. These changes are undocumented and were not included as part of this CEAP study.

Weed problems vary by ranch. Most ranchers interviewed experienced some weed problems as the forage adjusted to the drier conditions of non-irrigation. Overall most ranchers reported having fewer problems with weeds than before due to reduced erosion and stream bank damage. Weed populations were examined during this study and found to be a site-specific problem in both irrigated and non-irrigated areas.

Because almost all cattle in the Wood River Valley are brought in from outside areas in the spring and removed in the late fall there is little need for supplemental feeding regardless of whether there is irrigation or not. Ranchers who switched to non-irrigation reported no change in the use of mineral block or protein supplements. It may be possible that a little more salt is used when pastures are irrigated because of the wetter soils and a higher percentage of water in forage species.

Cattle hauling costs did not change on a per animal basis between irrigated and non-irrigated ranches. However, with fewer cattle being grazed on the dryland pastures fewer animals were hauled.

Table 11 summarizes some of the benefits and costs assumed to result from a change in management practices.

10.4.5 Economic and Environmental Sustainability

Costs and returns reported by landowners varied considerably. The data and modeling results generated in this study should provide information to help individual ranchers determine what changes may be optimum for them economically.

Previous studies by KBRT and Oregon State University (Cuenca, 2004) show that converting irrigated pasture to dry land reduces evapotranspiration of water by 12.6 acre-inches per acre. Eliminating irrigation tail water intuitively should improve water quality. Restoring riparian habitat along with increasing summer base flows in valley streams by reducing irrigation diversions improves habitat for fish and other wildlife.

While this study did not specifically identify an environmental and economic sustainable level, it did provide information ranchers and natural resource managers can use to make this determination.

Table 11. Preliminary Economic Analysis.

Benefits	Costs
Increased Revenue • Increased weight gain • Reduced weight shrinkage during shipment Reduced Costs • Reduced irrigation costs • Reduced ditch maintenance • Decrease in pests - mosquito population • Decrease in vet bills • Decrease in fence maintenance • Decrease in labor due to irrigation Other • Reduced animal waste runoff into surface water • Improved water quantity and quality • Improved fish & wildlife habitat • Achievement of watershed goals	Decreased Revenues • Reduced grazing income – smaller heard • Increased pests – grasshopper outbreak Increased Costs • Increased livestock herding management •

11. Synthesis and Discussion of Study Component Results

11.1 Introduction

Chapter Three describes the various investigative components of the Wood River CEAP study. These investigative components were designed and implemented in response to the goals and objectives laid out in Chapter Two of this report. Although each of these different investigative components were implemented somewhat independently, the intention was to bring the pieces together to try and answer questions raised about shifts in irrigation and grazing management in the Wood River Valley over the last eight years or so.

Chapters Four through Ten described the different study components and the results and findings from the independent investigative components. Chapter Eleven attempts to unite the various components and describe those ties and relationships the investigators considered most significant; describe conclusions most clearly supported by our investigations; and describe information that would be most relevant to the landowners, land managers, and conservationists of the Wood River Valley area.

As noted in Chapter 3, section 3.4, the discussions contained in Chapters Four through Ten are summarizations from the many reports submitted by the different study teams. The technical appendices contain copies of the final, full reports prepared by the various investigative teams. For more complete information, findings, and conclusions on any of the investigative components refer to the technical appendices.

11.2 Summary of Significant Study Findings and Conclusions

11.2.1 Riparian Areas and Aquatic Habitats

As reported in Chapter 5 and 6, Sevenmile Creek in Aquatic Reaches 5 and 6 (see Figures 8, 9, 10) exhibited the most substantial changes to aquatic habitat and riparian condition from those measured and monitored in 2002 and 2003. Changes in management to the land along these reaches included riparian fencing, grazing management shifts, and cessation of flood irrigation in the nearby fields, including the stoppage of substantial water diversions that essentially dewatered portions of the creek in the summer and fall.

Aquatic Reach 6 exhibited the most significant measured changes to aquatic habitat. Aquatic Reach 6 likely saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches [coming off public lands with generally well-managed riparian conditions], (2) it has a much steeper gradient than the other reaches studied (4-5 times steeper) thus providing considerably more energy with the increased stream flows to scour the stream bed, and (3) it likely saw the highest percentage increase in base flow over the prior to the management, which essentially dewatered the reach for much of the summer. In addition, Aquatic Reach 6 received riparian fencing and grazing management shifts starting in 2004, whereas reaches further downstream received more recent riparian fencing and grazing management shifts. Aquatic Reach 5 and Aquatic Reach 2 received riparian fencing and grazing management shifts in 2006 and 2005 respectively.

Monitoring showed that fish habitat greatly improved as measured by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased, and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved condition of the riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Aquatic Reach 6 riparian vegetation was dominated by species more common to drier conditions, but with a component of species found only in riparian areas. Future monitoring of this reach should indicate whether the riparian vegetative community is changing to or away from species with good bank-holding or stabilizing root or rhizomatous root systems.

Aquatic Reach 6 demonstrated some of the possibilities for improvement to channel and riparian conditions in the Wood River Valley over a 5 year period with shifted management practices. However, conditions in other streams and creeks in the Wood River Valley tend to be more similar to Aquatic Reaches 2 and 5. That is, they are low gradient/low energy systems. Often water courses in the valley have been straightened, contained within dykes, have substantial irrigation water diversions or returns, and/or are freely accessed by cattle.

Aquatic Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This slow improvement is likely due to the very low gradient of the reach and probably the relatively recent riparian fencing and grazing management shift (2006 compared to 2004 in Aquatic Reach 6). With less energy available to foster change, shifts may take a much longer period of time to manifest. The Aquatic Reach 5 riparian zone is dominated by vegetation species with good bank-holding or stabilizing root or rhizomatous root systems, which can be considered a positive sign. Future monitoring will indicate whether the riparian zone vegetation is shifting towards or away from such a beneficial plant community.

It seems feasible that given the more recent shifts in management in Aquatic Reach 5 (as compared to Aquatic Reach 6) that this stretch of river may already be benefitting from the changes in grazing and riparian conservation practices. In addition, it seems likely that if Aquatic Reach 6 conditions continue to improve (e.g. amount of large woody debris in the system, in-stream morphology, amount and type of sediment transport, etc.) there may be a beneficial influence to downstream reaches, including Aquatic Reach 5 (which had management changes implemented two years later than Aquatic Reach 6).

Aquatic Reach 2 is the lowest-gradient, furthest downstream reach studied on Sevenmile Creek. It showed little change from the 2002/2003 aquatic habitat measurements. Riparian vegetation community delineation was not done for this stretch of river.

Overall, restoring riparian areas in the Wood River Valley contributes to improved riparian and aquatic habitats; increased populations of macroinvertebrates and fish; and deepened and narrowed stream channels in some reaches. Cessation of irrigation in some areas may amplify these effects where stream flows are improved.

11.2.2 Pasture Vegetation and Grazing Management

As noted in 11.2.1 above, changes in grazing and riparian area management, as well as reductions in irrigation water use, can have substantial impacts to aquatic and potentially riparian habitat and resources. This study also looked to see if shifts in grazing and water use (irrigation) would have similar impacts in upland areas. To that end, various components of this study examined how changes in management of irrigation and grazing might impact the composition of the pasture vegetative community (e.g. shifts in native and invasive species, annual biomass production, amount of bare ground, forage quality, etc.), affect the base nutritional plane for livestock, influence livestock condition, etc.

Because this study collected, analyzed, and modeled the data from just two grazing seasons, results and conclusions are limited in scope and reliability. Nevertheless, there are a number of tentative conclusions and potential trends suggested by the work done in this study.

The cessation of irrigation has had an impact on the plant communities of those ranches where this change was made. Eliminating irrigation has encouraged a shift from wetland (obligate) to grass vegetation (facultative). This shift towards a grass community has increased the percentage of bare ground in the pastures. Although there was a statistically significant increase in the amount of bare ground on the non-irrigated sites as compared to the irrigated sites, it is unclear from this study how long the percentage of bare ground might continue to increase in the coming years. The percentage of bare ground increase on the non-irrigated sites may be appropriate for the grass plant community composition that is developing on the non-irrigated ranches.

The shift towards more of a grass community does not appear to have encouraged an increase in invasive species. Invasive or weed species appear to be a localized, site-specific concern on both irrigated and non-irrigated pastures in the valley. Indeed, the vegetation monitoring showed that non-irrigated sites had a greater percentage of native species than the irrigated sites.

The nutritional value of forage was maintained during the shift away from wetland plant species. That is, both wetland and grass communities provide adequate nutrition to the livestock grazing the valley throughout the growing season. Measurements of the important criteria stayed within the commonly recommended guidelines for maintenance and growth of livestock. In addition, it appears that the forage in the non-irrigated pasture may be stronger, more vigorous, and of better quality.

One of the many questions surrounding cessation of irrigation on some of the ranches in the valley revolved around if, and how much, forage production might drop without irrigation. The modeling done for this study suggests that a productivity drop of between 15 to 25 percent is not unreasonable in the Wood River Valley. Such a loss of potential forage has important implications for the economic situation of those ranchers moving towards dryland grazing practices. Such a drop in forage production would require reduced stocking rates to keep the available forage balanced with animal demand or risk long-term damage or negative impacts to the environment. This might be partially offset by what appears to be stronger, more vigorous, better quality forage of the non-irrigated pastures.

The modeling done for the study also suggests that there are various actions ranchers in the valley could take to lessen the economic impacts of ceasing irrigation, having reduced forage available, and having to reduce stocking rates. The modeling process examined a variety of scenarios with different irrigation frequency and rotational grazing management (different vegetation rest/recovery periods). The following conservation planning applications discussion presents some of the potential actions that could be taken by individual ranches to try and balance forage production, irrigation and water savings, environmental benefits, and economic considerations. Implementation of these kinds of conservation practices will depend on individual ranch economics (e.g. as discussed in the preliminary economic analysis), operational considerations, etc.

11.3 Conservation Planning Applications

The following discussion presents some of the resource concerns likely to be encountered if ranches in the Wood River Valley continue to forego irrigation or start on the path of converting from irrigated pasture to dryland conditions. These concerns should be addressed in the planning and operations of a given ranch.

Changes to the Soil Resource:

- Increases in amounts of bare ground and plant spacing (basal gaps) can be expected (consistent with the capability and potential of the site).
- Soil moisture levels may decline to the wilting point on non-irrigated sites by mid to late summer.

Changes to the Water Resource:

- Reduction in nutrient laden run-off to surface waters (reducing anthropogenic sources of phosphorus).
- Decrease in low dissolved oxygen, high pH, and excessive algal growth to Upper Klamath/Agency Lake.
- Partial restoration of historic hydrology.

Changes to the Plant Resource:

- Lowered annual forage production and potential re-growth. Without changing grazing management, reductions could be severe (greater than 1100 lbs/ac or about 0.4 AUM/ac).
- A shift in the growth curve that may leave less potential for mid to late season growth/re-growth.
- With no irrigation, the water table lowers below the rooting zone (3 ft.) by June and does not re-enter the rooting zone until January.
- Plant community composition will shift from obligate and facultative wet species to more deeply rooted native grass species.
- If heavy forage producers such as clovers are present in the irrigated plant community, they will become a minor component with the change to no irrigation.

Changes to the Animal Resource:

- Minimal changes to forage quality in the short-term (long-term changes are unknown).
- Animal health may improve from absence of water related ailments.

- Reduction in water-borne pests such as mosquitoes.
- Enhanced fish and wildlife habitat from improvement of riparian areas.

11.4 Conservation Planning Applications – Alternatives Development

The following discussion presents a number of conservation practices, generally NRCS practices with practice numbers in parentheses, which may be applicable to shifting irrigation and grazing management towards dryland production. The use of these practices will depend on the needs and objectives of the individual landowners/operators. However, these practices ought to be considered when alternative management scenarios are developed during the planning process. These considerations are based on the findings related to the study objectives as well as being related to the recommendations provided in the following chapter.

General conservation practices:

- Switching to non-irrigated rangeland grazing will require a minimum conservation system consisting of Prescribed Grazing (528) and, in some cases, Fence (382). Other practices may include Watering Facility (614), Pipeline (516), Prescribed Burning (338), and Heavy Use Area Protection (561).
- Riparian areas will need extra protection from adverse grazing (frequency, timing, and duration; intensity may be varied depending on the plant community and application of the other factors). These areas should have conservation systems developed to restore, enhance, or maintain desirable channel morphology and mosaic of vegetation.
- Livestock water is adequately provided via existing waterways and ditches. Some water gaps and hardened access points may be needed in some riparian areas.
- Reseeding is not recommended on these soils where deep plowing will bring excess pumice to the surface, reducing the potential seedbed and decreasing water holding capability and adversely affecting nutrient cycling (based on the experience of long-term ranchers in the valley).
- Among accelerating practices, Prescribed Burning (338) may prove the most useful (not usually a ground disturbing practice) to purposely alter plant communities (Tufted hairgrass ranges require intermittent disturbance to prevent deterioration to less desirable plant communities).

Prescribed Grazing Considerations:

- Harvest efficiencies may decline. Current harvest efficiencies of up to 40 percent on irrigated pastures may need to be lowered to the rangeland default level of 25 percent of standing crop allocated to livestock.
- If continuous stocking is used before and after conversion (less than or equal to 10 day rest periods between grazing events), stocking rate will need to be significantly reduced (the MIKE SHE & Daisy model simulations suggest a decrease of about 20 percent from irrigated to non-irrigated).

- If rest periods are extended to 30 days or more, stocking rate may not need to decline (the MIKE SHE & Daisy model simulations suggest a decrease of about three to five percent from irrigated to non-irrigated).
- If rotational grazing is used before and after conversion (30 day or more rest periods between grazing events) stocking rate will be significantly reduced (the MIKE SHE & Daisy model simulations suggest a decrease of about 15 percent from irrigated to non-irrigated).
- Grazing plans should include periods of grazing and rest necessary to develop the most resilient plant community, ease soil compaction problems, and to provide the best potential assemblage of plants for livestock production.
- Fenced pastures need to be monitored for potential increases in invasive and/or toxic plants. Grazing plans must be adjusted to accommodate appropriate treatments (excluding soil disturbing treatments).
- A monitoring plan should include grazing records, photo points, and measurements to capture changes in (1) plant community composition, (2) production (from field measurements and/or evaluation of grazing records – harvest amounts vs. planned trend), and (3) amount of bare ground. Additional measurements of water table level through the year may also be collected (and compared with climate records).
- A contingency plan will be necessary since drought may have more severe effects on the plant community and soil surface without irrigation. Planning for forage reductions from wild fire are also advisable (alternate feed and forage sources, destocking, etc.).

In addition to the general considerations presented above there are many other site and operation specific technical considerations that should be incorporated into grazing management plans for various ranches in the Wood River Valley. Appendix 1 presents a synthesis of the pasture and exclosure vegetation clipping, production, and hydrologic modeling work done in this study. From these data production growth curves, annual forage production, and stocking rates for irrigated (at different irrigation levels) and non-irrigated pastures is presented. This technical appendix should be considered during the process of planning grazing management in the Wood River Valley.

12. Recommendations

The following are recommendations the study authors felt confident in making in spite of study limitations and uncertainties, such as having just two years of data to analyze. As noted in Chapter 11, there are a number of tentative conclusions and potential trends suggested by the analysis done in this study. Implementation of these recommendations will need to be carefully monitored, analyzed, and adjusted and adapted to minimize unintended consequences.

As with most scientific investigation and analysis, further study and analysis is recommended to answer questions that did not get answered, were discovered or asked during this study process, and could not be addressed by this study for one reason or another (e.g. limits to funding).

Recommended additional monitoring, study, or follow up:

- Repeat the riparian area monitoring on Sevenmile Creek in three to five years based on the protocols and benchmark locations established during this study process to document trends.
- Monitor aquatic habitat in the future to document changes and verify that positive trends noted in this study continue.
- Repeat some of the vegetation monitoring to analyze changes in the amount of increase in bare ground and basal gaps resulting from cessation or reduction of irrigation. Longer term changes in plant composition (species shift) and productivity should also be measured to document when the pastures reach a new potential/ equilibrium state that displays a stable combination of composition, production, bare ground, basal gaps, and invasive species characteristics.
- Work with producers who make management shifts to verify or refute predictions made through the modeling process so that adaptive management may occur.
- Encourage landowners and managers to continue near infrared reflectance spectroscopy (NIRS) analysis of fecal samples through the Texas A&M University's Grazingland Animal Nutrition (GAN) Lab (with technical assistance from NRCS) to document further changes to the nutritional plane of the animal diet from converting pastures.
- Test, on a small acreage scale, nitrogen as a limiting factor in forage production in the valley as suggested by study modeling.
- Monitor changes in the amount of non-irrigated acreage and the shallow ground water table.
- Staff of the NRCS State Office and West National Technical Service Center should follow up by reporting results of the study to the local ranchers and partners. Those staff should also work with the ranchers and local partners in developing tools, such as an economic tool for calculating costs/benefits, that the ranchers can use in evaluating ranch-specific changes in irrigation and grazing management.

Despite limitations of this study, the report authors were able to reach the following conclusions:

Restoring riparian areas can

- Improve riparian and aquatic habitat

- Increase populations of macro invertebrates and fish
- Deepen and narrow stream channels

Reducing or eliminating irrigation from grazing lands can

- Encourage a shift from wetland (obligate) to grass (facultative) vegetation
- Increase the percentage of bare ground and basal gaps
- Reduce forage production by 15 to 25 percent
- Change the accumulation (rate and distribution) of biomass throughout the growing season
- Apparently maintain the nutritional value of forage

Improving grazing management (Rotational grazing) can

- Increase forage production (with a 30 day rest versus 10 day rest or continuous grazing)
- Ameliorate adverse changes to soil surface, micro-environment, infiltration, water holding capacity, risk from erosion, animal nutrient management, and increases of invasive plant infestations.

Reductions in forage production will result from complete cessation of irrigation. Not all producers in the valley are likely to convert to a non-irrigated operation for a variety of reasons.

Economic loss will be incurred from forage production reductions in a non-irrigated operation. There will need to be economic off-sets of that income loss to keep producers economically viable. Reductions in costs and other sources of income should be evaluated by individual operators. Some potential off-sets may include:

- Instead of complete non-irrigation, moving to a reduced irrigation operation, such as a one late season irrigation to reduce the percentage of forage production loss, may be an economically feasible option for some ranches.
- Develop a water market for water savings from foregone irrigation; consider in-stream or other water rights leases/sales, or find other similar compensatory mechanism for not using irrigation water.
- Rotational grazing with longer (30 days or more) rest/recovery times in pastures so that the vegetation stays healthy, vigorous, and achieves more optimal re-growth.
- For non-irrigated sites with grass species in the pasture, especially if the vegetation shifts to a tufted hairgrass community, consider prescribed burning as a management tool to help increase forage production.

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Appendix 1

Final Wood River Conservation Effects Assessment Project Report

Introduction to Appendix 1

Appendix 1 contains three parts. Part 1 is the original vegetation CEAP monitoring design proposal prepared by Jeff Repp, Rangeland Management specialist with the USDA NRCS West National Technical Service Center in Portland, Oregon. The proposal contains the background, materials, costs, and methodologies used in the pasture vegetation monitoring portion of the Wood River CEAP study.

Part 2 of Appendix 1 is the summary report prepared by Jeff Repp on the exclosure clipping piece of the Wood River CEAP study. The report summarizes the data collected by the Oregon State University (OSU) team that did the field data collection. Appendix 2 of this final Wood River CEAP report contains the final statistical analysis report prepared by the OSU team for the vegetation monitoring field data.

Finally, Part 3 of Appendix 1 is a report prepared by Jeff Repp summarizing the Near Infrared Spectrometry forage quality assessment.

Appendix 1

Final Wood River Conservation Effects Assessment Project Report

Part 1

WOOD RIVER RANGELAND VEGETATION MONITORING PROPOSAL UNDER THE NRCS CONSERVATION EFFECTS ASSESSMENT PROJECT (CEAP) Joint Study between NRCS and the Oregon State University Rangeland Resources Department

BACKGROUND

Wood River grazinglands are highly productive native rangelands that have been modified by season-long irrigation and the addition of few introduced species such as Kentucky bluegrass, Meadow foxtail, and various clovers (which can provide significant pounds of forage for livestock consumption). The ecological sites are relatively intact; there has been almost no tillage of the soils for other uses. The waterways in the valley channel significant amounts of water from 7-Mile creek from the northwest, Annie Creek from the north, and Wood River from the northeast. Only Wood River makes its way (relatively undisturbed) to Agency Lake. Annie Creek dissipates in the northern part of the valley, and 7-Mile Creek is straightened into a drainage ditch in the lower portion of the valley. Flood irrigation from field ditches is used exclusively and amounts of irrigation water usually exceed consumptive use. Water is usually available and plentiful throughout the growing season.

Grazing occurs annually from late April to early November with cattle generally imported from other areas. Livestock are either cow/calf pairs or growing animals (stockers). Some grazinglands are rotated with movement groups of livestock while others are grazed season-long. Stocking rates vary with condition of plant community and irrigation water management and have a range of 2.5 - 10.0 AUMs/acre/year. Harvest efficiencies are usually quite high with up to 45% of annual growth (by air-dry weight) being harvested by grazing animals. Grazing efficiencies are 80 – 120% of allocated forage (based on desired average 4" stubble heights at end of grazing season). Appearance of plants, irrigation scheduling, and calendar dates are generally used to determine movements.

Soils and Ecological Sites

The majority of the grazed portion of the valley consists of two major soil map units: 33 (Kirk Chock association) and 46 (Lather series). The Kirk and Chock soils are very deep, poorly drained soils derived from pumaceous cinders and ash. They are loams over loamy sands with 5-15% cinder content (increasing with depth). They are currently correlated to the Wet Meadow 14-40" PZ ecological site (021XY406OR – a report is available at: Wet Meadow 14-40 PZ). An ecological site concept that is quite similar (in vegetation community types and ecological dynamics) to these sites occurs in the Klamath mountains in wet meadows with significant amounts of coarse pumice in the control section (006XB013OR – a report is available at: Wet Pumice Meadow 14-26 PZ).
All of the plots measured will be located on the Kirk and Chock soils. The photo above shows a profile of the Kirk Chock association in a cut bank of 7-Mile creek on the west side of the valley. The loamy and sandy loam surfaces are underlain by a thick layer of pumice beginning at 12–18 inches depth. Roots can penetrate well into the pumice layer.

The historic climax plant community of this site is dominated by Tufted hairgrass and Nebraska sedge and has a range of production from about 1850 to 3325 lbs./acre/year (these estimates are probably too low when compared to good condition pastures with higher stocking rates; many fields examined in the spring of 2004 averaged 5.0 AUMs/acre/year; at 50% harvest efficiency this would be 9000 lbs./acre/year). This correlated site as written does not represent the potential productivity of these sites. These sites are a bit wetter than the Wet Meadow site and there are only remnants of the Tufted hairgrass that was once dominant here (mostly fine leaved sedges); a revision of the ecological site description is needed and will be an end product of these investigations (produced by NRCS). Productivity of these sites is strongly influenced by additional irrigation water: productivity can exceed 10 AUMs/acre/year with good grazing and irrigation water management. Sites that are no longer irrigated are still influenced by adjacent irrigation water, sub flow through the valley, and tail water from other irrigated fields.

OBJECTIVES

To Be Completed By OSU Rangeland Resources Department

- Determine and measure changes that may occur to plant community production, composition, and structure between irrigated and non-irrigated rangelands.
- Determine and measure changes in aggregate stability that may occur to the soil surface between irrigated and non-irrigated rangelands.
- Determine changes to sustainable stocking rates between irrigated and non-irrigated rangelands.
- Determine changes in the base nutritional plane of the plant communities (compare irrigated to non-irrigated). Use weight tickets on the trucks hauling livestock into and out of project pastures, number of days on pasture and number of livestock per truck to calculate average daily rate of gain.
- Determine if changes in groundwater hydrology (rate of decline of water table during the growing season) affect changes in the forage production, species composition and forage quality.

To Be Completed by NRCS

- Develop ecological site description (including state and transition models and plant community descriptions) for the map units and review correlations.
- Develop sustainable forage/livestock balance alternatives for each participating landowner using GSAT (Grazinglands Spatial Analysis Tool).

DATA COLLECTION

Vegetation Monitoring Methods

The project will employ the inventory/monitoring protocols in USDA-ARS "Monitoring Manual for Grassland, Shrubland, and Savannah Ecosystems" Herrick et. al., 2005 [Monitoring Manual], NRCS Field Office Technical Guide, and NRCS Range and Pasture Handbook, 2003 [National Range & Pasture Handbook]. The Rangeland Database and Field Data Entry System, developed by ARS, USGS, NRCS, and BLM will be used to record, store, and transfer field data. Information on the Access-based software can be found at: [Rangeland Database Field Entry System]. A customized database will be supplied to the contractors and/or partners who will be collecting data.

Each plot location has two 150 foot transects for collecting data (***See Appendix A – Plot Design, Appendix C – Protocol Standards, and Appendix D – Plot Locations***). The following protocols will be used to collect data on the plots:

- **Photo points;** (visual record of data). Photos of plot and each transect annually at height of growing period, before and after grazing (May and October).

Monitoring Manual, Volume I (pages 6-8) - *Use Photo points to qualitatively monitor how vegetation changes over time. Permanent photographs of a landscape are useful for detecting changes in vegetation structure and for visually documenting measured changes. Take at least one photo of each transect.*

- **Line-Point Intercept;** (plant cover and composition). Plant canopy cover %, plant basal cover %, and bare ground %. Two 150 foot transects/plot. (June/July).

  Monitoring Manual, Volume I (pages 9-15) - *Line-point intercept is a rapid, accurate method for quantifying soil cover, including vegetation, litter, rocks and biotic crusts. These measurements are related to wind and water erosion, water infiltration and the ability of the site to resist and recover from degradation.*

- **Basal and Canopy Gap Intercept;** (monitor for erosion and/or weed invasion). Proportion of line covered by large (defined) gaps between plant bases and proportion of line covered by large (defined) gaps between plant canopies. Two 150 foot transects/plot (June/July).

  Note: This method was developed for upland plant communities, however if an appropriate gap size can be determined for the wet meadow communities the data gathered may show significant changes in gap size associated with removal of irrigation. OSU Range will test gap sizes in the communities of interest and determine if an appropriate gap can be identified. If an appropriate gap can be determined OSU Range will include this method in the data collection protocols.

  Monitoring Manual, Volume I (pages 16-22) - *Gap intercept measurements provide information about the proportion of the line covered by large gaps between plants. Large gaps between plant canopies are important indicators of potential wind erosion and weed invasion. Large gaps between plant bases are important indicators of runoff and water erosion.*

- **Plant Production;** (all above ground air-dry plant production during a single growing year). Total annual forage production will be calculated from total production (using the double sampling method) to determine annual stocking rates (AUMs/Acre). Ten subplots (2 clipped, 8 estimated by weight units) located along the two transects (June/July).

  Monitoring Manual, Volume II, Chapter 9 (pages 51-56) –*Total annual production, which includes woody material, is an expression of all aboveground plant production during a single growing year, regardless of accessibility or palatability to grazing animals.*

- **Soil Aggregate Stability Test;** (monitor for changes in soil surface structure and ability to resist erosion). Eighteen samples on two 150 foot transects/plot (June/July).

  Monitoring Manual, Volume I (pages 23-29) - *The Soil stability test provides information about the degree of soil structural development and erosion resistance. It also reflects soil biotic integrity, because the "glue" (organic matter) that binds soil particles together must constantly be renewed by plant roots and soil organisms. This test measures the soil's stability when exposed to rapid wetting. It is affected by soil texture, so it is important to limit comparisons to similar soils that have similar amounts of sand, silt and clay.*

- **Belt Transect (Plant Density) for Measuring Invasive Plants**; (monitor for the presence of invasive perennial plants). Two 150 foot transects, belt width or quadrat size to be determined in the field.

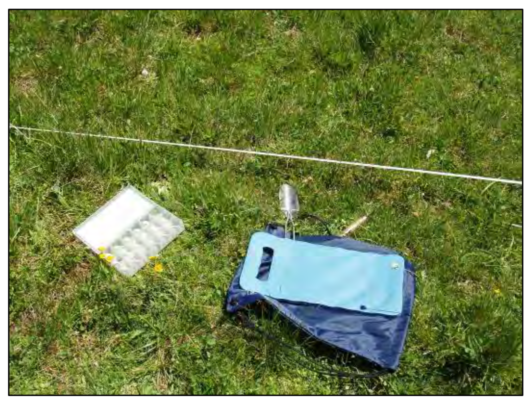
(June/July). Non-irrigated sites may be subject to an increase in bull thistle. This technique may determine if thistles are increasing as meadows are de-watered.

Monitoring Manual, Volume I (pages 23-29) – *The Belt transect provides a way to measure the presence of invasive plants or woody seedlings. Belt transects provide a good means of monitoring brush or shrub encroachment. For seedlings, small annuals and other species that are hard to see, substitute the belt with a quadrat placed at regular intervals along the line.*

- **Compaction Test;** (monitor for relative differences in soil compaction between irrigated and non-irrigated sites). Eighteen samples on two 150 foot transects (timing to be determined by soil moisture). Note: if soils on irrigated sites remain moist throughout the year the method may be inappropriate. Determination will be made in sampling season 2007.

Monitoring Manual, Volume II (pages 43-48) – *The impact penetrometer is used to monitor changes in soil compaction that can limit water infiltration, root growth and microorganism activity. Because Penetrometer measurements are very sensitive to soil moisture, measurements can be compared among years only if soil moisture content is the same during each sampling period. The penetrometer can help determine whether or not a soil is currently compacted, if reference data for similar soils with the same moisture content are available. However, qualitative methods (e.g., Pellant et al. 2000, In Press) are generally more reliable for determining whether soil is compacted. For example, platy soil structure and abrupt changes in root growth patterns not related to a texture change are good indicators of compaction.*

Vegetation Plots



The number of plots is derived from the two types of water regimes present (whether the site is irrigated or non-irrigated). There are thirty-six plots to read each year over the three years of the study (there are two transects per plot for 72 total transects). Each type of water regime will have at least eighteen plots on the Wet Meadow 14-40 PZ site (more than the original 36 may be added if needed and feasible). The valley has significantly more of the Kirk-Chock Association than any other soil type (map unit 33, correlated to the Wet Meadow 14-40 PZ site). Since the majority of the upper valley is composed of one soil map unit and one ecological site, all plots are located on the single site. The Lather Muck soils in the lowest areas of the valley (southern end of the valley) are frequently inundated early in the season and wet throughout the year and are less likely to exhibit changes in vegetation over the course of the project.

Wherever possible, the plots are located away from fences, gates, irrigation ditches, livestock watering sources, and heavy use areas. Plots are located as close as possible to existing (and planned) punctual piezometer sites. One non-irrigated and one irrigated plot are located in Wetland Reserve acreages and receive no livestock grazing. Each of these plots would take a crew of two approximately 4-5 hours to complete. Access is good in most places and there would be little need for extensive hiking to reach plots. An experienced crew could read two plots each work day. All plots could be read within a 4-week period each year.

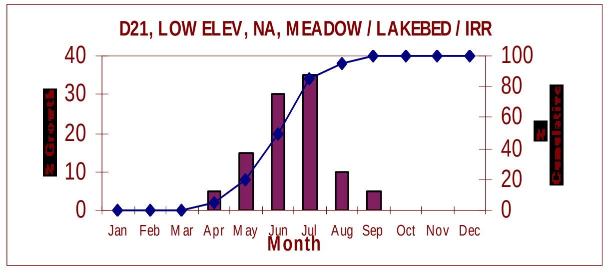
Non-irrigated plots exhibit slight differences in transformation from irrigated rangelands to more normal hydrologic conditions. Funding was provided via a variety of programs to offset the cost of not irrigating (generally based of suspected decreases in productivity and available forage amounts). Different land units entered into the agreements at different times. The table below shows when the non-irrigated plots had irrigation water removed and how many seasons they have been non-irrigated (including the 2006 season).

NON-IRRIGATED VEGETATION MONITORING PLOT STRATIFICATION					
Year Irrigation Ended					
Plot Numbers	2002	2003	2004	2005	Seasons (inc. 2006)
8,9,15-17				✓	**2**
10-12			✓		**3**
13,14,18		✓			**4**
1-7	✓				**5**

Irrigated and non-irrigated plots are grouped by geographic location and land ownership for evaluation. Each group contains between two and four plots that exhibit similar response. Non-irrigated plots are also grouped by length of time since they were regularly irrigated. Each grouping will have an exclosure for determining growth curve and to add to production capability determinations (clipping and weight estimation on the plots needs to be reconstructed for annual air-dry weight, clipping in exclosures and be air-dried and weighed by month for comparison).

VEGETATION MONITORING PLOT STRATIFICATION					
Non-Irrigated			Irrigated		
Group	Plots	Number	Group	Plots	Number
1n	**1,2,3**	**3**	**1i**	**1,2**	**2**
2n	**4,5,6,7**	**4**	**2i**	**3,4,5,6**	**4**
3n	**8,9**	**2**	**3i**	**7,8,9,10**	**4**
4n	**15,16,17**	**3**	**4i**	**13,14,15,16**	**4**
5n	**13,14,18**	**3**	**5i**	**11.12**	**2**
6n	**10,11,12**	**3**	**6i**	**17,18**	**2**

Exclosures



Increased accuracy of production can be measured by clipping plant communities monthly to determine both a growth curve and productivity. The addition of localized growth curves will increase the precision and accuracy of reconstruction of annual above-ground growth for the plots. Simple Exclosures can be set up on the ecological site with and without irrigation resulting in growth curves (showing monthly percentage of growth and accumulated percent growth) for each water regime (2 curves). An example growth curve is shown (estimated for Wet Meadow site in spring, 2004). Differences in growth accumulation across the valley can be determined for the project period.

Ten exclosures can be established from readily available materials (wire panels and metal or wooden posts; 8' x 8'). Exclosures should be large enough to allow clipping of 1.92 ft^2 subplots each month (enough room for at least six subplots). Exclosures are placed along existing fence lines within plot groups and represent the vegetation expressed in the plots. Each month a new subplot is clipped and beginning the second month, previously clipped subplots may be re-clipped to determine regrowth weight and if there is an associative effect of grazing on overall productivity for these plant communities (compensatory growth).

Each of these plots would take a crew of two approximately 2-3 hours to complete. Access is good in most places and there would be little need for extensive hiking to reach plots. An experienced crew could read 3-4 plots each work day. All plots could be read within two weeks time each year (***See Appendix B – Exclosure Design***).

Monitoring Wells

Changes in wet meadow types of ecological are frequently tied to the rate of decrease of the water table as the growing season progresses. Methods employed can utilize existing and planned punctual piezometers and shallow monitoring wells (augured holes lines with perforated PVC pipe that can be periodically measure depth to water table).

Perforated PVC pipe wells (diameter to be determined by OSU to accommodate recording devices) will be installed in close proximity to the vegetation monitoring sites. NRCS is responsible for well installation; however location must be coordinated with OSU Range. A subset of wells located in both irrigated and non-irrigated pastures will be instrumented with continuous recorders to provide an accurate measurement of groundwater drawdown and fluctuation through out the growing season. Non-instrumented wells will be read periodically (not to exceed 14 days) during the growing season. Groundwater data will be recorded from the beginning of May through the end of October.

Grazing Management Methods

Additional information is needed to determine the sustainability of livestock production without irrigation. Critical factors include past and projected future stocking rates and productivity, forage quality and the overall nutrient plane of the plant communities, and changes in grazing pressure on the de-watered rangelands. The following information will be collected in conjunction with the vegetation monitoring.

Grazing Records

Collect annual grazing records from producers showing animal kind, weight, dates in and out for each pasture and each grazing period. Demand (AUMs harvested) per pasture per year will be calculated. Each landowner participating in the study will keep records that will be evaluated with trend, utilization, and photo points each year to determine changes needed to Prescribed Grazing and to use for determining long-term sustainable stocking rates. Past grazing records will also be evaluated to determine the benchmark level of harvest per year per fenced management unit. OSU Range will make contact with cooperators in September and October 2006 to collect annual grazing records showing animal kind, weight in and weight out, dates in and out for each pasture and each grazing period. ***See Appendix E – Rangeland Grazing Records.***

The records will be analyzed for grazing management types, referring to different levels of grazing management. Stocking rates and management level vary. Season long grazing is continuous grazing within the grazing period May to October. Herds may be split into smaller movement groups, but pastures are grazed throughout the season without the opportunity to recover from grazing through rest (generally heavy stocking at or around 1.5 to 2.0+ Animal Units/acre/year – for 6 month period = 9.0 to 12.0 AUMs/acre/year harvested). A thirty day period was chosen to stratify higher levels of grazing management because most of these plant communities in this location can recover from grazing in a 30-day period of rest. Pastures that get less than 30 days of rest may be prone to overuse (generally moderate stocking at or around 1.0 to 1.5 Animal Units/acre/year – for 6 month period = 6.0 to 9.0 AUMs/acre/year harvested); pastures that get 30 or more days of rest will generally recover condition and productivity before being grazed again (generally light stocking at or around 0.5 to 1.0 Animal Units/acre/year – for 6 month period = 3.0 to 6.0 AUMs/acre/year harvested).

VEGETATION MONITORING PLOT STRATIFICATION					
	Grazing Management Level/Intensity Type (source: KBRT)				
Water Regime	High /Light	Medium /Light	Low /Light	Low /Moderate	Low /Heavy
Non-Irrigated	**4-7,11-18**	**1-3,8,9**	**0**	**0**	**0**
Irrigated	**0**	**0**	**0**	**17,18**	**1-16**

Evaluate Forage Quality

Collect fecal samples from grazing herds every month. Submit to GAN lab for NIRS analysis. Develop consultation in NUTBAL program and map/graph Crude Protein %, Digestible Organic Matter (DOM), fecal N, and fecal P. Information about the Grazing Animal Nutrition Lab is available at: http://cnrit.tamu.edu/ganlab/. Information about the Automated NIRS/NUTBAL Advisory System is available at: http://cnrit.tamu.edu/autosystem/. ***See Appendix F – The GAN Lab's NIRS/NUTBAL PRO SYSTEM - A Rancher's Tool for Monitoring Livestock Nutrition and Forage Quality.***

Utilization Monitoring

Measure rangeland utilization at the end of the grazing period at (or near) each plot (October). Remaining plant material is measured by stubble height. Utilization (remaining stubble height) is used to determine if seasonal grazing pressure was applied according to planned levels and to aid in adaptive management in fine-tuning the prescribed grazing system. ***See Appendix G – Rangeland/Pasture Utilization Estimate – Key Forage Plant Method.***

Crater Lake rim from Wood River Valley

ANNUAL ACTIVITIES

- Study design will be set up by NRCS (West National Technical Support Center, Oregon State Office, Klamath Falls Field Office, and Klamath Basin Team). The Klamath Basin Rangeland Trust (KBRT) is an integral partner in developing and completing the project. Additional assistance may be obtained from the Rangeland Resources Department of Oregon State University.
- 2006 data will be collected by NRCS, partners, and contractor(s) as required.
- 2007 and 2008 data will be collected by Rangeland Resources Department of Oregon State University with quality assessment by NRCS.
- Annual summary report of study progress and data collection efforts will be completed jointly by NRCS (West National Technical Support Center, Oregon State Office, Klamath Falls Field Office, and Klamath Basin Team) and Rangeland Resources Department of Oregon State University.

FINAL DELIVERABLES

Data will be analyzed by NRCS (West National Technical Support Center, State Office, Klamath Basin Team, and National Grazinglands Team) annually and at the end of the three-year period. Data analysis and preparation of final report will be administered by OSU Range in coordination with NRCS.

PROJECT ACTIVITIES BY YEAR			
Method	Year		
	2006	2007	2008
Evaluate Grazing Records	✓	✓	✓
Fecal Sampling/Forage Quality	✓1	✓	✓
Utilization Monitoring	✓1	✓	✓
Exclosures/Clipping	✓1	✓	✓
Photo points	✓1	✓	✓
Line-Point Intercept		✓	✓
Basal/Canopy Gap - Gap size determination		✓[2]	✓[3]
Plant Production		✓	✓
Soil Stability Testing		✓	✓
Belt Transect (Plant Density)		✓	✓[3]
Penetrometer		✓	✓[3]
Piezometer/Monitoring Wells	✓[1]	✓	✓
[1] Activity may be performed by NRCS, KBRT, or other appropriate entity. [2] Gap size determinations to occur in 2007. [3] Activity may occur in these years if appropriate.			

ANNUAL BUDGET FOR OSU RANGE RESOURCES DEPARTMENT

Personnel	
0.49 FTE Research Assistant (point person for field work)	$22,344.00
OPE	$6,511.00
Field Technician (400 hours per year @$10/hr)	$4,000.00
OPE (.08)	$320.00
Total Annual Estimated Personnel Cost	**$33,175.00**
Travel	
Motor pool Truck: 3 months @ $420/month	$1,260.00
Motor pool Truck: 1500 miles/month @ 31 cents/mile	$1,395.00
Personal Truck (6 months): Mileage: 1000 miles/month @ 44.5	$2,670.00
Miscellaneous Travel (lodging, extra trips etc.)	$500.00
Total Annual Estimated Travel Cost	**$5,825.00**
Fecal Sample Analysis	
GAN Lab: (60 samples @ $20/ea)	$1,200.00
Total Annual Estimated Fecal Sampling Cost	**$1,200.00**
Project Management & Data Analysis	
Faculty: Dr. Tamzen Stringham: (Approx. 1 month including OPE)	$9,210.00
Total Annual Estimated Project Management & Data Analysis Cost	**$9,210.00**
Total Annual Expenses	
Year 1 subtotal	**$49,410.00**
Year 2 subtotal	**$49,410.00**
Total Annual Estimated Cost (2 years)	**$98,820.00**
Equipment and Supplies (one-time expenses)	
Hobo Water Level Logger: (14 wells @ $500/well)	$7,000.00
Optic USB Base Station	$150.00
HOBO ware Starter Kit	$100.00
Misc. equipment	$1,000.00
Notebooks, clipboards, office supplies, photocopying, telephone etc	$930.00
Indirect Cost (10%)	$12,000.00
Total Annual Estimated Equipment and Supplies Cost	**$21,180.00**
Total Project Cost	
Total Estimated Project Cost	***$120,000.00***

APPENDICES

A. PLOT DESIGN

B. EXCLOSURE DESIGN

   1. Design/Methods
   2. Example Growth Curve Calculations

C. PROTOCOL STANDARDS

   1. Line-Point Intercept
   2. Line-Point Intercept Calculations
   3. Basal & Canopy Gap
   4. Plant Production
   5. Soil Aggregate Stability
   6. Belt Transect (Plant Density)
   7. Compaction Test

D. PLOT LOCATIONS

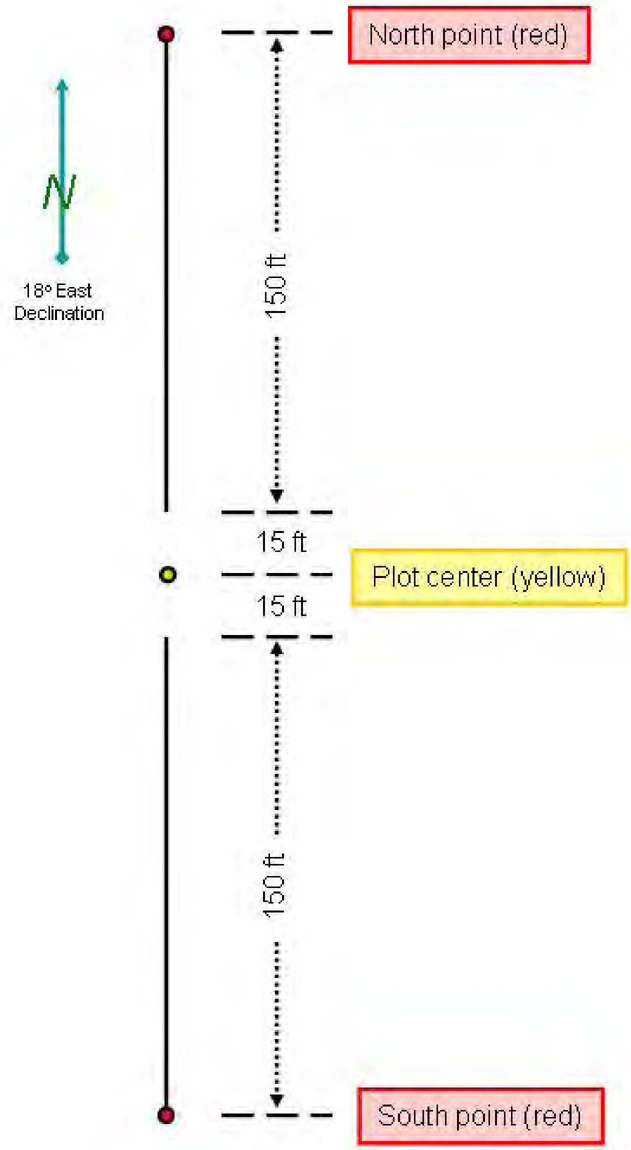
   1. Non-Irrigated plots 1N – 4N
   2. Non-Irrigated plots 5N – 8N
   3. Non-Irrigated plots 9N – 12N
   4. Non-Irrigated plots 13N – 16N
   5. Non-Irrigated plots 17N & 18N and Irrigated plots 1I & 2I
   6. Irrigated plots 3I – 6I
   7. Irrigated plots 7I – 10I
   8. Irrigated plots 11I – 14I
   9. Irrigated plots 15I – 18I
   10. GPS Locations – plots 1-9
   11. GPS Locations – plots 10-18

E. RANGELAND GRAZING RECORDS

F. THE GAN LAB'S NIRS/NUTBAL PRO SYSTEM

G. RANGELAND/PASTURE UTILIZATION ESTIMATE – KEY FORAGE PLANT METHOD

Appendix A - PLOT DESIGN



Plots are identified by three pins (24" steel rebar) with plastic caps set into the ground. Each pin has a GPS coordinate (UTM Zone 10T) and are identified by the plot number, irrigated or non-irrigated, and north and south indicators (the center pin has just the first two: e.g.. 7N = plot #7, non-irrigated center, 7NN = plot #7, non-irrigated north, 7NS = plot #7, non-irrigated south).

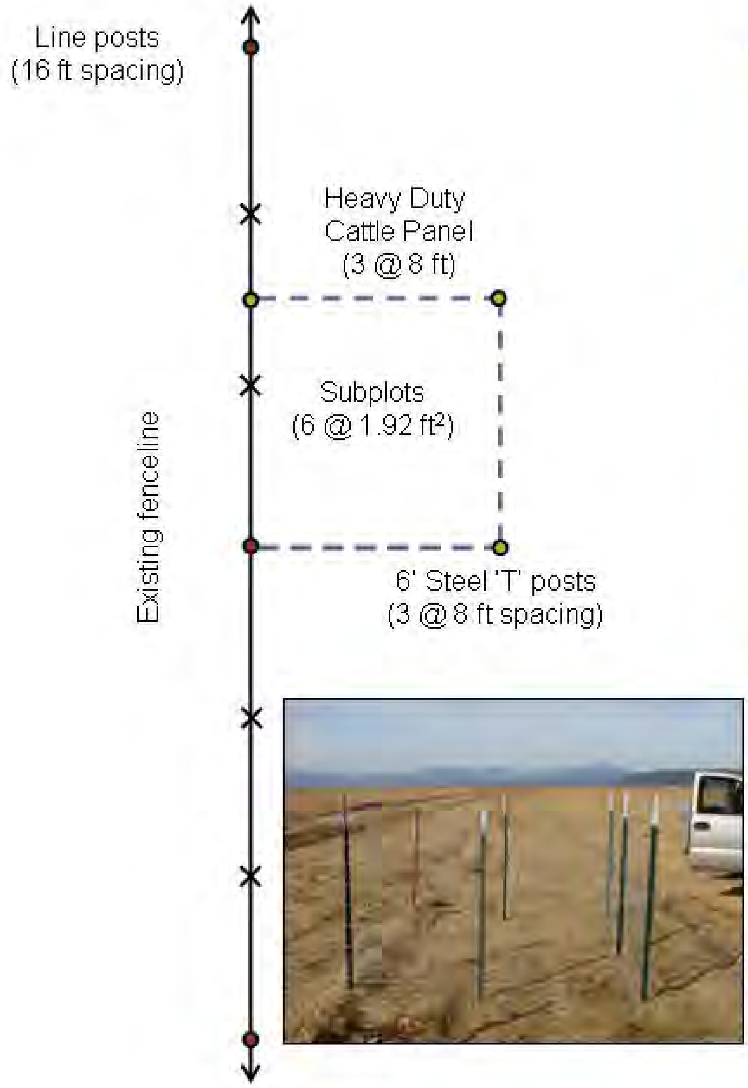
Center pins have yellow caps and end pins have red (or orange) caps. Each plot consists of a center point and two 150 foot transects that are oriented north and south using 18º east declination. The transects begin 15 feet from the center pin and extend to the end pins.

Plots will be read annually, during the peak of the growing season when the plant community has fully developed for the year. Protocols measured annually:

- Photo Points
- Line Point Intercept
- Canopy & Basal Gap
- Production (Double Sampling)
- Soil Aggregate Stability Test

Plot center pin (24") with cap in place

Appendix B - EXCLOSURE DESIGN (page 1)

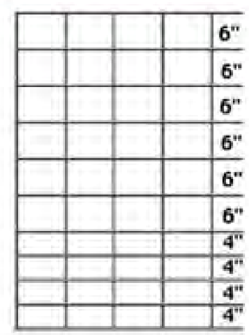


Exclosures are defined by three 8" cattle panels attached (wired) to 6 ft steel 'T' posts. A line post on the existing fence is used as the forth side of the exclosure. Most existing fences in the area have 16 ft spacing between posts so an additional steel post may be needed to anchor one of the panels.

Exclosures will be read monthly using 1.92 ft^2 clipping frames and gram scales. A new area in the exclosure will be clipped month and past clipping areas will be re-clipped. Green weights will be recorded in the field and paper bagged samples will be air-dried and weighed later to determine 1) air-dry weight in grams in each subplot, and 2) percent of air-dry material at time of clipping.

Dry samples in an oven at 140º F for 24 hours or air-dry at room temperature for 72 hours to obtain air-dry weight (grams air-dry * 50 = lbs./acre).

Heavy Duty Cattle Panel
•16' x 52"
(cut in half for 8' sections)
•1/4" Rod Diameter
•2 3/4 Gauge Rod
•47 lbs.

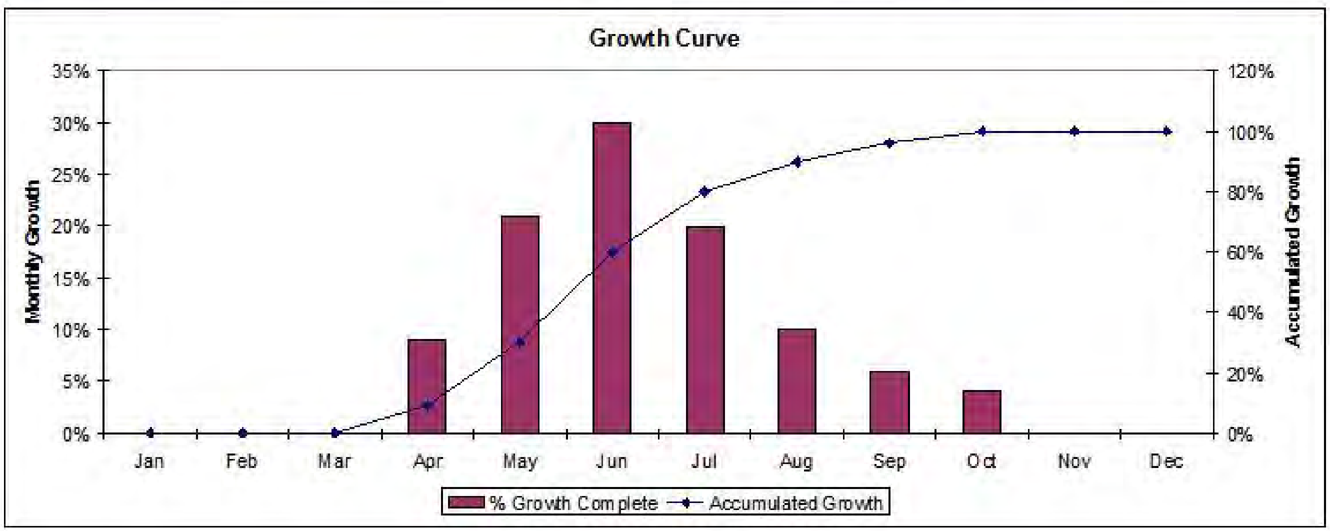


Appendix B - EXCLOSURE DESIGN (page 2)

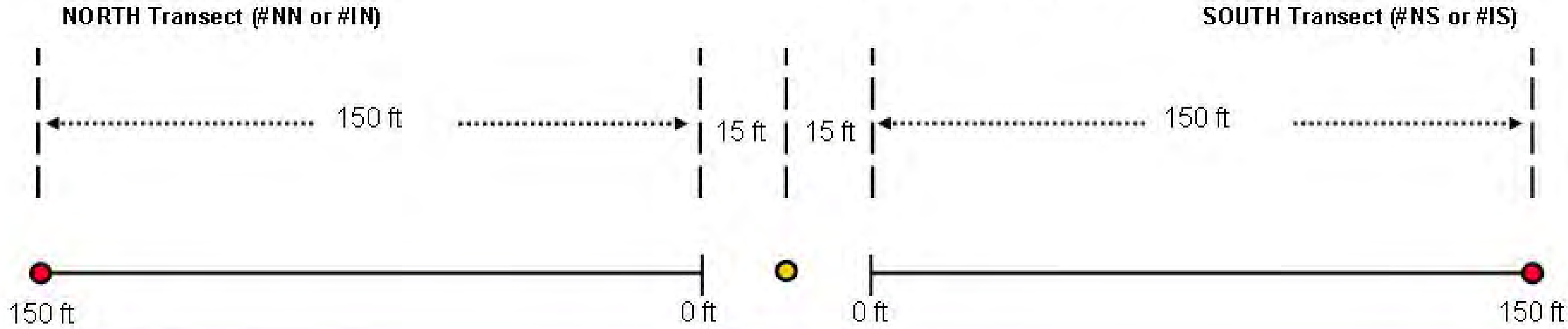
Plot ID	EX1N
Conversion Factor	50

Example Growth Curve Calculations (from monthly clipping data)

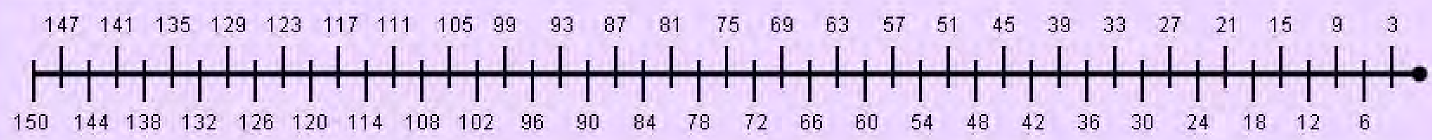
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Date				4/23/2006	5/21/2006	6/20/2006	7/13/2006	8/24/2006	9/12/2006	10/12/2006		
Green Wt. (grams)				10.0	30.0	40.0	46.0	50.0	55.0	56.0		
Green Wt. (lbs/ac)	0.00	0.00	0.00	500.00	1500.00	2000.00	2300.00	2500.00	2750.00	2800.00	0.00	0.00
Air-Dry Wt. (grams)				4.5	15.0	30.0	40.0	45.0	48.0	50.0		
% Air-Dry	0.00	0.00	0.00	0.45	0.50	0.75	0.87	0.90	0.87	0.89	0.00	0.00
Air-Dry Wt. (lbs/ac)	0.00	0.00	0.00	225.00	750.00	1500.00	2000.00	2250.00	2400.00	2500.00	0.00	0.00
% Normal Climate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monthly Air-Dry Wt. (lbs/ac)	0.00	0.00	0.00	225.00	525.00	750.00	500.00	250.00	150.00	100.00	0.00	0.00
% Growth Complete	0.0%	0.0%	0.0%	9.0%	21.0%	30.0%	20.0%	10.0%	6.0%	4.0%	0.0%	0.0%
Accumulated Growth	0.0%	0.0%	0.0%	9.0%	30.0%	60.0%	80.0%	90.0%	96.0%	100.0%	100.0%	100.0%



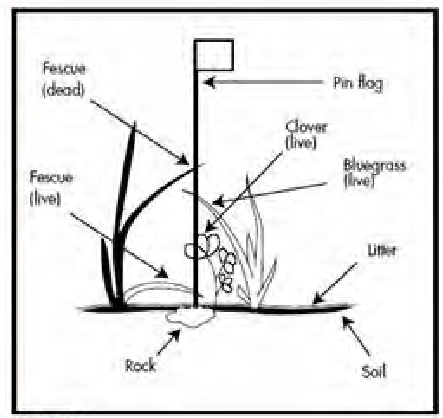
Appendix C –PROTOCOL STANDARDS (page 1)



Line-Point Intercept: Measure intercept every 3 feet on each 150 foot transect (beginning at 3). Record top canopy, lower canopy layers, and soil surface or plant base using plant species codes (from USDA Plants Database www.Plants.usda.gov), lower canopy layer codes, and soil surface codes. Data is recorded in the Range Data Base software provided. Subplot locations shown below:



- **Top canopy codes:** national species code or **NONE** (no canopy)
- **Lower canopy layers codes:** national species code, **L** (herbaceous litter), **W** (woody litter, > 5 mm (~1/4 in) diameter)
- **Soil surface codes:** national species code (for plant bases), **R** (rock fragment (> 5 mm (~1/4 in) diameter), **BR** (bedrock), **M** (moss), **LC** (visible lichen crust on soil), **S** (soil without any other soil surface code), **EL** (embedded litter), **D** (duff), **WA** (water).



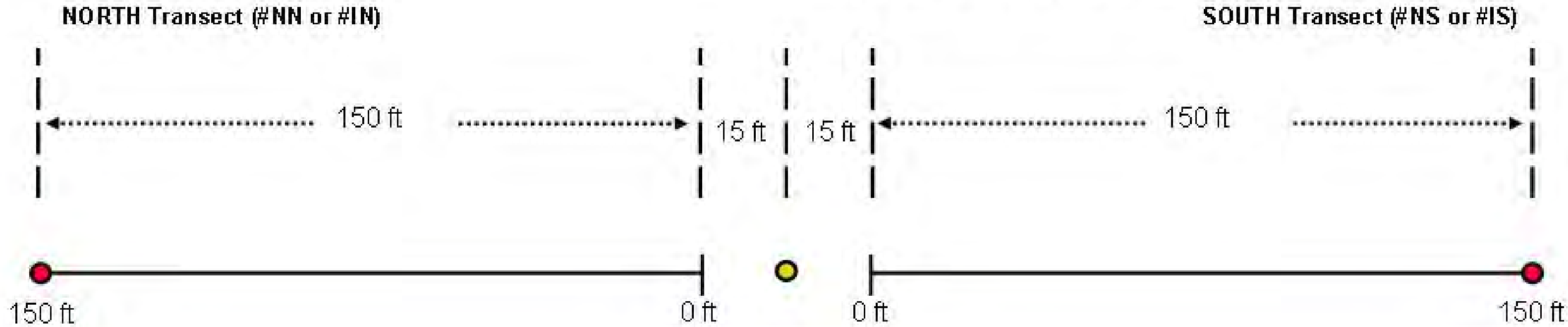
Point 1

Appendix C –PROTOCOL STANDARDS (page 2)

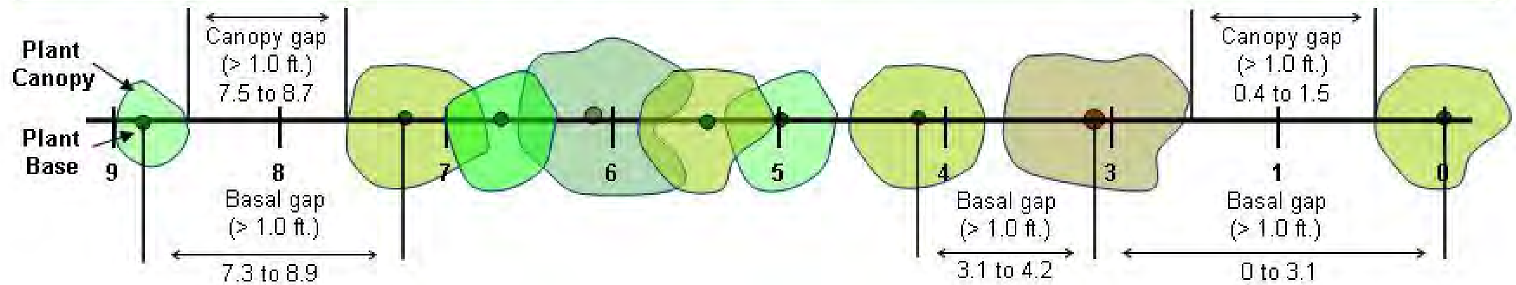
Line Point Intercept Calculations [Range Database]

- ❑ **% Canopy Cover** = [(total number of positions where Top Canopy is 'Real Plant Code')/(total number of positions completed)] * 100
- ❑ **% Bare Ground** = [(total number of positions where Top Canopy is 'None' AND Surface is 'S')/(total number of positions completed)] * 100
- ❑ **% Basal Cover** = [(total number of positions where Surface is 'Real Plant Code')/(total number of positions completed)] * 100. This calculation is also computed per species code in the same manner.
- ❑ **% Ground Cover Total** = [(total number of positions where EITHER any Lower slot is 'L' or 'W' AND/OR Surface is NOT 'S')/(total number of positions completed)] * 100
- ❑ **% Ground Cover Between Plant Canopy** = [(total number of positions where Top Canopy is 'None' AND (any Lower slot has 'L' or 'W' AND/OR Surface is NOT 'S'))/(total number of positions completed)] * 100
- ❑ **% Ground Cover Under Plant Canopy** = [(total number of positions where Top Canopy is 'Real Plant Code' AND (any 'Lower' slot has 'L' or 'W' AND/OR Surface is NOT 'S'))/(total number of positions completed)] * 100
- ❑ **% Total Litter** = [(total number of positions where EITHER any Lower slot is 'L' or 'W' OR Surface is 'D' or 'EL')/(total number of positions completed)] * 100
- ❑ **% Litter Between Plant Canopy** = [(total number of positions where Top Canopy is 'None' AND (any Lower slot is 'L' or 'W' OR Surface is 'D' or 'EL'))/(total number of positions completed)] * 100
- ❑ **% Litter Under Plant Canopy** = [(total number of positions where Top Canopy is 'Real Plant Code' AND (any Lower slot is 'L' or 'W' OR Surface is 'D' or 'EL'))/(total number of positions completed)] * 100
- ❑ **% All Plants** = [(total number of positions where 'Real Plant Code' is 'Checked')/(total number of 'Real Plant Codes' entered)] * 100
- ❑ **% Top Canopy Plants** = [(total number of positions where Top Canopy is 'Real Plant Code' AND 'Checked')/(total number of positions where Top Canopy is 'Real Plant Code')] * 100
- ❑ **% Top Canopy Points** = [(total number of positions where Top Canopy is 'Checked')/(total number of Top Canopy positions completed)] * 100
- ❑ **% Soil Surface** = [(total number of positions where Surface is 'Checked')/(total number of Surface positions completed)] * 100
- ❑ **Species Canopy Cover** = [(total number of positions where Any Canopy Layer is 'Real Plant Code')/(total number of positions completed)] * 100

Appendix C –PROTOCOL STANDARDS (page 3)



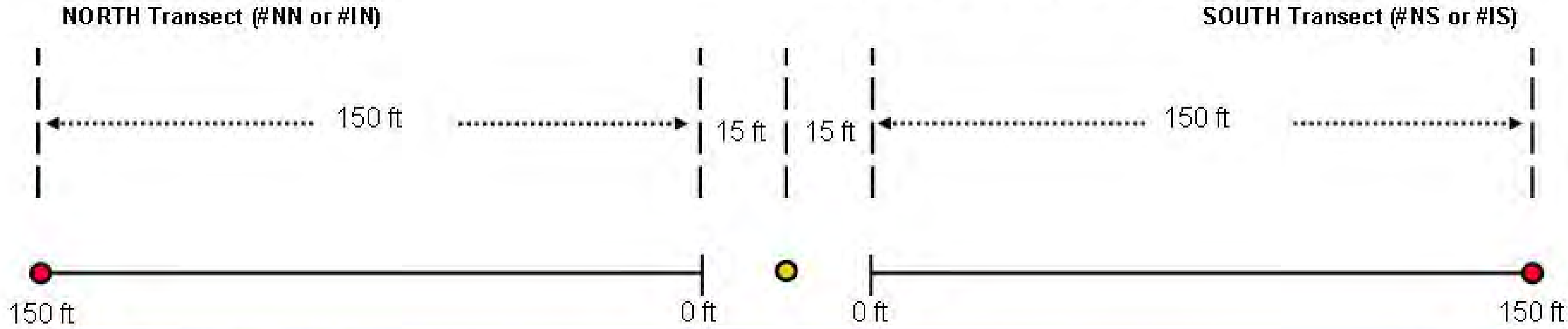
Basal and Canopy Gap: For each 150 foot transect, record the beginning and end measurement of gaps between perennial plant bases greater than the selected minimum gap size and between perennial plant canopy greater than the selected minimum gap size (a minimum gap size will be determined and will be < 1.0 foot).



Basal & Canopy Gap Calculations **[Range Database]**

- ❑ **Gap Size** = end of gap - start of gap
- ❑ **Gap Sum (per size class)** = sum of gap sizes
- ❑ **% of Line in Gaps (per size class)** = (gap sum/line length) * 100

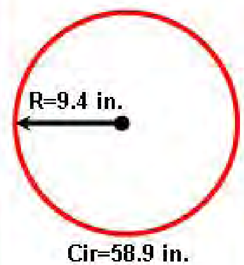
Appendix C –PROTOCOL STANDARDS (page 4)



Plant Production: Each 150 foot transect contains five subplots of 1.92 ft^2 area at the following locations: 5, 40, 75, 110, & 145 feet. The subplot at 75 feet is clipped by species, all other subplots are estimated by weight units. Data is recorded in the Range Data Base software provided. Subplot locations shown below:

Hoop Size	Radius (in)	Circumference (in)	Circumference (ft)	Conversion factor
1.92	9.4	58.9	4.9	50

Harvest all current year's growth by species. Weigh grams of each species and multiply by the conversion factor (50) to get lbs./acre green weight. Determine reconstructed annual air-dry weight using reconstruction factors [% air-dry weight, % ungrazed, % growth complete, & % of normal climate].

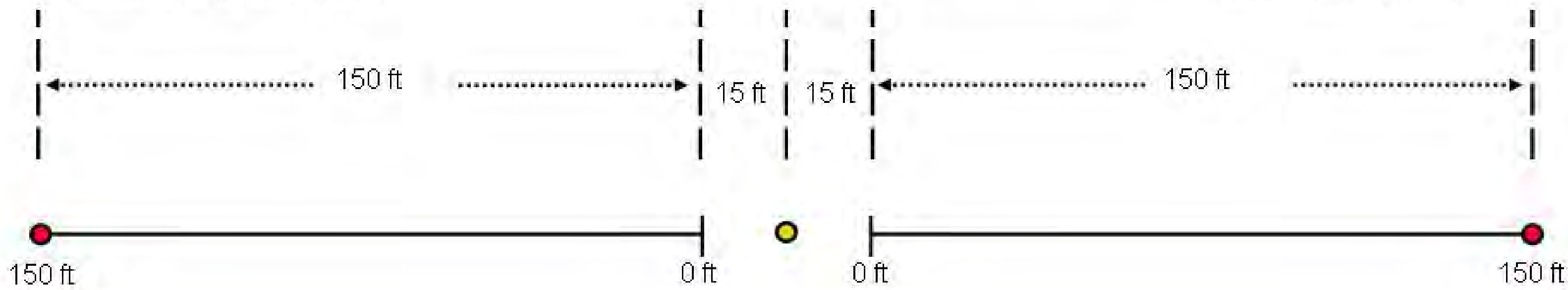


Plant Production Calculations [Range Database]

- Plant Species Total Weight (lbs/ac) = (total wt units * wt unit wt * plot size CF * % air-dry wt. * clip/est. CF)/(utilization adj * number of sub-plots * % growth * % normal climate)
- Total Production (lbs/ac) = sum of species total weights

Appendix C –PROTOCOL STANDARDS (page 5)

NORTH Transect (#NN or #IN) **SOUTH Transect (#NS or #IS)**



Soil Aggregate Stability: Each 150 foot transect has nine (9) positions for testing soil aggregate stability at 15 foot intervals starting at 15 feet. Type of plant cover is recorded at each location. Data is recorded in the Range Data Base software provided. Subplot locations shown below:

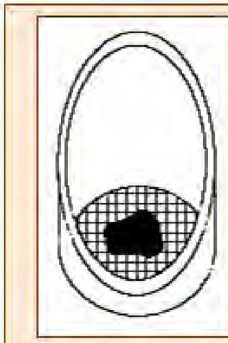
Soil Stability Calculations [Range Database]

❑ **Average Stability** = sum of stability rankings/total number of samples completed

- All Samples Taken = all samples (surface and subsurface)
- Protected Samples = samples with Vegetation (Grass, Forb, Shrub, or Tree)
- Unprotected Samples = samples without Vegetation (NC)
- No Vegetation Specified = samples where Vegetation is left blank
- Line Average = average per transect
- Plot Average Stability by Vegetation Class = plot average per Vegetation class

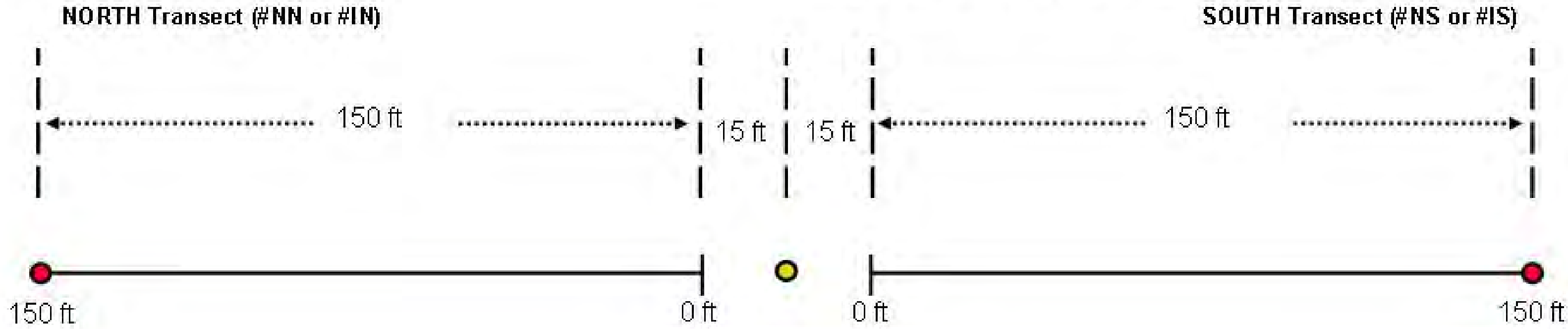
❑ **% of Samples Equal to '6'** = (total number of samples where 'Soil Stability' is '6'/total number of samples completed) * 100

The soil sample should be no larger than ~1/4 in diameter

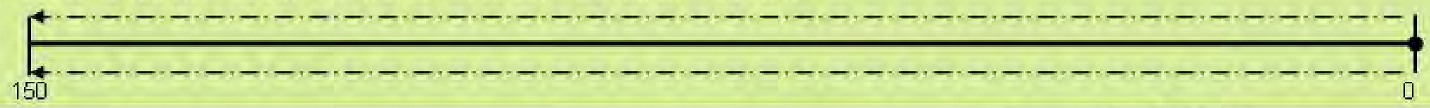


Sample in sieve, drawn to scale

Appendix C –PROTOCOL STANDARDS (page 6)



Belt Transect (Plant Density): Each 150 foot transect is examined and the number of plants within the belt are recorded. Data is recorded in the Range Data Base software provided. The effective subquadrat size with a 3 foot belt = 450 ft^2; 6 ft belt = 900 ft^2; 12 ft belt = 1800 ft^2; 20 ft belt = 3000 ft^2.

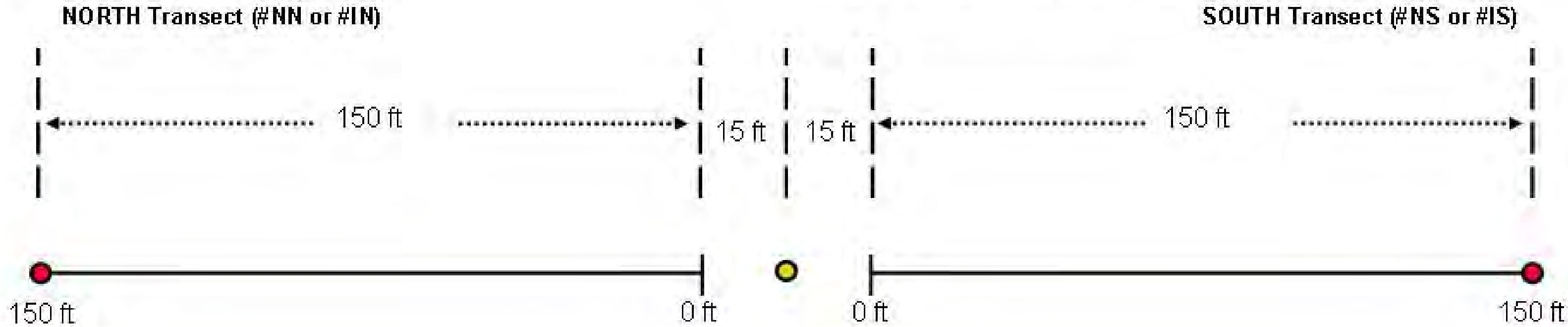


Belt Transect (Plant Density) Calculations [Range Database]

- ❑ **Total by Class** = total number of plants per class
- ❑ **Density by Class (plants/ha)** = (total number of plants)/(quad size m2/10,000 m2 per ha)
- ❑ **Density by Class (plants/ha)** = (total number of plants)/[(quad size ft2 * 0.093 m2/ft2)/(10,000 m2 per ha)]
- ❑ **Total Overall** = total number of plants in all classes
- ❑ **Total Density (plants/ha)** = sum of densities for all classes

Estimated individuals of a given species per 6x100 m plot	Suggested belt width
<100	6 m (20 ft)
100-200	4 m (12 ft)
200-400	2 m (6 ft)
>400	1 m (3 ft)

Appendix C –PROTOCOL STANDARDS (page 7)



Compaction Test: Each 150 foot transect has nine (9) positions for compaction testing using an impact penetrometer at 15 foot intervals starting at 15 feet. Type of plant cover is recorded at each location. Data is recorded in the Range Data Base software provided. Subplot locations shown below:

Compaction Test Calculations [Range Database]

❑ **Avg # of Strikes (per line & per plot, by depth)** = sum of strikes/total number of measurements completed

- All Samples Taken = all samples
- Non-Veg Samples = samples without Veg (NC)
- Veg Samples = samples with Veg (G, F, Sh, or T)

❑ **Ratio of Non-Veg to Veg Samples (per line & per plot, by depth)** = avg non-veg strikes/avg veg strikes

Appendix D – PLOT LOCATIONS (page 1)

Plot 1N: 150 foot transect (1NN)

Plot 1N: 150 foot transect (1NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 1N	4717002	587174
Pin 1NN	4717056	587172
Pin 1NS	4716953	587177

Plot 2N: 150 foot transect (2NN)

Plot 2N: 150 foot transect (2NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 2N	4717440	587395
Pin 2NN	4717490	587390
Pin 2NS	4717390	587399

Plot 3N: 150 foot transect (3NN)

Plot 3N: 150 foot transect (3NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 3N	4716482	587586
Pin 3NN	4716532	587583
Pin 3NS	4716432	587589

Plot 4N: 150 foot transect (4NN)

Plot 4N: 150 foot transect (4NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 4N	4720219	586162
Pin 4NN	4720263	586165
Pin 4NS	4720168	586164

Appendix D – PLOT LOCATIONS (page 2)

Plot 5N: 150 foot transect (5NN)

Plot 5N: 150 foot transect (5NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 5N	4719570	586002
Pin 5NN	4719619	585998
Pin 5NS	4719519	586002

Plot 6N: 150 foot transect (6NN)

Plot 6N: 150 foot transect (6NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 6N	4720164	585532
Pin 6NN	4720212	585527
Pin 6NS	4720114	585537

Plot 7N: 150 foot transect (7NN)

Plot 7N: 150 foot transect (7NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 7N	4720633	585203
Pin 7NN	4720682	585200
Pin 7NS	4720582	585209

Plot 8N: 150 foot transect (8NN)

Plot N: 150 foot transect (8NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 8N	4731430	581090
Pin 8NN	4731468	581086
Pin 8NS	4731380	581092

Appendix D – PLOT LOCATIONS (page 3)

Plot 9N: 150 foot transect (9NN)

Plot 9N: 150 foot transect (9NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 9N	4730810	580919
Pin 9NN	4730858	580916
Pin 9NS	4730765	580901

Plot 10N: 150 foot transect (10NN)

Plot 10N: 150 foot transect (10NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 10N	4730696	577468
Pin 10NN	4730746	577465
Pin 10NS	4730649	577472

Plot 11N: 150 foot transect (11NN)

Plot 11N: 150 foot transect (11NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 11N	4730329	576121
Pin 11NN	4730379	576115
Pin 11NS	4730280	576124

Plot 12N: 150 foot transect (12NN)

Plot 12N: 150 foot transect (12NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 12N	4729271.828	576285.4145
Pin 12NN	4729323.065	576281.417
Pin 12NS	4729220.402	576291.7892

Appendix D – PLOT LOCATIONS (page 4)

Plot 13N: 150 foot transect (13NN)

Plot 13N: 150 foot transect (13NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 13N	4727340	576134
Pin 13NN	4727388	576133
Pin 13NS	4727284	576140

Plot 14N: 150 foot transect (14NN)

Plot 14N: 150 foot transect (14NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 14N	4727005	577141
Pin 14NN	4727061	577134
Pin 14NS	4726957	577137

Plot 15N: 150 foot transect (15NN)

Plot 15N: 150 foot transect 15(NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 15N	4725567	575516
Pin 15NN	4725612	575511
Pin 15NS	4725510	575514

Plot 16N: 150 foot transect (16NN)

Plot 16N: 150 foot transect (16NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 16N	4724719	576458
Pin 16NN	4724772	576455
Pin 16NS	4724671	576460

Appendix D – PLOT LOCATIONS (page 5)

Plot 17N: 150 foot transect (17NN)

Plot 17N: 150 foot transect (17NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 17N	4724596	576703
Pin 17NN	4724649	576698
Pin 17NS	4724546	576704

Plot 18N: 150 foot transect (18NN)

Plot 18N: 150 foot transect (18NS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 18N	4728269	576523
Pin 18NN	4728318	576523
Pin 18NS	4728218	576523

Plot 1I: 150 foot transect (1IN)

Plot 1I: 150 foot transect (1IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 1I	4731847	582505
Pin 1IN	4731893	582526
Pin 1IS	4731801	582483

Plot 2I: 150 foot transect (2IN)

Plot 2I: 150 foot transect (2IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 2I	4731835	581913
Pin 2IN	4731883	581929
Pin 2IS	4731784	581895

Appendix D – PLOT LOCATIONS (page 6)

Plot 3I: 150 foot transect (3IN)

Plot 3I: 150 foot transect (3IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 3I	4720282	582789
Pin 3IN	4720326	582810
Pin 3IS	4720234	582769

Plot 4I: 150 foot transect (4IN)

Plot 4I: 150 foot transect (4IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 4I	4719771	583016
Pin 4IN	4719822	583031
Pin 4IS	4719725	582998

Plot 5I: 150 foot transect (5IN)

Plot 5I: 150 foot transect (5IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 5I	4719456	582905
Pin 5IN	4719503	582919
Pin 5IS	4719407	5828862

Plot 6I: 150 foot transect (6IN)

Plot 6I: 150 foot transect (6IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 6I	4719291	583146
Pin 6IN	4719335	583161
Pin 6IS	4719243	583130

Appendix D – PLOT LOCATIONS (page 7)

Plot 7I: 150 foot transect (7IN)

Plot 7I: 150 foot transect (7IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 7I	4723371	579314
Pin 7IN	4723420	579338
Pin 7IS	4723324	579293

Plot 8I: 150 foot transect (8IN)

Plot 8I: 150 foot transect (8IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 8I	4723278	578969
Pin 8IN	4723322	578989
Pin 8IS	4723219	578946

Plot 9I: 150 foot transect (9IN)

Plot 9I: 150 foot transect (9IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 9I	4723258	578649
Pin 9IN	4723305	578665
Pin 9IS	4723205	578637

Plot 10I: 150 foot transect (10IN)

Plot 10I: 150 foot transect (10IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 10I	4723405	578143
Pin 10IN	4723454	578161
Pin 10IS	4723354	578120

Appendix D – PLOT LOCATIONS (page 8)


Plot 11I: 150 foot transect (11IN)


Plot 11I: 150 foot transect (11IS)


Plot 12I: 150 foot transect (12IN)


Plot 12I: 150 foot transect (12IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 11I	4720947	582072
Pin 11IN	4720995	582062
Pin 11IS	4720896	582080

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 12I	4721298	582254
Pin 12IN	4721351	582249
Pin 12IS	4721250	582265


Plot 13I: 150 foot transect (13IN)


Plot 13I: 150 foot transect (13IS)


Plot 14I: 150 foot transect (14IN)


Plot 14I: 150 foot transect (14IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 13I	4720783	583247
Pin 13IN	4720832	583241
Pin 13IS	4720741	583254

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 14I	47218456	584525
Pin 14IN	4721897	584522
Pin 14IS	4721797	584528

Appendix D – PLOT LOCATIONS (page 9)

Plot 15I: 150 foot transect (15IN)

Plot 15I: 150 foot transect (15IS)

Plot 16I: 150 foot transect (16IN)

Plot 16I: 150 foot transect (16IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 15I	4721896	585183
Pin 15IN	4721946	585180
Pin 15IS	4721846	585187

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 16I	4721310	585929
Pin 16IN	4721361	585925
Pin 16IS	4721259	585935

Plot 17I: 150 foot transect (17IN)

Plot 17I: 150 foot transect (17IS)

Plot 18I: 150 foot transect (18IN)

Plot 18I: 150 foot transect (18IS)

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 17I	4730855	582568
Pin 17IN	4730904	582564
Pin 17IS	4730803	582572

GPS Locations (WGS 84, UTM 10T)	Y Projection	X Projection
Pin 18I	473536	582536
Pin 18IN	4731586	582535
Pin 18IS	4731484	582538

Appendix D – PLOT LOCATIONS (page 10)

Plot	latitude	longitude	Y_projection	X_projection	Date
1I	42.73470031	-121.9921041	4731846.8753	582504.8381	12-JUL-06 12:21:37PM
1IN	42.73511471	-121.9918428	4731893.1476	582525.6824	12-JUL-06 12:24:07PM
1IS	42.73428658	-121.9923723	4731800.6708	582483.4301	12-JUL-06 12:29:32PM
1N	42.60052146	-121.9373544	4717002.1569	587173.9129	07-JUN-06 9:49:50AM
1NN	42.60100443	-121.9373683	4717055.7726	587172.0984	07-JUN-06 9:57:33AM
1NS	42.60008083	-121.9373225	4716953.2613	587177.1466	07-JUN-06 9:54:33AM
2I	42.73465899	-121.9993381	4731835.2426	581912.7232	12-JUL-06 12:47:00PM
2IN	42.73509057	-121.9991283	4731883.3708	581929.3291	12-JUL-06 12:48:31PM
2IS	42.73419916	-121.9995641	4731783.9618	581894.8298	12-JUL-06 12:52:15PM
2N	42.60444009	-121.9345909	4717440.1403	587395.1414	07-JUN-06 10:09:52AM
2NN	42.60488911	-121.9346441	4717489.9456	587390.1546	07-JUN-06 10:11:35AM
2NS	42.60398587	-121.9345477	4717389.7474	587399.3242	07-JUN-06 10:14:06AM
3I	42.63054142	-121.9903174	4720282.4504	582789.2881	12-JUL-06 2:28:12PM
3IN	42.63093528	-121.9900573	4720326.4402	582810.0923	12-JUL-06 2:29:39PM
3IS	42.63010983	-121.9905697	4720234.2786	582769.1724	12-JUL-06 2:33:45PM
3N	42.59578812	-121.9324063	4716481.6651	587586.4620	07-JUN-06 9:14:45AM
3NN	42.59624569	-121.932446	4716532.4336	587582.5682	07-JUN-06 9:35:18AM
3NS	42.59533986	-121.9323887	4716431.9076	587588.5337	07-JUN-06 9:33:29AM
4I	42.62591285	-121.9876241	4719771.1218	583016.2766	12-JUL-06 2:55:45PM
4IN	42.62636958	-121.9874376	4719822.0212	583030.9630	12-JUL-06 2:57:51PM
4IS	42.62549677	-121.9878506	4719724.6970	582998.2576	12-JUL-06 3:02:22PM
4N	42.62959938	-121.9492018	4720218.9043	586161.9122	07-JUN-06 10:34:32AM
4NN	42.62999953	-121.9491518	4720263.3889	586165.4568	07-JUN-06 10:37:49AM
4NS	42.62914156	-121.9491891	4720168.0796	586163.5818	07-JUN-06 10:43:59AM
5I	42.62308622	-121.9890313	4719455.8659	582904.6381	12-JUL-06 3:17:24PM
5IN	42.62351235	-121.9888534	4719503.3587	582918.6582	12-JUL-06 3:15:52PM
5IS	42.62265245	-121.9892666	4719407.4685	582885.9193	12-JUL-06 3:20:32PM
5N	42.62377144	-121.9512514	4719569.6689	586001.8716	07-JUN-06 10:55:25AM
5NN	42.62421912	-121.9512919	4719619.3392	585997.9284	07-JUN-06 11:00:08AM
5NS	42.62331798	-121.9512525	4719519.3145	586002.4064	07-JUN-06 11:02:42AM
6I	42.62157823	-121.9861174	4719291.2746	583145.6002	12-JUL-06 3:32:51PM
6IN	42.62197394	-121.985923	4719335.4063	583161.0142	12-JUL-06 3:30:48PM
6IS	42.62114162	-121.9863184	4719242.5949	583129.6975	12-JUL-06 3:35:11PM
6N	42.62917215	-121.9568967	4720163.6543	585531.5338	07-JUN-06 11:14:36AM
6NN	42.62960616	-121.9569458	4720211.7982	585526.9118	07-JUN-06 11:23:07AM
6NS	42.62872171	-121.9568418	4720113.6917	585536.6523	07-JUN-06 11:18:44AM
7I	42.65871509	-122.0322666	4723370.7275	579313.8224	14-JUL-06 9:38:04AM
7IN	42.65915547	-122.0319642	4723419.9123	579338.0485	14-JUL-06 9:42:04AM
7IS	42.65829775	-122.0325304	4723324.1373	579292.7270	14-JUL-06 9:47:58AM
7N	42.63343074	-121.9608334	4720632.5664	585202.9206	07-JUN-06 11:33:21AM
7NN	42.63387976	-121.9608621	4720682.3980	585199.9582	07-JUN-06 11:35:21AM
7NS	42.63297494	-121.9607681	4720582.0190	585208.8966	07-JUN-06 11:37:20AM
8I	42.65791336	-122.0364816	4723277.7554	578969.3799	14-JUL-06 10:26:30AM
8IN	42.65831024	-122.0362346	4723322.0569	578989.1224	14-JUL-06 10:24:46AM
8IS	42.65738832	-122.0367708	4723219.1833	578946.3429	14-JUL-06 10:29:10AM
8N	42.73110003	-122.0094445	4731430.2835	581090.0582	12-JUL-06 11:16:29AM
8NN	42.7314421	-122.0094899	4731468.2248	581085.8935	21-AUG-06 2:44:03PM
8NS	42.73064783	-122.0094269	4731380.0861	581092.0882	21-AUG-06 2:53:06PM
9I	42.65776944	-122.0403867	4723258.1339	578649.4967	14-JUL-06 10:39:45AM
9IN	42.65819424	-122.0401882	4723305.4896	578665.2286	14-JUL-06 10:41:30AM
9IS	42.65729427	-122.040542	4723205.2252	578637.3719	14-JUL-06 10:44:30AM
9N	42.7255316	-122.0116265	4730809.8474	580918.6720	12-JUL-06 11:40:10AM
9NN+	42.72596888	-122.0116567	4730858.3759	580915.6262	21-AUG-06 4:10:34PM
9NS+	42.72505869	-122.0115526	4730757.4043	580925.3386	21-AUG-06 4:02:21PM

Appendix D – PLOT LOCATIONS (page 11)

Plot	latitude	longitude	Y_projection	X_projection	Date
10I	42.65914399	-122.0465451	4723405.0575	578143.0357	14-JUL-06 11:15:39AM
10IN	42.65957968	-122.0463141	4723453.6513	578161.4158	14-JUL-06 11:09:14AM
10IS	42.65868232	-122.0468307	4723353.5283	578120.2014	14-JUL-06 11:14:12AM
10N	42.72486507	-122.0537866	4730696.2918	577467.8020	08-JUN-06 9:32:35AM
10NN	42.7253166	-122.0538108	4730746.4093	577465.2572	08-JUN-06 9:34:31AM
10NS	42.7244355	-122.0537359	4730648.6370	577472.4883	08-JUN-06 9:36:20AM
11I	42.63660195	-121.9989686	4720946.9965	582071.9576	23-AUG-06 1:26:12PM
11IN	42.63703505	-121.9990829	4720994.9782	582062.0222	23-AUG-06 1:30:02PM
11IS	42.63614472	-121.9988793	4720896.3112	582079.8842	23-AUG-06 1:32:27PM
11N	42.72169637	-122.0702869	4730329.4203	576120.7655	08-JUN-06 10:10:31AM
11NN	42.72214422	-122.0703488	4730379.0956	576115.1532	08-JUN-06 10:18:42AM
11NS	42.7212487	-122.0702498	4730279.7427	576124.3529	08-JUN-06 10:14:44AM
12I	42.63973863	-121.9967038	4721297.5020	582253.5117	23-AUG-06 1:51:01PM
12IN	42.64022151	-121.9967552	4721351.0724	582248.6633	23-AUG-06 1:56:19PM
12IS	42.6393073	-121.9965739	4721249.7323	582264.7313	23-AUG-06 1:58:05PM
12N	42.7121571	-122.0684187	4729271.8275	576285.4145	08-JUN-06 10:40:46AM
12NN	42.71261886	-122.0684606	4729323.0653	576281.4170	08-JUN-06 10:47:14AM
12NS	42.71169341	-122.0683477	4729220.4017	576291.7892	08-JUN-06 10:44:41AM
13I	42.63499841	-121.9846679	4720782.9110	583246.5826	23-AUG-06 2:30:12PM
13IN	42.63544248	-121.9847248	4720832.1657	583241.3246	23-AUG-06 2:35:53PM
13IS	42.63461804	-121.9845896	4720740.7508	583253.5087	23-AUG-06 2:41:19PM
13N	42.69478074	-122.0705311	4727340.3859	576133.6562	07-JUN-06 2:50:16PM
13NN	42.69520654	-122.0705298	4727387.6695	576133.2458	07-JUN-06 2:55:37PM
13NS	42.69426886	-122.0704577	4727283.6111	576140.2963	07-JUN-06 2:53:00PM
14I	42.64442185	-121.9689161	4721844.9397	584525.3244	24-AUG-06 8:59:08AM
14IN	42.6448904	-121.9689488	4721896.9361	584522.0036	24-AUG-06 9:12:54AM
14IS	42.64398633	-121.9688963	4721796.5981	584527.5356	24-AUG-06 9:10:45AM
14N	42.69166125	-122.05828	4727005.0992	577141.0284	07-JUN-06 2:06:39PM
14NN	42.69216299	-122.0583642	4727060.7373	577133.5069	07-JUN-06 2:10:14PM
14NS	42.69122472	-122.058334	4726956.5761	577137.1468	07-JUN-06 2:12:19PM
15I	42.64481253	-121.9608891	4721896.3763	585182.8296	24-AUG-06 9:43:58AM
15IN	42.64526281	-121.960922	4721946.3436	585179.5141	24-AUG-06 9:45:11AM
15IS	42.64436016	-121.9608508	4721846.1824	585186.5866	24-AUG-06 9:42:44AM
15N	42.67887759	-122.0783072	4725567.4684	575515.9693	07-JUN-06 3:12:52PM
15NN	42.67928277	-122.0783671	4725612.4073	575510.5685	07-JUN-06 3:15:47PM
15NS	42.67836093	-122.0783431	4725510.0647	575513.6561	07-JUN-06 3:17:39PM
16I	42.63944593	-121.9518747	4721309.5732	585929.1924	25-OCT-06 10:21:42AM
16IN	42.63990593	-121.9519232	4721360.6036	585924.5807	25-OCT-06 10:23:58AM
16IS	42.6389923	-121.9518058	4721259.2708	585935.4654	25-OCT-06 10:26:17AM
16N+	42.67114537	-122.0669294	4724719.0873	576457.6629	25-OCT-06 3:10:30PM
16NN+	42.6716228	-122.0669509	4724772.0832	576455.3126	25-OCT-06 3:12:23PM
16NS+	42.67071454	-122.0669059	4724671.2679	576460.1142	25-OCT-06 3:18:51PM
17I	42.72576093	-121.9914755	4730854.8213	582568.1490	25-OCT-06 11:38:06AM
17IN	42.72620282	-121.991525	4730903.8424	582563.5144	25-OCT-06 11:39:32AM
17IS	42.72529255	-121.9914428	4730802.8424	582571.4531	25-OCT-06 11:41:34AM
17N	42.67001423	-122.0639568	4724596.1752	576702.6331	07-JUN-06 1:09:54PM
17NN	42.67049359	-122.0640041	4724649.3619	576698.1693	07-JUN-06 1:13:28PM
17NS	42.66956127	-122.0639497	4724545.8835	576703.7735	07-JUN-06 1:17:01PM
18I	42.73189925	-121.9917679	4731536.1616	582536.0737	25-OCT-06 12:25:43PM
18IN	42.7323491	-121.9917629	4731586.1199	582535.8889	25-OCT-06 12:27:01PM
18IS	42.73142994	-121.991756	4731484.0590	582537.6702	25-OCT-06 12:29:14PM
18N+	42.70310364	-122.0656473	4728269.0037	576523.4814	25-OCT-06 1:51:25PM
18NN+	42.70354168	-122.0656517	4728317.6413	576522.5790	25-OCT-06 1:53:12PM
18NS+	42.70264431	-122.0656579	4728217.9883	576523.1734	25-OCT-06 1:56:25PM

Appendix E

Rangeland Grazing Records

GRAZING RECORD - RANGE								
Pasture Number / Name:								
Year or Season:					Acres:		Eco Site:	
Livestock Type	Livestock Number	Date In	Date Out	Days Grazed	Animal Units	AUMs (Days * AUs / 30.4)	Use Class (1-5)	Notes
AUMs Available:					Total ->		AUM Balance:	
Use Class: 1 = None (0-15%) 2 = Light (16-35%) 3 = Moderate (36-65%) 4 = Heavy (66-80%) 5 = Severe (81-100%)								
Notes:								

Example

GRAZING RECORD - RANGE								
Pasture Number / Name:	*North Thompson Place*							
Year or Season:	*summer*				Acres:	*430*	Eco Site:	*Wet Meadow 14-40*
Livestock Type	Livestock Number	Date In	Date Out	Days Grazed	Animal Units	AUMs (Days * AUs / 30.4)	Use Class (1-5)	Notes
pairs	*350*	*6/15*	*7/15*	*31*	*385*	*393*	*2*	*spring deferred*
pairs	*350*	*8/15*	*9/1*	*16*	*385*	*203*	*3*	*30 day rest*
stockers	*600*	*9/2*	*10/10*	*39*	*480*	*616*	*3*	*irrigated all season*
AUMs Available:	*1290*				Total ->	*1212*	AUM Balance:	*78*
Use Class: 1 = None (0-15%) 2 = Light (16-35%) 3 = Moderate (36-65%) 4 = Heavy (66-80%) 5 = Severe (81-100%)								
Notes:	*Good forage growth year. Deferred pasture until mid June. 30-day rest July-August.*							
Moved cow herd to Jordan pasture in July for 1 month. Shipped stockers 10/11.								
Pasture produced about 3.5 AUMs/acre this year. Rmaining stubble heights exceeded 4" on average.								

Appendix F

The GAN Lab's NIRS/NUTBAL PRO SYSTEM
A Rancher's Tool for Monitoring Livestock Nutrition and Forage Quality

In recent years, the analysis of fecal samples, a.k.a. manure, has proven to be a useful and effective diagnostic and management tool. A fecal sample collected out in the pasture can be sent to the Grazingland Animal Nutrition (GAN) Lab. The GAN Lab analyzes the fecal sample using near infrared reflectance spectroscopy (NIRS) to determine the quality of the forage the animals were consuming 36 hours prior to defecating.

WHAT CAN A FECAL SAMPLE TELL YOU

The GAN Lab offers an analysis package that includes percent crude protein (CP) and percent digestible organic matter (DOM). Digestible organic matter is a measure of energy as is TDN or total digestible nutrients. Fecal samples are also analyzed for percent fecal nitrogen (FN) and percent fecal phosphorus (FP). FN and FP refers to the proportion of these minerals in the manure deposited on the ground. All four analyses are predicted for a cost of $25 per fecal sample. One composite fecal sample can represent an entire herd.

WHAT IS NUTBAL PRO & WHAT CAN NUTBAL PRO TELL YOU

The second component of the system, NUTBAL Pro, is a decision support software developed at Texas A&M University by Dr. Jerry Stuth and the GAN Lab team. An update of the DOS-based version, NUTBAL Pro employs many new tools and the latest scientific knowledge on grazing animal nutrition. The software asks you for information regarding animal attributes, environmental conditions, pasture conditions, feeding program, and metabolic modifiers as well as incorporates GAN Lab results (CP, DOM, FN and FP) as forage quality values. The Nutritional Balance Analyzer software determines: 1) if animals are on a positive or negative nutritional plane, 2) daily weight gain/loss, and 3) the most cost effective feeding option if supplementation is needed from the information you supply.

NUTBAL Pro produces two reports. The Standard NUTBAL Report describes nutritional intake, requirements, and balance for the following: protein, net energy for maintenance and net energy for gain. This report also estimates average daily gain, identifies the limiting nutrient (energy or protein), and reports dry matter intake, milk production, and fecal output. The Mediation Report selects the most cost efficient feed alternative. The user identifies one or more protein or energy supplements available to use. The program evaluates the feeds' value with regards to the animal's nutrient deficiency or desired gain. The Mediation report then identifies the cost efficient option, amount to be fed, and cost per day. The report also calculates the price per ton required for other selected supplements to be competitive with the best choice. NUTBAL Pro is available on CD-Rom only. The CD also includes electronic copies of training materials, sampling instructions and other helpful information.

WHAT IS THE NIRS/NUTBAL PRO SYSTEM

The combined NIRS/NUTBAL Pro System is a diagnostic and management tool that enables you to monitor the changes in forage quality over time, estimate animal performance and supplement more efficiently. A regular monitoring program such as a monthly fecal sampling schedule provides a wealth of information that brings a new level of confidence to your decision making process.

HOW CAN I USE THIS INFORMATION

The NIRS/NUTBAL Pro System generates a vast amount of data that may be applied numerous ways, especially when you use the system as a nutritional monitoring program sampling on a regular basis. The following are just a few brief highlights. A downward trend in nutritional status may indicate it is time to move the animals to new pasture. The estimated gain or loss per day may help you decide when to start feeding or moving stockers. Dry matter intake can be used to determine if forage will be sufficient for grazing period. Fecal phosphorous and nitrogen output reported in lbs/day provides actual data with which to manage nutrient-loading concerns.

Appendix F – continued

CONTACT THE GAN LAB

First, contact the GAN Lab or visit the web site. The GAN Lab will mail you a starter kit that includes a Styrofoam box with ice substitute, sample sheets, instructions for collecting the fecal sample and completing the sample sheet, and additional articles that you may find informative. Additional kits or boxes are available upon request.

Grazingland Animal Nutrition Lab
Texas A&M University, Rangeland Ecology & Management
2126 TAMU
College Station, TX 77843-2126
979-845-5838 Phone, 979-845-2542 Fax
ganlab@cnrit.tamu.edu, http://cnrit.tamu.edu/ganlab

SUPPLIES NEEDED

The GAN Lab supplies Styrofoam boxes, ice substitute, and original sample sheet that can be copied for future samples. You will need to have on hand plastic bags that seal, mailing labels, tape, permanent marker or labels, and disposable spoons or gloves for picking up the sample. Please do not use fold over baggies. As you can imagine, they leak.

COLLECTING A FECAL SAMPLE

Now that you have the GAN Lab starter kit and have read the instructions, you are ready to begin.

1. Freeze the ice pack overnight and label Styrofoam lid with your address and the GAN Lab address.
2. Gather together zip-loc type sandwich or freezer bags, tape, plastic gloves and/or disposable spoons, permanent marker, pen, sample form and Styrofoam box.
3. One fecal sample can represent a herd or pasture. Collect a "heaping tablespoon" from 5 to 10 fresh fecal piles to get a composite sample. Collect at least a half cup, but no more than a pint is needed. Deposit manure in bag. Sample should be free of dirt, insects, and grass. The Styrofoam box should hold 4 to 6 samples and the ice pack.
4. Allow sample to cool to increase the life of the ice substitute and label each plastic bag with a sample or pasture ID, date collected and any other pertinent information using a permanent marker or stick-on label. The label on the bag should match the ID on the sample sheet. Remember that in route the contents of the Styrofoam box may take on moisture. Please keep that in mind when labeling your sample bags. Samples can be frozen and mailed later if more convenient.
5. Place in the Styrofoam box the cooled fecal sample, and ice substitute. In a separate plastic bag, place the completed sample sheet and any photos of land/cattle that may be useful if you desire a NUTBAL advisory report.
6. Seal the box with packing tape around and across the lid. Use any mail service that guarantees two-day delivery, i.e. 2-day Priority Mail through the Postal Service.
7. Receive results approximately 4 days after collecting sample via fax or e-mail.

Appendix F – continued

Completing the GAN Lab Sample Form

To be used with NUTBAL Pro Version 1.0 software

Answers to questions often asked concerning the sample form. One fecal sample per sample sheet, please.

Client Section:
This information is used to set up or identify the account to be billed. NRCS personnel may use this section for other purposes as long as the NRCS contract number is filled out in the Lab Use Only section.

Ranch Name:
Complete this entire section with every sample you send in. The ranch name is used to file and store sample results. Be consistent. If you refer to the ranch as Blue Valley Demo Farm for the first few samples, please do not change and label the sheet BVDF instead. This makes retrieving data for you difficult and time consuming.

Client Rep:
The lab sends results to the person specified in this section. Check one of the options through which the lab can send results. Always include your phone number, city and state. If the address, phone, fax or client rep has changed, please indicate.

Sample ID:
Use an ID that is meaningful to you or the rancher. Make sure that the ID on the sample sheet matches the label on the bag of fecal sample.

Date Collected:
Is the day the fecal sample was collected.

ANIMAL ATTRIBUTES:
Several columns are provided for multiple profiles or subgroups represented by the fecal sample. This information is needed to produce a NUTBAL advisory report.

Profile Name: Use something meaningful to the rancher to correspond to their way of referring to a group of animals. NUTBAL Pro will ask for this name.
Breedtype: If the sample was collected from a herd made up of Angus cows and cows that are ½ Gelbvieh and ½ Red Angus, this would constitute two profiles so you would fill out two columns of information.
Age: A herd of 3-year-old cows and 6-year-old cows would also be two profiles ~ two columns of information.
Number of Head: Include only non-nursing animals. Example, for a herd of 20 cows and 10 of them have calves, the number of animals would be 20, not 30, not "half of them", etc.
Lactation: Can be translated into age of the offspring nursing the females.
BCS of dam at parturition: Body condition score of dam at birth. This effects milking potential of the cow.
Offspring age (mo)/weight at weaning: This information can be used to determine peak milk yield of dam.
Current body weight: The weight of the animal described in this information, not the offspring.
Current body condition score: The BCS of the animal described in this information, not the offspring.
Desired avg. daily gain/loss: Of the animal described in this information, not the offspring.

FEEDS and METABOLIC MODIFIERS:
This section can be used to describe feeds, ionophores, hormones, antibiotics, probiotics, etc. that alter an animal's metabolism. If the item is not currently used but you want to evaluate the possible affect on performance, please indicate that the item is not yet applied. Include a copy of the feed tag or literature on metabolic modifier.

FORAGE/ENVIRONMENT CONDITIONS:

Vegetation Type: If possible, list the primary species in order of dominance. Common names are accepted. Please be more specific than just warm season or cool season. If you do not know, at least define the land by rangeland, woodland, pastureland, cropland, specifying the name of the pasture or crop species.
Coat condition: Usually "Dry" except in cases of deep snow, long stretches of wet weather (hurricanes), etc.

Appendix F – continued

Rangeland Ecology and Management
408B Animal Industries Building
2126 TAMU
Texas A&M University
College Station, Texas 77843-2126

Grazingland Animal Nutrition Lab

Phone: 979-845-5838
Fax: 979-845-2542
Email: ganlab@rasc-sparc.tamu.edu
Web Page: http://cnrit.tamu.edu/ganlab

Client: ______________________
(Person who receives **Invoice** by: Fax ___ Mail ___)
Address:
City: State: Zip:
Phone: Fax:
Email:

Ranch/Farm/Property Name:
Miles: Direction:
City: State:

Client Rep: ______________________
(Person who receives **Results** by: Fax ___ Mail ___ Email ___)
Address:
City: State: Zip:
Phone: Fax:
Email:

Your Sample ID (ex: Smith 01)						
Date Collected						
ANIMAL ATTRIBUTES	**Example**					
Profile Name	Mama Cows					
Breedtype	Herefrd x Brah					
% Bos indicus (tropical)	50					
% British or Contential	50					
% Dual Purpose	0					
% Dairy	0					
Class	cow					
Age (mo only)	60-95					
Number of Head	125					
Pregnancy (days)	0					
Lactation (days)	45					
Current offspring weight (lb)	125					
BCS of dam at parturition	5					
Offspring age (mo)/wgt at weaning	500 lb/ 210 d					
Internal parasite load (H, M, L-N)	Low					
External parasite load (H, M, L-N)	Low					
Current body weight	1000					
Current body condition score	4.5					
Impant Used ?	no					
Desired avg daily gain/loss (lb/d)	0					

FEEDS and METABOLIC MODIFERS FED	**Example**					
Name of feed	XR2 Breeder					
Type of feed (liquid, cube, tub, block, loose)	cube					
Amount allocated (lb/head/day)	1					
Crude protein on tag (% as fed basis)	20					
TDN on tag or lot number (% as fed basis)	72					
Ash on tag or lot number (% as fed basis)	5					
Moisture content (tag or lot #) (% as fed basis)	8					
Cost per ton from dealer ($/ton)	150					
Wastage from storage to consumption (%)	3					
Storage cost of feed	none					
Processing cost of feed	none					
Cost of labor, equipment per ton to feed	5					
Metabolic modifier name in feed (if any)	Growfast					
Feed tag enclosed with sample?	yes					
Estimated rumen degradability of feed (% of CP)	?					
Phosphorus content of feed (%)	0.25					

FORAGE/ENVIRONMENTAL CONDITIONS	**Example**	
Vegetation type	Native Range	
Slope greater/less than 15% where grazed?	less	
Is water well distributed in pasture?	yes	
Past 30 day average high temperature (F)	75	
Past 30 day average low temperature (F)	50	
Past 30 day average humidity (%)	40	
3-5 day Current average high temperature (F)	85	
3-5 day Current average low temperature (F)	65	
3-5 day Current average humidity (%)	30	
3-5 day Current average windspeed (mph)	10	
Sunlight exposure per day (hours)	10	
Coat condition (Dry, Muddy, etc…)	Dry	
Size of paddock or effective grazing area (ac)	1000 ac	
Expected days in grazing area	90	
Estimated available forage standing crop (lb/ac)	2000 lb/a	
Forage growth rate (lb/ac/d) 5, 15, 30 (L,M,H)	5	
Non-grazable standing crop (lb/ac)	100	

Comments:

Lab use only unless contract # is known

Gan Lab #	
Date Received:	
Client # :	
Contract # :	
NIR file name:	
Date Reported:	
Results	
CP	
DOM	
FN	
FP	
DIP	
DUP	

Appendix G

Rangeland / Pasture Utilization Estimate – Key Forage Plant Method

RANGELAND / PASTURE UTILIZATION ESTIMATE (Stubble Height) - KEY FORAGE PLANT METHOD				
Client:			Mgt. Unit:	
Forage Suitability Group or Eco Site & Condition:			Response Unit:	
Transect Location:			Examiner:	
Season of Use:			Date:	
Soil Moisture or Plant Growth:			Key Species:	
Stubble Height	Factor (a)	Tally (checks or marks)	Grazed Plants (b)	Current Use (b)x(a)
1"	1			
2"	2			
3"	3			
4"	4			
5"	5			
6"	6			
7"	7			
8"	8			
		TOTALS -->	(c)	(d)
		AVERAGE STUBBLE HEIGHT	(d)/(c) -->	
Notes:				

The Utilization estimate will give you a quick look at how your most important plants in each pasture were used, season of grazing use, and relative amount of soil moisture or plant growth for the year.

At the top of the form enter the **Client**, **Soil**, **Pasture Condition** (indicate excellent, good, fair, or poor), **Management Unit**, **Response Unit**, and **Examiner**. For **Season of Use**; indicate the season (or seasons) that grazing occurred. To the right, enter the **Date** the estimate was conducted. Circle the appropriate amount of **Soil Moisture or Plant Growth** apparent during the grazing season. To the right, enter the **Key Species** to be evaluated for each Key Species.

Checking Utilization:

Check utilization just after the last grazing event in the pasture. Begin by selecting a key area. A good key area is one that doesn't get too much or too little grazing pressure. Stay away from water, gates, trails, and other areas of more frequent use (about 1/4 mile). Avoid inaccessible areas or areas of little or no use also. Pick a spot you can come back to each time you check utilization.

It will be very helpful to develop a photo point at the key site. Drive a metal post so you can go back to the same spot. Take pictures of the pasture at the four compass points (north, east, south, and west) and one at the ground at the post. The photographic information will be valuable in comparing pastures, annual growth, and variations in utilization.

Begin a step transect by walking in one direction from the post. Take two steps; at the second step, stop, and estimate which stubble height is apparent for the key species nearest your foot. Enter a check or hash mark in the **Tally (checks or marks)** blank on the form in the row that represents the **Stubble height** of the plant (1" through 10"). Continue walking and entering the stubble height of key species at each second step until you have examined at least 100 points. Unless utilization is extremely even you will have checks or marks in several rows of the form.

Appendix G – continued

When the step transect is completed, calculate utilization by adding the checks or marks for each stubble height and enter the result in the **Grazed Plants** column (b). Multiply the **Factor** numbers (a) by the **Grazed Plants** number (b) and enter in the **Current Use** column. Total both the Grazed Plants and Current Use columns and enter the result in the blocks marked **(c)** and **(d)**. The estimated percent utilization of the key species is obtained by dividing the number in (d) by the number in (c). Enter this number in the lower right block on the form.

Example

RANGELAND / PASTURE UTILIZATION ESTIMATE (Stubble Height) - KEY FORAGE PLANT METHOD				
Client:		Testcase	Mgt. Unit:	#8
Forage Suitability Group or Eco Site & Condition:		Wet Meadow - FAIR	Response Unit:	
Transect Location:		300' west of SW gate	Examiner:	JPR
Season of Use:		Summer/fall	Date:	9/1
Soil Moisture or Plant Growth:		adequate - normal precip.	Key Species:	Orchardgrass
Stubble Height	Factor (a)	Tally (checks or marks)	Grazed Plants (b)	Current Use (b)x(a)
1"	1	xxxxx xxxxx xx	12	12
2"	2	xxxxx xxxxx xxxxx xxxxx xxxxx xxxxx xxxxx xxxxx xxxxx x	46	92
3"	3	xxxxx xxxxx xxxxx xxxxx xxxxx	25	75
4"	4	xxxxx xxxxx xxxxx xxxxx	20	80
5"	5	xxxxx xxxxx xx	12	60
6"	6	xxxxx	5	30
7"	7		0	0
8"	8		0	0
		TOTALS (C & D) -->	120	349
		AVERAGE STUBBLE HEIGHT	(d)/(c) -->	3
Notes:				

Appendix 1

Final Wood River Conservation Effects Assessment Project Report

Part 2

Natural Resources Conservation Service
West National Technology Support Center
1201 NE Lloyd Boulevard, Suite 1000
Portland, OR 97232

Jeffrey P. Repp *CPRM (CP01-430)*
Rangeland Management Specialist
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2007-2008 Exclosure Clipping Study Results
Wood River Special Emphasis CEAP Watershed, Upper Klamath Basin, Oregon

Introduction

The Wood River Rangeland Vegetation Monitoring CEAP project sought to quantify changes to a highly productive wet meadow rangeland ecological site that has received supplemental irrigation water for several decades. The area is an important resource for raising stocker cattle in the summer (a few herds of cow-calf pairs are present also). The natural hydrology of the valley has been changed by supplemental irrigation, diking, ditching, and drainage of wetlands. Recent efforts to assist threatened and endangered anadromous fish stocks and suckers in the Klamath River system included the temporary cessation of irrigation on these lands to allow more flow to reach the upper river for increased fish survival. If irrigation water was not available or limited to supply these pastures, what would be the short-term consequences to pasture plant composition, productivity, nutrient quality, and finally stocking rates?

One of the objectives of the Wood River Rangeland Vegetation Monitoring CEAP project was to "Determine changes to sustainable stocking rates between irrigated and non-irrigated rangelands". To accomplish this, annual air-dry productivity and the monthly accumulation of peak standing crop needs to be determined for each type. Stocking rates can then be determined (annual and incremental) for increased utility in making sound irrigation and grazing management decisions. This report will summarize the efforts to determine irrigated and non-irrigated annual productivity, develop growth curves (monthly and accumulated growth as peak standing crop), and stocking rates at commonly used levels of harvest (harvest efficiencies of 25-35% of available standing crop).

Semi-permanent plots were set up in the Wood River valley in 2006 on several participating cooperators to measure plant, soil, and groundwater changes between irrigated and non-irrigated rangeland (18 on irrigated pastures and 18 on non-irrigated pastures; read in 2007 and 2008). The entire area is mapped to one map unit and correlated to a common ecological site description, although management levels and stocking rates were not similar between land ownerships (see *Table 4*). One of the measurements made at the plots in 2007 was annual productivity (reconstructed annual air-dry lbs/acre). Plots were clustered in irrigated and non-irrigated groups that had similar land ownership, plant community, condition, and management.

In addition, 12 initial and 2 subsequent exclosures were established to provide an estimate of monthly peak standing crop and regrowth of the different areas of the study to examine productivity and regrowth potential differences between irrigated and non-irrigated pastures, develop characteristic growth curves, and determine appropriate stocking rates (AUMs/acre). The exclosure clipping could also be compared to the production sampling conducted at each plot as an extra measure of accuracy in determining annual production.

Methods

Plots

Annual reconstructed air-dry production was measured one time (2007) on the semi-permanent vegetation plots. The 36 plots were divided between the two types of water regimes present (irrigated or non-irrigated). They were read each year over the two years of the study (there are two transects per plot for a total of 72 transects). Since the majority of the upper valley is composed of one soil map unit and one ecological site, all plots are located on a single ecological site. The valley has significantly more of the Kirk-Chock Association than any other soil type (map unit 33, correlated to the Wet Meadow 14-40 PZ site). The Lather Muck soils in the lowest areas of the valley (southern end of the valley) are frequently inundated early in the season and wet throughout the year and are less likely to exhibit changes in vegetation over the course of the project. These soils were avoided in setting up plot locations.

Wherever possible, the plots were located away from fences, gates, irrigation ditches, livestock watering sources, and heavy use areas. Plots were located as close as possible to existing piezometer sites. One non-irrigated and one irrigated plot are located in Wetland Reserve acreages and receive no livestock grazing. All plots were read within a 4-week period each year after peak growth (late June – July).

Non-irrigated plots exhibit slight differences in transformation from irrigated rangelands to more normal hydrologic conditions. Funding was provided via a variety of programs to offset the cost of not irrigating (generally based on assumed, but not quantified, decreases in productivity and available forage amounts). Different land units entered into the agreements at different times. Table 1, below shows when the non-irrigated plots had irrigation water removed and how many seasons they have been non-irrigated (including the 2006 season).

Table 1. **Non-Irrigated Vegetation Monitoring Plot Stratification**

	Year Irrigation Ended				
Group/Plot Numbers	**2002**	**2003**	**2004**	**2005**	**Years (through 2008)**
3N08,3N09,4N15, 4N16, 4N17				✓	4
6N10, 6N11, 6N12			✓		5
5N13, 5N14,5N18		✓			6
1N01, 1N02, 1N03, 2N04, 2N05, 2N06, 2N07	✓				7

Irrigated and non-irrigated plots are grouped by geographic location and land ownership and management for evaluation. Each group contains between two and four plots that exhibit similar response. Non-irrigated plots are also grouped by length of time since they were regularly irrigated (*Table 2*). Each group had an exclosure for determining growth curve and to add to production capability determinations (see Appendix D for plot group and exclosure locations).

Table 2. **Vegetation Monitoring Plot Stratification**

Non-Irrigated			Irrigated		
Group	**Plots**	**Exclosure**	**Group**	**Plots**	**Exclosure**
1N	1,2,3	NEx01	1I	1,2	IEx03*
2N	4,5,6,7	NEx02	2I	3,4,5,6	2I*
3N	8,9	NEx04	3I	7,8,9,10	IEx09
4N	15,16,17	NEx08	4I	13,14,15,16	IEx11
5N	13,14,18	NEx05	5I	11.12	IEx10
6N	10,11,12	NEx06	6I	17,18	6I

* Exclosures IEx03 and 2I were moved (new exclosures were added) in 2008: the original locations were also clipped in 2008 (but were in less desirable positions).

Exclosures

Increased accuracy of production can be measured by clipping plant communities monthly to determine both a growth curve and productivity. The addition of localized growth curves can increase the precision and accuracy of reconstruction of annual above-ground growth for the plots. Simple Exclosures were set up on the ecological site with and without irrigation resulting in growth curves (showing monthly percentage of growth and accumulated percent growth) for each water regime (2 curves). An example growth curve is shown (estimated for Wet Meadow site in spring, 2004). The bars represent monthly growth (left Y axis) and the line is accumulated growth (right Y axis). Differences in growth accumulation across the valley can be determined for the project period.

Twelve (initial and two subsequent) exclosures were established from readily available materials (wire panels and metal or wooden posts; 8' x 8'). Exclosures were large enough to allow clipping of 1.92 ft^2 subplots each month (enough room for at least nine subplots). Exclosures are placed along existing fence lines within plot groups and represent the vegetation expressed in the plots (see Appendix B for exclosure design). Operators generally objected to exclosures constructed in the center of the pastures, where they would represent the condition of the plant community better, but would present undesirable obstacles, so they were built along fences in the best observable locations. Each month a new subplot is clipped for peak standing crop and beginning the second month, previously clipped subplots were re-clipped to determine regrowth weight and if there is an associative effect of grazing on overall productivity for these plant communities (compensatory growth).

Annual Productivity (Double Sampling in Plots)

Annual productivity (all above ground air-dry plant production during a single growing year) was measured in 2007 at each of the 18 irrigated and 18 non-irrigated point data collection plots using a double sampling method. Annual air-dry weights were determined by using reconstruction factors and by determining percent air-dry weight (by clipping and weighing green and subsequently air-dried samples). Reconstruction factors are estimated in the field and include air-dry percentage, percent growth completed (by species), percent of clipped subplot ungrazed (if grazed at all), and percent of "normal" precipitation/temperature regime for the year. Ten subplots (2 clipped and all 10 estimated by weight units) located along the two transects were read at each plot (June/July). The procedure reference is in the USDA-ARS Monitoring Manual, Volume II; Chapter 9 (pages 51-56). The procedure design is displayed in Appendix A. Exclosure locations are shown in Appendix D.

Growth Curves (Clipping in Exclosures)

Peak standing crop was clipped each month from April to October in 2007 and May to October in 2008 (climate conditions were too cold for appreciable growth in April and field conditions were too snowy and wet for effective clipping). The exclosures were large enough to accommodate the seven 1.92 ft^2 circular hoop subplots. For accumulated peak standing crop, an unclipped subplot was clipped each month. The fresh, green plant material was weighed with a gram scale (the amount of grams is multiplied by the conversion factor of 50 for lbs/acre) and placed in a paper bag. The bags were allowed to air-dry for approximately 72 hours at room temperature (at KBRT headquarters) and re-weighed to determine percent air-dry of the green plant material. Monthly and re-clipped average weights for 2007 and 2008 irrigated and non-irrigated exclosures are shown in Appendix C.

Growth curves were developed using both the monthly peak standing crop and re-clipped weights. Averages of irrigated and non-irrigated exclosures of peak standing crop and re-clipped weights for both years (2007-2008) were used to develop growth curves. Growth curves were developed for each of the exclosures but due to differences in plant community composition, irrigation frequency and application depth, and grazing management, there was no clear pattern to the curves. Monthly clipped weights were added to re-clipped weights for both years to determine a histogram of monthly peak standing crop. From this the accumulated weight was calculated: the charts in this document have the monthly histogram corresponding to the 1st Y axis (left) and the accumulated line corresponding to the 2nd Y axis (right). The tabular and graphic data is displayed in the results section for irrigated and non-irrigated exclosures.

Stocking Rates (AUMs/Acre)

Stocking rates were calculated according to procedures in the 2003 NRCS National Range and Pasture Handbook (Chapter 5, section 3, part 600.0509, (C) (1): Usable Production Method). Generally the determination is made using air-dry production (annual or incremental) and applying a harvest efficiency. Harvest efficiency is the total percent of vegetation ingested by a grazing animal compared to the total amount of vegetation grown in the area in a given year. Harvest efficiencies of 20%, 30%, and 40% were selected as representative of the grazing pressure present in the Wood River Valley. Harvest efficiencies of 25 to 35% are considered appropriate for these types of ecological sites. The tabular and graphic data is displayed in the results section for irrigated and non-irrigated exclosures. Stocking rate calculations and an example are shown in Figure 1.

Figure 1. *Stocking Rate Calculations*

$$\frac{\text{Annual Air-Dry lbs/acre * Harvest Efficiency}}{\text{912.5 lbs/AUM}} = \text{Stocking Rate AUMS/Acre}$$

Example: 2650 lbs/acre annual air-dry production at 30% harvest

$$\frac{\text{2560 lbs/acre * 0.30}}{\text{912.5 lbs/AUM}} = \text{0.87 AUMS/Acre}$$

For comparison between irrigated and non-irrigated pastures, the stocking rates were calculated with exclosure data (monthly peak standing crop and added re-clip weights) at 20%, 30% and 40% harvest efficiencies. Stocking rates in AUMs per acre were calculated for each month (AUMs produced during the month) and the accumulated AUMs during the growing season. The accumulation of AUMs is useful for designing grazing prescriptions: animal numbers can be balanced with available forage present in the unit when the grazing period begins. This approach allows managers to avoid overuse of plants before there is adequate growth and to insure the protection of soil and water resources. They can also predict the subsequent growth of forage from any point within the growing season. The annual stocking rate is not available until the end of the growing season and is used primarily for coarse forage/livestock balance analysis.

Results

Climate 2005 – 2008

Annual precipitation has a direct effect on the amount of above-ground productivity (George, et. al., 1989, Mohamed et. al., 2004). Figure 2, below, shows monthly precipitation (inches) and temperature (degrees F) for 2005 through 2008 for the nearest weather station at Chiloquin, Oregon (USDC-NOAA, WRCC Remote Automated Weather Station data: http://www.raws.dri.edu/wraws/orF.html). The average temperature pattern is consistent throughout the four year period with high and low patterns, progressions, and temperatures similar through the years. Average precipitation is not as consistent for the period. 2005 had peaks of precipitation in May and December whereas the 2006 growing season had decreasing precipitation through June and did not increase until October. The study years of 2007 and 2008 were different still. 2007 had adequate winter precipitation followed by a relatively wet growing season with 0.5 to just over 2.0 inches per month (April – September) with peaks in April and October. 2008 had even less winter precipitation followed by adequate spring moisture (0.5 to >2.0 inches April and May). Subsequent months had almost no precipitation until October and November. Current year's precipitation only accounts for some of the change in productivity; previous year's have a significant impact. Productivity is buffered if wet years and dry years alternate and fluctuations are amplified if there are series of either wet or dry years (Oesterheld et. al., 2001)

This variability in precipitation is reflected in the growth curve calculations. Appendix C shows 2007 and 2008 growth curves for irrigated and non-irrigated exclosures. The accumulation and distribution of growth is quite different between the years. Table 3 shows clipped peak standing crop from irrigated and non-irrigated exclosures from 2007 and 2008. The precipitation patterns are expressed in the monthly clipping weight estimates. Total precipitation for the years decreased 36% from 2005 to 2008 (2005: 22.2", 2006: 18.7", 2007: 17.0" and 2008: 14.4"). In 2007 both irrigated and non-irrigated exclosures experienced a decrease in standing crop in September. It is uncertain why so much senescence occurred: August and September had some precipitation but the erratic pattern previous to August may have had an effect. Possible too is that the accumulation of high elevation snowpack was smaller so late season water supplies were limited. Ground water tables on non-irrigated sites lowered below the effective rooting depth (about 36") during August and September. Water tables on irrigated sites lowered as well but generally stayed within the effective rooting depth of the forage plants. Consumption of plant materials in the exclosures by rodents and/or insects may also have caused the decrease.

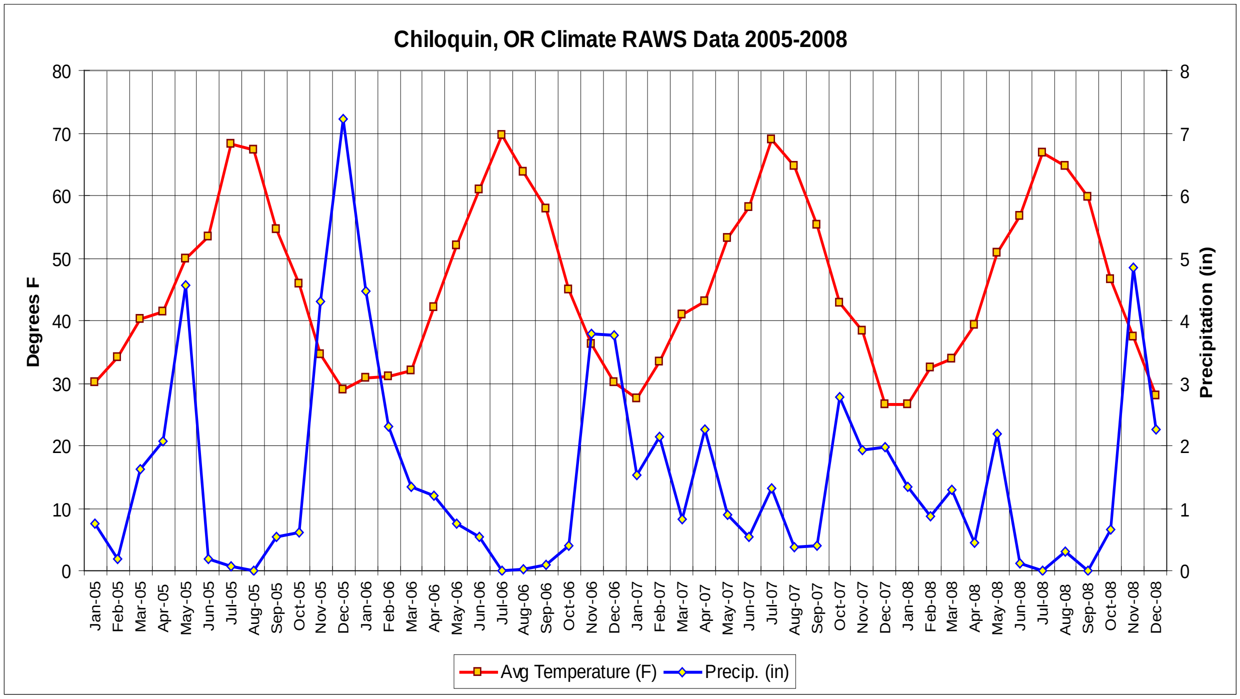


Figure 2. *USDC-NOAA, Western Regional Climate Center Remote Automated Weather Station climate (precipitation and temperature) data for Chiloquin, OR 2005-2008*

The situation was even more severe in 2008: the low (64% of 2005 precipitation) annual precipitation included a lower snow pack, a single spike in May and low precipitation June through October resulted in more decreases in monthly peak standing crop. Non-irrigated exclosures showed negative growth (senescence) in June, August, and September while irrigated exclosures had had negative growth in June, August, and October; growth was very low in September as well (75.8 lbs/acre). Cumulative growth was much less for irrigated and non-irrigated exclosures in 2008 compared with 2007 (cumulative October values). *Note*: In April 2008 the pastures were too cold and wet to show much growth and exclosure clipping could not be completed. The May peak standing crop amounts may appear too large, however, they include growth that occurred in late April before the field crew began their work.

Table 3. **2007-2008 Peak Standing Crop from Exclosures (lbs/acre)**

	Apr	May	Jun	Jul	Aug	Sep	Oct
Irrigated Exclosures - 2007							
Monthly	1643.3	1366.7	1737.5	657.5	1982.5	-1147.5	1707.5
Cumulative	1643.3	3010.0	4747.5	5405.0	7387.5	6240.0	7947.5
Non-Irrigated Exclosures - 2007							
Monthly	1868.3	985.0	1464.2	60.8	1114.2	-898.3	1607.5
Cumulative	1868.3	2853.3	4317.5	4378.3	5492.5	4594.2	6201.7
Irrigated Exclosures - 2008							
Monthly	n/a	5764.2	-1947.5	1590.0	-405.0	75.8	-785.0
Cumulative	n/a	5764.2	3816.7	5406.7	5001.7	5077.5	4292.5
Non-Irrigated Exclosures - 2008							
Monthly	n/a	4640.8	-147.5	528.3	-310.8	-692.5	586.7
Cumulative	n/a	4640.8	4493.3	5021.7	4710.8	4018.3	4605.0

Plot Clipping 2007

The 2007 plot clipping (double sampling) estimated annual air-dry above ground production. Clipping at the plots was not completed in 2008. Table 4 shows the production by plot for irrigated and non-irrigated plots. The numbers correspond to the groups of plots (1I-6I for irrigated or 1N-6N for non-irrigated). Plot locations are shown in Appendix D.

Table 4. **Air-dry annual production derived from double sampling**

2007 Irrigated Production Data*		2007 Non-Irrigated Production Data*	
Plot	**Lbs/Acre**	**Plot**	**Lbs/Acre**
1I-01	22922.7	**1N-01**	5937.61
1I-02	9909.4	**1N-02**	2873.02
2I-03	9591.6	**1N-03**	4067.85
2I-04	9453.7	**2N-04**	14556.11
2I-05	7153.0	**2N-05**	10254.13
2I-06	5771.4	**2N-06**	11978.92
3I-07	5598.8	**2N-07**	6248.15
3I-08	6849.7	**3N-08**	9961.83
3I-09	15783.8	**3N-09**	22051.92
3I-10	33145.3	**4N-15**	6321.57
4I-14	6277.4	**4N-16**	3882.51
4I-15	12121.8	**4N-17**	4961.68
4I-16	7576.6	**5N-13**	6552.74
5I-11	5032.8	**5N-14**	7619.5
5I-12	n/a	**5N-18**	6418.48
5I-13	7543.4	**6N-10**	10792.98
6I-17	n/a	**6N-11**	11666.45
6I-18	2226.1	**6N-12**	11267.92
Average	10434.8	**Average**	8745.2
Std Dev	7517.7	**Std Dev**	4533.5
Confidence (50%)	1267.7	**Confidence (50%)**	720.7
Stocking Rate Error (AUMs/Acre)	+/-0.42	**Stocking Rate Error (AUMs/Acre)**	+/-0.24
Confidence (75%)	2162.0	**Confidence (75%)**	1229.2
Stocking Rate Error (AUMs/Acre)	+/-0.71	**Stocking Rate Error (AUMs/Acre)**	+/-0.40

The plot clipping (double sampling) results show a large amount of variability from one pasture to the next. The averages here are only used to help calibrate the exclosure clipping for making generalizations about differences in stocking rates from irrigated and non-irrigated pastures. The confidence intervals show that at only 75% confidence that the stocking rates could be off by as much as +/-0.71 AUMs/acre for irrigated sites and +/-0.40 AUMs/acre for non-irrigated sites. These figures reiterate the need to develop meaningful stocking rates for each management unit with locally collected production data.

Actual Use Records 2005-2006

Actual use records (grazing records) are another useful way to define appropriate stocking rates. Data collected annually on the class, type, number, and weight of livestock grazed, pastures used, and length of time in each unit yields actual harvest (AUMs/acre) based on the animal type and their expected forage intake. Grazing records were collected in 2005 and 2006 from operators participating in programs to pay for loss of production due to the cessation of irrigation for three year periods. The actual use rates are shown in Table 5. 2005-2006 actual use ranged from 48% to 105% of 2007 estimated stocking rates (calculated by group from 2007 plot clipping data). The stocking rates may have been lower because of participation in the cost-share program that required lighter stocking along with payments to cease irrigation.

Table 5. **Stocking Rates by Group (2007 Production vs. 2005-06 Actual Use)**

Group	2007 Air-Dry lbs/ac	Harvest Efficiency	2007 Stocking Rates AUMs/ac	2005-06 Actual Use AUMs/ac	Percent of 2007 AUMs/ac
1N	4292.8	30%	1.41	1.48	105%
2N	10759.3	30%	3.54	2.17	61%
3N	16006.9	30%	5.26	2.01	38%
4N	5055.3	30%	1.66	1.74	104%
5N	6863.6	30%	2.26	1.77	78%
6N	11242.5	30%	3.70	1.77	48%
Averages	**9036.7**		**3.0**	**1.8**	**73%**

Growth Curves

Very little information is available on a reasonable method for determining site-specific growth curves from simple exclosure (or other) clipping that can be accomplished by technicians, managers, and practitioners. Additionally there has not been an adequate accounting for senescence of plant material during the growing season. The results of the peak standing crop clipping were surprising, in that there were months with apparent negative growth: in actuality this negative growth was a combination of within month growth (current clipped growth minus to-date accumulated growth) minus above-ground respiration, translocation belowground, death and detachment, and consumption (Lauenroth et. al., 1986, Milner and Hughes, 1968, Singh et. al., 1975). In the exclosures, the consumption component was not identified but could have been the result of insect or small rodent activity. There may be a situation within the exclosures that does not occur in the pastures. The addition of water to the system and the relatively frequent defoliation of plants may retard reproduction (by removing reproductive shoots and stimulating growth) and delay senescence. Plants in the exclosures have the ability to mobilize nutrients and materials into reproductive organs (which are detached from the plant by September) and may actually experience more reduction in weight than plants outside the exclosure (Leopold, 1961). These effects may have been exacerbated in the non-irrigated exclosures compared to the irrigated exclosures.

Rationale: The tabular (Tables 6 and 7) and graphic data (Figures 3 and 4) that follows shows the growth curve calculations for 2007 and 2008 irrigated and non-irrigated averages based on *monthly peak standing crop clipping and re-clipping combined*. Monthly clipping of a new subplot each month was intended to capture accumulated growth. A subsequent month's clipping would thereby contain all of the previously accumulated weight. Re-clipping each month captured additional growth that may not have been captured in the monthly clippings. Adding these two amounts is a common way of arriving at modeling growth curves (Gale Dunn, ARS, personal communication).

Monthly peak standing crop and monthly regrowth were combined to more accurately estimate above-ground biomass on the sites. Growth curves created only from clipping of monthly peak standing crop inadequately described the total annual production of the pastures when compared to reconstructed plot clipping (double sampling from 2007) and did not account for periods where regrowth made up for senescence (see Appendix C). Average monthly peak standing crop weights are added to re-clipped weights to estimate the combination of monthly accumulation of biomass with regrowth (compensatory growth) following simulated monthly defoliations. Actual defoliation by grazing animals is likely quite different and more frequent but the monthly clipping of regrowth was a logistical compromise (clipping in the exclosure could not approximate the variety of frequency of forage removal by grazing animals across the groups). Optimal management scenarios would allow at least 21 days after grazing allowing adequate regrowth (this could be slightly shorter during rapid growth and longer as growth rates decrease).

Clipped and re-clipped weights are averages of the two year's results. Each monthly weight as well as accumulated weight is displayed. The sum of monthly combined weight is compared to the 2007 (double sampling) plot weights as a check. The pounds per acre difference and the percent difference are calculated: Exclosure clipping of irrigated pastures was 11% greater than the average 2007 plot clipping data: non-irrigated exclosures were 9% greater than the average 2007 plot data. This comparison shows that clipping solely for peak standing crop monthly will underestimate annual above-ground productivity.

The graphs (Figures 3 and 4) show the monthly (left Y axis) and accumulated weights (right Y axis) of each of the treatments. These will be used to calculate incremental and annual stocking rates and can be used in the development of prescribed grazing (the Grazinglands Spatial Analysis Tool (GSAT), CGraze, and other software tools use growth curves to determine seasonality of stocking rates for selected herds and to create a forage/livestock balance. Clipping results by treatment and year are shown in Appendix C (peak standing crop and regrowth).

The resulting growth curves were revealing in that they did not fit the "classic" interpretation of monthly and accumulated growth (see the estimated growth curve under Methods – Exclosures). Accumulation of growth early in the season and the inclusion of senescence (loss of forage weight) later in the hottest, driest parts of the summer, offers new interpretations and different ways of thinking about when forage grows and how it accumulates. A major difference between irrigated and non-irrigated growth curves is the amount of plant material senescence (in 2007 and especially 2008) on the non-irrigated pastures (as expressed by the exclosure clipping). By September, non-irrigated pastures may experience a drop in the overall accumulation of forage (on average approximately 480 lbs/acre). Conversely, on the irrigated pastures, the application of water minimizes the forage loss during September but just barely (regrowth makes the September growth amount positive but only by approximately 27 lbs/acre). Irrigated pastures show an increased amount of growth in favorable conditions (May) that adds significantly to the total forage supply.

The differences in overall annual production are significant as well (about 11750 lbs/acre irrigated vs. 9650 lbs/acre non-irrigated: a 2100 lbs/acre or 21.8% difference). These observations are general though, and represent averages of sometimes divergent growth amounts and accumulation; however, they seem to fit observed growth patterns and do not provide contrary information to present livestock harvest and management.

Irrigated Group Exclosures

Table 6. **2007 & 2008 Wood River CEAP Irrigated Average Air-Dry weights (includes senescence: lbs/acre)**

	Apr	May	Jun	Jul	Aug	Sep	Oct	Totals	Plot Data*
Clipped	821.7	3565.4	(-105.0)	1123.8	788.8	(-535.8)	461.2	6120.0	**10434.8**
Re-clipped	n/a	1712.5	1064.6	1100.3	763.7	563.3	424.0	5628.4	**Difference**
Monthly	821.7	5277.9	959.6	2224.0	1552.4	27.5	885.3	**11748.4**	1313.6
Cumulative	821.7	6099.6	7059.2	9283.2	10835.6	10863.1	11748.4		**% Difference**
									11%

*** Production (double sampling with reconstruction) from 2007 plot data**

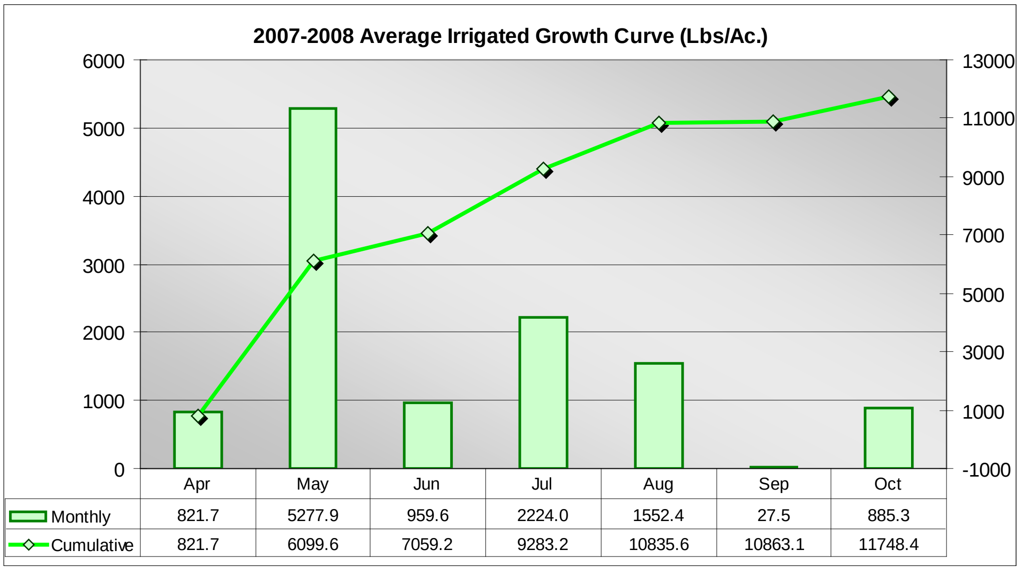


***Figure 3**. Average irrigated exclosure growth curve for 2007-2008 constructed from peak standing crop and regrowth from monthly clipping. The curve reflects rapid growth before June, sustained growth through August, senescence in September, and fall growth (October) before freeze-up in November.*

Non-Irrigated Group Exclosures

***Table 7.* 2007 & 2008 Wood River CEAP Non-Irrigated Average Air-Dry weights (includes senescence: lbs/acre)**

	Apr	May	Jun	Jul	Aug	Sep	Oct	Totals	Plot Data*
Clipped	934.2	2812.9	658.3	294.6	401.7	(-795.4)	1097.1	5403.3	**8745.2**
Re-clipped	n/a	1623.3	1085.8	502.3	400.3	313.0	317.2	4241.9	**Difference**
Monthly	934.2	4436.3	1744.2	796.8	802.0	(-482.4)	1414.3	**9645.3**	900.1
Cumulative	934.2	5370.4	7114.6	7911.4	8713.4	8231.0	9645.3		**% Difference**
									9%

*** Production (double sampling with reconstruction) from 2007 plot data**

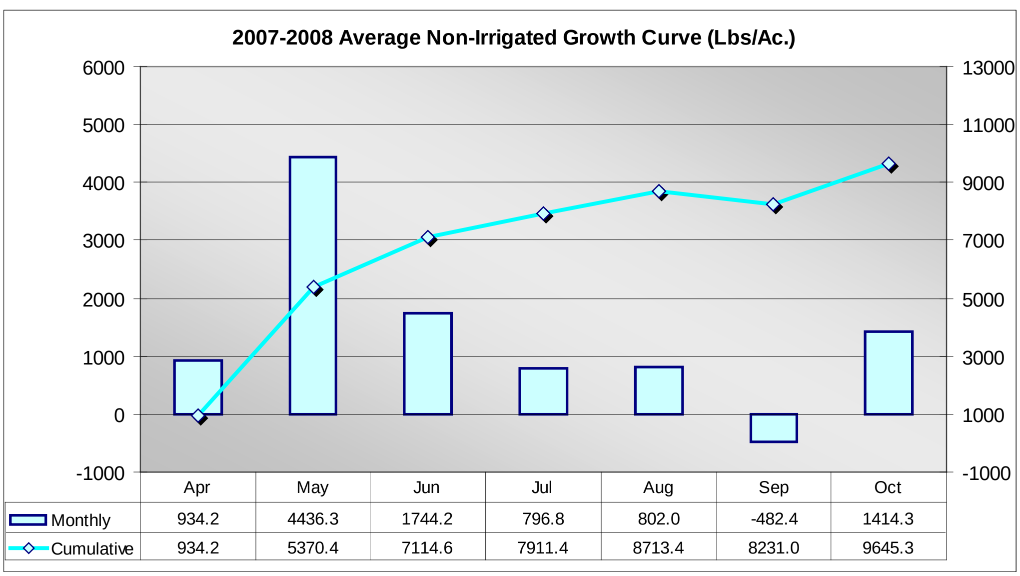


***Figure 4**. Average non- irrigated exclosure growth curve for 2007-2008 constructed from peak standing crop and added regrowth from monthly clipping. The curve reflects rapid growth before June, sustained growth through August, increased senescence in September, and fall growth (October) before freeze-up in November. Overall productivity is less than irrigated exclosures.*

Stocking Rates

Stocking rates in AUMs per acre were developed for each month of growth and for the accumulation of forage resource throughout the growing season using the averages of the two year's data from irrigated and non-irrigated exclosures (based on the average growth curves discussed previously). Stocking rates are calculated monthly and cumulatively to give managers a more accurate idea of the potential forage amounts available for any planned grazing period (see Figure 1). This supply of forage is ever changing throughout the year as forages grow senesce and regrow. The three harvest efficiencies were chosen as representative of forage harvest on these types of rangelands at light (20% of available forage present at time of grazing), moderate (30%), and heavy (40%).

The tabular (Tables 8 and 9) and graphic data (Figures 5 and 6) below show the average monthly and accumulated AUMs per acre (derived from the formula in Figure 1) for irrigated and non-irrigated sites. Stocking rates are shown for all three harvest efficiencies. The graph depicts the average accumulation of AUMs/acre throughout the growing season (2007 and 2008 data are combined and averaged).

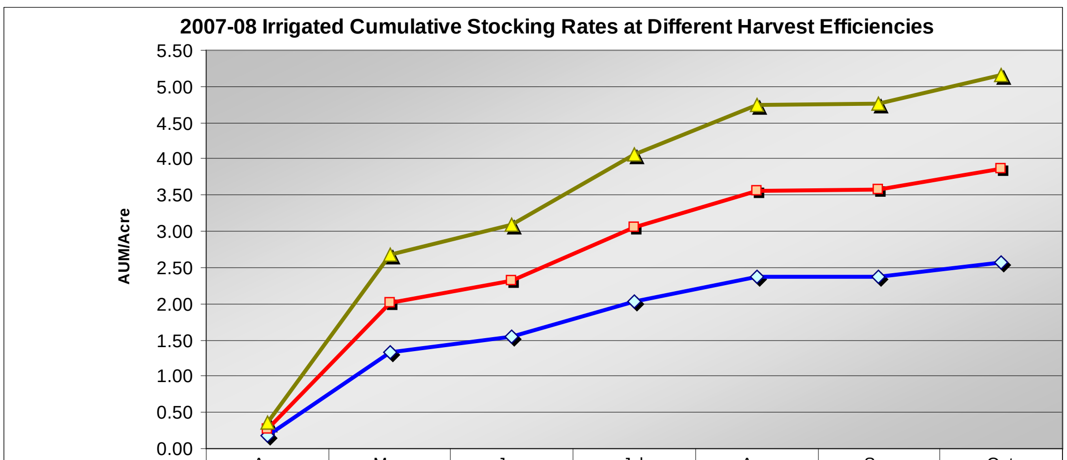
Irrigated

For irrigated exclosures, the accumulation of forage reaches 92.2% by August (Table 8): as with the growth curves, there is a rapid accumulation in the spring (steeper part of lines), a slower accumulation June through August, practically no growth in September, and a slight increase in October when rains return to the higher country around the valley and begin to recharge local water tables: late summer irrigations may also account for the increase. Total annual stocking rates are 2.6 AUMs/ac (20% HE), 3.9 (30% HE), and 5.2 (40% HE).

Table 8. **2007 & 2008 Wood River CEAP Irrigated Average Stocking Rates (AUMs/Acre)***

Month	Monthly lbs.	Monthly (20% HE)	Monthly (30% HE)	Monthly (40% HE)	Cumulative lbs.	Percent
Apr	821.7	0.180	0.270	0.360	821.7	7.0%
May	5277.9	1.157	1.735	2.314	6099.6	51.9%
Jun	959.6	0.210	0.315	0.421	7059.2	60.1%
Jul	2224.0	0.487	0.731	0.975	9283.2	79.0%
Aug	1552.4	0.340	0.510	0.681	10835.6	92.2%
Sep	27.5	0.006	0.009	0.012	10863.1	92.5%
Oct	885.3	0.194	0.291	0.388	11748.4	100.0%
Totals	**11748.4**	**2.57**	**3.86**	**5.15**		

*** Harvest efficiencies represent 20, 30 & 40 % of available forage consumed by the grazing animal.**



	Apr	May	Jun	Jul	Aug	Sep	Oct
Light (20% HE)	0.180	1.337	1.547	2.035	2.375	2.381	2.575
Moderate (30% HE)	0.270	2.005	2.321	3.052	3.562	3.571	3.862
Heavy (40% HE)	0.360	2.674	3.094	4.069	4.750	4.762	5.150

Figure 5. Average irrigated stocking rate accumulation based on exclosure growth curve for 2007-2008. The 30% harvest efficiency represents the recommended allowable harvest amount for most management. Units needing rehabilitation could graze at the 25% rate and more intensive management systems on healthy, resilient sites could use the 40% harvest efficiency.

Non-Irrigated

For non-irrigated exclosures, the accumulation of forage reaches 90.3% by August: as with the growth curves, there is a rapid accumulation in the spring (steeper part of lines), a slower accumulation June through August, a decrease in forage amount growth in September (-482.4 lbs/acre; about a 5% decrease), and a significant increase in October when rains return to the higher country around the valley and begin to recharge local water tables. In some cases, the increase in irrigation water for neighboring ranches may recharge the water tables in the non-irrigated sites, increasing growth in October. Total annual stocking rates are lower than irrigated 2.1 AUMs/ac (20% HE), 3.2 (30% HE), and 4.3 (40% HE).

Table 9. **2007 & 2008 Wood River Non-Irrigated Average Stocking Rates (AUMs/Acre)***

Month	Monthly lbs.	Monthly (20% HE)	Monthly (30% HE)	Monthly (40% HE)	Cumulative lbs.	Percent
Apr	934.2	0.205	0.307	0.409	934.2	9.7%
May	4436.3	0.972	1.458	1.945	5370.4	55.7%
Jun	1744.2	0.382	0.573	0.765	7114.6	73.8%
Jul	796.8	0.175	0.262	0.349	7911.4	82.0%
Aug	802.0	0.176	0.264	0.352	8713.4	90.3%
Sep	-482.4	-0.106	-0.159	-0.211	8231.0	85.3%
Oct	1414.3	0.310	0.465	0.620	9645.3	100.0%
Totals	**9645.3**	**2.11**	**3.17**	**4.23**		

*** Harvest efficiencies represent 20, 30 & 40 % of available forage consumed by the grazing animal.**

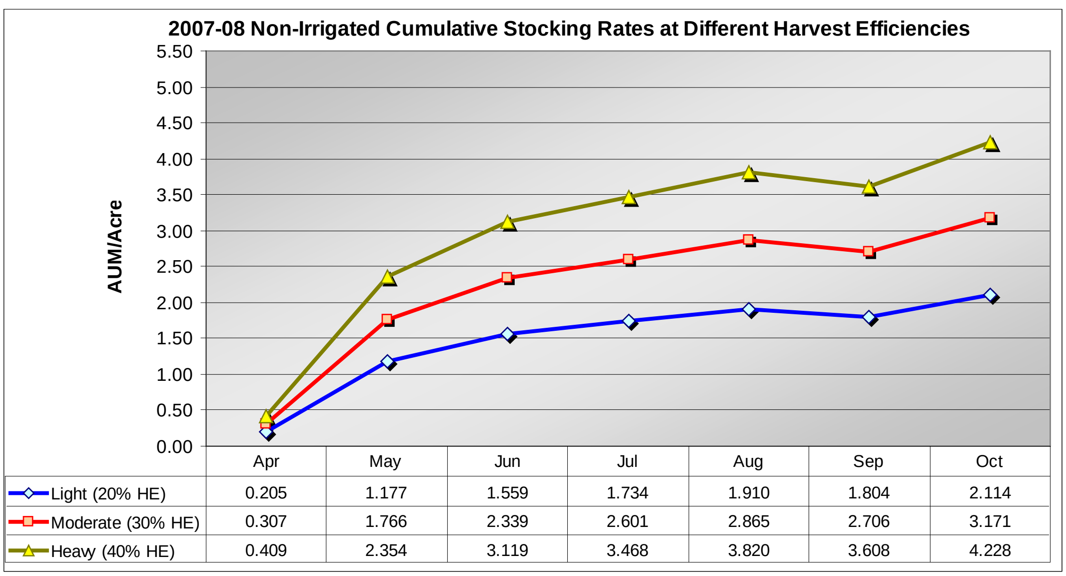


Figure 6. Average non- irrigated stocking rate accumulation based on exclosure growth curve for 2007-2008. The 30% harvest efficiency represents the recommended allowable harvest amount for most management. Units needing rehabilitation could graze at the 25% rate and more intensive management systems on healthy, resilient sites could use the 40% harvest efficiency. The Y axis scale is the same as the irrigated stocking rate graph to show overall decrease in productive capability.

Recommendations

Deriving growth curves by itself is a difficult endeavor. Used in ecological site descriptions (ESIS-ESD) and automated tools for prescribed grazing, the curves give planners and grazing managers a functional tool for determining seasonality of forage supply as well as total annual yield in order to properly balance animal demand with expected supply and avoid resource extension and damage. There is also no widely used or recommended functional approach for measuring growth and yield from which stocking rates can be developed. Many efforts (excluding research-based growth analysis and modeling) to develop growth curves are based on sampling peak standing crop over a repeated time period. This approach in the Wood River Valley resulted in growth curves with monthly *negative* growth where an expected increase in the annual accumulation of forage was measured to decrease in weight (see Appendix C).

1. Two years of clipping data is marginal in determining trends and patterns in plant community growth and response to climatic fluctuations. Neither 2007 nor 2008 represented a "normal" distribution of precipitation for the area with 2008 being especially dry.
2. The exclosure clipping was variable within treatments. There was only one exclosure per group so no trends can be inferred by individual exclosure results. Differences in management and original condition and composition of the plant communities gave different growth, regrowth, and annual productivity.
3. The growth curves and stocking rates are only guides to determining proper stocking of the range: they need to be compared to actual use records and tied to local monitoring to insure that soil site stability, hydrologic function, and biotic integrity are not adversely affected by the selected grazing pressure.
4. Differences in irrigated and non-irrigated sites are time-dependent: the longer a site has not been irrigated, the more the plant community functional groups may change, influencing yields and growth patterns. Similarly, irrigated sites have a wide range of irrigation water applications, frequency, and grazing patterns that influence growth and yield (several managers graze livestock while the fields are being irrigated resulting in areas of unused forage and soil compaction – loafing/ruminating areas that are slightly higher and drier are sometimes severely used).
5. Since there was significant variability between exclosures, only averages of all exclosures within a treatment over both years are used, as such, they represent observed/measured trend over the years of the study. They may mirror longer-term trends though.
6. There are differences in production and stocking rates that have implications for managing livestock. There was an 18% difference between irrigated and non-irrigated exclosures (2103 lbs/acre or 0.7 AUMs/acre at the 30% harvest efficiency).

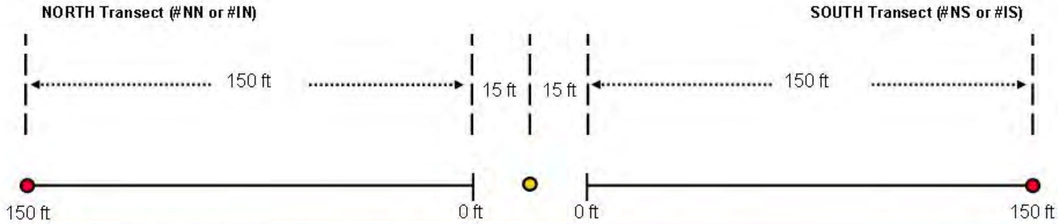
In conclusion, there were measured differences (on average) between the irrigated and non-irrigated sites. Annual productivity was different enough (18%) to warrant different stocking and management on the sites. Non-irrigated sites have a more critical period of non-growth/senescence in the late summer that can lead to resource damage if grazing is not carefully managed. Differences in irrigation frequencies and water applications, in concert with grazing management affect growth, regrowth, and productivity on irrigated sites. Soil compaction (from animal hoof action on wet soils), loss of desirable vegetation (from overgrazing and species replacement), and changes in plant functional groups (continually low, wet areas promote growth of coarse sedges and other obligates that have low palatability) have been observed on these sites.

In lieu of these results a few management recommendations are evident:

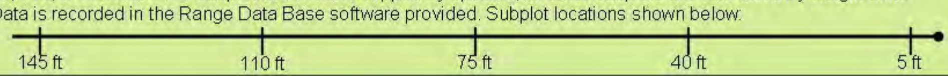
- Adjust stocking rates at each individual ownership and management unit (fenced pasture). The exclosures and plot double sampling can be used for these site-specific adjustments.
- Use growth curves and stocking rates to develop grazing prescriptions for each ownership and management unit. Each management unit can be grazed to a desired harvest level and rested to allow regrowth before the next grazing period.
- For all management units, balance forage supply with animal demand (use 25% or 30% harvest efficiencies as initial rates, depending on management level and condition/health/trend of pastures).

- Include contingency plans for adjusting stocking for drought years (in general a contingency plan may be triggered when the previous year's precipitation was low and the current year is also appearing to be deficient).
- For irrigated management units, integrate irrigation with grazing periods; avoid grazing livestock when the field is being irrigated and allow a period of time for plants to take advantage of watering to produce leaf area to become more resistant to grazing.
- Develop appropriate monitoring: at least photo points are necessary to observe changes in plant community with the application of management. Other monitoring can address specific questions at each management unit (i.e.: amount of bare ground, increases/decreases in type or species of plants, etc.).
- Keep accurate grazing records that include management unit, animal numbers, kinds, and types, and dates in and out. This will allow calculation of AUMs actually used by management unit. Compare actual use with visual observation of management units and other forms of monitoring data to adjust rates as necessary each year.

Appendix A: Annual Production Design (double sampling)

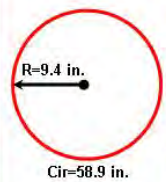


Plant Production: Each 150 foot transect contains five subplots of 1.92 ft^2 area at the following locations: 5, 40, 75, 110, & 145 feet. The subplot at 75 feet is clipped by species, all other subplots are estimated by weight units. Data is recorded in the Range Data Base software provided. Subplot locations shown below.



Hoop Size	Radius (in)	Circumference (in)	Circumference (ft)	Conversion factor
1.92	9.4	58.9	4.9	50

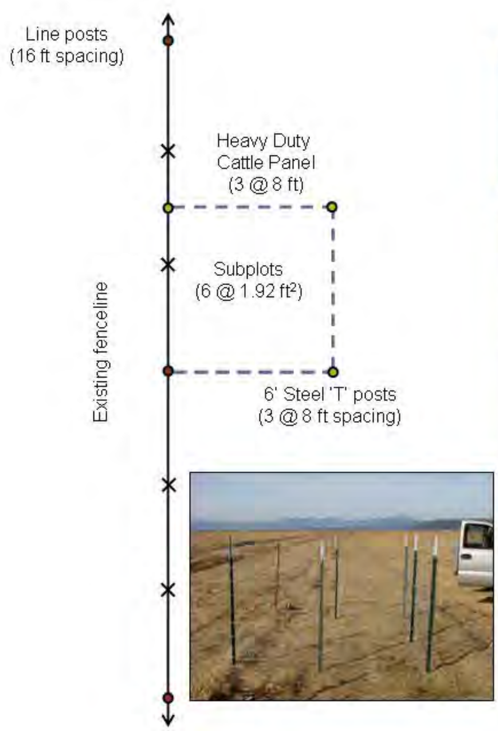
Harvest all current year's growth by species. Weigh grams of each species and multiply by the conversion factor (50) to get lbs./acre green weight. Determine reconstructed annual air-dry weight using reconstruction factors [% air-dry weight, % ungrazed, % growth complete, & % of normal climate].



Plant Production Calculations **[Range Database]**

- ❑ **Plant Species Total Weight (lbs/ac)** = (total wt units * wt unit wt * plot size CF * % air-dry wt. * clip/est. CF)/(utilization adj * number of sub-plots * % growth * % normal climate)
- ❑ **Total Production (lbs/ac)** = sum of species total weights

Appendix B: Exclosure Design

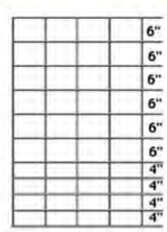


Exclosures are defined by three 8" cattle panels attached (wired) to 6 ft steel 'T' posts. A line post on the existing fence is used as the forth side of the exclosure. Most existing fences in the area have 16 ft spacing between posts so an additional steel post may be needed to anchor one of the panels.

Exclosures will be read monthly using 1.92 ft^2 clipping frames and gram scales. A new area in the exclosure will be clipped month and past clipping areas will be re-clipped. Green weights will be recorded in the field and paper bagged samples will be air-dried and weighed later to determine 1) air-dry weight in grams in each subplot, and 2) percent of air-dry material at time of clipping.

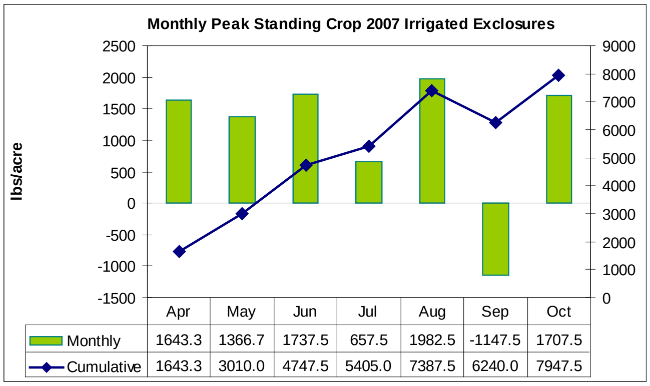
Dry samples in an oven at 140º F for 24 hours or air-dry at room temperature for 72 hours to obtain air-dry weight (grams air-dry * 50 = lbs./acre).

Heavy Duty Cattle Panel
- •16' x 52"
  (cut in half for 8' sections)
- •1/4" Rod Diameter
- •2 3/4 Gauge Rod
- •47 lbs.



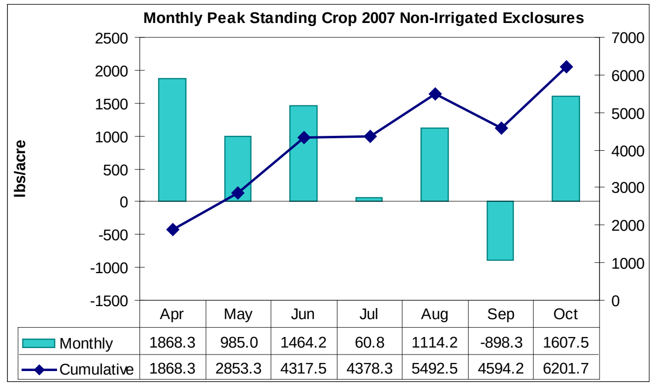
Appendix C: Average Exclosure Peak Standing Crop and Re-Clipping Weights

Irrigated: 2007

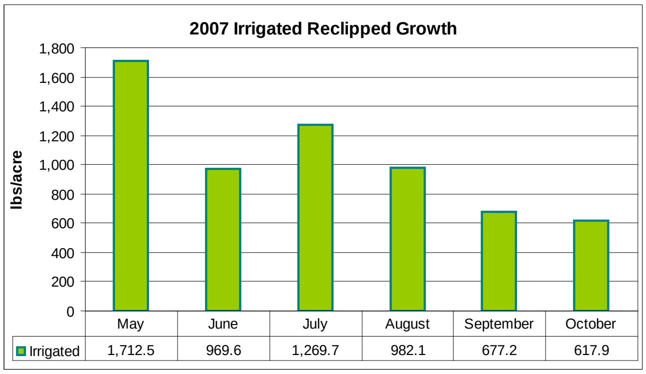


	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly	1643.3	1366.7	1737.5	657.5	1982.5	-1147.5	1707.5
Cumulative	1643.3	3010.0	4747.5	5405.0	7387.5	6240.0	7947.5

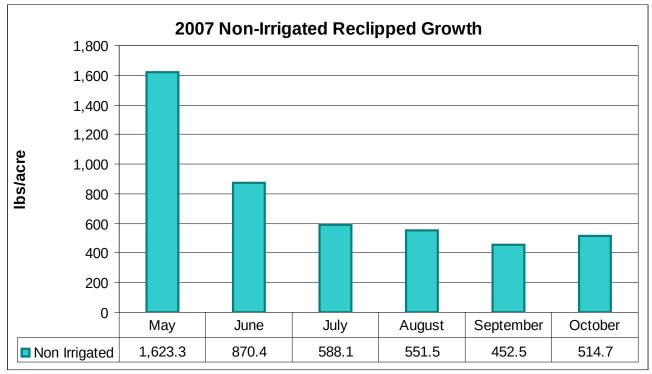
Non-Irrigated: 2007



	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly	1868.3	985.0	1464.2	60.8	1114.2	-898.3	1607.5
Cumulative	1868.3	2853.3	4317.5	4378.3	5492.5	4594.2	6201.7

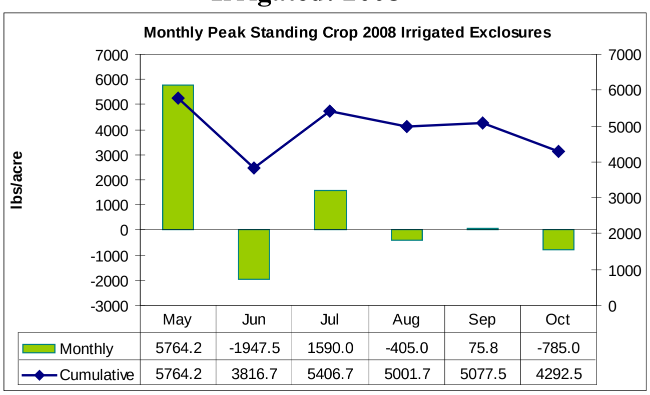


	May	June	July	August	September	October
Irrigated	1,712.5	969.6	1,269.7	982.1	677.2	617.9



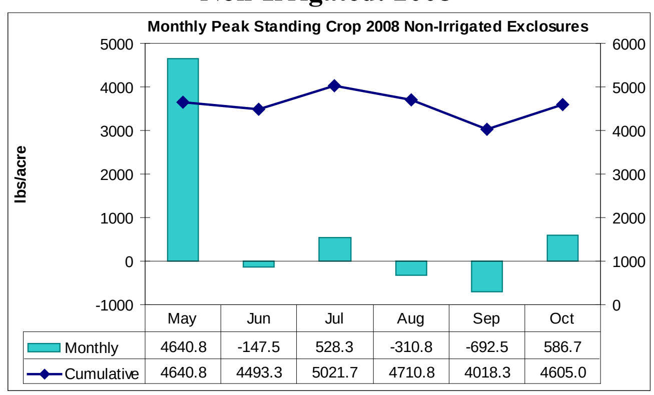
	May	June	July	August	September	October
Non Irrigated	1,623.3	870.4	588.1	551.5	452.5	514.7

Irrigated: 2008

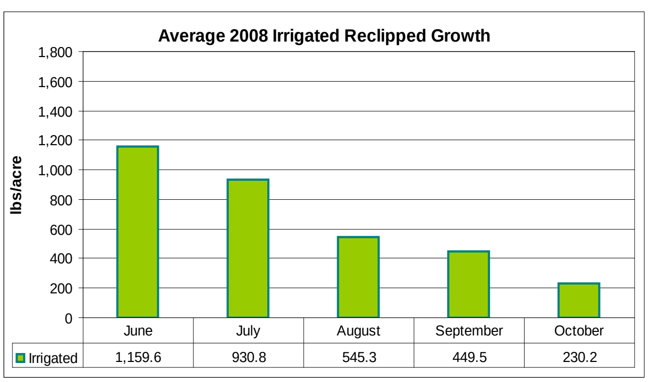


	May	Jun	Jul	Aug	Sep	Oct
Monthly	5764.2	-1947.5	1590.0	-405.0	75.8	-785.0
Cumulative	5764.2	3816.7	5406.7	5001.7	5077.5	4292.5

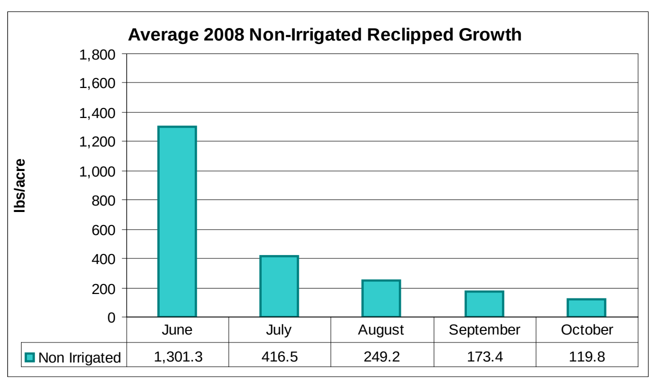
Non-Irrigated: 2008



	May	Jun	Jul	Aug	Sep	Oct
Monthly	4640.8	-147.5	528.3	-310.8	-692.5	586.7
Cumulative	4640.8	4493.3	5021.7	4710.8	4018.3	4605.0

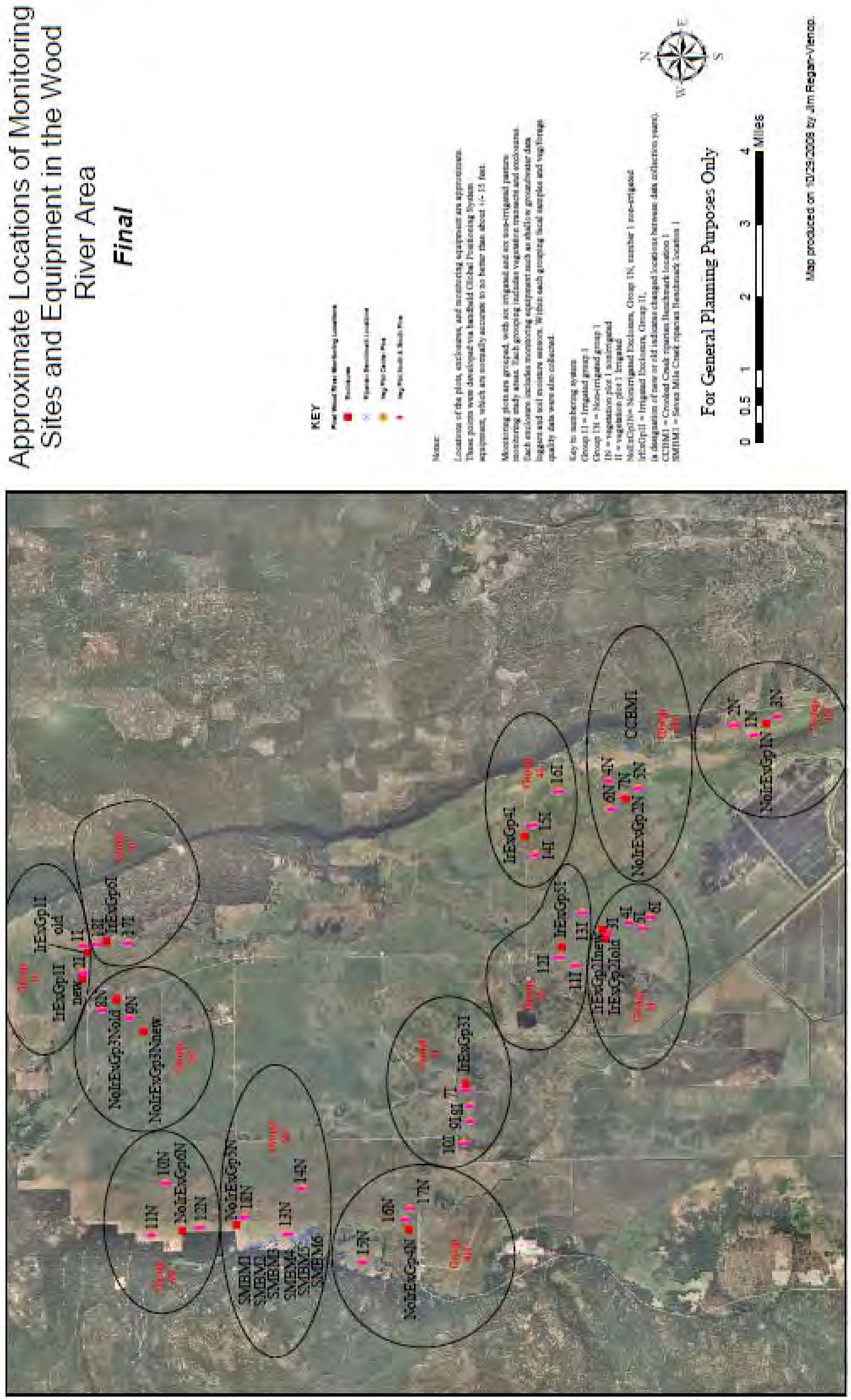


	June	July	August	September	October
Irrigated	1,159.6	930.8	545.3	449.5	230.2



	June	July	August	September	October
Non Irrigated	1,301.3	416.5	249.2	173.4	119.8

Appendix D: Group/Exclosure Locations



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Appendix 1

Final Wood River Conservation Effects Assessment Project Report

Part 3

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West National Technology Support Center
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2007-2008 NIRS Forage Quality Assessment
Wood River Special Emphasis CEAP Watershed, Upper Klamath Basin, Oregon

Introduction

As part of the investigation of changes to the biotic community in the Wood River Valley from ceasing supplemental irrigation on mountain meadows, the forage quality assessment was designed to determine if there were apparent forage quality differences between irrigated and non-irrigated rangelands. Near infrared reflectance spectroscopy (NIRS) evaluation of fecal samples was used to determine the relative amounts of crude protein (CP) and digestible organic matter (DOM) in the diet of the grazing animals. NRCS has worked with Texas A&M University and the Grazingland Animal Nutrition Laboratory (GAN Lab) for nearly two decades in using NIRS to give managers information for effective decision-making. Despite the research limitations (as it was applied here – there are not enough samples for statistical analysis and only grazed pastures were evaluated) the results can indicate on a general level the seasonality and amount of CP and DOM in the diets of the grazing animals. A complimentary study utilizing wet chemistry of forage grab samples will be used to quantify forage quality within and outside of the exclosures.

Most of the grazeable land in the Wood River Valley has two similar soil types. The Kirk and Chock soils are very deep, poorly drained soils derived from pumaceous cinders and ash. They are loams over loamy sands with 5-15% cinder content (increasing with depth). They are currently correlated to the Wet Meadow 14-40” PZ ecological site (021XY406OR) and have similar potentials for plant community development.

The area historically has been utilized to grow stocker cattle and support a few herds of cow-calf pairs. Animals typically are trucked in to the area in April through early June and are grazed until October through November, depending on climate and growth conditions. Very few animals are overwintered in the valley. Stocker gains and rebreeding percentages from producer records show that the base forage supplies a very good nutritional plane that allows economically feasible gains in growing and mature animals.

Methods

A major limitation to supporting nutritional management decisions is the inability of managers and advisors to determine diet quality under field conditions where animals graze freely across diverse landscapes or complex pasture mixes. However, recent advances in NIRS have made it possible to detect fecal by-products of digestion and relate these constituents to dietary CP and DOM. Prediction equations are developed from fecal samples of intact animals and extrusa of esophageal fistulated animals by sharing the same landscape over a wide array of forage conditions or by creating a variety of diets in a controlled stall-feeding experiment.

In 1992 an equation was developed that predicted dietary CP and DOM at similar levels of accuracy as standard wet chemistry laboratory analyses for cattle. To date, dietary prediction equations for cattle appear to be reliable across a broad spectrum of forage types including:

- Subtropical shrublands
- Temperate and tropical pastureland
- Temperate and subtropical grasslands
- Desert shrublands
- Desert grasslands
- Mediterranean annual grasslands
- Hardwood forests
- Coniferous forest
- Marshland
- Mountain meadows (consistent with Klamath Basin cool-season forages)

The NIRS analysis of the fecal samples reliably reports recent (36 hours previous to sampling) diet constituents of the herd tested, namely Crude Protein (CP) and Digestible Organic Matter (DOM). For more information and references, see: http://cnrit.tamu.edu/ganlab/Technology/nirs_technology.htm.

The Wood River CEAP study area is divided into twelve groups of pastures of common ownerships (group locations are shown in Appendix B). There are six groups of irrigated and six of non-irrigated pastures. In 2007 and 2008, fecal samples were collected from animals in each grouping each month, May through October. When animals were not present on pastures within a group, no fecal sample was collected. Groups and samples collected in 2007 and 2008 are shown in Table 1. NIRS results of fecal samples for each month and group are in Appendix A.

Fecal samples were taken from fresh manure piles from at least five different animals, frozen, and shipped to the GAN Lab at Texas A&M University. Results were emailed from the lab and included percent Crude Protein, percent Digestible Organic Matter, percent fecal Nitrogen, and percent fecal Phosphorus. Percent fecal N and P do not reflect forage value and are not included in these results.

The ratio of DOM% to CP% is analyzed to determine rumen efficiency. Values of the DOM:CP between 4.0 and 8.0 are considered acceptable with 4 being optimal. The ratio also helps determine if the forage is providing the most advantageous balance between protein and energy to meet animal maintenance needs. Values below 4 indicate a protein-rich diet that is likely to produce deficiencies in energy and pass-through Nitrogen to the environment. Values above 8 indicate energy-rich diets and protein deficiencies.

The samples were accompanied by a field worksheet describing the herd and environmental attributes. This information is used for NUTBAL (Nutritional Balance Analyzer) consultation to determine animal performance using the results of NIRS evaluation of the fecal matter. In this assessment only the NIRS results are used. Information generated from the NUTBAL program are inconsequential due to the limited information on animal age, breed, body condition score, and other factors used in the NUTBAL consultation. No estimation of animal performance has been made, only the levels of CP and DOM (and the ratio of the two) have been used to compare irrigated and non-irrigated pastures.

Table 1: Forage Quality Assessment by Group, 2007-2008					
Samples Collected: Irrigated			Samples collected: Non-Irrigated		
Group	2007	2008	Group	2007	2008
1N	6, May-Oct	5, May-Sep	1I	6, May-Oct	5, May-Aug, Oct
2N	6, May-Oct	4, May-Jun, Aug, Oct	2I	2, Sep-Oct	6, May-Oct
3N	6, May-Oct	5, May-Jun, Aug-Oct	3I	6, May-Oct	6, May-Oct
4N	6, May-Oct	6, May-Oct	4I	4, Jun, Aug-Oct	6, May-Oct
5N	6, May-Oct	4, May-Aug	5I	6, May-Oct	6, May-Oct
6N	5, Jun-Oct	6, May-Oct	6I	5, May, Jul-Oct	6, May-Oct

***Figure 1**: Fecal samples were taken from several fresh manure piles, frozen, and mailed in a Styrofoam container, with a field sheet describing herd and environmental attributes, to the GAN Lab for analysis.*

Results

Results from NIRS fecal analysis are designed to provide information for decision-making. They can represent general conditions regarding the nutrient content of forages as selected by the grazing animals themselves. Accumulation of crude protein and digestible organic matter content of ingested forages over a period of time provides indicators of trend and change over time as well as indicating if the nutrient plane of the pastures is adequate for maintenance and growth.

Estimates of forage quality from irrigated and non-irrigated pastures in the Wood River valley from two years cannot capture any longer term changes in nutrient plane. These changes would probably be mostly influenced by changes in the plant community components from the cessation of irrigation: different plant species providing different combinations and levels of nutrients. There will likely be more significant changes the longer a pasture is non-irrigated.

Table 2 shows the length of time non-irrigated pastures have been without additional water. Additionally, benchmark condition of the pastures has an observed effect on nutrient plane. Pastures in groups 2N and 4N had been grazed closely (< 2" remaining fall stubble height) for several years prior to the NRCS initial inventory in 2002. Consequently, these groups had the lowest late season CP% and at least one month when the DOM:CP ratio exceeded 8.0.

Table 2: Non-Irrigated Vegetation Monitoring Plot Stratification

	Year Irrigation Ended				
Group	2002	2003	2004	2005	Seasons (inc. 2008)
3N				✓	4
4N				✓	4
6N			✓		5
5N		✓			6
1N	✓				7
2N	✓				7

General Observations:

1) CP% varied from 10.3 to 15.2; cattle begin to lose condition when CP dips below 7%. The range tested shows a relatively consistent amount of CP available during the year (some individual pastures had lowered CP% in Aug and Sept but most of the area provides adequate protein throughout the grazing period). There appears to be little difference in CP% from irrigated (10.3 to 14.1) vs. non-irrigated pastures (10.4 to 15.2).

2) DOM% varied from 58.2 to 71.2; the irrigated pastures had only slightly higher levels of DOM (58.2 to 71.2) vs. the non irrigated (58.5 to 70.0). The rate of decline in DOM was more rapid on the non-irrigated compared to the irrigated pastures, indicating a slightly better balance between protein and energy in the irrigated pastures although all of the figures are acceptable. There may be a correlation to plant community composition and time since irrigation was suspended (see Table 2 and Figures 5 & 9).

3) The DOM:CP ratio varied between 4.1 and 8.9 (all pastures, both years). The lower readings were recorded early in the spring when the new forage is very high in protein and there is lowered energy available (carry-over forage often makes up for this deficit - there is very little carry-over forage in the study area due to the grazing pressure from previous years).

4) Irrigated pastures had a tighter range of DOM:CP (4.7 to 6.9) vs. non-irrigated pastures (4.1 to 8.9); non-irrigated pastures are more at-risk of not providing adequate energy earlier in the season. Irrigated pastures likely had high Nitrogen pass through in May and June.

5) Previous grazing pressure and current stocking rates (which in a few cases are in excess of productive capability) seems to have an effect on perseverance of CP% and DOM% on non-irrigated pastures as the season progresses. The lowest CP% and the highest DOM:CP ratios were found on groups that were grazed heavily for several years prior to 2002.

6) Differences in irrigated and non-irrigated pastures and groups are more evident after July and through October (see Figures 3-9).

7) Excreted fecal Nitrogen and Phosphorous percentages, although not related to diet quality, decrease through the season at different rates. Both fecal Nitrogen and Phosphorous on non-irrigated pastures decreases more (and more rapidly) than on irrigated pastures (where the percentages of both remain higher). Percentages are virtually the same early in the season and diverge by July (see tables 7 & 8 and figures 10 & 11). There may be some implications suggesting contributions of nutrients to receiving waters in the irrigated fields leading to decreased water quality.

Additional statistical evaluations from the Oregon State University study:

8) Is forage quality (fecal analysis) related to annual production and species composition?

a) Is crude protein related to total production of the plots (averaged by group)? There is little evidence to suggest a linear relationship between CP and average total production at the plots ($p = 0.18$)

b) Is crude protein related to production of grasses at the plots (averaged by group)? There is no evidence to suggest a linear relationship between CP and average grass production at the plots ($p = 0.53$)

c) Is crude protein related to production of grass-likes at the plots (averaged by group)? There is suggestive evidence that a positive linear relationship exists between CP and average grass-like production at the plots ($p = 0.06$), although this relationship may be driven by outliers.

d) Is crude protein related to production of forbs at the plots (averaged by group)? There is little evidence to suggest a linear relationship between CP and average forb production at the plots ($p = 0.30$)

9) Is there a difference between irrigated and non-irrigated treatments and is there a relationship with time since irrigation?

a) Early season analysis

i) The average DOM:CP ratio for early season fecal samples is 5.9 and 5.8 for irrigated and non-irrigated pastures, respectively. There is no evidence to suggest there is a difference between the early season DOM:CP ratio for irrigated and non-irrigated treatments ($p = 0.80$).

ii) There is no evidence to suggest there is a linear relationship between early season DOM:CP ratios and the time (years) since the pastures were last irrigated ($p = 0.89$).

b) Late season analysis

i) The average late season DOM:CP ratio for irrigated and non-irrigated groups is 6.4 and 7.1 respectively. There is moderate evidence to suggest there is a difference between the DOM:CP ratio between irrigated and non-irrigated treatments ($p = 0.07$).

ii) There is some evidence to conclude there is a positive linear relationship between the DOM:CP ratio and time since irrigation ceased ($p = 0.09$).

Tabular and Graphic Data – Non-Irrigated Groups

Table 3: Average Non-Irrigated Pasture NIRS Results (2007-2008)						
	May	Jun	Jul	Aug	Sep	Oct
CP%	15.2	12.7	11.0	10.5	10.2	8.4
DOM%	67.6	65.9	63.1	61.8	61.2	60.5
DOM:CP	4.5	5.2	5.7	5.9	6.0	7.2

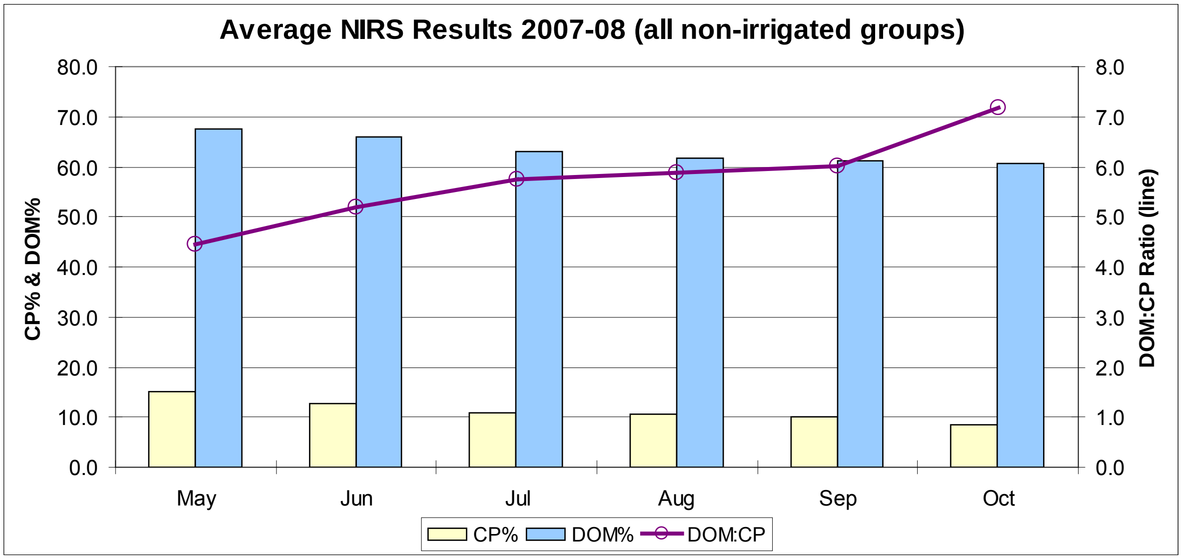


Figure 2: *Average percent Crude Protein did not register below 7% (a critical marker for maintenance) but decreased throughout the growing season. DOM showed a steady decrease through the season. DOM:CP ratio stayed within the recommended guidelines of 4 to 8 but raised sharply in September and October when protein content in forages decreased.*

Table 4: Average Non-Irrigated Pasture NIRS Results by Group (2007-2008)							
Group		May	Jun	Jul	Aug	Sep	Oct
1N	CP%	13.44	12.22	11.97	11.11	10.44	9.08
	DOM%	63.65	64.78	60.43	61.36	61.85	59.32
	DOM:CP	4.74	5.30	5.05	5.52	5.92	6.53
2N	CP%	12.60	14.63	12.20*	10.11	7.39	8.77
	DOM%	65.26	66.27	63.00*	60.38	60.88	59.00
	DOM:CP	5.18	4.53	5.16*	5.97	8.24	6.73
3N	CP%	15.83	14.19	9.18	12.62	10.48	9.78
	DOM%	68.70	67.41	62.66	64.30	62.21	64.69
	DOM:CP	4.34	4.75	6.83	5.10	5.94	6.61
4N	CP%	16.66	12.38	12.61	8.77	10.47	7.57
	DOM%	69.99	66.18	64.45	60.93	60.99	59.29
	DOM:CP	4.20	5.35	5.11	6.95	5.83	7.83
5N	CP%	17.15	12.18	10.10	9.58	7.61	8.36
	DOM%	71.63	66.11	63.43	61.61	61.34	60.00
	DOM:CP	4.18	5.43	6.28	6.43	8.06	7.18
6N	CP%	16.07	14.70	10.99	10.85	9.78	7.68
	DOM%	68.04	67.06	65.01	61.88	60.09	59.92
	DOM:CP	4.23	4.56	5.91	5.71	6.14	7.80

** Group 2 had no grazing in July either year: the CP% and DOM% data points for July were inserted to represent an intermediate point (consistent slope). See figures 3, 4, & 5.*

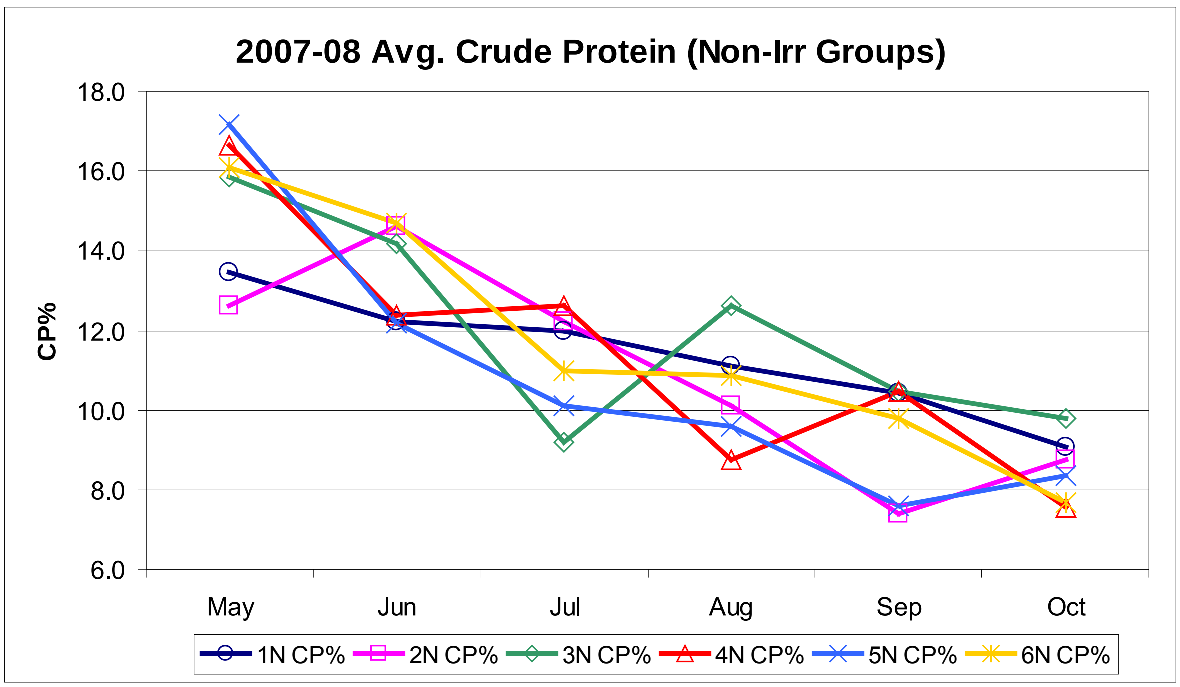


Figure 3: *Average CP% by groups on non-irrigated pastures shows a consistent decrease from May to October. Protein levels in the forage stay above 7% even at their lowest levels and are above 8% most of the season. Group 3 may have responded differently because it is surrounded by irrigated pastures and receives excess water (Aug).*

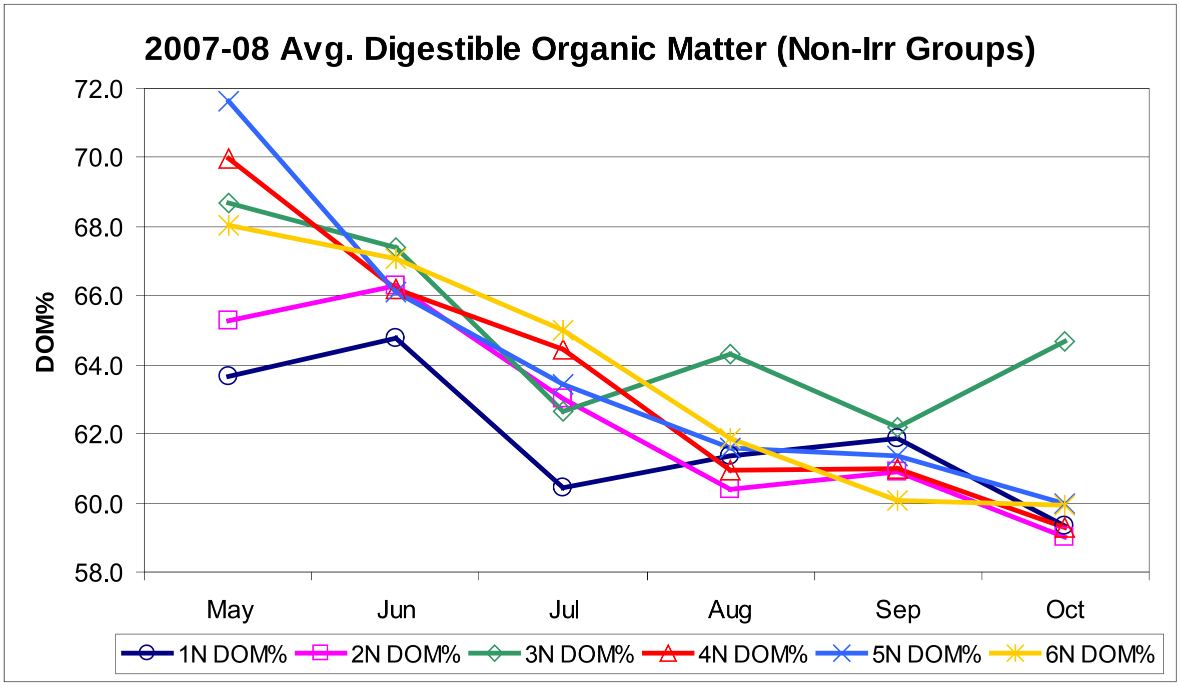


Figure 4: *Average DOM% by groups on non-irrigated pastures shows a consistent decrease from May to October. Group 3 may have responded differently because it is surrounded by irrigated pastures and receives excess water (Aug).*

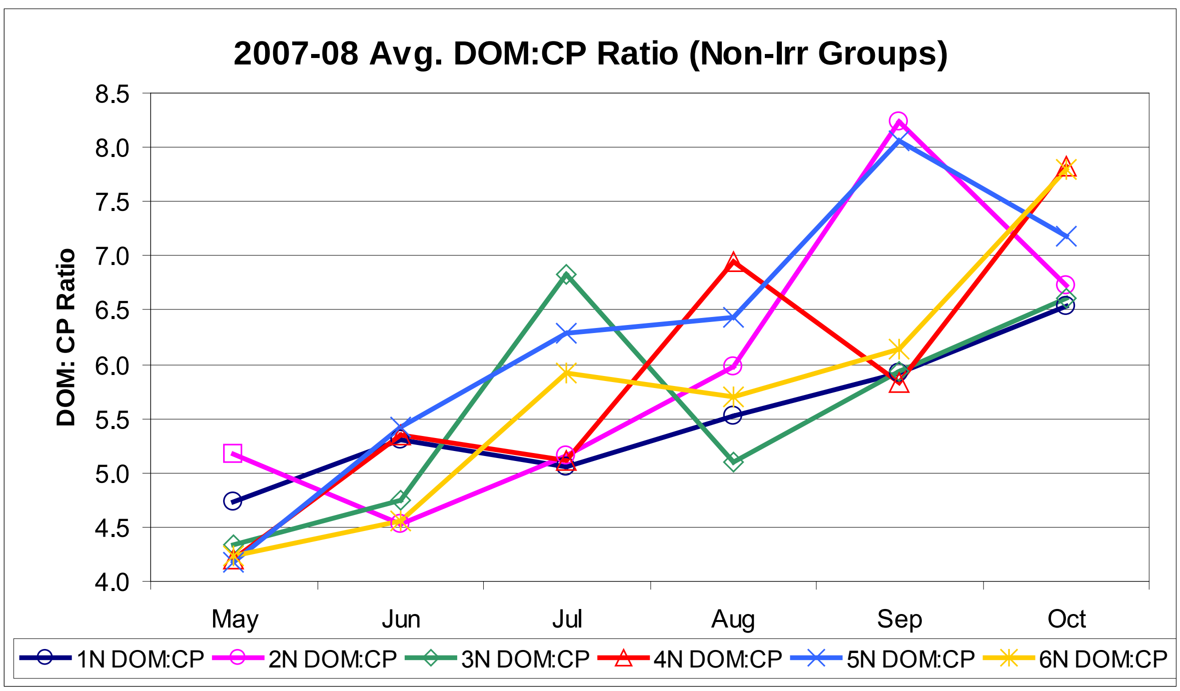


Figure 5: *Average DOM:CP ratio for non-irrigated pastures shows an upward trend through the growing season within the limits of rumen efficiency (4.0 to 8.0). Groups 1, 2, & 5 have been non-irrigated the longest (see Table 2).*

Tabular and Graphic Data – Irrigated Groups

Table 5: Average Irrigated Pasture NIRS Results (2007-2008)						
	May	Jun	Jul	Aug	Sep	Oct
CP%	14.1	11.7	10.3	11.0	11.8	8.9
DOM%	65.7	64.3	63.0	62.8	64.3	61.5
DOM:CP	4.7	5.5	6.1	5.7	5.4	6.9

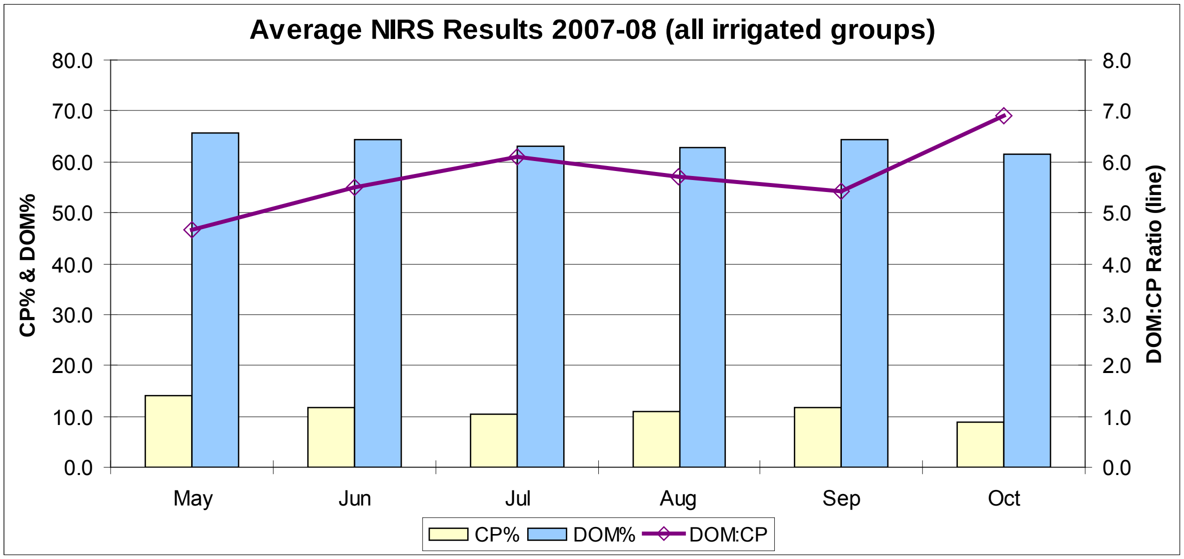


Figure 6: *Average percent Crude Protein did not register below 7% (a critical marker for maintenance) but decreased from May to July rebounded in August and September (likely due to irrigation water) and decreased again in October. DOM did not change much throughout the season. DOM:CP ratio stayed within the recommended guidelines of 4 to 8) but increased from May to July and after a decrease in August raised sharply in September and October when protein content in forages decreased.*

Table 6: Average irrigated Pasture NIRS Results by Group (2007-2008)							
Group		May	Jun	Jul	Aug	Sep	Oct
1I	CP%	15.04	11.64	10.40	11.65	13.23	8.74
	DOM%	68.58	64.87	63.21	64.19	67.46	61.85
	DOM:CP	4.56	5.57	6.08	5.51	5.10	7.08
2I	CP%	13.75	10.22	9.54	9.45	8.67	7.91
	DOM%	64.20	62.39	62.18	62.03	62.92	59.49
	DOM:CP	4.67	6.11	6.52	6.57	7.26	7.52
3I	CP%	14.53	12.61	9.42	10.87	10.59	8.75
	DOM%	67.13	64.73	61.94	62.53	63.43	60.90
	DOM:CP	4.62	5.13	6.57	5.76	5.99	6.96
4I	CP%	12.97	11.36	11.83	11.13	15.02	9.32
	DOM%	65.83	64.12	63.58	62.48	65.84	62.41
	DOM:CP	5.08	5.64	5.38	5.62	4.38	6.70
5I	CP%	13.37	11.96	9.43	9.80	10.44	8.97
	DOM%	64.89	63.54	62.09	61.00	63.04	60.73
	DOM:CP	4.85	5.31	6.59	6.23	6.04	6.77
6I	CP%	15.21	12.27	11.43	13.08	13.23	9.85
	DOM%	62.65	66.10	64.91	64.32	64.76	63.83
	DOM:CP	4.12	5.39	5.68	4.92	4.90	6.48

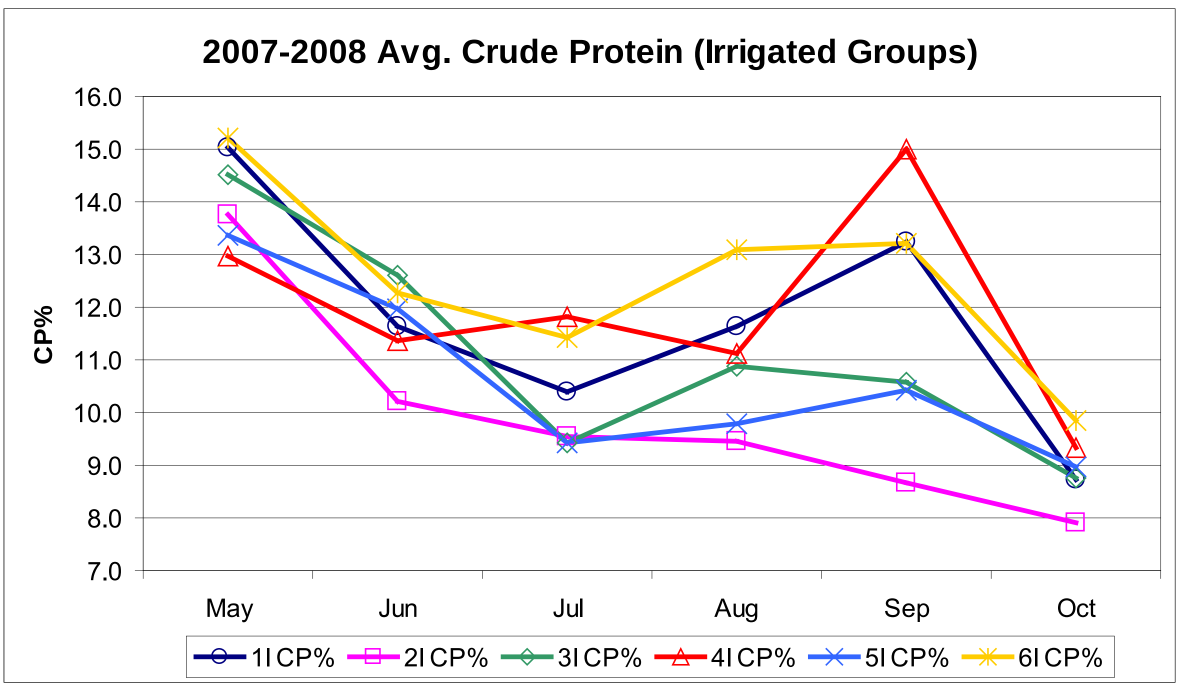


Figure 7: *Average CP% by groups on irrigated pastures shows the general trend in decrease May-July and an increase from the driest part of the season (July) to September when additional irrigation water is applied. Protein levels in the forage stay above 7% even at their lowest levels and are above 9% most of the season. CP% drops in October as irrigation ends and pastures are usually at their lowest stubble heights.*

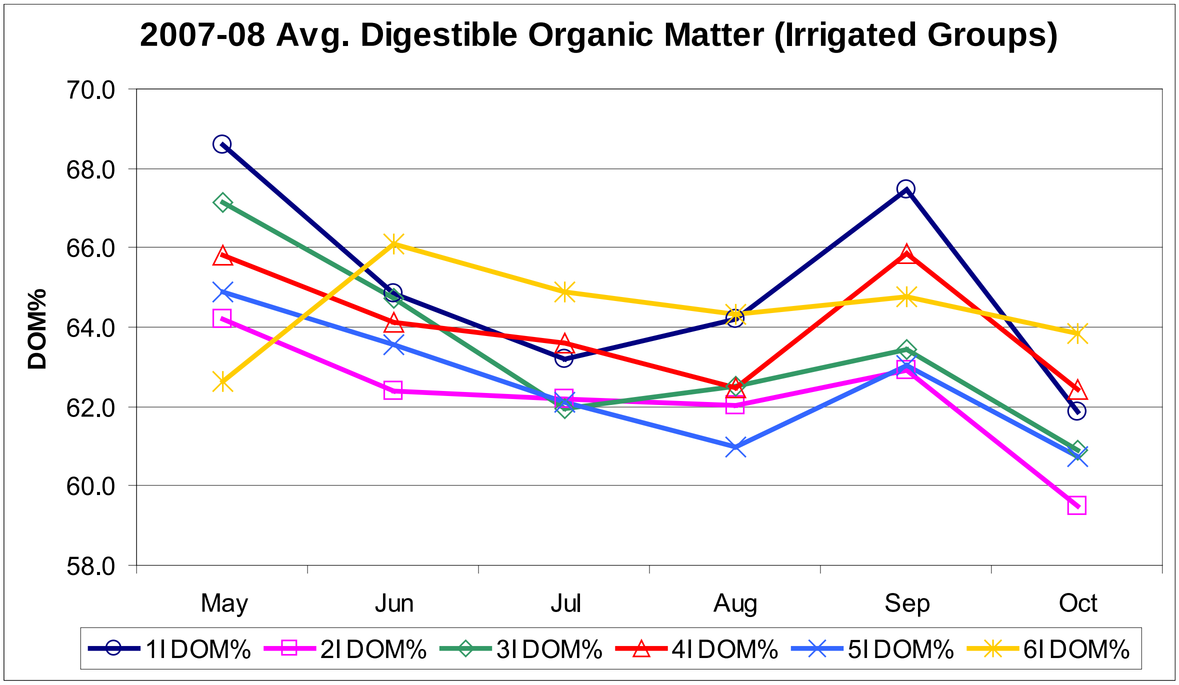


Figure 8: *Average DOM% by groups on irrigated pastures shows a moderate decline during the first four months of the season followed by an uptick in September and decline at the end of the season (perhaps due to irrigation water applications in late August and September and cessation of irrigation in October). Group 6I may be responding to additional sub irrigation, a different plant community phase, or an entirely different ecological site due to it's proximity to the origins of the Wood River (hence the different shape of the line) or a response to the heavy grazing that occurs on these pastures each year.*

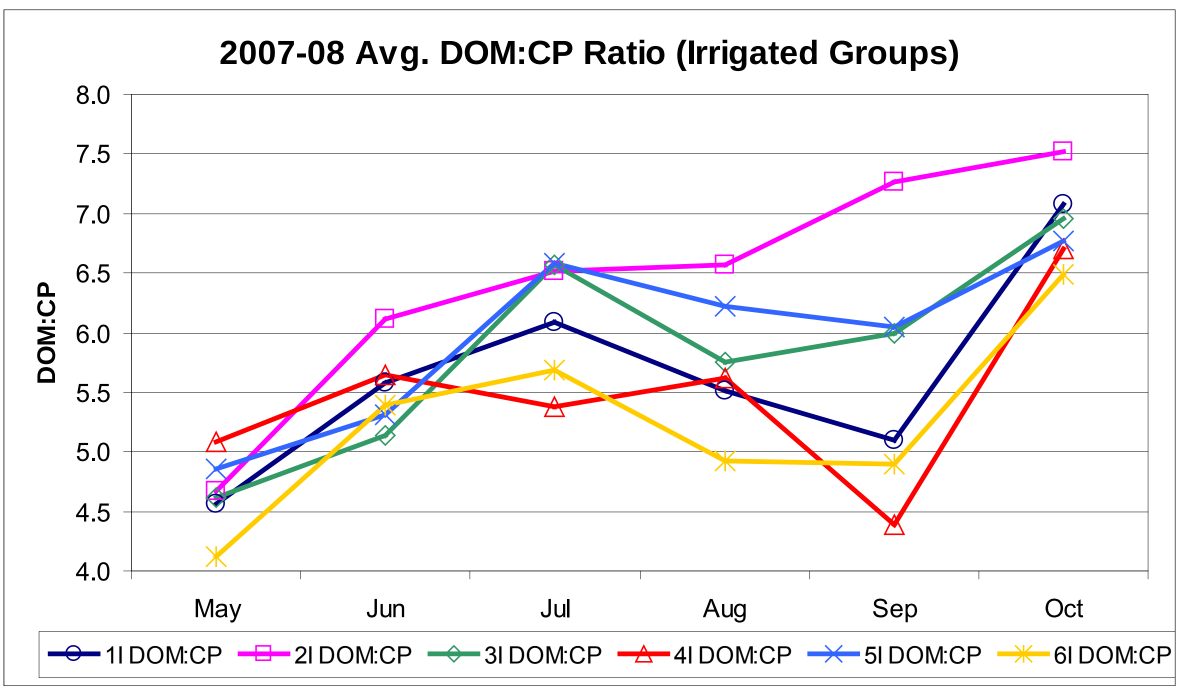


Figure 9: *Average DOM:CP ratio by groups on irrigated pastures shows an upward trend through the growing season within the limits of rumen efficiency (4.0 to 8.0).*

Tabular and Graphic Data – Fecal Nitrogen and Phosphorous

Table 7: Average Non-Irrigated Pasture NIRS Results (2007-2008)						
	May	Jun	Jul	Aug	Sep	Oct
Fecal N (N-I)	2.4	2.2	1.9	1.7	1.5	1.4
Fecal P (N-I)	0.6	0.6	0.5	0.4	0.3	0.4

Table 8: Average Irrigated Pasture NIRS Results (2007-2008)						
	May	Jun	Jul	Aug	Sep	Oct
Fecal N (I)	2.4	2.2	2.1	2.0	1.8	1.6
Fecal P (I)	0.6	0.6	0.5	0.5	0.5	0.4

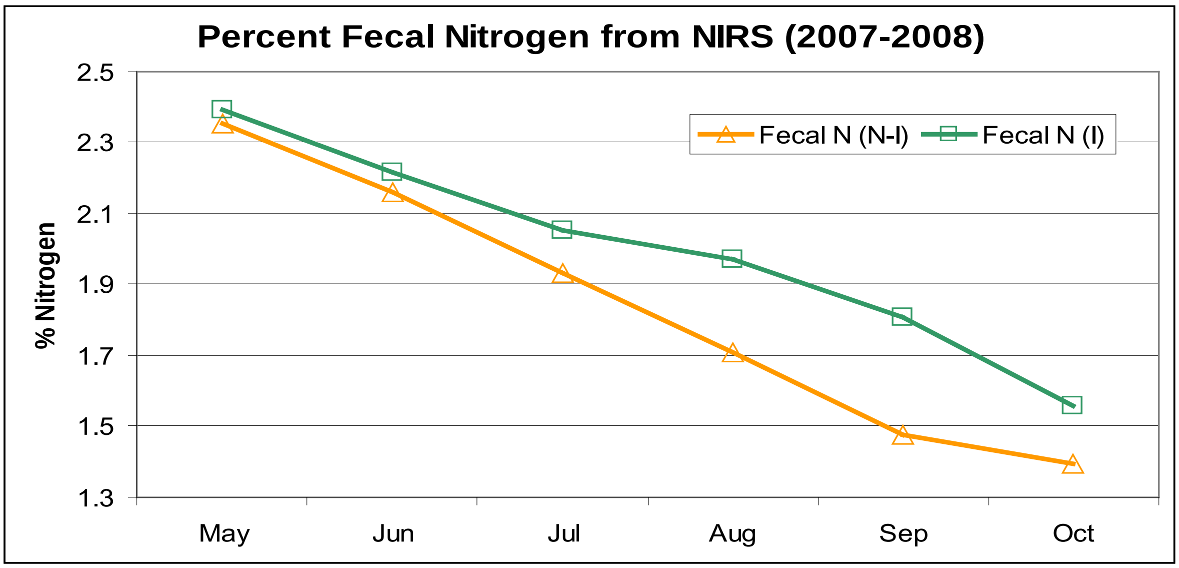


Figure 10: *Average percent fecal Nitrogen from NIRS analysis for all groups and both years showing a predictable decrease through the season. Early season % fecal N is similar for irrigated and non-irrigated pastures. From July to October, non-irrigated pastures show lower levels of % fecal N.*

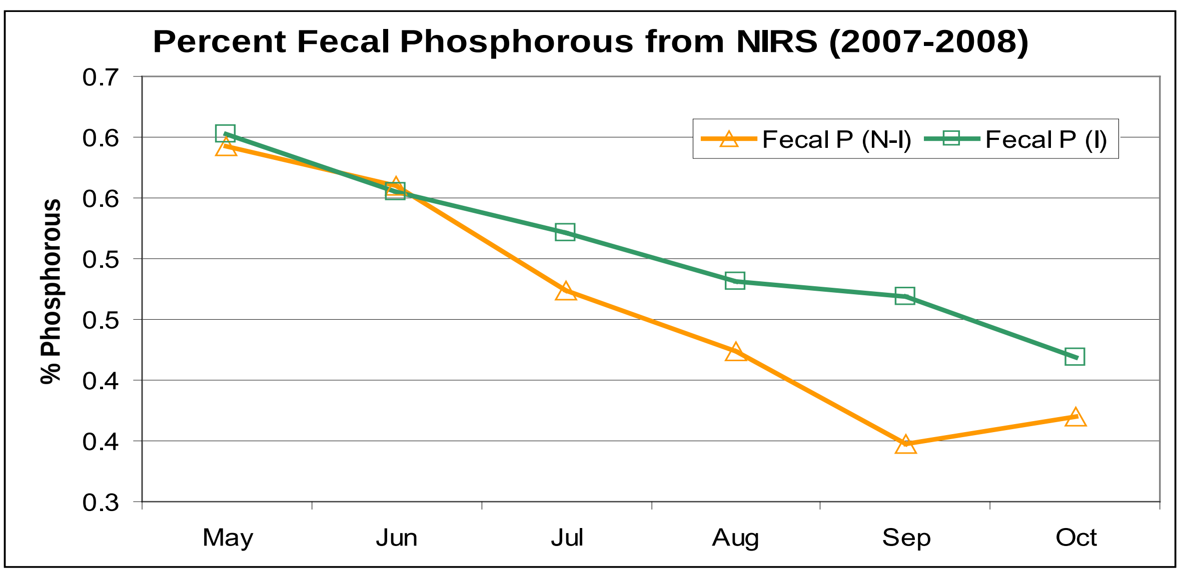


Figure 11: *Average percent fecal Phosphorous from NIRS analysis for all groups and both years showing a predictable decrease through the season. Early season % fecal P is almost identical for irrigated and non-irrigated pastures. From July to October, non-irrigated pastures show lower levels of % fecal P.*

Recommendations

The advantages of NIRS analysis of fecal samples (easy to collect, use of the animal to collect diet, rapid delivery of results, relative low cost) can be magnified by NUTBAL consultations that can give landowners useful information on animal performance. Follow-up with individualized NIRS/NUTBAL consultations for interested landowners can give them a monitoring tool to track changes as management is adjusted (especially if non-irrigation will be continued on parcels in the valley or if there is a change in kind and class of grazing animal). NIRS fecal analysis combined with NUTBAL consultations can track body condition score (BCS), average daily gain, projected weight/BCS for designed time periods and track the balance of protein and net metabolizable energy for the kind and class of grazing animal.

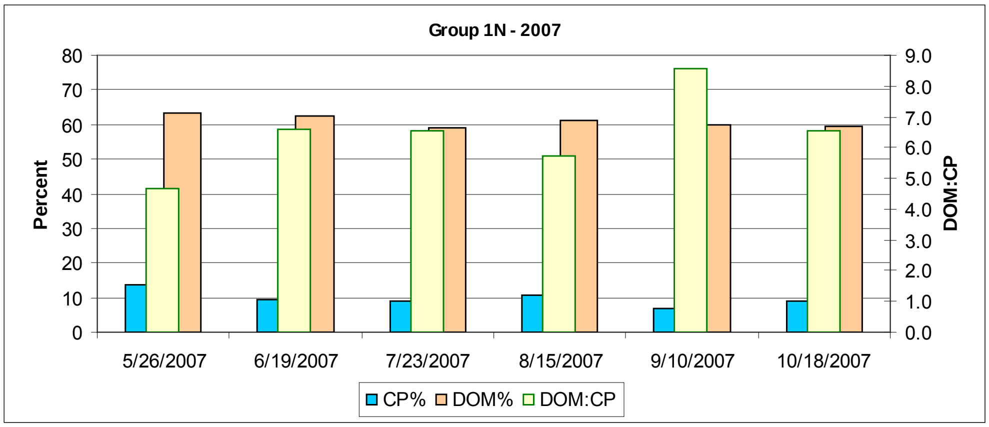
Evaluation of grazing records annually is strongly recommended to ensure that stocking rates are in balance with the productive capability of the pastures. Initial stocking rates based on the production estimated from the 36 plots and 13 exclosures will be developed for each pasture group. An accurate estimate of forage available by month will be derived from growth curve calculations so that the initial stocking rate can be known for any time during the season.

Forage quality and animal performance can probably be enhanced by utilizing different pastures for grazing. Adequate time required for regrowth following grazing should be planned: these plant communities are relatively resilient and can respond well when grazing pressure is removed and there is adequate soil water and temperatures. Integrating irrigation water management into the prescribed grazing will also help both the plant communities and animals. Since alternative methods of applying irrigation water are impractical in the valley, moving grazing animals out of a pasture before irrigation then grazing will benefit plants animals and will help to reduce soil compaction.

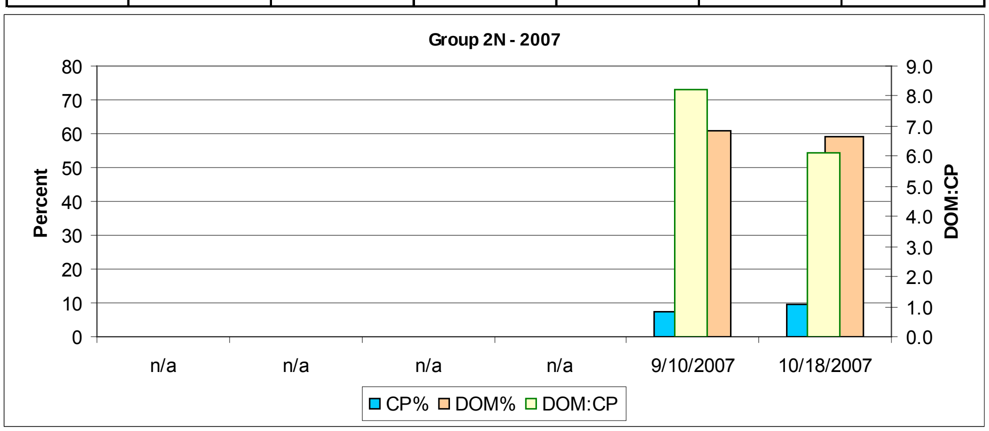
Appendix A: NIRS Fecal Sample Results by Group and Month 2007-2008

Non-Irrigated: 2007

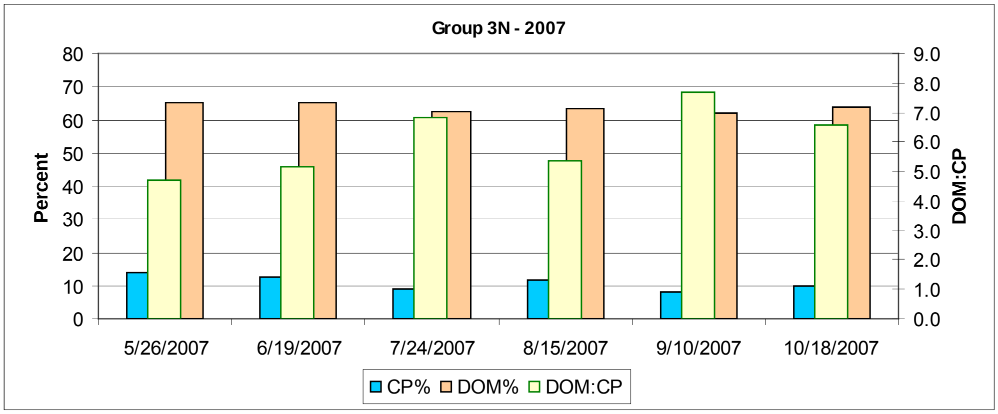
Sample ID	Group_1N					
Date	5/26/2007	6/19/2007	7/23/2007	8/15/2007	9/10/2007	10/18/2007
CP%	13.63	9.48	8.99	10.67	6.98	9.08
DOM%	63.47	62.61	58.83	61.19	59.8	59.32
DOM:CP	**4.66**	**6.60**	**6.54**	**5.73**	**8.57**	**6.53**
Fecal N	1.81	1.77	1.96	1.49	1.34	1.47
Fecal P	0.5	0.46	0.38	0.42	0.134	0.4



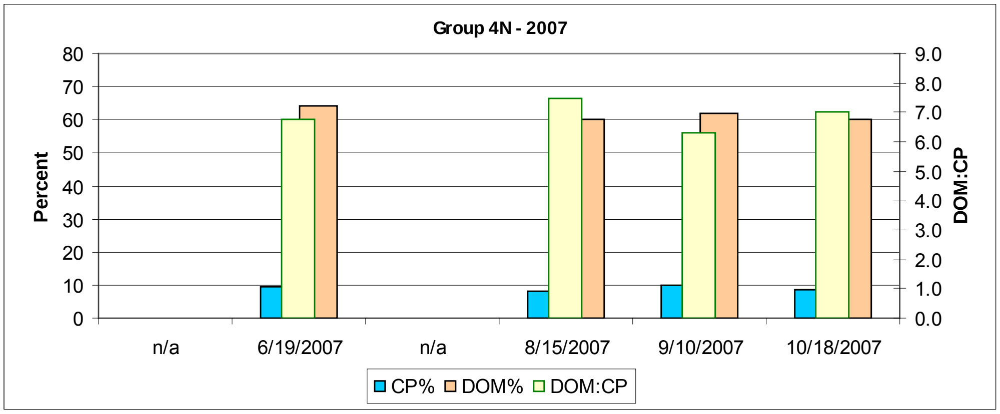
Sample ID	Group_2N					
Date	n/a	n/a	n/a	n/a	9/10/2007	10/18/2007
CP%					7.39	9.65
DOM%					60.88	59.04
DOM:CP					**8.24**	**6.12**
Fecal N					1.87	1.62
Fecal P					0.50	0.40



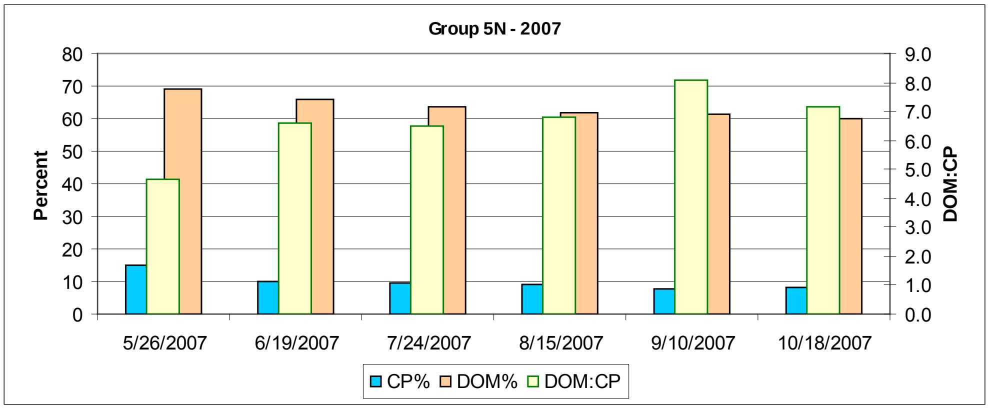
Sample ID	Group_3N					
Date	5/26/2007	6/19/2007	7/24/2007	8/15/2007	9/10/2007	10/18/2007
CP%	13.83	12.64	9.18	11.8	8.09	9.74
DOM%	64.99	65.11	62.66	63.49	62.21	63.89
DOM:CP	**4.70**	**5.15**	**6.83**	**5.38**	**7.69**	**6.56**
Fecal N	2.12	2.23	2.02	1.76	1.55	1.72
Fecal P	0.48	0.57	0.52	0.42	0.37	0.46



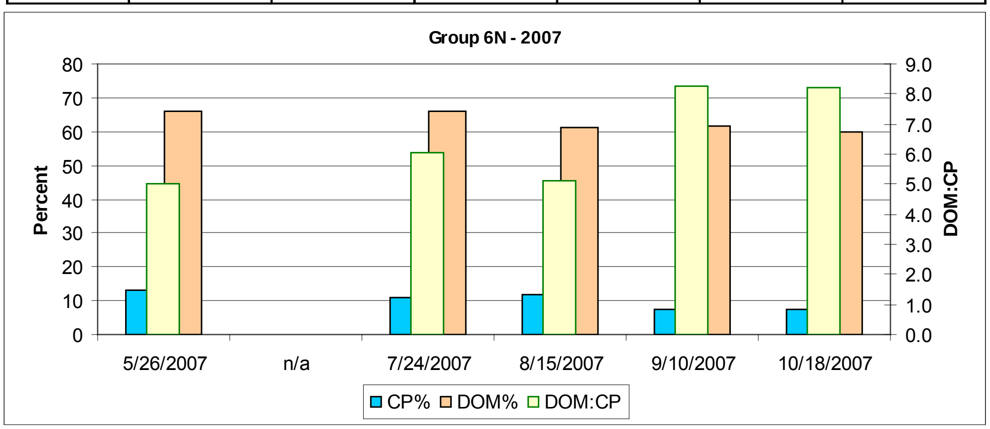
Sample ID	Group_4N					
Date	n/a	6/19/2007	n/a	8/15/2007	9/10/2007	10/18/2007
CP%		9.53		8.06	9.78	8.57
DOM%		64.39		60.12	61.88	60.09
DOM:CP		**6.76**		**7.46**	**6.33**	**7.01**
Fecal N		1.96		1.82	0.7	0.7
Fecal P		0.46		0.35	0.17	0.17



Sample ID	Group_5N					
Date	5/26/2007	6/19/2007	7/24/2007	8/15/2007	9/10/2007	10/18/2007
CP%	14.94	9.94	9.76	9.12	7.61	8.36
DOM%	69.18	65.76	63.45	61.88	61.34	60
DOM:CP	**4.63**	**6.62**	**6.50**	**6.79**	**8.06**	**7.18**
Fecal N	2.63	2.18	1.87	1.74	1.25	1.48
Fecal P	0.63	0.52	0.37	0.41	0.33	0.36



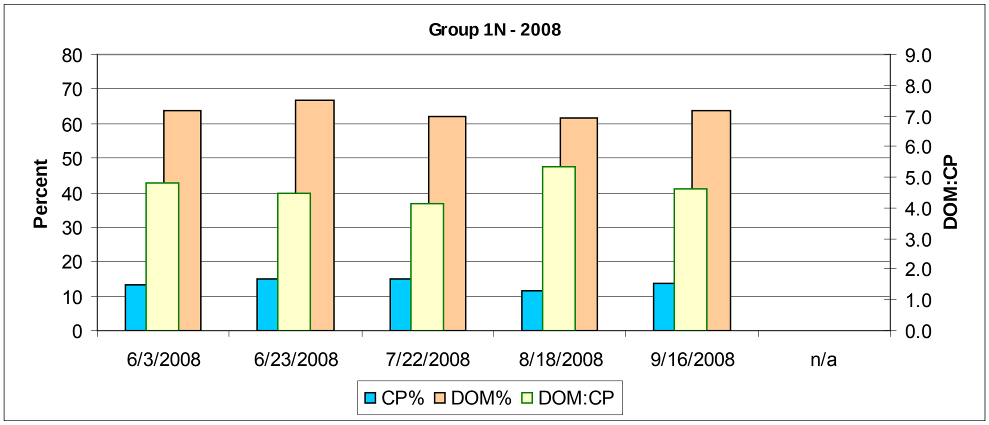
Sample ID	Group_6N					
Date	5/26/2007	n/a	7/24/2007	8/15/2007	9/10/2007	10/18/2007
CP%	13.15		10.93	11.93	7.46	7.29
DOM%	66.21		66.2	61.08	61.55	59.84
DOM:CP	**5.03**		**6.06**	**5.12**	**8.25**	**8.21**
Fecal N	1.92		1.89	1.8	1.21	1.15
Fecal P	0.45		0.43	0.4	0.121	0.34



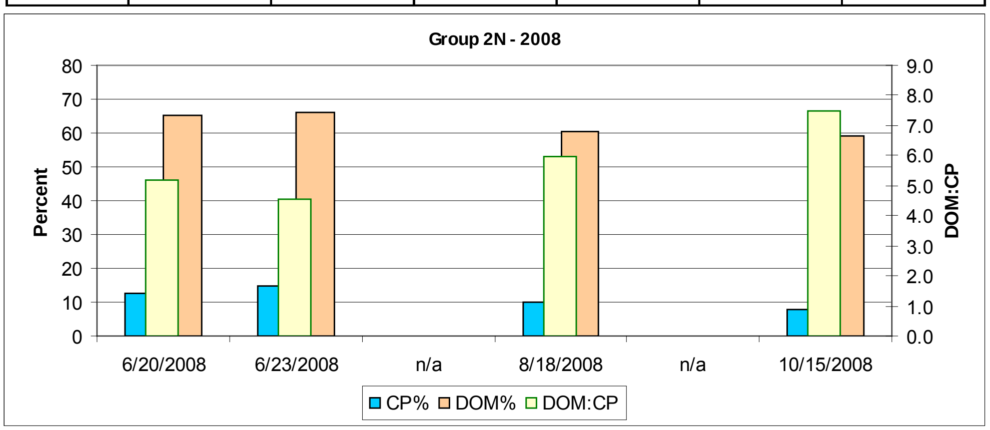
AVERAGES - all 2007 non-irrigated groups						
CP	13.89	10.40	9.72	10.32	7.89	8.78
DOM	65.96	64.47	62.79	61.55	61.28	60.36
DOM:CP	4.75	6.20	6.46	5.97	7.77	6.87
Fecal N	2.12	2.04	1.94	1.72	1.32	1.36
Fecal P	0.52	0.50	0.43	0.40	0.27	0.36

Non-Irrigated: 2008

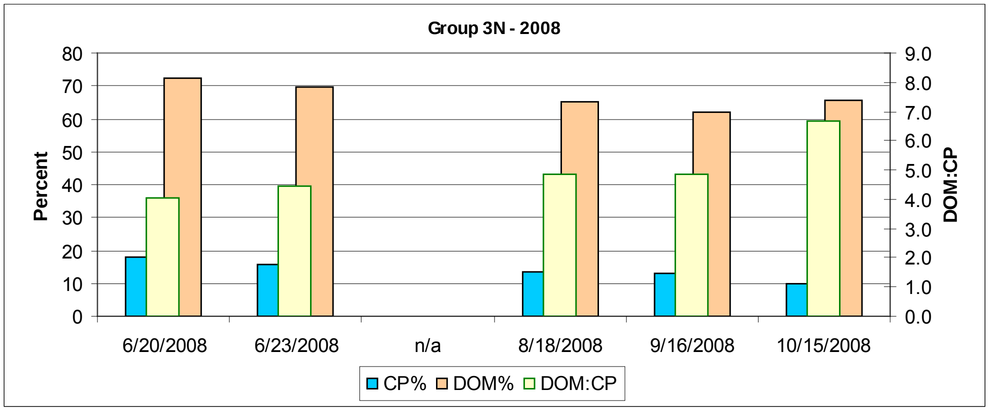
Sample ID	Group_1N					
Date	6/3/2008	6/23/2008	7/22/2008	8/18/2008	9/16/2008	n/a
CP%	13.25	14.96	14.94	11.54	13.9	
DOM%	63.82	66.95	62.03	61.52	63.9	
DOM:CP	4.82	4.48	4.15	5.33	4.60	
Fecal N	2.12	1.85	1.91	1.60	1.80	
Fecal P	0.51	0.53	0.61	0.38	0.47	



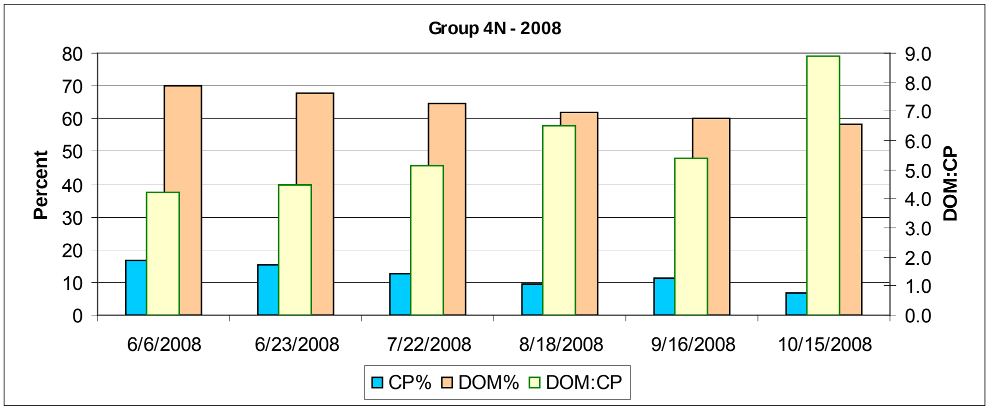
Sample ID	Group_2N					
Date	6/20/2008	6/23/2008	n/a	8/18/2008	n/a	10/15/2008
CP%	12.6	14.63		10.11		7.89
DOM%	65.26	66.27		60.38		58.96
DOM:CP	5.18	4.53		5.97		7.47
Fecal N	2.18	2.40		1.78		1.42
Fecal P	0.50	0.66		0.45		0.35



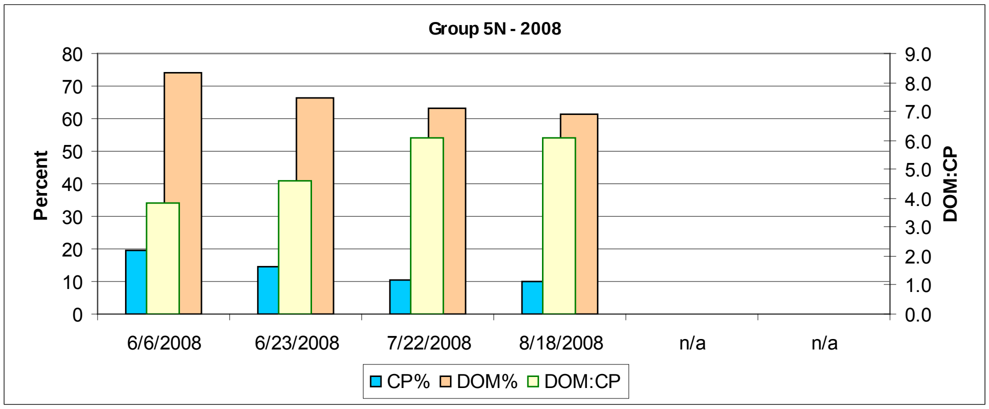
Sample ID	Group3N					
Date	6/20/2008	6/23/2008	n/a	8/18/2008	9/16/2008	10/15/2008
CP%	17.83	15.73		13.44	12.87	9.82
DOM%	72.41	69.7		65.11	62.21	65.49
DOM:CP	**4.06**	**4.43**		**4.84**	**4.83**	**6.67**
Fecal N	2.79	2.43		1.87	1.67	1.62
Fecal P	0.71	0.66		0.53	0.44	0.41



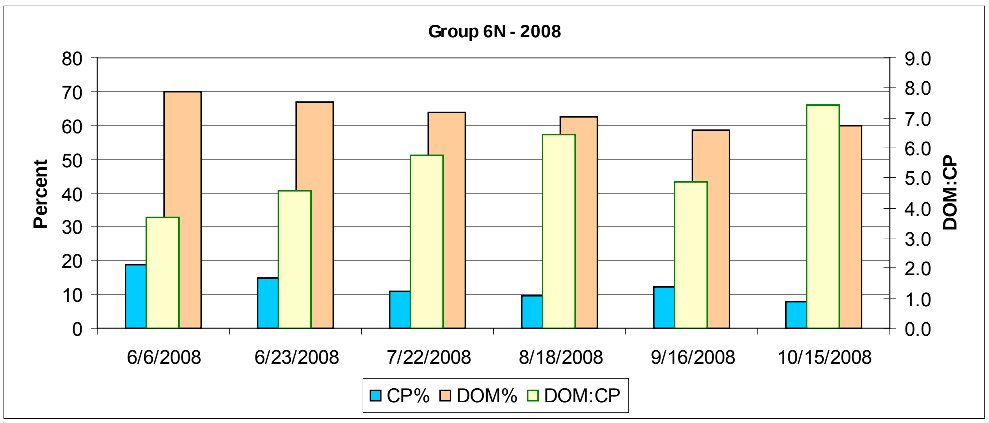
Sample ID	Group_4N					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	9/16/2008	10/15/2008
CP%	16.66	15.22	12.61	9.47	11.15	6.57
DOM%	69.99	67.96	64.45	61.74	60.09	58.49
DOM:CP	**4.20**	**4.47**	**5.11**	**6.52**	**5.39**	**8.90**
Fecal N	2.51	2.19	1.96	1.69	1.42	1.38
Fecal P	0.66	0.61	0.50	0.40	0.36	0.37



Sample ID	Group_5N					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	n/a	n/a
CP%	19.35	14.42	10.44	10.04		
DOM%	74.07	66.45	63.4	61.34		
DOM:CP	**3.83**	**4.61**	**6.07**	**6.11**		
Fecal N	2.85	2.41	1.88	1.48		
Fecal P	0.81	0.62	0.43	0.43		



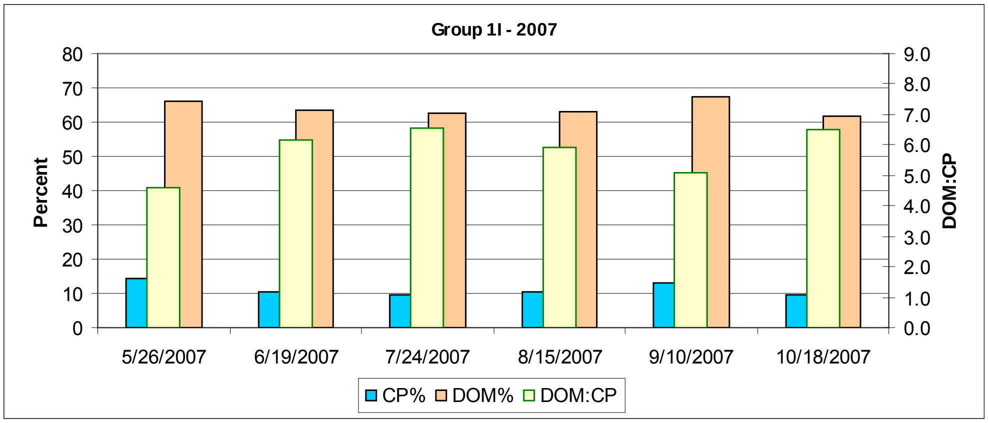
Sample ID	Group_6N					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	9/16/2008	10/15/2008
CP%	18.99	14.7	11.05	9.76	12.1	8.07
DOM%	69.86	67.06	63.81	62.67	58.62	60
DOM:CP	**3.68**	**4.56**	**5.77**	**6.42**	**4.84**	**7.43**
Fecal N	3.05	2.42	1.97	1.73	1.63	1.32
Fecal P	0.83	0.62	0.55	0.49	0.43	0.41



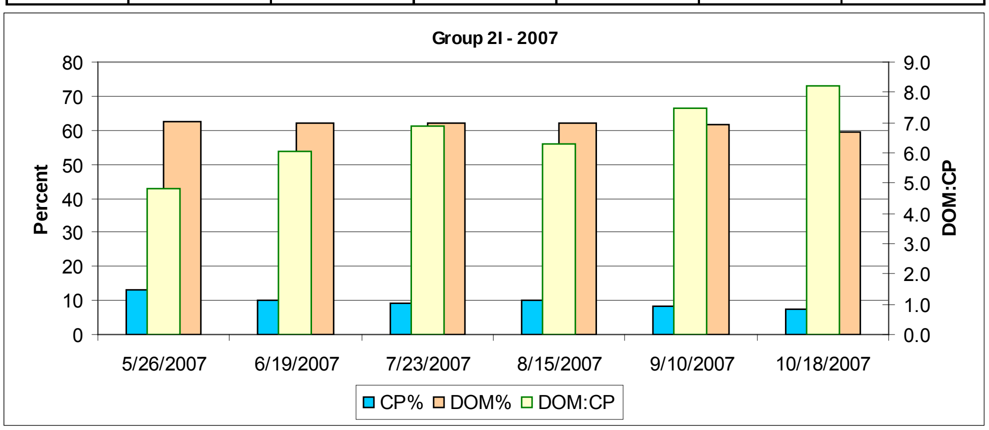
AVERAGES - all 2008 non-irrigated groups						
CP	16.45	14.94	12.26	10.73	12.51	8.09
DOM	69.24	67.40	63.42	62.13	61.21	60.74
DOM:CP	4.21	4.51	5.17	5.79	4.89	7.51
Fecal N	2.58	2.28	1.93	1.69	1.63	1.44
Fecal P	0.67	0.62	0.52	0.45	0.43	0.39

Irrigated: 2007

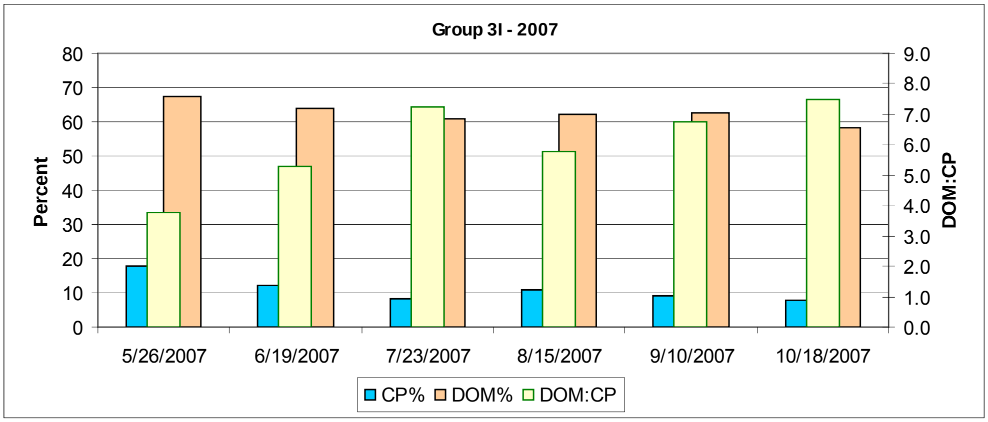
Sample ID	Group_1I					
Date	5/26/2007	6/19/2007	7/24/2007	8/15/2007	9/10/2007	10/18/2007
CP%	14.33	10.36	9.57	10.65	13.23	9.45
DOM%	65.96	63.66	62.52	63.16	67.46	61.66
DOM:CP	**4.60**	**6.14**	**6.53**	**5.93**	**5.10**	**6.52**
Fecal N	2.49	2.24	2.03	1.84	1.42	1.29
Fecal P	0.55	0.55	0.50	0.44	0.35	0.31



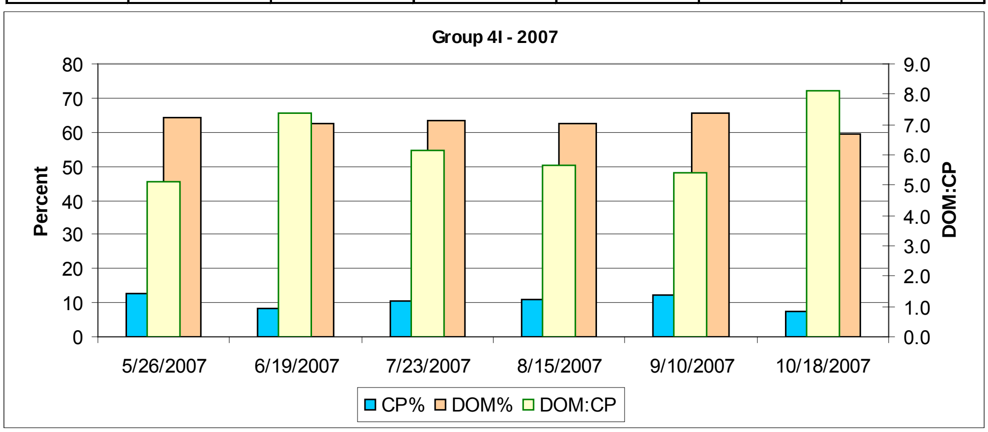
Sample ID	Group_2I					
Date	5/26/2007	6/19/2007	7/23/2007	8/15/2007	9/10/2007	10/18/2007
CP%	12.98	10.25	9.04	9.84	8.28	7.24
DOM%	62.41	62.1	62.12	61.93	61.8	59.46
DOM:CP	**4.81**	**6.06**	**6.87**	**6.29**	**7.46**	**8.21**
Fecal N	2.63	2.2	2.14	2.09	1.71	1.55
Fecal P	0.63	0.52	0.54	0.48	0.43	0.41



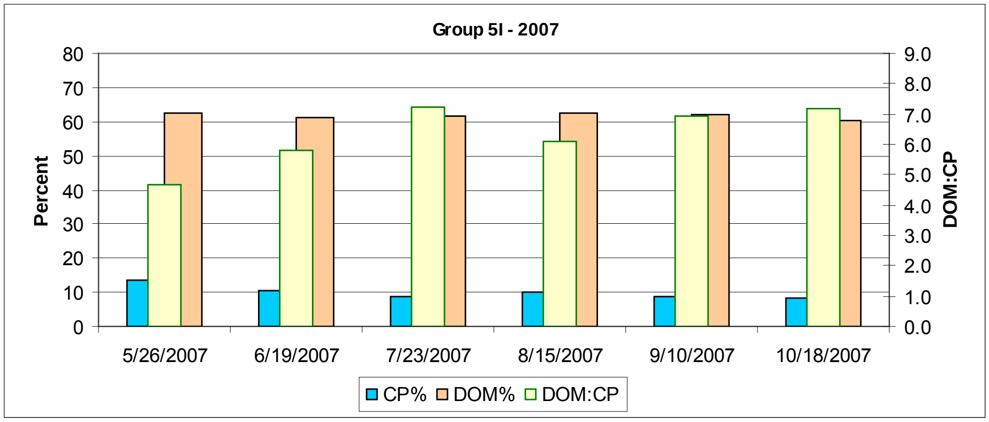
Sample ID	Group_3I					
Date	5/26/2007	6/19/2007	7/23/2007	8/15/2007	9/10/2007	10/18/2007
CP%	17.83	12.03	8.41	10.78	9.25	7.8
DOM%	67.57	63.82	61.03	62.13	62.61	58.23
DOM:CP	**3.79**	**5.31**	**7.26**	**5.76**	**6.77**	**7.47**
Fecal N	2.44	2.11	2.17	2.09	1.88	1.52
Fecal P	0.56	0.52	0.51	0.51	0.47	0.45



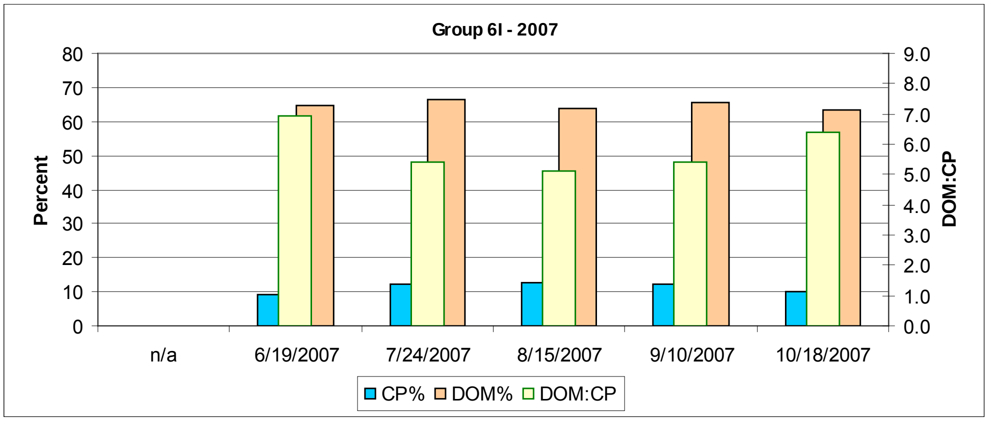
Sample ID	Group_4I					
Date	5/26/2007	6/19/2007	7/23/2007	8/15/2007	9/10/2007	10/18/2007
CP%	12.57	8.48	10.33	11.09	12.14	7.31
DOM%	64.29	62.42	63.33	62.5	65.64	59.4
DOM:CP	**5.11**	**7.36**	**6.13**	**5.64**	**5.41**	**8.13**
Fecal N	2.47	1.94	1.99	2.22	0.9	0.7
Fecal P	0.60	0.50	0.50	0.52	0.26	0.17



Sample ID	Group_5I					
Date	5/26/2007	6/19/2007	7/23/2007	8/15/2007	9/10/2007	10/18/2007
CP%	13.37	10.58	8.55	10.25	8.92	8.37
DOM%	62.41	61.16	61.7	62.3	61.9	60.15
DOM:CP	**4.67**	**5.78**	**7.22**	**6.08**	**6.94**	**7.19**
Fecal N	2.19	2.27	1.96	2.07	1.9	1.58
Fecal P	0.55	0.55	0.51	0.52	0.51	0.46



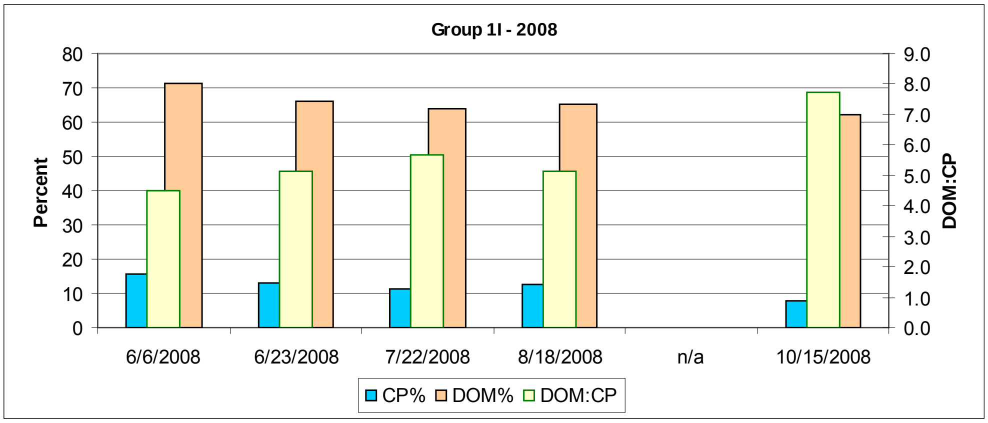
Sample ID	Group_6I					
Date	n/a	6/19/2007	7/24/2007	8/15/2007	9/10/2007	10/18/2007
CP%		9.338	12.22	12.46	12.14	9.9
DOM%		64.54	66.27	63.9	65.64	63.35
DOM:CP		**6.91**	**5.42**	**5.13**	**5.41**	**6.40**
Fecal N		2.26	2.37	1.92	1.83	2.06
Fecal P		0.53	0.62	0.49	0.50	0.62



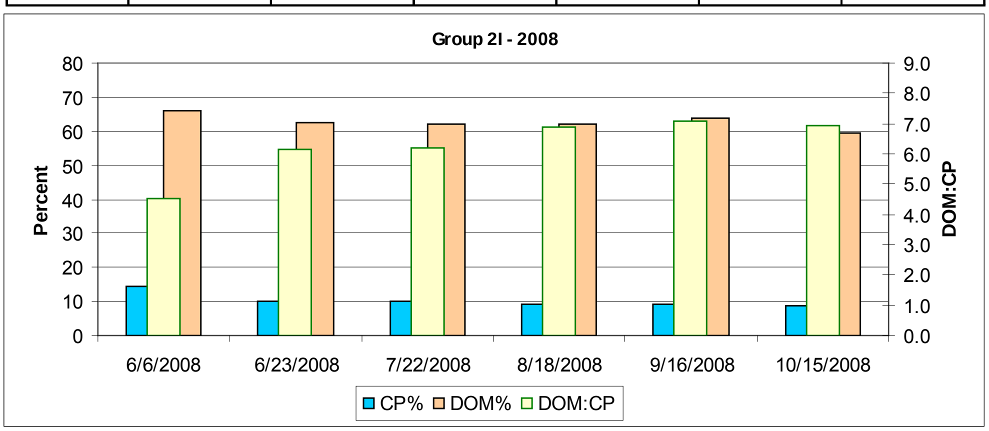
AVERAGES - all 2007 irrigated groups						
CP	14.22	10.17	9.69	10.85	10.66	8.35
DOM	64.53	62.95	62.83	62.65	64.18	60.38
DOM:CP	4.54	6.19	6.49	5.78	6.02	7.23
Fecal N	2.44	2.17	2.11	2.04	1.61	1.45
Fecal P	0.58	0.53	0.53	0.49	0.42	0.40

Irrigated: 2008

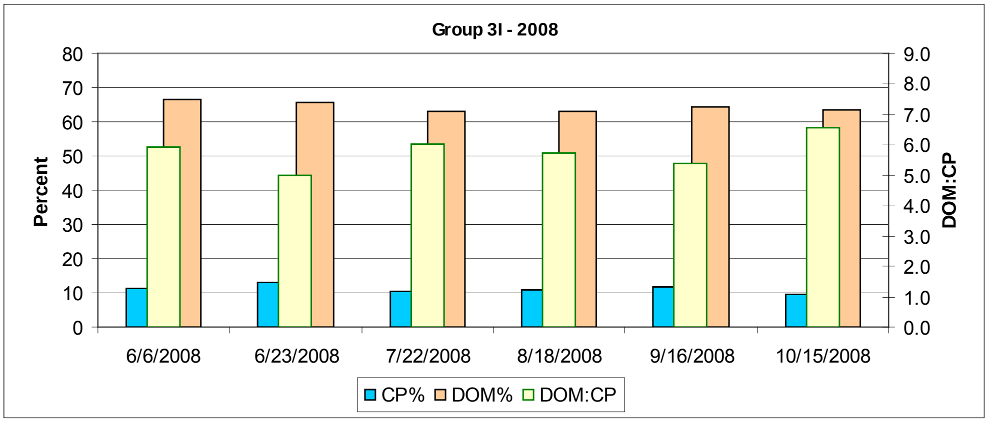
Sample ID	Group_1I					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	n/a	10/15/2008
CP%	15.74	12.92	11.22	12.65		8.03
DOM%	71.2	66.07	63.89	65.22		62.04
DOM:CP	4.52	5.11	5.69	5.16		7.73
Fecal N	2.55	2.13	1.97	2.01		1.44
Fecal P	0.67	0.53	0.49	0.45		0.38



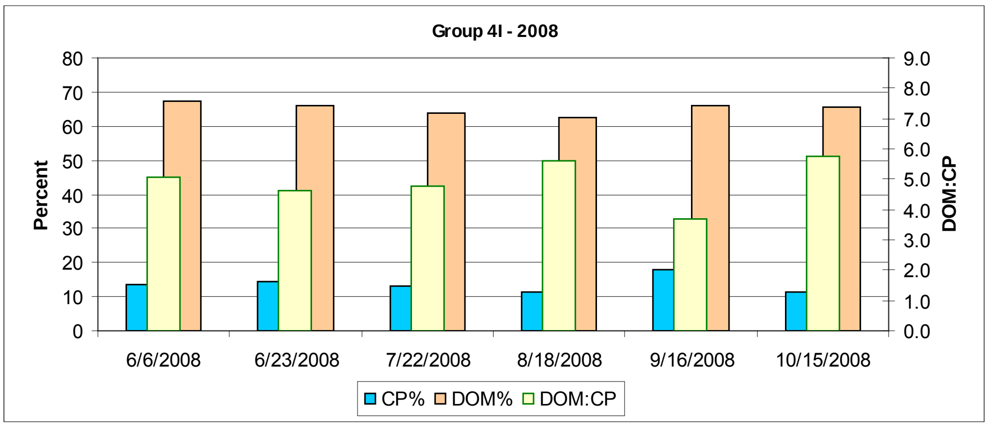
Sample ID	Group_2I					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	9/16/2008	10/15/2008
CP%	14.51	10.18	10.04	9.05	9.05	8.58
DOM%	65.99	62.67	62.23	62.12	64.04	59.51
DOM:CP	4.55	6.16	6.20	6.86	7.08	6.94
Fecal N	2.37	1.97	2.03	1.88	1.95	1.70
Fecal P	0.61	0.49	0.48	0.48	0.46	0.41



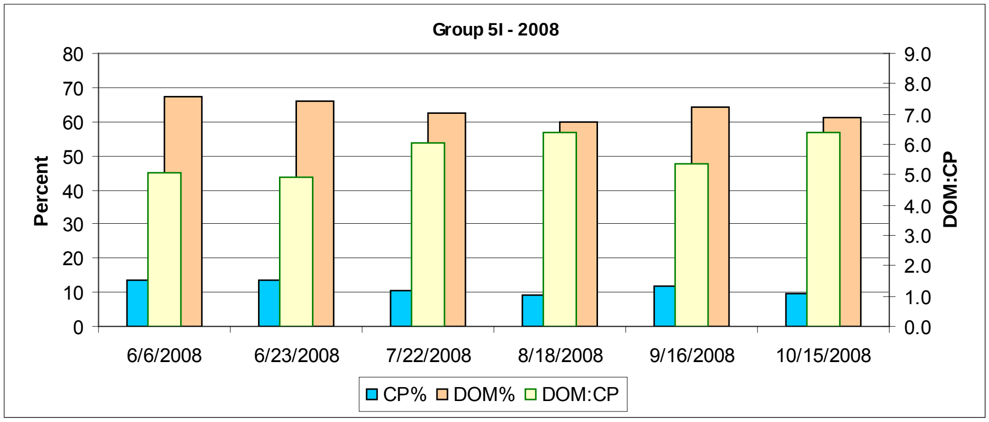
Sample ID	Group_3I					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	9/16/2008	10/15/2008
CP%	11.23	13.19	10.43	10.95	11.93	9.7
DOM%	66.68	65.63	62.84	62.93	64.24	63.56
DOM:CP	**5.94**	**4.98**	**6.02**	**5.75**	**5.38**	**6.55**
Fecal N	2.13	2.32	2.03	1.97	1.86	1.66
Fecal P	0.60	0.62	0.54	0.53	0.53	0.47



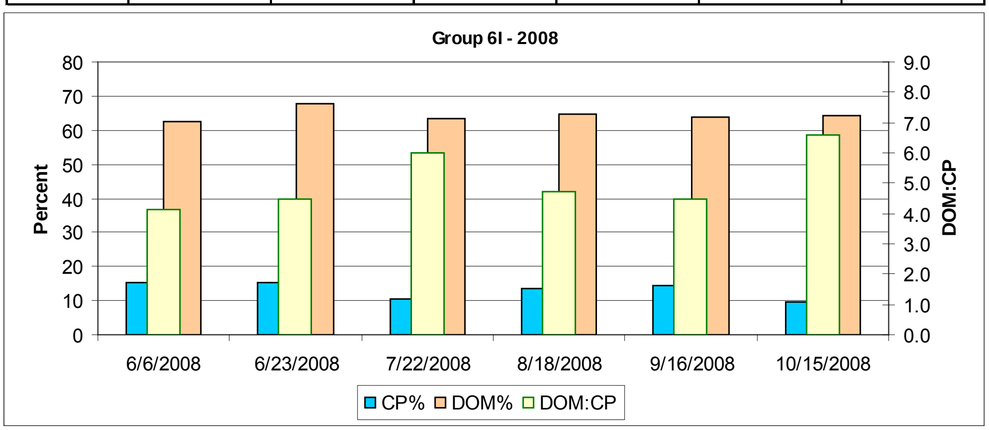
Sample ID	Group_4I					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	9/16/2008	10/15/2008
CP%	13.36	14.24	13.32	11.16	17.89	11.33
DOM%	67.36	65.82	63.83	62.45	66.04	65.42
DOM:CP	**5.04**	**4.62**	**4.79**	**5.60**	**3.69**	**5.77**
Fecal N	2.22	2.43	2.09	1.99	2.46	1.84
Fecal P	0.62	0.66	0.54	0.54	0.62	0.44



Sample ID	Group_5I					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	9/16/2008	10/15/2008
CP%	13.36	13.34	10.3	9.34	11.95	9.57
DOM%	67.36	65.92	62.48	59.69	64.17	61.3
DOM:CP	**5.04**	**4.94**	**6.07**	**6.39**	**5.37**	**6.41**
Fecal N	2.22	2.19	1.94	1.61	1.75	1.65
Fecal P	0.62	0.55	0.51	0.30	0.48	0.46

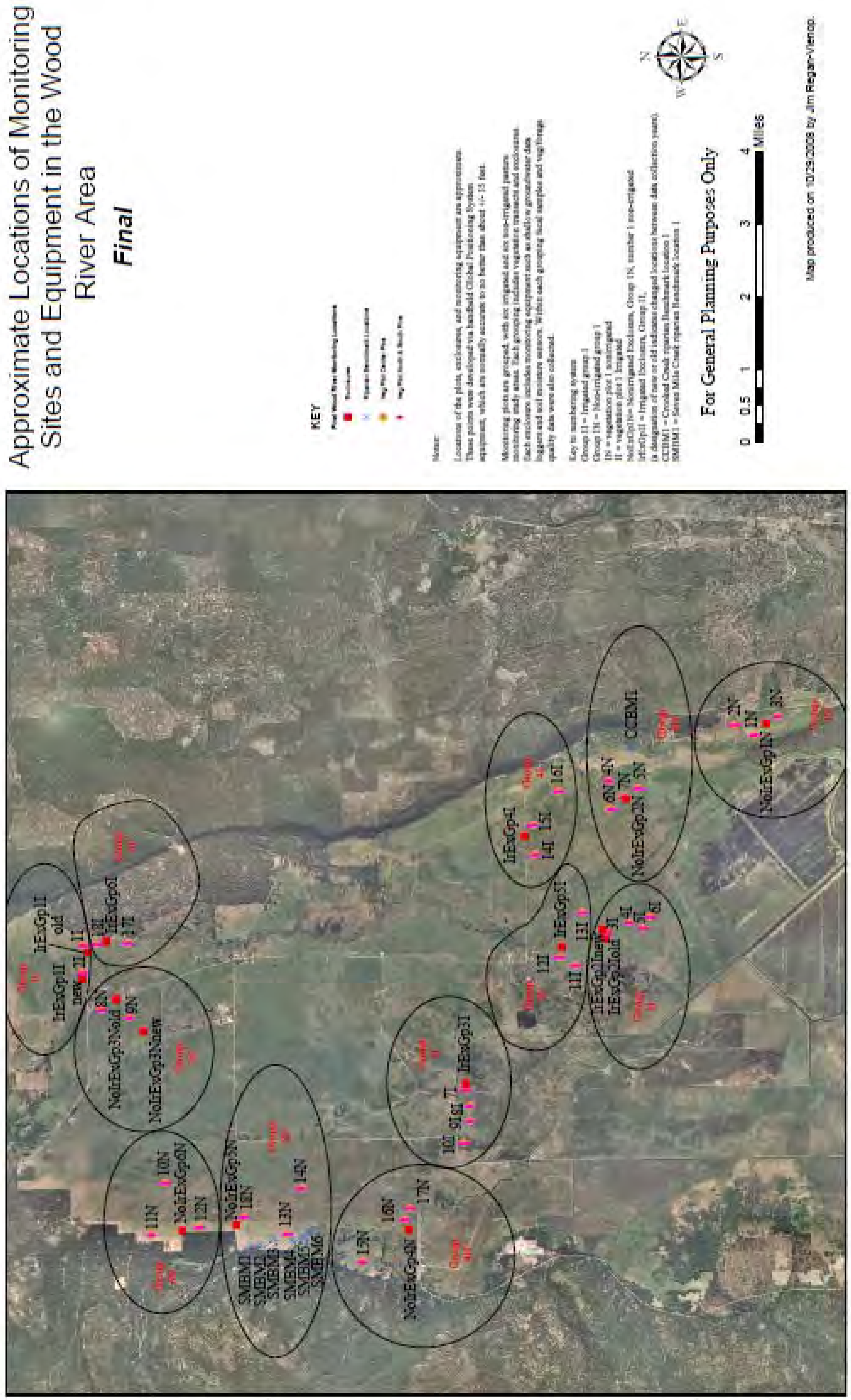


Sample ID	Group_6I					
Date	6/6/2008	6/23/2008	7/22/2008	8/18/2008	9/16/2008	10/15/2008
CP%	15.21	15.2	10.63	13.7	14.31	9.79
DOM%	62.65	67.66	63.54	64.73	63.88	64.3
DOM:CP	**4.12**	**4.45**	**5.98**	**4.72**	**4.46**	**6.57**
Fecal N	2.54	2.51	1.92	1.96	2.02	1.73
Fecal P	0.64	0.64	0.51	0.51	0.50	0.44



AVERAGES - all 2008 irrigated groups						
CP	13.90	13.18	10.99	11.14	13.03	9.50
DOM	66.87	65.63	63.14	62.86	64.47	62.69
DOM:CP	4.81	4.98	5.74	5.64	4.95	6.60
Fecal N	2.34	2.26	2.00	1.90	2.01	1.67
Fecal P	0.63	0.58	0.51	0.47	0.52	0.43

Appendix B: Group/Exclosure Locations



Appendix 2

Final Wood River Conservation Effects Assessment Project Report

Introduction to Appendix 2

Appendix 2 contains two parts. Appendix 2, Part 1 contains a summary of the statistically significant findings or significant relationships of the Oregon State University (OSU) team's pasture vegetation monitoring data analysis. The summary presented in Part 1 of this appendix was prepared by the OSU study team and was pulled from their final report containing the full statistical analysis done on the pasture vegetation monitoring data. The full statistical analysis report is presented in Part 2 of this appendix.

Appendix 2

Final Wood River Conservation Effects Assessment Project Report

Part 1

Significant relationships were found with these measurements:

- The average total gap length was shorter in irrigated than in non-irrigated meadows in 2007. The average total length of gap was 140 cm (3% of the line) for irrigated meadows and the average total length was 197 cm (4% of the line) for non-irrigated meadows in 2007. Total gap length increased with time since the meadow was last irrigated. The average gap size for irrigated meadows was slightly smaller than the gap size in non-irrigated meadows in 2007. The average gap size for irrigated meadows was 5.8 cm and the average gap size for non irrigated meadows was 6.2 cm in 2007, however, these measurements were not significant in 2008. The difference between years may be attributed to differences between observers.

- Percentage of bare ground was different between treatments and there was a linear relationship between time since irrigation and percentage of bare ground (Fig. 1). Irrigated meadows had an average of 0.15% bare ground and non-irrigated meadows had an average of 1.4% bare ground.

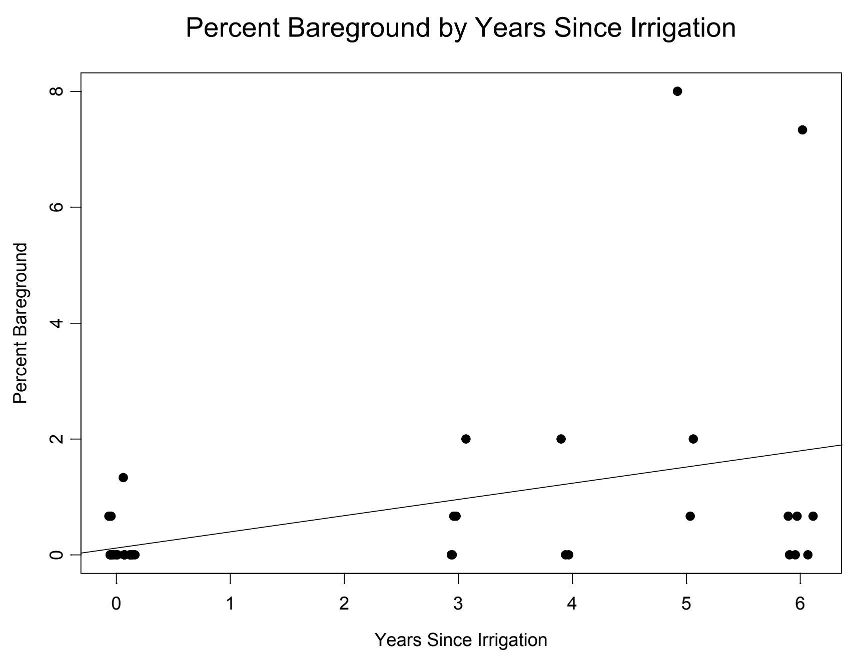


Figure 6. Linear regression of percent bare ground by the number of years since irrigation was stopped. Model: Percent bareground = 0.19 + 0.28(years) + error.

- Average percentage of soil cover was different between groups and increases over time. Average percent soil cover for irrigated meadows was 1% and 18% for non-irrigated meadows.

- May through August re-clip weights were different between treatments in 2007.
    - Table 2. Average dry weight of re-clipped plots by month 2007.

Month	Irrigated	Non-Irrigated
May	151.15	113.42
June	160.2	124.5
July	162.2	125
August	174.1	129.3

- One-time clip weights were different in July and August of 2007, although one-time clip weights were only different between irrigated and non-irrigated meadows in May of 2008. There was no difference in dry weight between irrigated and non-irrigated exclosures the months of June through October of 2008.

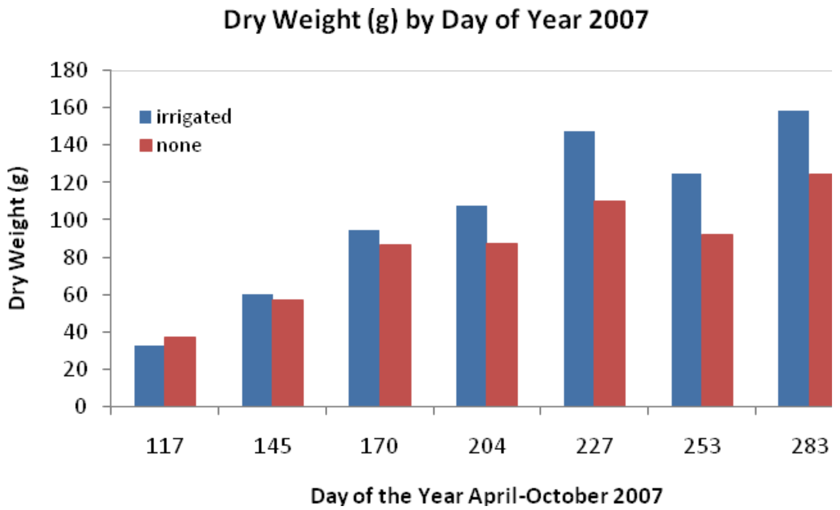


Table 1. Average dry weight of clipped plots by month in 2007. *Signifies a significant relationship between treatments.

Month (day of year)	Irrigated	Non-irrigated	SE	*p* value
April (117)	32.9	37.4	6.3	0.49
May (145)	60.2	57.1	6.9	0.66
June (170)	94.9	86.3	5.2	0.13
July (204)	108.1	87.6	8.9	0.044*
August (227)	147.8	109.9	19.2	0.076*
September (253)	124.8	91.9	24.7	0.211
October (283)	159.0	124.0	25.1	0.195

Table 5. Production for irrigated and non-irrigated exclosures in grams of oven-dry weight 2008. *Significant at the 0.05 level

Month (day of year)	Irrigated (g)	Non-Irrigated (g)	SE	*p* value
May (148)	69.7	48.5	6.0	0.0005*
June (174)	85.6	85.4	10.5	0.98
July (202)	119.1	96.7	19.0	0.27
August (230)	122.8	91.4	28.9	0.30
September (258)	119.8	81.5	20.5	0.09
October (293)	89.8	85.5	14.9	0.78

- Bulk density over time decreases and was different between treatments in the exclosures. The average bulk density in the irrigated exclosures is 0.90 and the average in the non-irrigated exclosures was 0.85. There was moderate evidence to suggest a decrease in bulk density with time since the pasture was irrigated (Fig. 2).

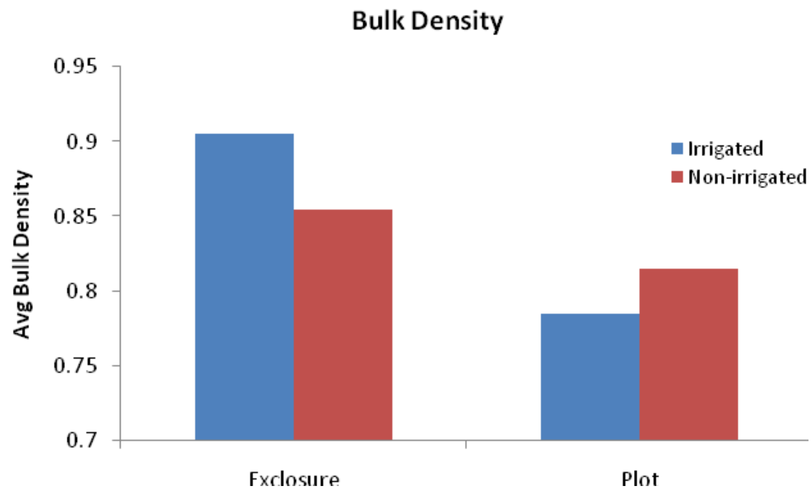


Figure 7. Bulk density between irrigated and non irrigated exclosures on the left of the graph and between transect lines (plot) on the right of the graph.

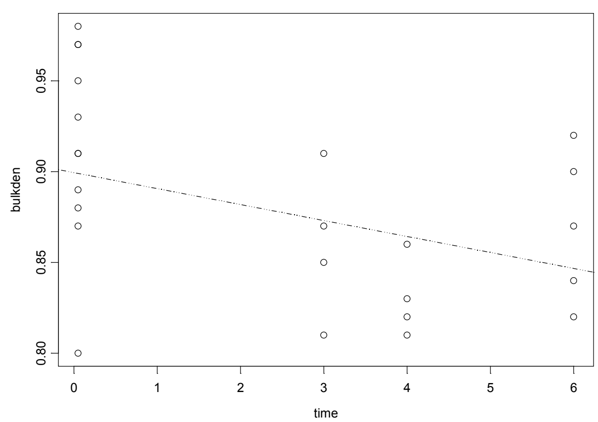


Figure 8. Linear regression of soil bulk density at each exclosure over time since irrigation ceased

- *Carex nebrascensis* decreased over time and had a higher percentage in the top canopy in irrigated meadows. The average percentage of *Carex nebrascensis* in the top canopy in irrigated meadows was 20% and the average percentage in non-irrigated meadows was 10%.

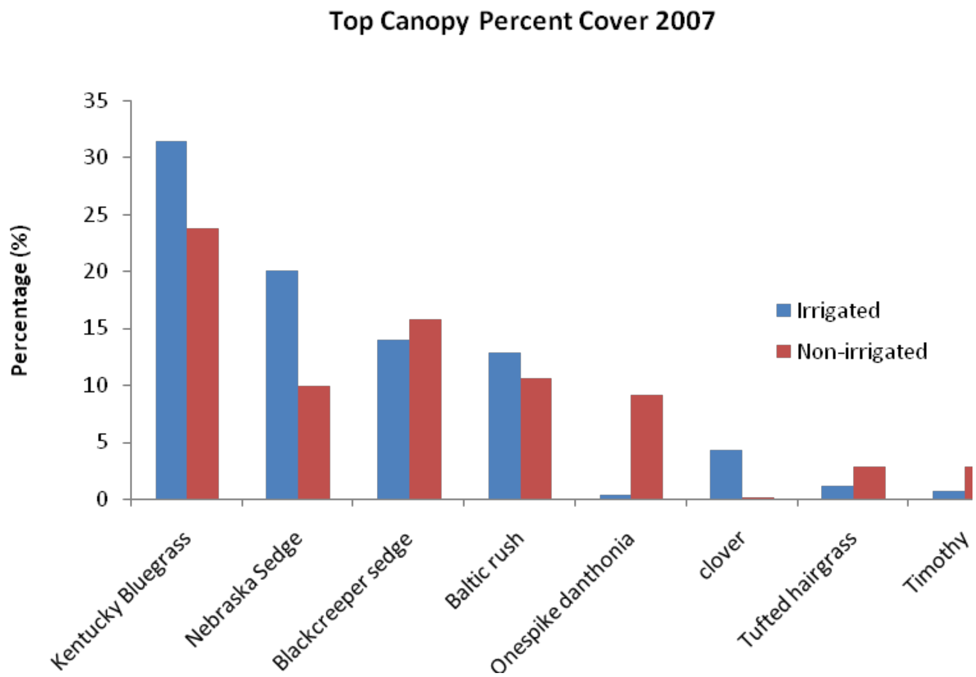


Figure 2. Species percentages in the top canopy layer. Irrigated meadows are in blue, non-irrigated meadows are in red.

- *Carex praegracilis* showed a weak trend to increase over time in the top canopy layer.

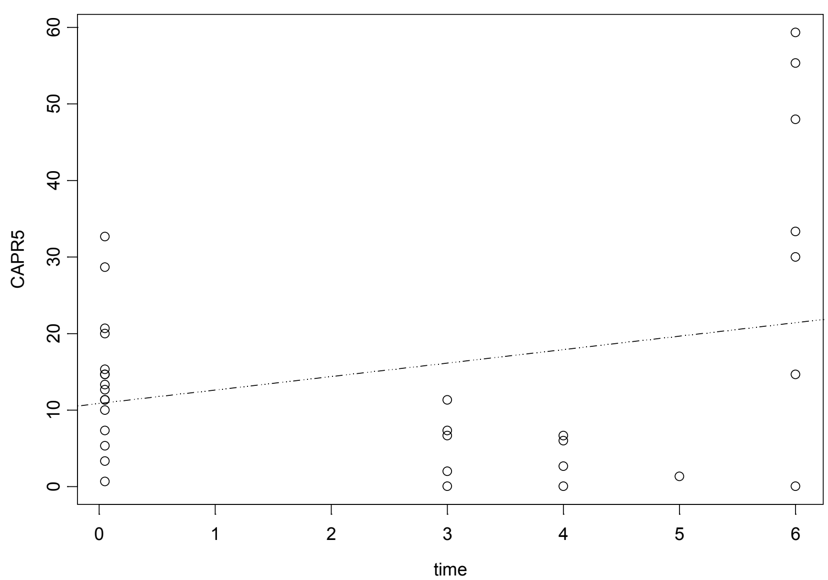


Figure 4. Linear regression of percentage of *Carex praegracilis* by time since irrigation ceased.

- Percentage of grass increased over time and had a higher percentage in non-irrigated meadows in the top canopy. The average percentage of grasses in the top canopy in irrigated meadows was 39% and the average percentage in non-irrigated meadows was 49%.

- Grass-like (sedges and rushes) percentage was higher in irrigated meadows in the top canopy. The average percentage of grass-likes in the top canopy for irrigated meadows was 48% and the average percentage in non-irrigated meadows was 37%.

- Facultative species percentage shows a possible decrease over time and lower percentage in non-irrigated meadows in the second canopy layer. The average percentage of facultative species in the second canopy for irrigated meadows was 22% and the average percentage in non-irrigated meadows was 15%.

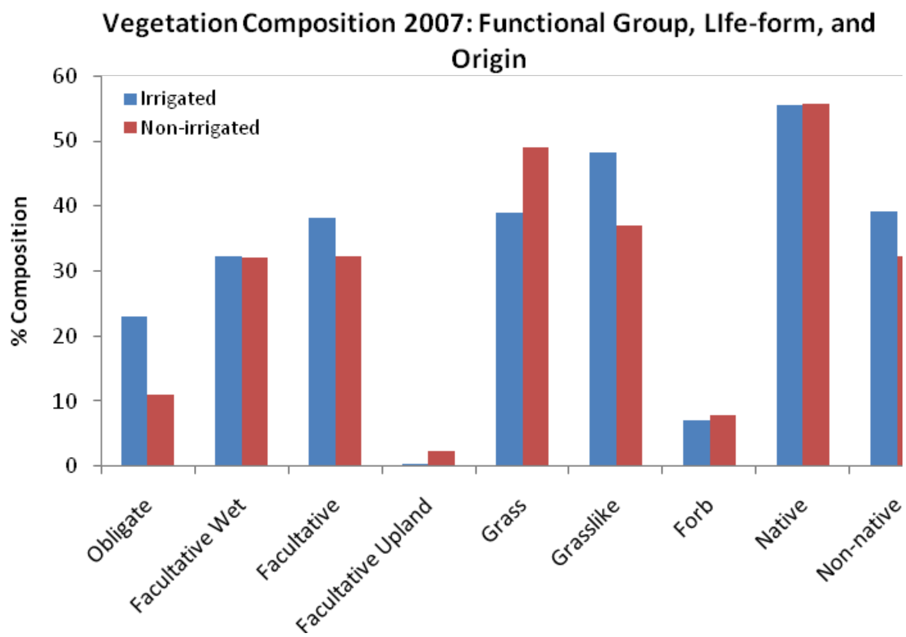


Figure 5. Cover percentages in the top canopy layer between functional groups. No significant differences were found between treatments.

- The percent soil moisture at the meadow sites was different in the months of July, August, and September.

Table 4. Percent soil moisture for months that were significantly different ($p < 0.05$) between irrigated and non-irrigated pastures.

Month	Irrigated	Non-irrigated	SE	*p* value
July	36%	25%	3.2%	0.0006
August	36%	18%	3.6%	<0.0001
September	37%	19%	2.7%	<0.0001

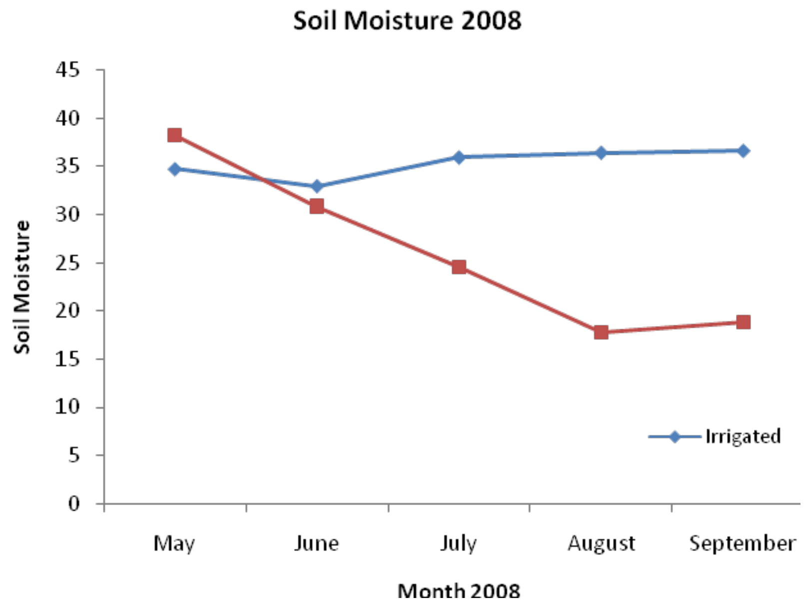


Figure 9. Percent soil moisture for the 2008 growing season in irrigated and non-irrigated pastures.

Appendix 2

Final Wood River Conservation Effects Assessment Project Report

Part 2

Wood River Valley Vegetation Monitoring Summary 2007-2008

Tamzen K. Stringham and Sarah E. Quistberg
Rangeland Ecology and Management
Oregon State University
December 2008

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Introduction

The Wood River valley has been influenced by human activities for the past century resulting in alteration in meadow hydrology. Concern has recently increased with high water demands in the Klamath Basin. Water resource allocation in the upper Klamath Basin, specifically the Wood River valley, is generally used for pasture irrigation.

The Wood River valley grazing lands are highly productive native rangelands that have been modified by season-long irrigation and the addition of non-native species, predominantly Kentucky bluegrass. The elaborate irrigation system diverts significant amounts of water from Sevenmile Creek, Annie Creek and the Wood River. Grazing can occur from the beginning of snowmelt in April or May to early November. The cattle are generally brought in from other areas and are either cow/calf pairs or stockers. Pasture management varies between landowners in the study and also varies year to year.

The objectives of this study were to:

1. Determine and measure changes that may have occurred to plant community production, composition and structure between irrigated and non-irrigated rangelands.
2. Determine and measure changes in soil bulk density between irrigated and non-irrigated rangelands.
3. Determine and measure changes on monthly soil moisture between irrigated and non-irrigated rangelands.
4. Determine if there was a significant increase in basal gap size between irrigated and non-irrigated rangelands.

Methods

The project used the monitoring protocols in USDA-ARS “Monitoring Manual for Grassland, Shrubland, and Savannah Ecosystems” (Herrick et al. 2005). The data was entered into the Rangeland Database and Field Entry Data System, developed by ARS, USGS, NRCS and BLM. There were 36 sites total in this study; 18 irrigated meadows, and 18 non-irrigated meadows. Each site had two vegetation transects where all measurements were taken. Sites were grouped by time since irrigated (Groups 1N-2N, 7 years; 5N, 6 years;6N, 5 years; 3N-4N, 4 years) and by landowner for a total of 12 groups, six of each treatment (irrigated/non-irrigated).

Line-point intercept was used to quantify vegetation canopy cover and soil cover in both 2007 and 2008. Each vegetation transect was 150 feet long with two transects per site, one running north and the second running south. Measurements were taken every 2 feet along the length of the 150 foot line for a total of 75 points per transect. The top canopy, lower canopy layers and soil surface were recorded.

Photo points were taken at the same time as line-point intercept measurements, July-early August in 2007 and in late June-July in 2008. There were a total of four photos taken at each site. One photo was taken for each transect along with one oblique photo (camera pointed down toward ground) of each transect.

Basal gap intercept was used to determine if a change in gap size was related to a change in vegetation composition. The beginning and end measurement of gaps between perennial plant bases greater than 3 cm were recorded for the first 25 feet of the transect. Basal gap was measured in 2007 and 2008.

Total annual forage production was calculated from total production using the double sampling method. All above ground growth was clipped and separated by species in a 1.92 ft^2 plot on each transect. Four other hoops were estimated by weight units established by the clipped weight of each species. Plant production at the site level was only collected in 2007.

Belt transect was used to record the number of invasive species along the transect line, specifically thistles, along the transect line. Along the two 150 foot transects, a belt width of 6 feet (3 feet on either side of the transect line) was measured. All the thistles present within this area were counted and a density value calculated. Belt transect measurements were taken in 2007 and 2008.

Soil moisture was taken at each of the sites once a month May through September 2008. Two samples were taken every month if irrigation water was not present at the surface and the soil was not saturated. The samples were weighed in the field, obtaining an initial wet weight. The soil samples were then dried in an oven at 105° C for 24 hours. The soil samples were then re-weighed to obtain a dry weight. These measurements were used to obtain a percentage of soil moisture for each site by month.

Exclosures were constructed within each group for a total of 12 exclosures during 2007. Additional exclosures (three) were constructed at the end of 2007 because some of the original exclosures were not representative of the production or vegetation found in the group (Group 1I, 2I, and 3N). The dry weights for the exclosures in a group were averaged to obtain one number for use in the statistical analysis. Exclosures were clipped monthly using a 1.92ft^2 clipping hoop and an electric gram scale. A new area in the exclosure was clipped every month in 2007 and 2008 and past clipped areas were re-clipped monthly. Field (green) weights were recorded and samples were dried in an oven at 50 degrees F and reweighed after 24 hours of drying. In addition, bulk densities were measured at each grazing exclosure and at each transect line in 2008.

Results

2007 Summary

Production

Exclosures were clipped once a month April through October 2007. Dry weights for each exclosures were similar between treatments (fig 1). Only July and August dry weights were significantly different between treatments (table 1).

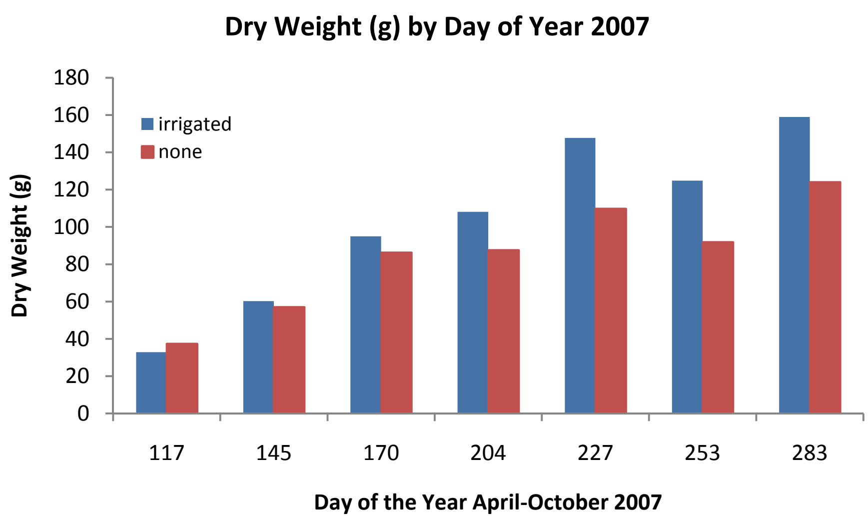

Figure 1. Dry weight by day of the year, April through October 2007.

Table 1. Average dry weight of clipped plots by month in 2007. *Signifies a significant relationship between treatments.

Month (day of year)	Irrigated	Non-irrigated	SE	*p* value
April (117)	32.9	37.4	6.3	0.49
May (145)	60.2	57.1	6.9	0.66
June (170)	94.9	86.3	5.2	0.13
July (204)	108.1	87.6	8.9	0.044*
August (227)	147.8	109.9	19.2	0.076*
September (253)	124.8	91.9	24.7	0.211
October (283)	159.0	124.0	25.1	0.195

Exclosure plots were also re-clipped successively every month. May through August re-clip weights were different between treatments, while there was no difference found between treatments the months of April, September, and October (table 2, see Appendix A for full statistical analysis).

Table 2. Average dry weight of re-clipped plots by month 2007.

Month	Irrigated	Non-Irrigated
May	151.15	113.42
June	160.2	124.5
July	162.2	125
August	174.1	129.3

Gap

The 2007 data showed that there was a difference between treatments for total gap length and percentage of the line in a gap. The average total length of gap in the 800 cm measured was 140 cm (18% of the line) for irrigated meadows and the average total length was 197 cm (25% of the line) for non-irrigated meadows. The average gap size was also different between treatments. The average gap size for irrigated meadows was 5.8 cm and the average gap size for non irrigated meadows was 6.2 cm. Total gap length and years since irrigation had a positive linear relationship, while there was no linear trend between species diversity and gap length.

Foliar Cover and Species Trends

Total foliar canopy cover was nearly the same between irrigated and non-irrigated meadows (95% and 94%, respectively) in 2007. There was no difference in the total percentage of foliar cover between treatments. The difference between the treatments was related to species composition in irrigated and non-irrigated meadows. Irrigated meadows tended to have a higher percentage of *Poa pratensis* (Kentucky bluegrass) and *Carex nebrascensis* (Nebraska sedge) which generally occur in wetter meadows (fig 2). These species can be found on drier non-irrigated sites, but there is a slight shift in species composition in non-irrigated meadows with higher percentages of *Carex praegracilis* and *Danthonia unispicata* in the top and second canopy layers. These species are adapted to drier conditions, thus they were found in higher foliar cover in non-irrigated meadows.

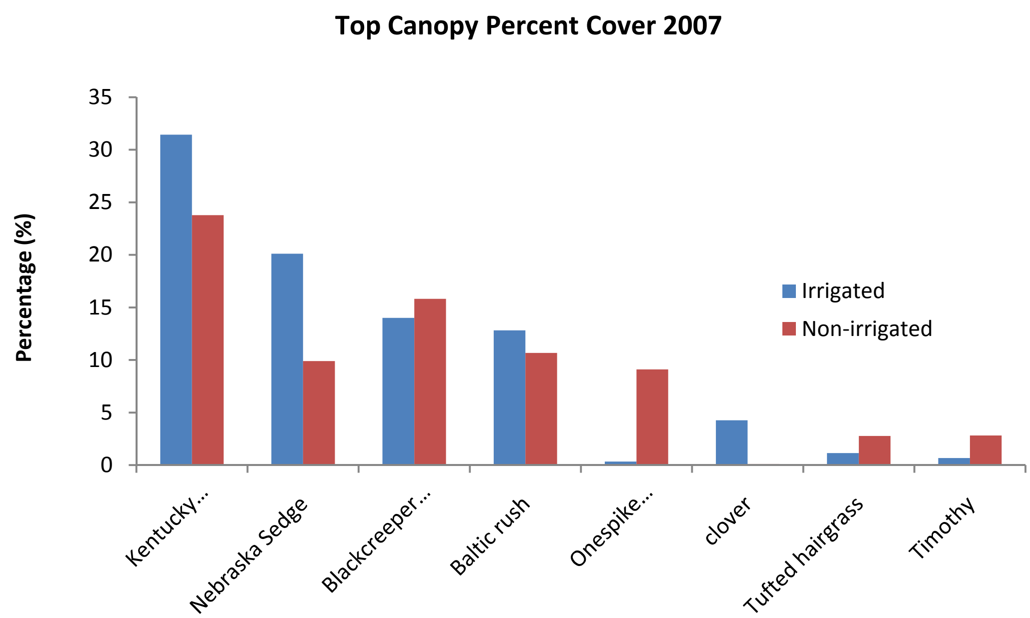

Figure 2. Species percentages in the top canopy layer. Irrigated meadows are in blue, non-irrigated meadows are in red.

Carex nebrascensis comprised a greater percentage of the top canopy in irrigated meadows (fig 2) and exhibited a dedrease in non-irrigated sites with time since irrigation was removed (fig 3).. The average percentage of *Carex nebrascensis* in the top canopy in irrigated meadows was 20% and the average percentage in non-irrigated meadows was 10%. *Carex praegracilis* also showed a weak trend to increase over time since irrigation was removed in the top canopy layer, however the apparent increase was not significant (fig 4). *Poa pratensis* foliar cover was not different in the top canopy between treatments and there was no trend to increase or decrease over time since irrigation ceased. The foliar cover of *Juncus balticus* and *Cirsium vulgare* had no difference in the top canopy between irrigated and non-irrigated meadows.

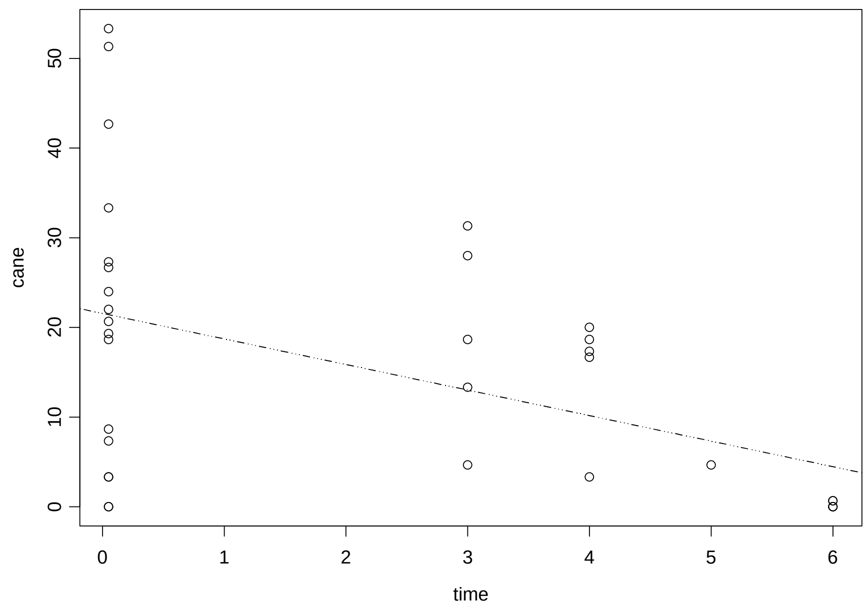

Figure 3. Linear regression of percentage of *Carex nebrascensis* by the time since irrigation ceased.

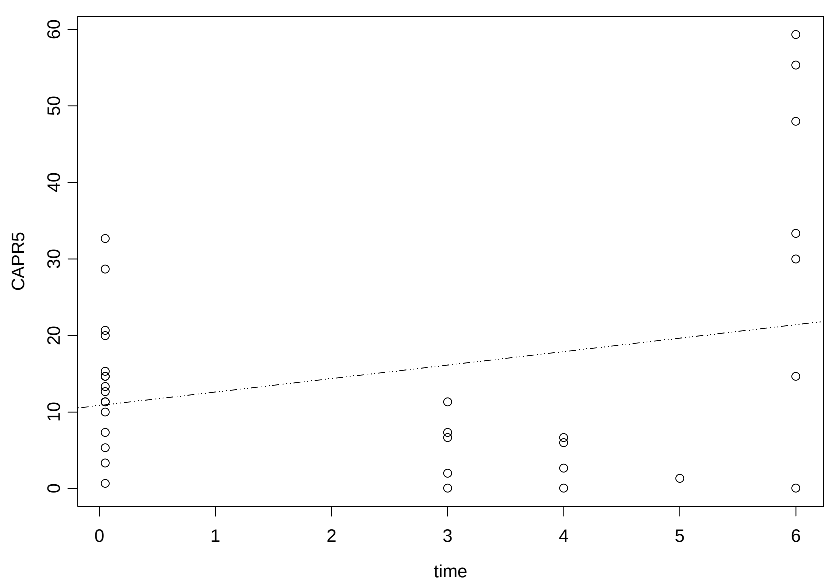

Figure 4. Linear regression of percentage of *Carex praegracilis* by time since irrigation ceased.

The foliar cover of grasses increased over time and had a higher percentage in non-irrigated meadows in the top canopy. The average percentage of grasses in the top canopy in irrigated meadows was 39% and the average percentage in non-irrigated meadows was 49% (fig 5). Grass-like (sedges and rushes) percentage was higher in irrigated meadows in the top canopy (fig 5). The average percentage of grass-likes in the top canopy for irrigated meadows was 48% and the average percentage in non-irrigated meadows was 37%. Foliar cover of grass-like showed no trend over time since last irrigated in the top canopy layer. The increase of grasses in drier meadows was probably due to the loss of water and soil moisture over time, creating conditions not suitable for grass-like species, such as *Carex* spp. *Danthonia unispicata, Phleum pratense,* and *Deschampsia cespitosa* have higher foliar cover in non-irrigated meadows while *Carex nebrascensis* and *Juncus balticus*, both grass-likes, have higher foliar cover in irrigated meadows. The percentage of forbs (flowering plants) showed no trend over time or difference between treatments in any canopy layer.

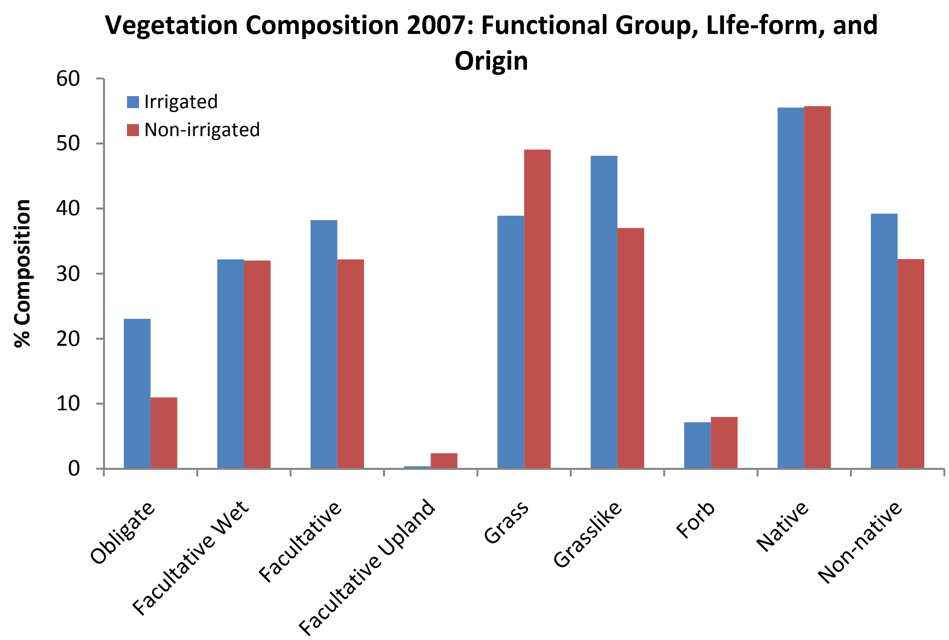

Figure 5. Cover percentages in the top canopy layer between functional groups. No significant differences were found between treatments.

The foliar cover of obligate wetland species percentage decreased over time since irrigation in the top canopy and was higher in irrigated meadows. The average percentage of obligate wetland species in the top canopy for irrigated meadows was 23% and the average percentage in non-irrigated meadows was 11% (fig 5). Obligate wetland species had a higher percentage in irrigated meadows probably due to the continuous water availability in these meadows. In the non-irrigated sites these obligate wetland species were not being replaced by other species adapted to saturated conditions. Facultative wet species and facultative species percentages showed no trend over time since last irrigated or difference between treatments in any canopy layer. Native and non-native species foliar cover was similar between irrigated and non-irrigated meadows. Native and non-native species percentages showed no trend over time or statistical difference between irrigated and non-irrigated meadows in any canopy layer.

The percentage of bare ground was different between treatments and there was a linear relationship between time since last irrigated and percentage of bare ground (Fig. 6). Irrigated meadows had an average of 0.15% bare ground and non-irrigated meadows had an average of 1.4% bare ground.

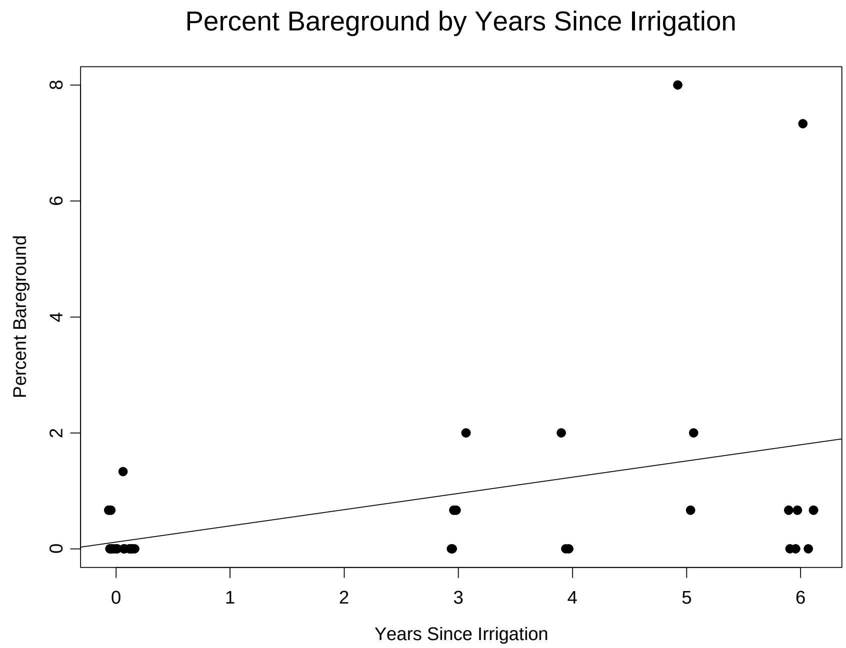

Figure 6. Linear regression of percent bare ground by the number of years since irrigation was stopped. Model: Percent bareground = 0.19 + 0.28(years) + error.

The average percentage of soil cover was also different between groups and increased over time. Average percent soil cover for irrigated meadows was 1% and 18% for non-irrigated meadows (see Appendix A).

2008 Summary

Bulk density

The average bulk density for irrigated meadows plots was 0.78 and 0.81 for non-irrigated meadows plots (fig 7). There was no significant difference between the bulk density at the plots for irrigated and non-irrigated meadows ($p = 0.38$). Bulk density between irrigated and non-irrigated exclosures was different between treatments ($p = 0.02$). The average bulk density in the irrigated exclosures was 0.90 and the average in the non-irrigated exclosures was 0.85. This difference may be a function of exclosure location. Exclosures were located generally along fence lines, while the plots were located out in the pastures.

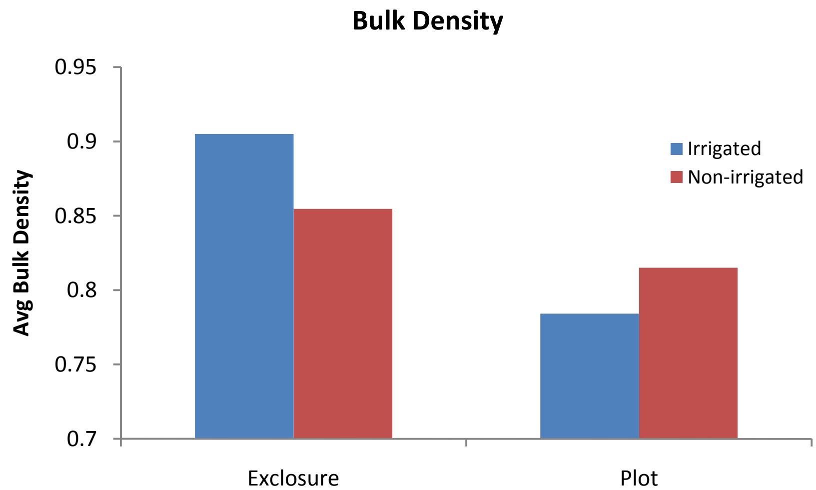

Figure 7. Bulk density between irrigated and non irrigated exclosures on the left of the graph and between transect lines (plot) on the right of the graph.

There was also moderate evidence to suggest a decrease in bulk density with time since the pasture was irrigated (fig 8).

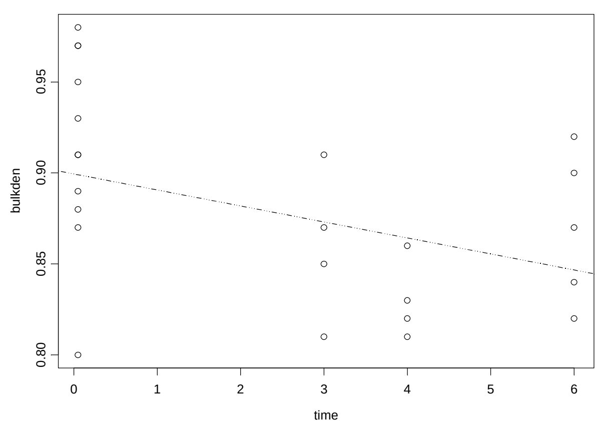

Figure 8. Linear regression of soil bulk density at each exclosure over time since irrigation ceased

Soil moisture

Soil moisture could not be taken at plots that had water ponded on the surface. These plots were assumed to be saturated (a soil moisture value of 50%, table 3).

Table 3. Irrigated plots that had soil moisture values (.50) filled in for analysis

Month	Plot(s)
May	5N, 6N, 3I, 2I, 10I
June	14I
July	7I, 8I, 10I, 3I, 18I
August	16I
September	3I, 11I

Soil moisture remained fairly constant in irrigated pastures while soil moisture decreased throughout the growing season in non-irrigated pastures (fig 9).

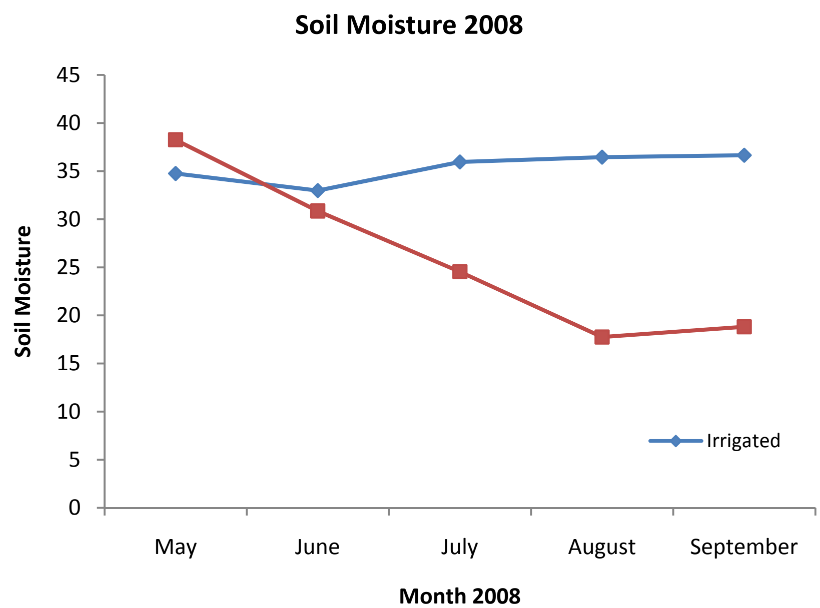

Figure 9. Percent soil moisture for the 2008 growing season in irrigated and non-irrigated pastures.

The average soil moisture for the month of May for irrigated and non-irrigated plots was 35% and 38% and was 33% and 31% for the month of June. There was no difference between irrigated and non-irrigated soil moisture percentages during the months of May (p=0.21) and June (p=0.44). Soil moisture was higher in irrigated pastures in the months of July, August, and September (table 4).

Table 4. Percent soil moisture for months that were significantly different ($p < 0.05$) between irrigated and non-irrigated pastures.

Month	Irrigated	Non-irrigated	SE	*p* value
July	36%	25%	3.2%	0.0006
August	36%	18%	3.6%	<0.0001
September	37%	19%	2.7%	<0.0001

Production

Plant production in irrigated and non-irrigated exclosures in 2008 were slightly lower than production in 2007, however, some of this difference may be attributed to subtracting bag weights from the samples in 2008 and it may be attributed to later snowmelt in the meadows and cooler temperatures in 2008. Dry weight increased in non-irrigated exclosures until about July, and then decreased slightly through the rest of the growing season, while dry weight increased though August in irrigated meadows and dry weight did not decrease until October at the end of the grazing season (fig 10). The only statistical difference seen in 2008 in dry weight between irrigated and non-irrigated exclosures was in May (table 5). Dry weight between irrigated and non-irrigated exclosures appears to have differences through mid-summer, but there was variability within each treatment.

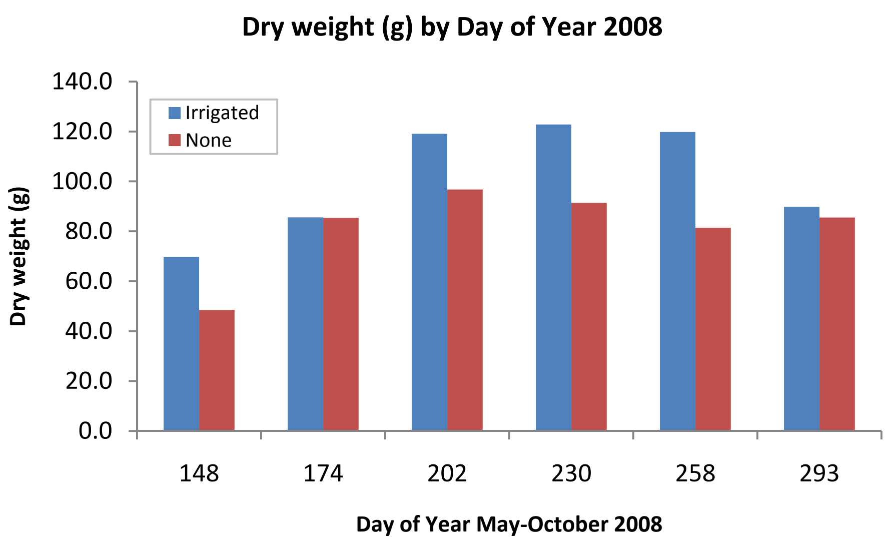

Figure 10. Dry weight in grams between irrigated and non-irrigated ("none") exclosures May through October 2008.

Table 5. Production for irrigated and non-irrigated exclosures in grams of oven-dry weight 2008. *Significant at the 0.05 level

Month (day of year)	Irrigated (g)	Non-Irrigated (g)	SE	*p* value
May (148)	69.7	48.5	6.0	0.0005*
June (174)	85.6	85.4	10.5	0.98
July (202)	119.1	96.7	19.0	0.27
August (230)	122.8	91.4	28.9	0.30
September (258)	119.8	81.5	20.5	0.09
October (293)	89.8	85.5	14.9	0.78

Gap

The average length of plant basal gaps for irrigated and non-irrigated groups was 193 cm and 234 cm (for the first 800 cm), respectively. There was little evidence to suggest there was a difference between the mean length of plant basal gaps for irrigated and non-irrigated pastures ($p = 0.19$).
The average percentage of plant basal gaps (out of 800 cm measured) for irrigated and non-irrigated groups was 24% and 29%, respectively. There was little evidence to suggest a difference between the mean percentage of plant basal gaps for irrigated and non-irrigated pastures ($p = 0.19$). Note that the p-

value for both percentage of plant basal gap and length of basal gap are equal, this is due to the fact the percents are based length data (they are 1:1 correlated). These were simply different methods of expressing the same measurement.

The average size of plant basal gaps for irrigated and non-irrigated groups was 4.7 cm and 5.1 cm, respectively. There was little evidence to suggest a difference between the average size of plant basal gaps for irrigated and non-irrigated pastures (p = 0.13).

There was little evidence to conclude there was a linear relationship between the amount of plant basal gap and the number of years since irrigation ceased (p = 0.185).

This methodology has not been applied to meadows systems and more research is needed to explain year to year differences in gap sizes. The measurement may not be suited for meadows or there may be too much variability in wetter systems than the drier systems this measurement was generally applied.

Species trends

Vegetation composition in 2008 for irrigated and non-irrigated pastures was similar to the trends seen in 2007 (fig 11). Obligate wetland plants were higher in irrigated pasture than non-irrigated pastures, a trend also seen in 2007. Statistics were not performed on vegetation data in 2008 because little visual differences between years could be detected. If subsequent monitoring was performed within the next 5 to 10 years at each location, changes between sampling date may be more apparent.

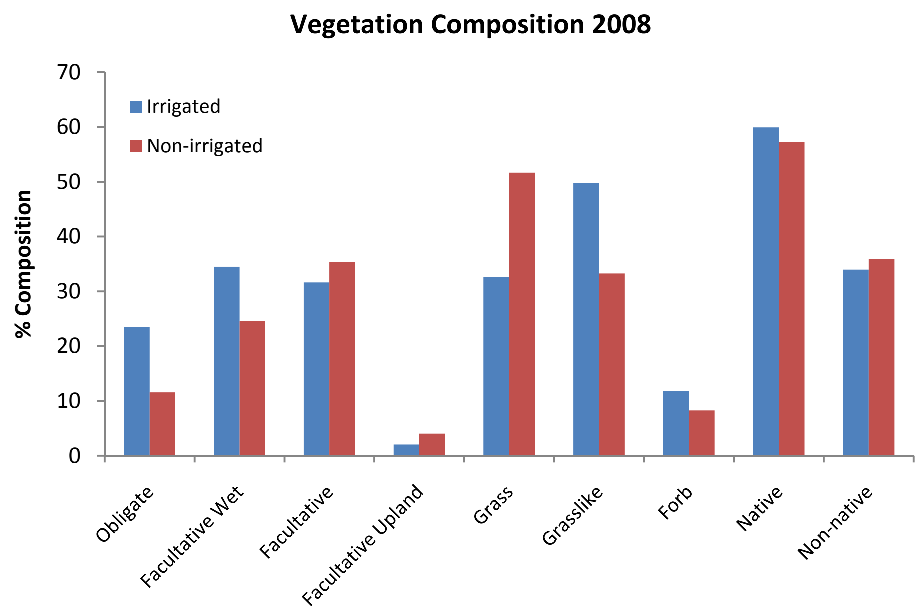

Figure 11. Vegetation composition (%) for 2008 growing season for irrigated and non-irrigated pastures.

Specific species trends between irrigated and non-irrigated pastures in 2008 were similar to trends observed in 2007 (fig 12). Nebraska sedge had a higher percent composition in irrigated meadows than non-irrigated meadows which was also found in 2007.

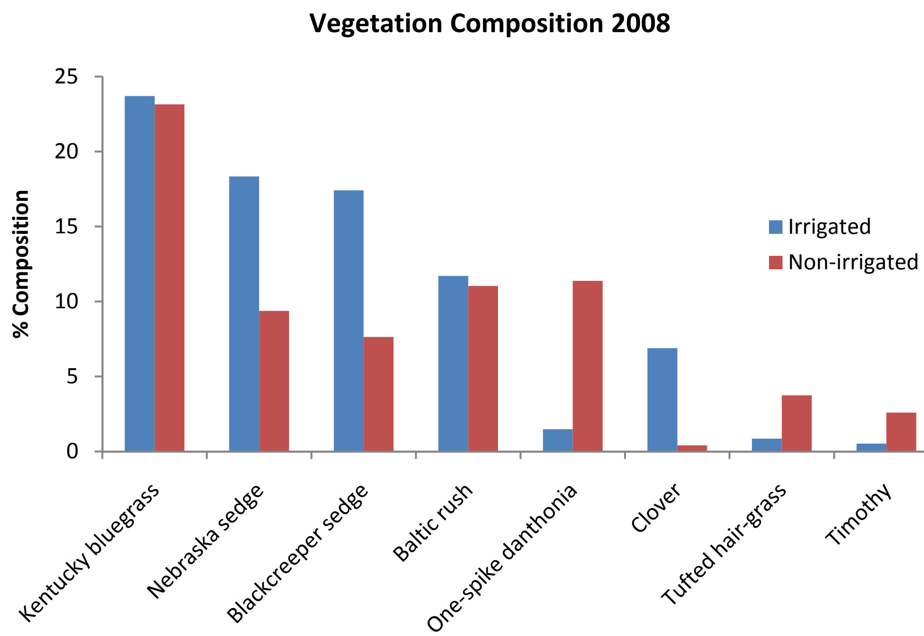

Figure 12. Vegetation composition for specific species in 2008 for irrigated and non-irrigated pastures.

Vegetation Cover Summary 2007 and 2008

Functional group composition and specific species composition trends between 2007 and 2008 were similar between irrigated and non-irrigated pastures. The graphs below separate trends between irrigated and non-irrigated pastures and year. Slight differences from 2007 to 2008 could be attributed to the difference in sampling date and climate differences between years. Differences between years may or may not be attributed to the presence or lack of irrigation water.

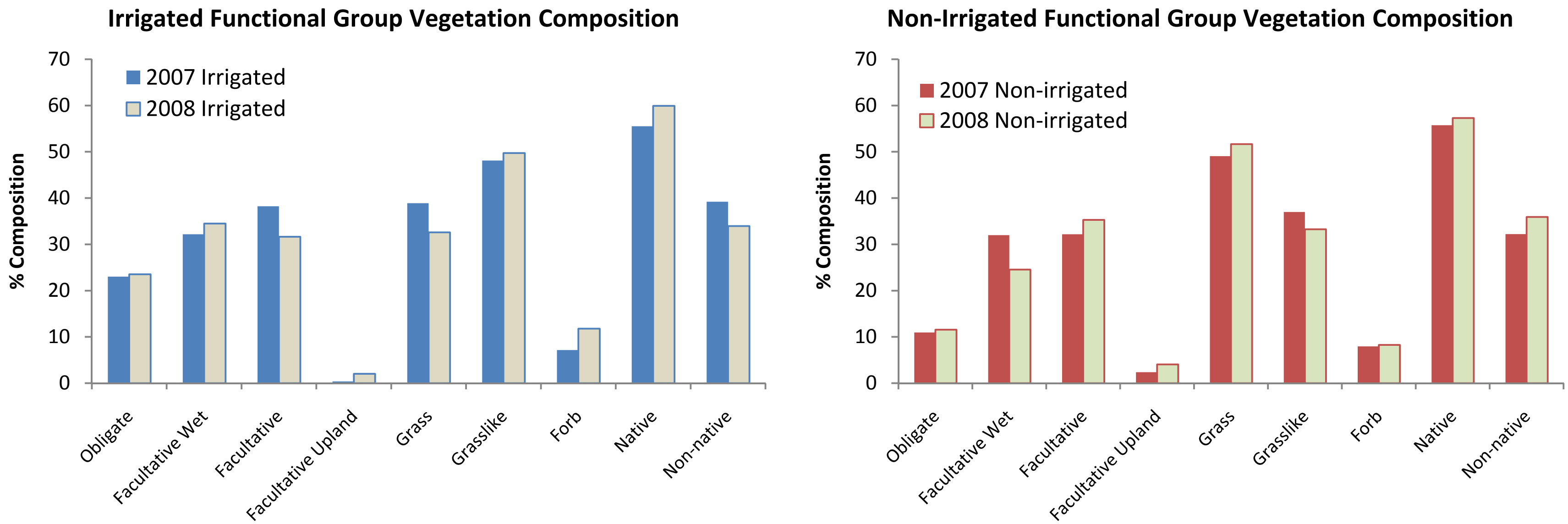

Figure 13. Functional group vegetative composition separated by treatment.

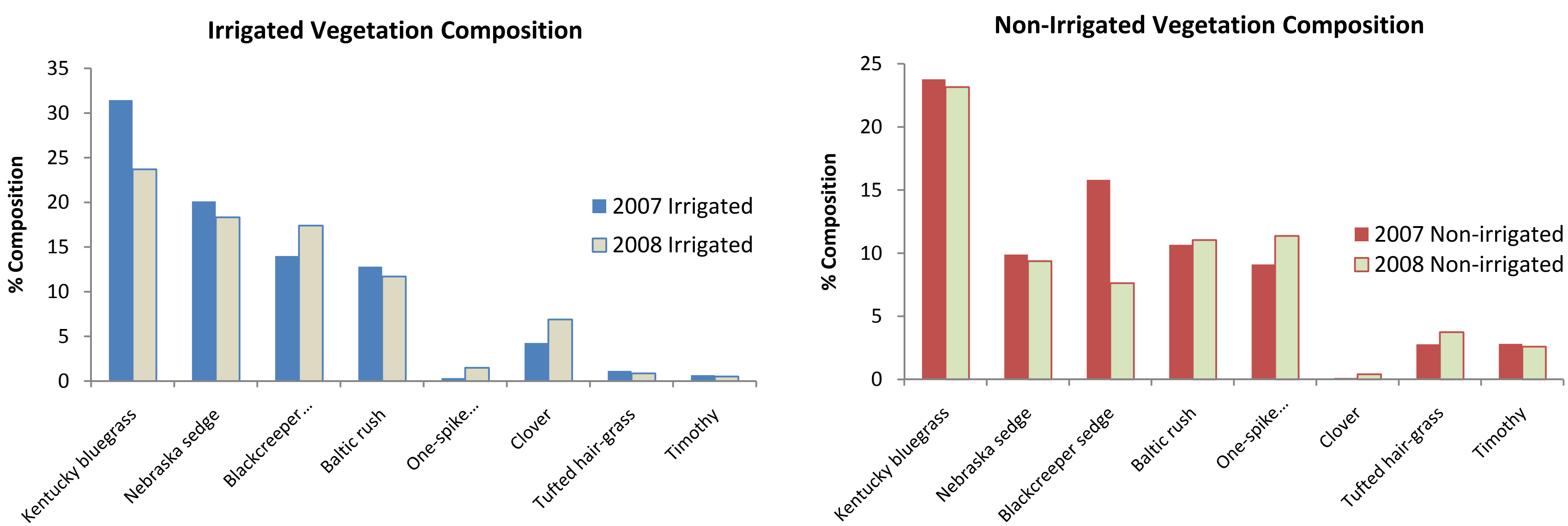

Figure 14. Vegetation composition by dominant species found in irrigated and non-irrigated pastures. Graphs are separated by treatment.

Conclusions

Significant relationships were found with these measurements:

- The average total gap length was shorter in irrigated than in non-irrigated meadows in 2007. The average total length of gap was 140 cm (3% of the line) for irrigated meadows and the average total length was 197 cm (4% of the line) for non-irrigated meadows in 2007. Total gap length increased with time since the meadow was last irrigated. The average gap size for irrigated meadows was slightly smaller than the gap size in non-irrigated meadows in 2007. The average gap size for irrigated meadows was 5.8 cm and the average gap size for non irrigated meadows was 6.2 cm in 2007, however, these measurements were not significant in 2008. The difference between years may be attributed to differences between observers.
- Percentage of bare ground was different between treatments and there was a linear relationship between time since irrigation and percentage of bare ground (Fig. 1). Irrigated meadows had an average of 0.15% bare ground and non-irrigated meadows had an average of 1.4% bare ground.
- Average percentage of soil cover was different between groups and increases over time. Average percent soil cover for irrigated meadows was 1% and 18% for non-irrigated meadows (see Appendix A).
- May through August re-clip weights were different between treatments in 2007.
- One-time clip weights were different in July and August of 2007, although one-time clip weights were only different between irrigated and non-irrigated meadows in May of 2008. There was no difference in dry weight between irrigated and non-irrigated exclosures the months of June through October of 2008.
- Bulk density over time decreases and was different between treatments in the exclosures. The average bulk density in the irrigated exclosures is 0.90 and the average in the non-irrigated exclosures was 0.85. There was moderate evidence to suggest a decrease in bulk density with time since the pasture was irrigated (Fig. 2).
- *Carex nebrascensis* decreased over time and had a higher percentage in the top canopy in irrigated meadows. The average percentage of *Carex nebrascensis* in the top canopy in irrigated meadows was 20% and the average percentage in non-irrigated meadows was 10%.
- *Carex praegracilis* showed a weak trend to increase over time in the top canopy layer.
- Percentage of grass increased over time and had a higher percentage in non-irrigated meadows in the top canopy. The average percentage of grasses in the top canopy in irrigated meadows was 39% and the average percentage in non-irrigated meadows was 49%.
- Grass-like (sedges and rushes) percentage was higher in irrigated meadows in the top canopy. The average percentage of grass-likes in the top canopy for irrigated meadows was 48% and the average percentage in non-irrigated meadows was 37%.
- Facultative species percentage shows a possible decrease over time and lower percentage in non-irrigated meadows in the second canopy layer. The average percentage of facultative species in the second canopy for irrigated meadows was 22% and the average percentage in non-irrigated meadows was 15%.

- The percent soil moisture at the meadow sites was different in the months of July, August, and September.

No significant relationship or difference between treatment (irrigated and non-irrigated) were found for these measurements:

- There was no difference between treatments in thistle numbers.
- There was no difference in the total percentage of foliar cover between treatments.
- There was no difference between April, September or October re-clip weights.
- *Poa pratensis* was not different in the top canopy between treatments and there was no trend to increase or decrease over time.
- *Juncus balticus* percentage had no difference in the top canopy between treatments.
- *Carex praegracilis* showed no difference between treatments in the top canopy.
- Native species percentages showed no trend over time or difference between treatments in any canopy layer.
- Non-native species percentage showed no difference in the top canopy between treatments.
- Grass-like percentage showed no trend over time in the top canopy layer.
- Forb percentage showed no trend over time or difference between treatments in any canopy layer.
- Facultative wet species percentages showed no trend over time or difference between treatments in any canopy layer.
- Facultative species percentages showed no trend over time or difference between species in the top canopy layer.
- There was no linear trend in species diversity and species diversity was not related to total gap length, although there was a slight difference in the number of species between treatments (~1 species).
- Bulk density was not different between irrigated and non-irrigated meadow sites.
- There was no difference in the percent soil moisture the months of May and June between irrigated and non-irrigated sites.

Appendices

Appendix A: 2007 Statistical Report…………………………………………………………………………………….pg 19
Appendix B: 2008 Statistical Summary……………………………………………………………………………….pg 116
Appendix C: Species list………………………………………………………………………………………………..pg 122
Appendix D: Additional Graphs……………………………………………………………………………………….pg 124

Appendix A: 2007 Statistical Report

WOOD RIVER DATA ANALYSIS FOR THE YEAR 2007
C.A. Matney

This document covers the analysis of 6 topics for the Wood River Study:

Thistle Abundance p. 19
Plant Basal Gaps p. 21
Point Intercept p. 27
Annual Production (One Time Clip: Weight by Species) p. 53
Annual Production (Re-clipping) p. 58
Annual Production (One Time Clip by Date) p. 71

Description
Within the document a series of 12 coded groups will be mentioned: a through f and g through l. These coded groups refer directly to groups 1-6 in both irrigated and non-irrigated treatments (irrigated: a=1, b=2, c=3, d=4, e=5, f=6; non-irrigated: g=1, h=2, i=3, j=4, k=5, l=6).

Throughout the document, questions were used to illustrate the basis of the statistical tests that were used. Following each question are data plots, statistical model output, summary statistics, and a conclusion based on the content of the question. Questions are highlighted in yellow.

Thistle Abundance

Question 1. Does thistle abundance differ between 2 treatments (Irrigated or Non-irrigated)?

Data
One outlier was removed from the irrigated treatment (value = 333).

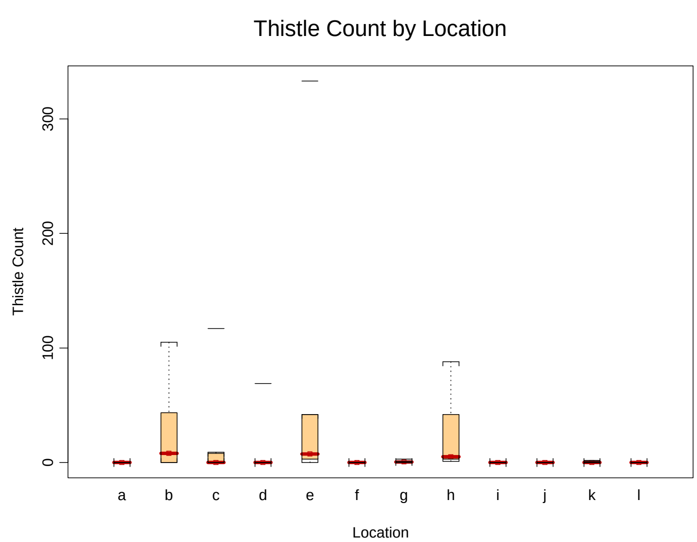

Figure 1. Boxplot of unedited thistle counts for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). An outlier is present in group e (value = 333). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

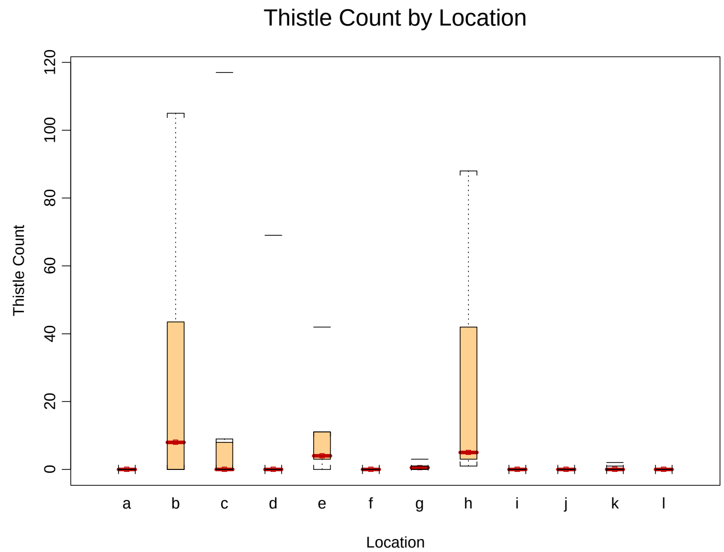

Figure 2. Boxplot of edited thistle counts for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i), with outlier removed from group e. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 1. Thistle Count Summary Statistics for Treatments

```
site:irrigated
              count
     Min:   0.00000
 1st Qu.:   0.00000
    Mean:  12.75676
  Median:   0.00000
 3rd Qu.:   8.00000
     Max: 117.00000
 Total N:  37.00000
   NA's :   0.00000
Std Dev.:  28.73771
 SE Mean:   4.72445
--------------------
```

```
site:none
              count
     Min:   0.00000
 1st Qu.:   0.00000
    Mean:   4.92500
  Median:   0.00000
 3rd Qu.:   1.00000
     Max:  88.00000
 Total N:  40.00000
   NA's :   0.00000
Std Dev.:  18.04750
 SE Mean:   2.85356
```

Table 2. ANOVA Model, Thistle Count = Treatment + Error

```
Terms:
                Treatment Residuals
 Sum of Squares  1178.93  42433.59
Deg. of Freedom        1        75
Residual standard error: 23.78615
Estimated effects may be unbalanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
Treatment  1   1178.93 1178.934 2.083727 0.1530404
Residuals 75  42433.59  565.781

Tables of means
Grand mean
 8.6883

Treatment
    irrigated   none
    12.757     4.925
rep 37.000    40.000
```

Conclusion
Average thistle counts for irrigated and non-irrigated groups are 12.76 and 4.93, respectively. There is little evidence to suggest there is a difference between the mean thistle counts for irrigated and non-irrigated treatments ($p = 0.153$).

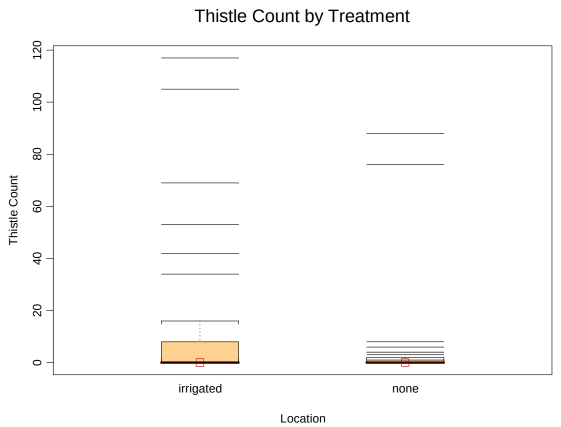

Figure 3. Boxplot of edited thistle counts for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Plant Basal Gaps
Question 1. Does the total amount of plant basal gap per transect differ between 2 treatments (Irrigated or Non-irrigated)?
Data

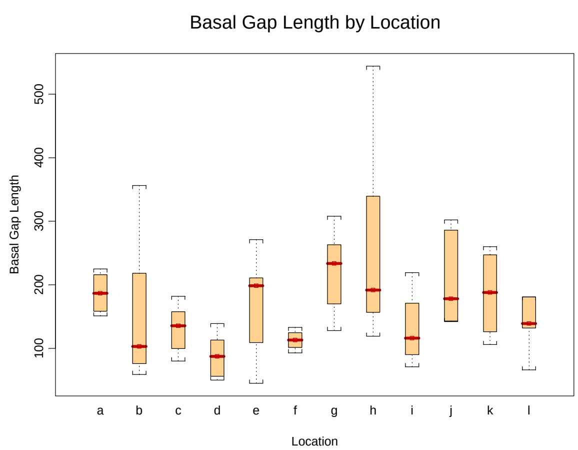

Figure 4. Boxplot of length of basal gaps for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 3. Total Basal Gap Summary Statistics for Treatments

```
treatment:irrigated                                  1st Qu.:  87.50000
           totalgap                                     Mean: 139.66286
     Min:  45.00000                                   Median: 131.00000
```

```
 3rd Qu.: 182.00000
     Max: 356.40000
 Total N:  35.00000
   NA's :   0.00000
Std Dev.:  68.09790
 SE Mean:  11.51065
--------------------
treatment:none
           totalgap
     Min:  66.00000
 1st Qu.: 131.00000
    Mean: 196.60833
  Median: 181.00000
 3rd Qu.: 232.25000
     Max: 544.00000
 Total N:  36.00000
   NA's :   0.00000
Std Dev.:  99.01707
 SE Mean:  16.50284
```

Table 4. ANOVA Model, Total Basal Gap = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   57548.1  500822.3
Deg. of Freedom         1        69
Residual standard error: 85.19562
Estimated effects may be unbalanced
          Df Sum of Sq  Mean Sq  F Value       Pr(F)
treatment  1   57548.1 57548.06 7.928592 0.006338316
Residuals 69  500822.3  7258.29

Tables of means
Grand mean
 168.54
 treatment
    irrigated   none
    139.66    196.61
rep  35.00     36.00
```

Conclusion

The average length of plant basal gaps for irrigated and non-irrigated groups are 139.7 cm and 196.6 cm, respectively. There is strong evidence to suggest there is a difference between the mean length of plant basal gaps for irrigated and non-irrigated treatments (p = 0.006).

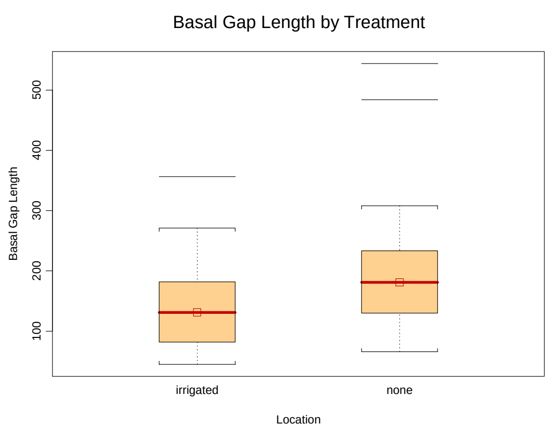

Figure 5. Boxplot of the length of basal gaps for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Question 2. Does the total percentage of plant basal gap per transect differ between 2 treatments (Irrigated or Non-irrigated)?

Data

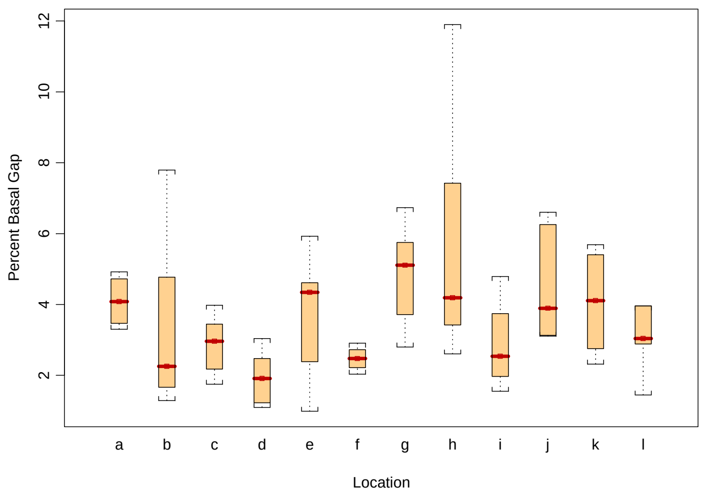

Figure 6. Boxplot of the percentage of plant basal gaps for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 5. Percentage Basal Gap Summary Statistics for Treatments

```
treatment:irrigated
            pctgap
     Min: 0.9842520
 1st Qu.: 1.9138233
    Mean: 3.0547432
  Median: 2.8652668
 3rd Qu.: 3.9807524
     Max: 7.7952756
 Total N: 35.0000000
   NA's : 0.0000000
Std Dev.: 1.4894553
 SE Mean: 0.2517639
-------------------
```

```
treatment:none
            pctgap
     Min: 1.4435696
 1st Qu.: 2.8652668
    Mean: 4.3002698
  Median: 3.9588801
 3rd Qu.: 5.0798338
     Max: 11.8985127
 Total N: 36.0000000
   NA's : 0.0000000
Std Dev.: 2.1657276
 SE Mean: 0.3609546
```

Table 6. ANOVA Model, Percent Basal Gap = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   27.5308  239.5914
Deg. of Freedom         1        69
Residual standard error: 1.863421
Estimated effects may be unbalanced
          Df Sum of Sq  Mean Sq  F Value       Pr(F)
treatment  1   27.5308 27.53076 7.928592 0.006338316
Residuals 69  239.5914  3.47234

Tables of means
Grand mean
 3.6863
 treatment
    irrigated   none
     3.055     4.300
rep 35.000    36.000
```

Conclusion

The average percentage of plant basal gaps for irrigated and non-irrigated groups are 3.05% and 4.30%, respectively. There is strong evidence to suggest there is a difference between the mean percentage of plant basal gaps for irrigated and non-irrigated treatments (p = 0.006). Note that the p-value for both percentage of plant basal gap and length of basal gap are equal, this is due to the fact the percents are based length data (they are 1:1 correlated). These are simply different methods of expressing the same measurement.

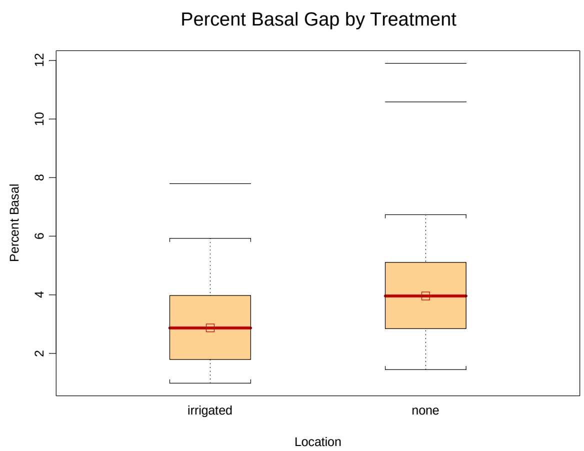

Figure 7. Boxplot of the percentage of plant basal gaps for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Question 3. Does the average plant basal gap size per transect differ between 2 treatments (Irrigated or Non-irrigated)?

Data

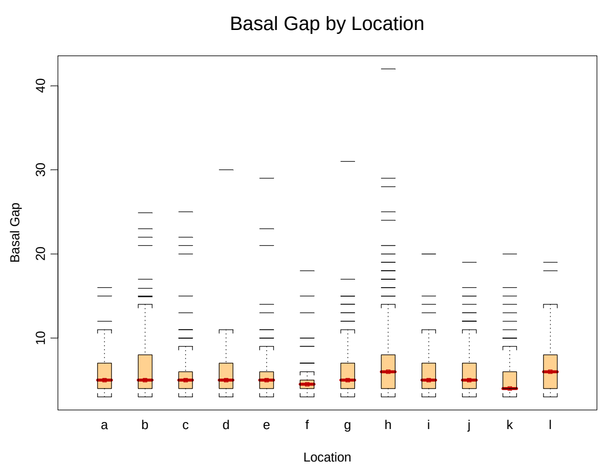

Figure 8. Boxplot of plant basal gaps (cm) for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 7. Basal Gap Size Summary Statistics for Treatments

```
treatment:irrigated
                  gap
     Min:    3.0000000
```

```
1st Qu.:    4.0000000
   Mean:    5.8541317
 Median:    5.0000000
```

```
 3rd Qu.:   7.0000000
     Max:  30.0000000
 Total N: 836.0000000
   NA's :   1.0000000
Std Dev.:   3.2124819
 SE Mean:   0.1111725
----------------------
treatment:none
                  gap
     Min:    3.000000
 1st Qu.:     4.000000
    Mean:     6.212379
  Median:     5.000000
 3rd Qu.:     7.000000
     Max:    42.000000
 Total N: 1148.000000
   NA's :     9.000000
Std Dev.:     3.562181
 SE Mean:     0.105549
```

Table 8. ANOVA Model, Basal Gap = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares     61.83  23047.15
Deg. of Freedom         1      1972
Residual standard error: 3.418654
Estimated effects may be unbalanced
            Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment    1     61.83 61.83431 5.290774 0.02154265
Residuals 1972  23047.15 11.68720
Tables of means
Grand mean
 6.0608
 treatment
    irrigated   none
       5.9       6.2
rep  835.0    1139.0
```

Conclusion

The average size of plant basal gaps for irrigated and non-irrigated groups are 5.85 cm and 6.21 cm, respectively. There is moderate evidence to suggest there is a difference between the average size of plant basal gaps for irrigated and non-irrigated treatments (p = 0.022).

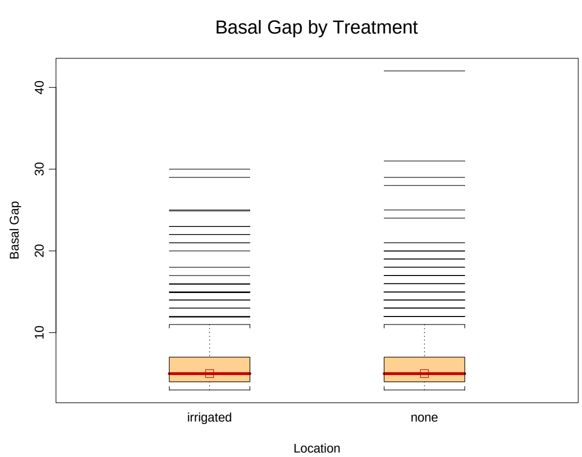

Figure 9. Boxplot of plant basal gaps (cm) for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Question 4. Is the total amount of plant basal gap per transect associated with the number of years since irrigation stopped?

Data

Table 9. Linear Model, Basal Gap (cm) = $\beta_0 + \beta_1$(Years No Irrigation) + Error

```
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) 135.1786  13.6791     9.8821   0.0000
      years  13.9524   3.9767     3.5085   0.0008

Residual standard error: 82.87 on 69 degrees of freedom
Multiple R-Squared: 0.1514
F-statistic: 12.31 on 1 and 69 degrees of freedom, the p-value is 0.0007978

Correlation of Coefficients:
      (Intercept)
years -0.6951
```

Conclusion

There is overwhelming evidence to conclude there is a linear relationship between the amount of plant basal gap and the number of years since irrigation was stopped (p = 0.0008). For every 1 year that passes since irrigation was stopped there is a 13.96 cm increase in plant basal gap per 150 ft line transect (Figure 10).

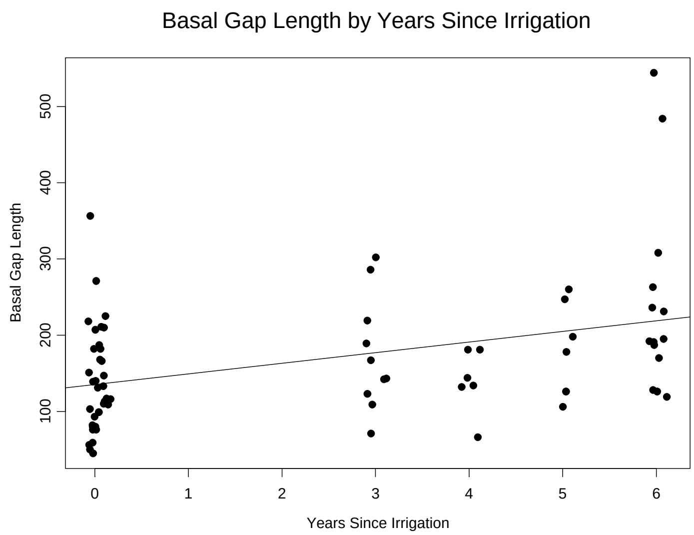

Figure 10. Linear regression of plant basal gap length (cm) per 150 foot transect by the number of years since irrigation was stopped. Model: gap length = 135.18 + 13.95(years) + error.

Question 5. Is the total percent of plant basal gap per transect associated with the number of years since irrigation stopped?

Data

Table 10. Linear Model, % Basal Gap = $\beta_0 + \beta_1$(Years No Irrigation) + Error

```
Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 2.9567 0.2992     9.8821  0.0000
      years 0.3052 0.0870     3.5085  0.0008
Residual standard error: 1.813 on 69 degrees of freedom
Multiple R-Squared: 0.1514
F-statistic: 12.31 on 1 and 69 degrees of freedom, the p-value is 0.0007978
Correlation of Coefficients:
      (Intercept)
years -0.6951
```

Conclusion
There is overwhelming evidence to conclude there is a linear relationship between percent plant basal gap and the number of years since irrigation was stopped (p = 0.0008). For every 1 year that passes since irrigation was stopped there is a 0.31% increase in plant basal gap per 150 ft line transect (Figure 11).

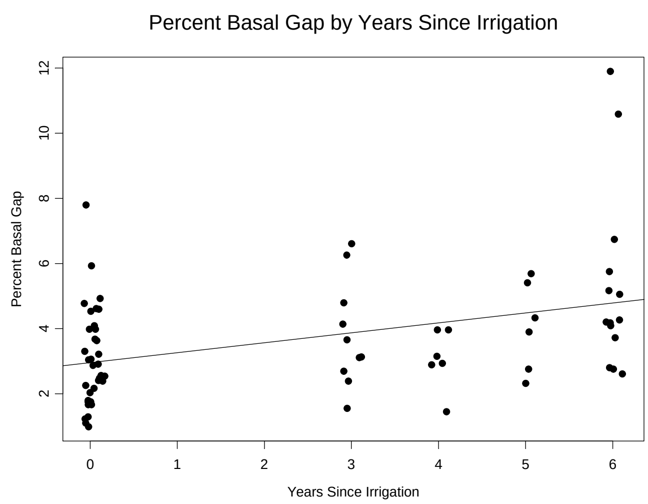

Figure 11. Linear regression of percent of transect that is basal gap by the number of years since irrigation was stopped. Model: Percent basal gap = 2.96 + 0.305(years) + error.

Point Intercept

Question 1. Does Percent All Plants Differ between treatments?
Data

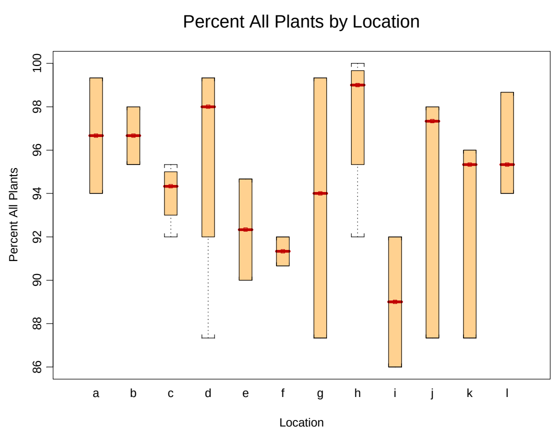

Figure 12. Boxplot of percent all plants for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 11. Percent All Plants Summary Statistics for Treatments
```
treatment:irrigated                                     Min: 87.3333333
           allplants                                1st Qu.: 92.5000000
```

```
   Mean: 94.7777778
 Median: 95.0000000
3rd Qu.: 97.6666667
    Max: 99.3333333
Total N: 18.0000000
  NA's :  0.0000000
Std Dev.:  3.4242503
SE Mean:  0.8071035
---------------------
treatment:none
           allplants
```

```
     Min:   86.000000
 1st Qu.:   92.000000
    Mean:   94.333333
  Median:   95.333333
 3rd Qu.:   98.500000
     Max: 100.000000
 Total N:   18.000000
   NA's :    0.000000
Std Dev.:    4.693202
 SE Mean:    1.106198
```

Table 12. ANOVA Model, Percent All Plants = Treatment + Error

```
                treatment Residuals
 Sum of Squares    1.7778  573.7778
Deg. of Freedom         1        34
Residual standard error: 4.108019
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    1.7778  1.77778 0.1053447 0.7474963
Residuals 34  573.7778 16.87582

Tables of means
Grand mean
 94.556
 treatment
 irrigated   none
 94.778    94.333
Standard errors for differences of means
        treatment
           1.3693
replic.   18.0000
```

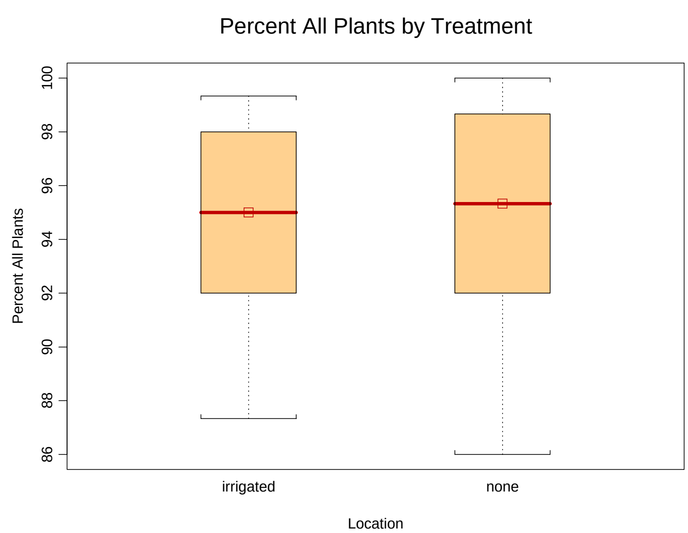

Figure 13. Boxplot of percent all plants for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of all plants for irrigated and non-irrigated groups is 94.8 and 94.3, respectively. There is no evidence to suggest there is a difference between the percent of all plants for irrigated and non-irrigated treatments (p = 0.75).

Question 2. Does Percent Bareground differ between treatments?

Data

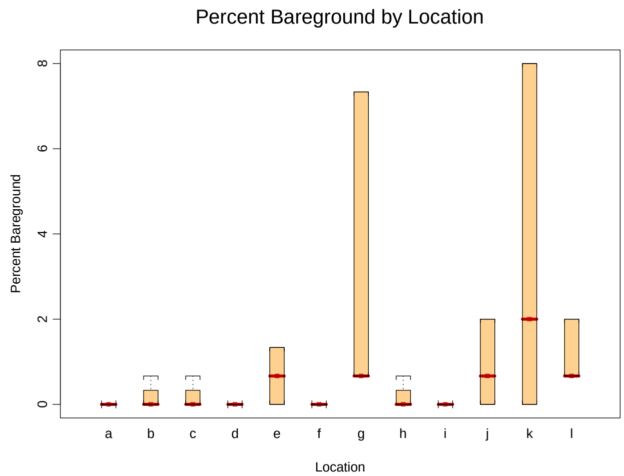

Figure 14. Boxplot of percent bareground for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 13. Percent Bareground Summary Statistics for Treatments

```
treatment:irrigated
             barepct
     Min:  0.0000000
 1st Qu.:  0.0000000
    Mean:  0.1481481
  Median:  0.0000000
 3rd Qu.:  0.0000000
     Max:  1.3333333
Total N: 18.0000000
   NA's :  0.0000000
Std Dev.:  0.3655459
 SE Mean:  0.0861600
---------------------
```

```
treatment:none
             barepct
     Min:  0.0000000
 1st Qu.:  0.0000000
    Mean:  1.4074074
  Median:  0.6666667
 3rd Qu.:  1.6666667
     Max:  8.0000000
Total N: 18.0000000
   NA's :  0.0000000
Std Dev.:  2.3861133
 SE Mean:  0.5624123
```

Table 14. ANOVA Model, Percent Bareground = Treatment + Error

```
                treatment Residuals
 Sum of Squares  14.27160  99.06173
Deg. of Freedom         1        34

Residual standard error: 1.706921
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1  14.27160 14.27160 4.898305 0.03369672
Residuals 34  99.06173  2.91358

Tables of means
Grand mean
 0.77778
```

```
 treatment
 irrigated   none
 0.1481    1.4074
Standard errors for differences of means
        treatment
          0.56897
replic.  18.00000
```

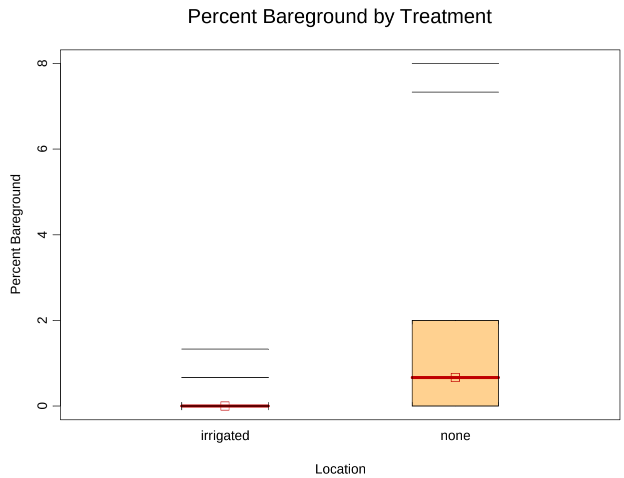

Figure 15. Boxplot of percent bareground for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of bareground for irrigated and non-irrigated groups is 0.15 and 1.4, respectively. There is moderate evidence to suggest there is a difference between the percent of bareground for irrigated and non-irrigated treatments (p = 0.03).

Question 3. Is Percent Bareground Associated with the Number of Years Since Irrigation Stopped?

Table 15. Linear Model, % Bareground = $\beta_0 + \beta_1$(Years No Irrigation) + Error

```
Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 0.1187 0.3875     0.3064  0.7612
      years 0.2795 0.1134     2.4638  0.0190
Residual standard error: 1.682 on 34 degrees of freedom
Multiple R-Squared: 0.1515
F-statistic: 6.07 on 1 and 34 degrees of freedom, the p-value is 0.01896
Correlation of Coefficients:
      (Intercept)
years -0.6904
```

Conclusion

There is moderate evidence to conclude there is a linear relationship between percent bareground and the number of years since irrigation was stopped (p = 0.02). For every 1 year that passes since irrigation was stopped there is a 0.28% increase in bareground per 150 ft line transect (Figure 16).

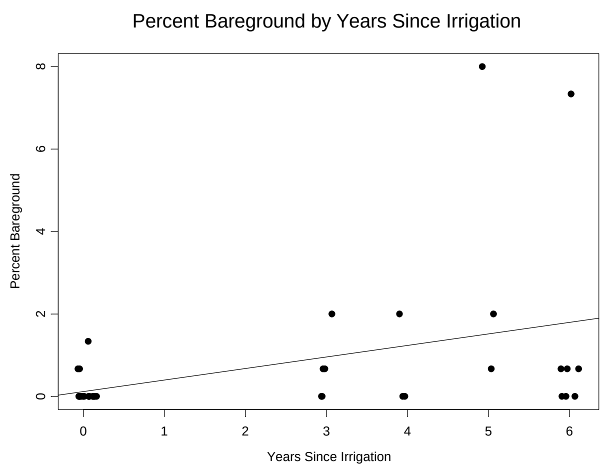

Figure 16. Linear regression of percent bareground by the number of years since irrigation was stopped. Model: Percent bareground = 0.19 + 0.28(years) + error.

Question 4. Does Percent Basal Cover Differ Between Treatments?

Data

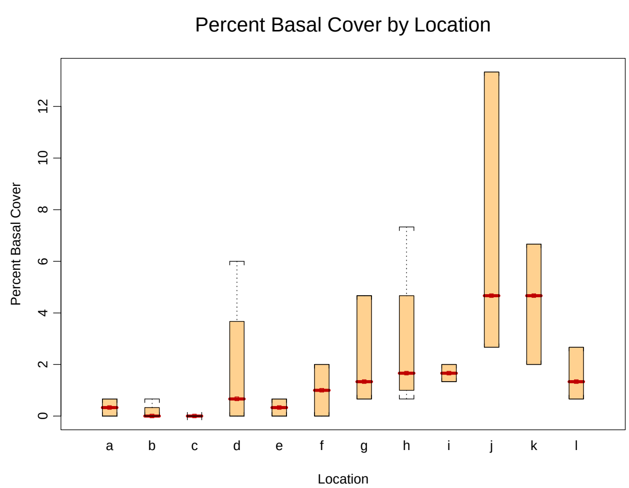

Figure 17. Boxplot of percent plant basal cover for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 16. Percent Basal Cover Summary Statistics for Treatments

```
treatment:irrigated                         treatment:none
            basalcov                                    basalcov
     Min:   0.0000000                            Min:   0.6666667
 1st Qu.:   0.0000000                        1st Qu.:   1.3333333
    Mean:   0.6296296                           Mean:   3.3333333
  Median:   0.0000000                         Median:   2.0000000
 3rd Qu.:   0.6666667                        3rd Qu.:   4.6666667
     Max:   6.0000000                            Max:  13.3333333
 Total N:  18.0000000                        Total N:  18.0000000
   NA's :   0.0000000                          NA's :   0.0000000
Std Dev.:   1.4547146                       Std Dev.:   3.2175987
 SE Mean:   0.3428795                        SE Mean:   0.7583953
--------------------
```

Table 17. ANOVA Model, Percent Basal Cover = Treatment + Error

```
                treatment Residuals
 Sum of Squares   65.7901  211.9753
Deg. of Freedom         1        34
Residual standard error: 2.496912
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value       Pr(F)
treatment  1   65.7901 65.79012 10.55248 0.002613565
Residuals 34  211.9753  6.23457
Tables of means
Grand mean
 1.9815
 treatment
 irrigated   none
 0.6296    3.3333
Standard errors for differences of means
        treatment
           0.8323
replic.   18.0000
```

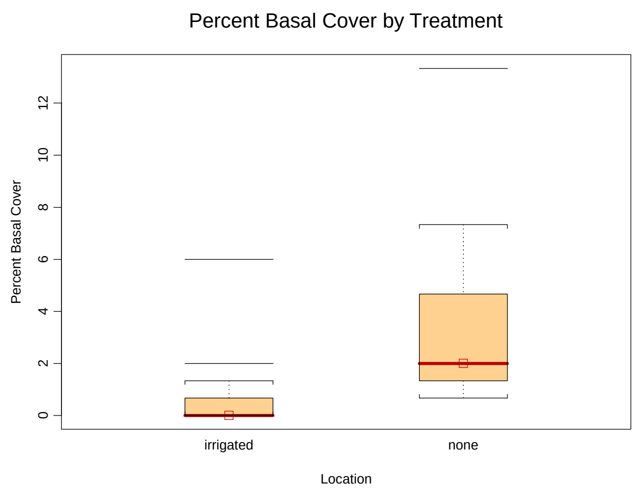

Figure 18. Boxplot of percent plant basal cover for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of plant basal cover for irrigated and non-irrigated groups is 0.63 and 3.33, respectively. There is strong evidence to suggest there is a difference between the percent of plant basal cover for irrigated and non-irrigated treatments ($p = 0.003$).

Question 5. Is Percent Plant Basal Cover Associated with the Number of Years Since Irrigation Stopped?

Table 18. Linear Model, % Plant Basal Cover = $\beta_0 + \beta_1$(Years No Irrigation) + Error

```
Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 0.7620 0.5847     1.3032  0.2013
      years 0.5171 0.1712     3.0210  0.0048
Residual standard error: 2.538 on 34 degrees of freedom
Multiple R-Squared: 0.2116
F-statistic: 9.126 on 1 and 34 degrees of freedom, the p-value is 0.004759
```

```
Correlation of Coefficients:
      (Intercept)
years -0.6904
```

Conclusion

There is strong evidence to conclude there is a linear relationship between percent basal cover and the number of years since irrigation was stopped ($p = 0.005$). For every 1 year that passes since irrigation was stopped there is a 0.52% increase in basal cover per 150 ft line transect (Figure 19).

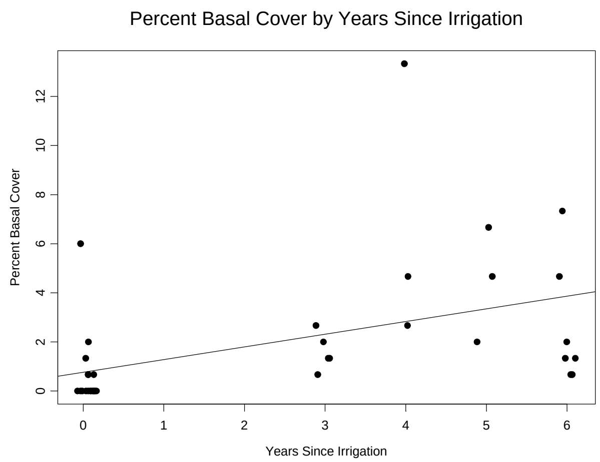

Figure 19. Linear regression of percent basal cover by the number of years since irrigation was stopped. Model: Percent basal cover = 0.76 + 0.52(years) + error.

Question 6. Does Percent Canopy Cover differ between treatments?

Data

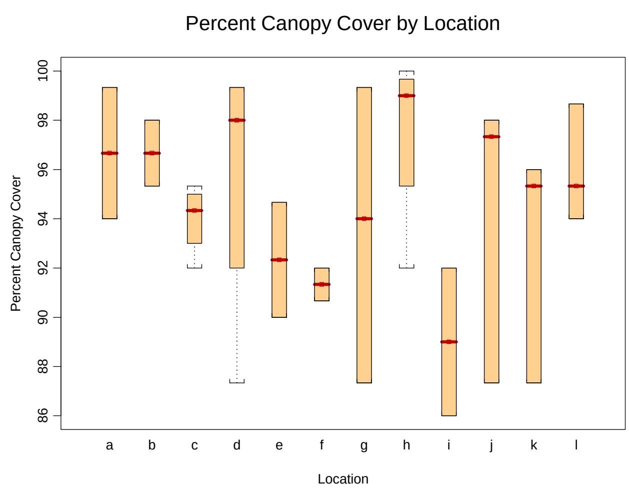

Figure 20. Boxplot of percent canopy cover for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 19. Percent Canopy Cover Summary Statistics for Treatments

```
treatment:irrigated                           treatment:none
          canopycover                                   canopycover
     Min:  87.3333333                             Min:   86.000000
 1st Qu.:  92.5000000                         1st Qu.:   92.000000
    Mean:  94.7777778                            Mean:   94.333333
  Median:  95.0000000                          Median:   95.333333
 3rd Qu.:  97.6666667                         3rd Qu.:   98.500000
     Max:  99.3333333                             Max:  100.000000
 Total N:  18.0000000                         Total N:   18.000000
   NA's :   0.0000000                           NA's :    0.000000
Std Dev.:   3.4242503                        Std Dev.:    4.693202
 SE Mean:   0.8071035                         SE Mean:    1.106198
----------------------
```

Table 20. ANOVA Model, Percent Canopy Cover = Treatment + Error

```
                treatment Residuals
 Sum of Squares    1.7778  573.7778
Deg. of Freedom         1        34
Residual standard error: 4.108019
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    1.7778  1.77778 0.1053447 0.7474963
Residuals 34  573.7778 16.87582
Tables of means
Grand mean
 94.556
 treatment
 irrigated   none
 94.778    94.333
Standard errors for differences of means
        treatment
           1.3693
replic.   18.0000
```

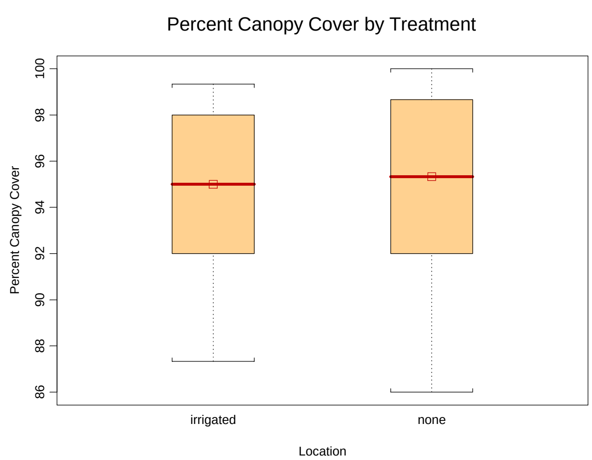

Figure 21. Boxplot of percent canopy cover for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of canopy cover for irrigated and non-irrigated groups is 94.8 and 94.3, respectively. There is no evidence to suggest there is a difference between the percent of canopy cover for irrigated and non-irrigated treatments (p = 0.75).

Question 7. Does Percent Cover between Plant Canopy differ between treatments?

Data

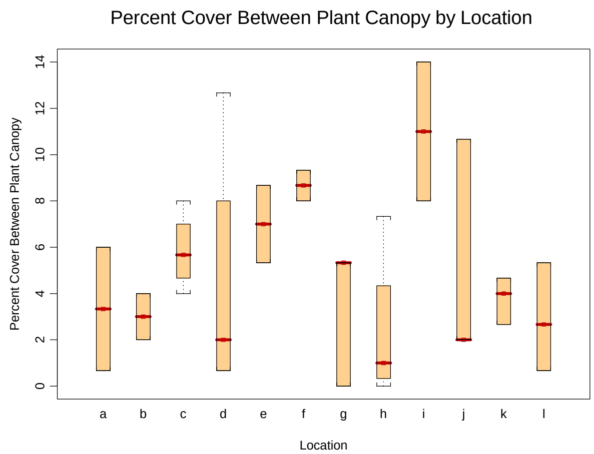

Figure 22. Boxplot of percent cover between plant canopy for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 21. Percent Cover Between Plant Canopy Summary Statistics for Treatments

```
treatment:irrigated                               treatment:none
          grcovbwpct                                        grcovbwpct
     Min:   0.6666667                                   Min:   0.0000000
 1st Qu.:   2.3333333                               1st Qu.:   1.5000000
    Mean:   5.0370370                                  Mean:   4.2592593
  Median:   4.6666667                                Median:   3.3333333
 3rd Qu.:   7.5000000                               3rd Qu.:   5.3333333
     Max:  12.6666667                                   Max:  14.0000000
 Total N:  18.0000000                               Total N:  18.0000000
   NA's :   0.0000000                                 NA's :   0.0000000
Std Dev.:   3.3546162                              Std Dev.:   3.8272425
 SE Mean:   0.7906906                               SE Mean:   0.9020897
----------------------
```

Table 22. ANOVA Model, Percent Cover Between Plant Canopy = Treatment + Error

```
                treatment Residuals
 Sum of Squares    5.4444  440.3210
Deg. of Freedom         1        34
Residual standard error: 3.598697
Estimated effects are balanced

          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    5.4444  5.44444 0.4204004 0.5210926
Residuals 34  440.3210 12.95062
Tables of means
Grand mean
 4.6481
 treatment
 irrigated   none
 5.0370    4.2593
Standard errors for differences of means
        treatment
           1.1996
replic.   18.0000
```

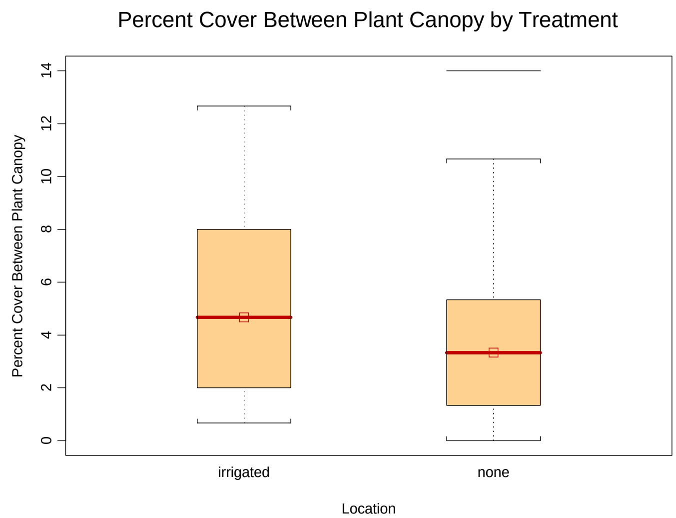

Figure 23. Boxplot of percent cover between plant canopy for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of cover between plant canopy for irrigated and non-irrigated groups is 5.04 and 4.26, respectively. There is no evidence to suggest there is a difference between the percent of cover between plant canopy for irrigated and non-irrigated treatments (p = 0.52).

Question 8. Does Percent Total Ground Cover differ between treatments?

Data

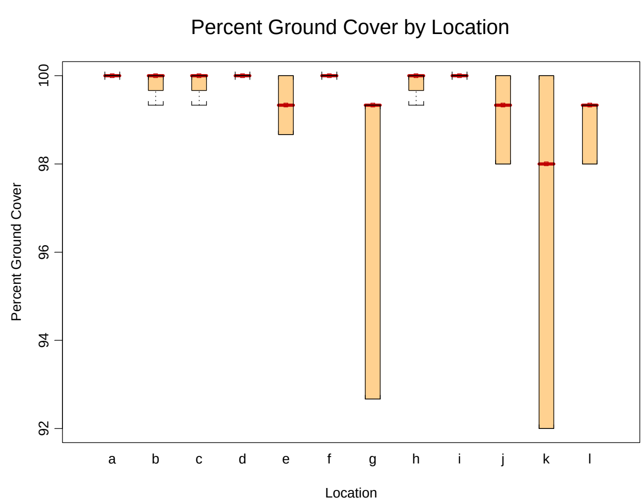

Figure 24. Boxplot of percent ground cover for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 23. Percent Ground Cover Summary Statistics for Treatments

```
treatment:irrigated
           grcoverpct
     Min:  98.6666667
 1st Qu.: 100.0000000
    Mean:  99.8518519
  Median: 100.0000000
 3rd Qu.: 100.0000000
     Max: 100.0000000
 Total N:  18.0000000
   NA's :   0.0000000
Std Dev.:   0.3655459
 SE Mean:   0.0861600
----------------------
treatment:none
           grcoverpct
     Min:  92.0000000
 1st Qu.:  98.3333333
    Mean:  98.5925926
  Median:  99.3333333
 3rd Qu.: 100.0000000
     Max: 100.0000000
 Total N:  18.0000000
   NA's :   0.0000000
Std Dev.:   2.3861133
 SE Mean:   0.5624123
```

Table 24. ANOVA Model, Percent Ground Cover = Treatment + Error

```
                treatment Residuals
 Sum of Squares  14.27160  99.06173
Deg. of Freedom         1        34
Residual standard error: 1.706921
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1  14.27160 14.27160 4.898305 0.03369672
Residuals 34  99.06173  2.91358
Tables of means
Grand mean
 99.222
 treatment
 irrigated   none
 99.852    98.593
Standard errors for differences of means
        treatment
          0.56897
replic.  18.00000
```

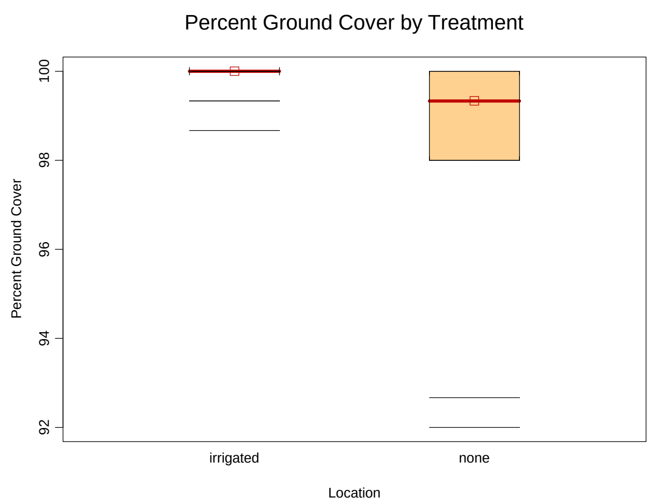

Figure 25. Boxplot of percent ground cover for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of ground cover for irrigated and non-irrigated groups is 99.9 and 98.6, respectively. There is moderate evidence to suggest there is a difference between the percent of ground cover for irrigated and non-irrigated treatments (p = 0.034).

Question 9. Is Percent Ground Cover Associated with the Number of Years Since Irrigation Stopped?

Table 25. Linear Model, % Ground Cover = $\beta_0 + \beta_1$(Years No Irrigation) + Error

```
Coefficients:
                Value Std. Error   t value  Pr(>|t|)
(Intercept)   99.8813    0.3875   257.7836    0.0000
      years   -0.2795    0.1134    -2.4638    0.0190

Residual standard error: 1.682 on 34 degrees of freedom
Multiple R-Squared: 0.1515
F-statistic: 6.07 on 1 and 34 degrees of freedom, the p-value is 0.01896

Correlation of Coefficients:
      (Intercept)
years -0.6904
```

Conclusion

There is moderate evidence to conclude there is a linear relationship between percent ground cover and the number of years since irrigation was stopped (p = 0.02). For every 1 year that passes since irrigation was stopped there is a 0.28% decrease in ground cover per 150 ft line transect (Figure 26).

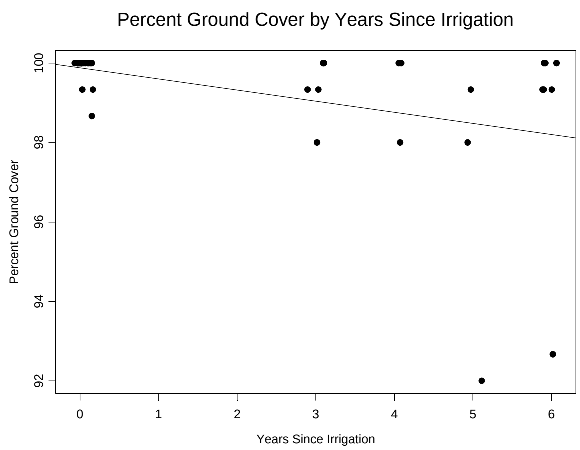

Figure 26. Linear regression of percent ground cover by the number of years since irrigation was stopped. Model: Percent ground cover = 99.88 - 0.28(years) + error.

Question 10. Does Percent Ground Cover Under Plant Canopy differ between treatments?

Data

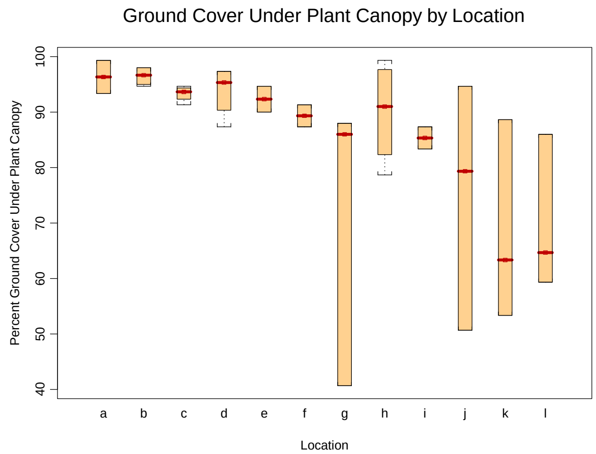

Figure 27. Boxplot of percent ground cover under plant canopy for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 26. Percent Ground Cover Under Plant Canopy Summary Statistics for Treatments

```
treatment:irrigated                                      treatment:none
            grundpct                                                grundpct
     Min: 87.3333333                                          Min: 40.666667
 1st Qu.: 91.8333333                                      1st Qu.: 63.666667
    Mean: 93.9259259                                         Mean: 76.962963
  Median: 94.3333333                                       Median: 84.666667
 3rd Qu.: 96.8333333                                      3rd Qu.: 87.833333
     Max: 99.3333333                                          Max: 99.333333
 Total N: 18.0000000                                      Total N: 18.000000
   NA's :  0.0000000                                        NA's :  0.000000
Std Dev.:  3.4820840                                     Std Dev.: 17.238386
 SE Mean:  0.8207351                                      SE Mean:  4.063127
----------------------
```

Table 27. ANOVA Model, Percent Ground Cover Under Plant Canopy = Treatment + Error

```
                treatment Residuals
 Sum of Squares  2589.679  5257.877
Deg. of Freedom         1        34
Residual standard error: 12.43557
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value        Pr(F)
treatment  1  2589.679 2589.679 16.74613 0.0002484165
Residuals 34  5257.877  154.643

Tables of means
Grand mean
 85.444
 treatment
 irrigated   none
 93.926    76.963
Standard errors for differences of means
        treatment
           4.1452
replic.   18.0000
```

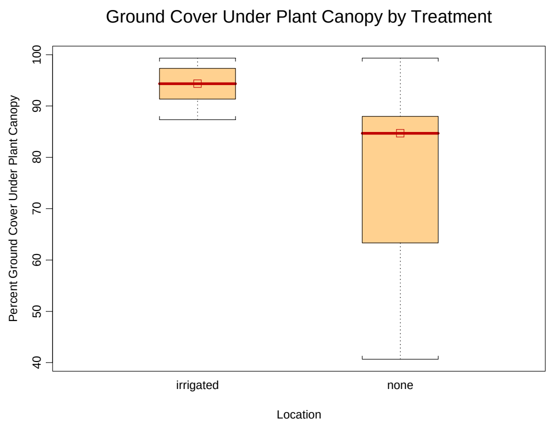

Figure 28. Boxplot of percent ground cover under plant canopy for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of ground cover under plant canopy for irrigated and non-irrigated groups is 93.9 and 77.0, respectively. There is overwhelming evidence to suggest there is a difference between the percent of ground cover under plant canopy for irrigated and non-irrigated treatments (p = 0.0002).

Question 11. Is Percent Ground Cover Under Plant Canopy Associated with the Number of Years Since Irrigation Stopped?

Table 28. Linear Model, % Ground Cover Under Plant Canopy = $\beta_0 + \beta_1$(Years No Irrigation) + Error

```
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  92.1286   3.0813    29.8992   0.0000
      years  -2.8343   0.9021    -3.1420   0.0035

Residual standard error: 13.37 on 34 degrees of freedom
Multiple R-Squared: 0.225
F-statistic: 9.872 on 1 and 34 degrees of freedom, the p-value is 0.003468

Correlation of Coefficients:
      (Intercept)
years -0.6904
```

Conclusion

There is strong evidence to conclude there is a linear relationship between percent ground cover under plant canopy and the number of years since irrigation was stopped (p = 0.004). For every 1 year that passes since irrigation was stopped there is a 2.83% decrease in ground cover under plant canopy per 150 ft line transect (Figure 29).

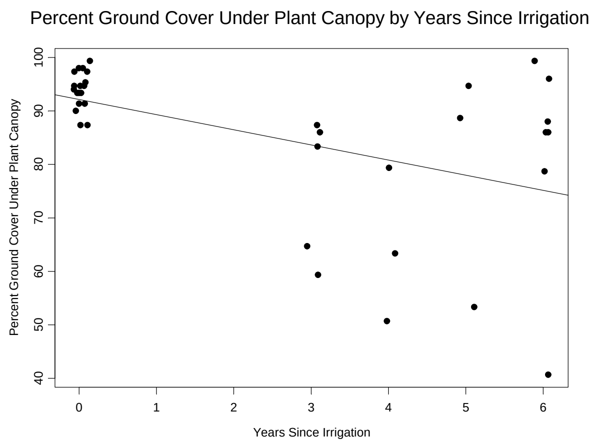

Figure 29. Linear regression of percent ground cover under plant canopy by the number of years since irrigation was stopped. Model: Percent ground cover under plant canopy = 92.13- 2.83(years) + error.

Question 12. Does Percent Litter Between Plant Canopy differ between treatments?

Data

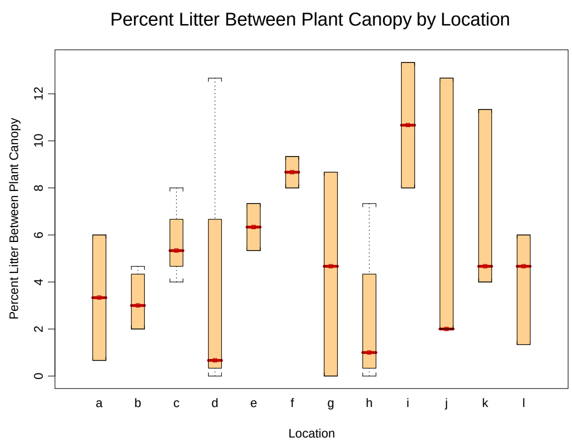

Figure 30. Boxplot of percent litter between plant canopy for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 29. Percent Litter Between Plant Canopy Summary Statistics for Treatments

treatment:irrigated	litbtwnpct	treatment:none	litbtwnpct
Min:	0.000000	Min:	0.000000
1st Qu.:	2.000000	1st Qu.:	1.500000
Mean:	4.777778	Mean:	5.148148
Median:	5.000000	Median:	4.666667
3rd Qu.:	7.000000	3rd Qu.:	7.833333
Max:	12.666667	Max:	13.333333
Total N:	18.000000	Total N:	18.000000
NA's :	0.000000	NA's :	0.000000
Std Dev.:	3.454655	Std Dev.:	4.282847
SE Mean:	0.814270	SE Mean:	1.009477

Table 30. ANOVA Model, Percent Litter Between Plant Canopy = Treatment + Error

```
                treatment Residuals
 Sum of Squares    1.2346  514.7160
Deg. of Freedom         1        34

Residual standard error: 3.890849
Estimated effects are balanced

          Df Sum of Sq  Mean Sq    F Value     Pr(F)
treatment  1    1.2346  1.23457 0.08155042 0.7769398
Residuals 34  514.7160 15.13871

Tables of means
Grand mean

 4.963

 treatment
 irrigated   none
 4.7778    5.1481

Standard errors for differences of means
        treatment
           1.2969
replic.   18.0000
```

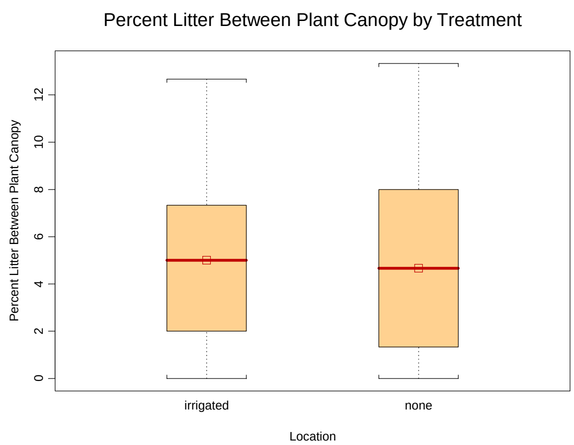

Figure 31. Boxplot of percent litter between plant canopy for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of litter between plant canopy for irrigated and non-irrigated groups is 4.78 and 5.15, respectively. There is no evidence to suggest there is a difference between the percent of litter between plant canopy for irrigated and non-irrigated treatments ($p = 0.78$).

Question 13. Does Percent Litter Under Plant Canopy differ between treatments?

Data

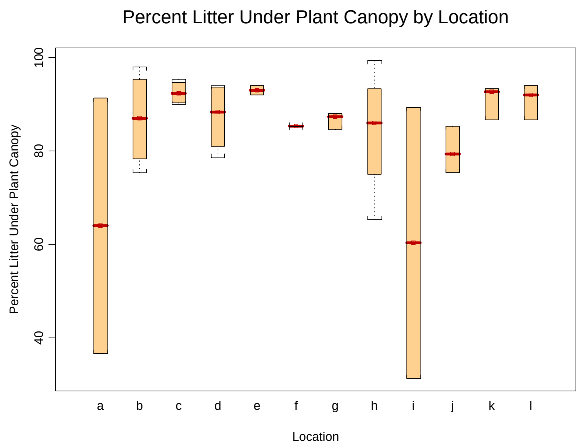

Figure 32. Boxplot of percent litter under plant canopy for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 31. Percent Litter Under Plant Canopy Summary Statistics for Treatments

```
treatment:irrigated                              treatment:none
          litundpct                                        litundpct
     Min: 36.666667                                    Min: 31.333333
 1st Qu.: 83.833333                                1st Qu.: 84.666667
    Mean: 86.185185                                   Mean: 83.481481
  Median: 91.000000                                 Median: 87.000000
 3rd Qu.: 93.833333                                3rd Qu.: 91.333333
     Max: 98.000000                                    Max: 99.333333
 Total N: 18.000000                                Total N: 18.000000
   NA's :  0.000000                                  NA's :  0.000000
Std Dev.: 13.835269                               Std Dev.: 15.066832
 SE Mean:  3.261004                                SE Mean:  3.551286
-------------------
```

Table 32. ANOVA Model, Percent Litter Under Plant Canopy = Treatment + Error

```
                treatment Residuals
 Sum of Squares     65.79   7113.21
Deg. of Freedom         1        34
Residual standard error: 14.46416
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1     65.79  65.7901 0.3144662 0.5786295
Residuals 34   7113.21 209.2121

Tables of means
Grand mean
 84.833
 treatment
 irrigated   none
 86.185    83.481
Standard errors for differences of means
        treatment
           4.8214
replic.   18.0000
```

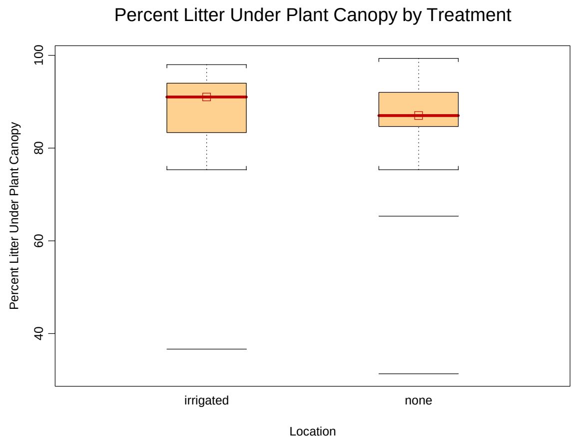

Figure 33. Boxplot of percent litter under plant canopy for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of litter under plant canopy for irrigated and non-irrigated groups is 86.2 and 83.5, respectively. There is no evidence to suggest there is a difference between the percent of litter under plant canopy for irrigated and non-irrigated treatments ($p = 0.58$).

Question 14. Does Percent Species Canopy Cover differ between treatments?

Data

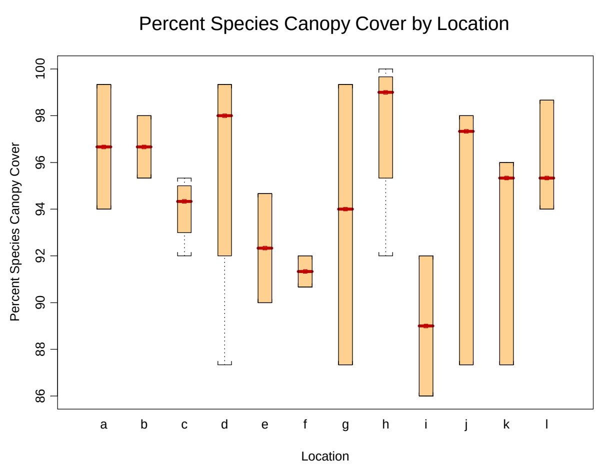

Figure 34. Boxplot of percent plant species canopy cover for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 33. Percent Plant Species Canopy Cover Summary Statistics for Treatments

```
treatment:irrigated
          sppcanopycov
     Min:   87.3333333
 1st Qu.:   92.5000000
    Mean:   94.7777778
  Median:   95.0000000
 3rd Qu.:   97.6666667
     Max:   99.3333333
 Total N:   18.0000000
   NA's :    0.0000000
Std Dev.:    3.4242503
 SE Mean:    0.8071035
-----------------------
```

```
treatment:none
          sppcanopycov
     Min:    86.000000
 1st Qu.:    92.000000
    Mean:    94.333333
  Median:    95.333333
 3rd Qu.:    98.500000
     Max:   100.000000
 Total N:    18.000000
   NA's :     0.000000
Std Dev.:     4.693202
 SE Mean:     1.106198
```

Table 34. ANOVA Model, Percent Species Canopy Cover = Treatment + Error

```
                treatment Residuals
 Sum of Squares    1.7778  573.7778
Deg. of Freedom         1        34
Residual standard error: 4.108019
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    1.7778  1.77778 0.1053447 0.7474963
Residuals 34  573.7778 16.87582

Tables of means
Grand mean
 94.556
 treatment
 irrigated   none
 94.778    94.333

Standard errors for differences of means
        treatment
           1.3693
replic.   18.0000
```

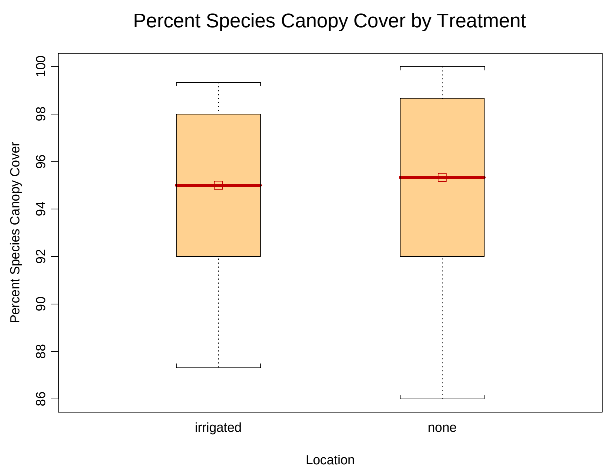

Figure 35. Boxplot of percent plant species canopy cover for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of litter plant species canopy cover for irrigated and non-irrigated groups is 94.8 and 94.3, respectively. There is no evidence to suggest there is a difference between the percent of plant species canopy cover for irrigated and non-irrigated treatments (p = 0.75).

Question 15. Does Percent Top Canopy Plants differ between treatments?

Data

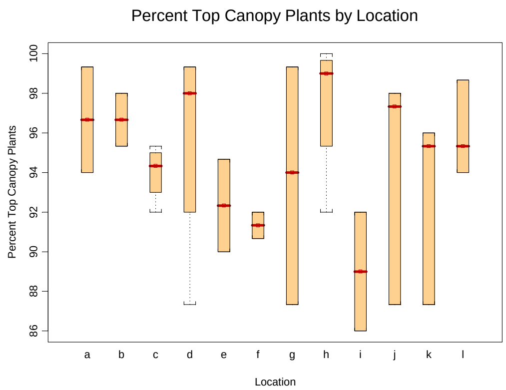

Figure 36. Boxplot of percent top canopy plants for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 35. Percent Top Canopy Plants Summary Statistics for Treatments

	treatment:irrigated topcanopypllants	treatment:none topcanopypllants
Min:	87.3333333	86.000000
1st Qu.:	92.5000000	92.000000
Mean:	94.7777778	94.333333
Median:	95.0000000	95.333333
3rd Qu.:	97.6666667	98.500000
Max:	99.3333333	100.000000
Total N:	18.0000000	18.000000
NA's :	0.0000000	0.000000
Std Dev.:	3.4242503	4.693202
SE Mean:	0.8071035	1.106198

Table 36. ANOVA Model, Percent Top Canopy Plants = Treatment + Error

```
                treatment Residuals
 Sum of Squares    1.7778  573.7778
Deg. of Freedom         1        34
Residual standard error: 4.108019
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    1.7778  1.77778 0.1053447 0.7474963
Residuals 34  573.7778 16.87582
Tables of means
Grand mean
 94.556
 treatment
 irrigated   none
 94.778    94.333
Standard errors for differences of means
        treatment
```

```
             1.3693
replic.     18.0000
```

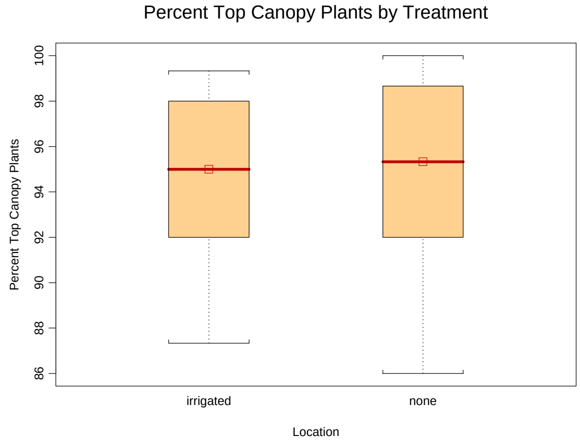

Figure 37. Boxplot of percent top canopy plants for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of top canopy plants for irrigated and non-irrigated groups is 94.8 and 94.3, respectively. There is no evidence to suggest there is a difference between the percent of top canopy plants for irrigated and non-irrigated treatments ($p = 0.75$).

Question 16. Does Percent Top Canopy Points differ between treatments?

Data

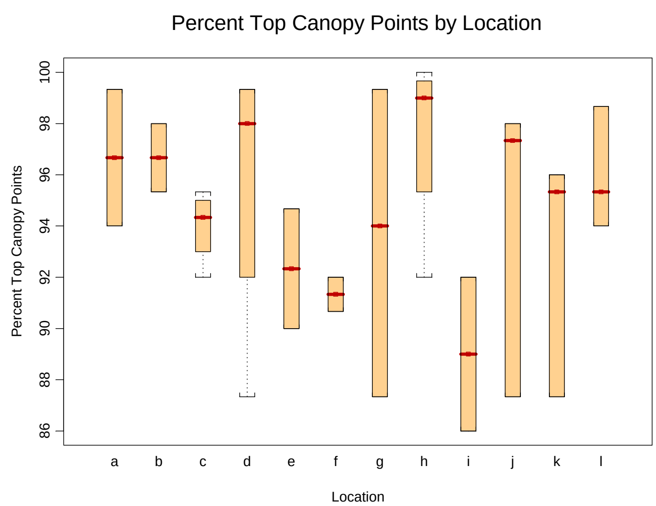

Figure 38. Boxplot of percent top canopy points for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 37. Percent Top Canopy Points Summary Statistics for Treatments

```
treatment:irrigated                              treatment:none
          topcanopypts                                     topcanopypts
     Min:   87.3333333                                Min:    86.000000
 1st Qu.:   92.5000000                            1st Qu.:    92.000000
    Mean:   94.7777778                               Mean:    94.333333
  Median:   95.0000000                             Median:    95.333333
 3rd Qu.:   97.6666667                            3rd Qu.:    98.500000
     Max:   99.3333333                                Max:   100.000000
 Total N:   18.0000000                            Total N:    18.000000
   NA's :    0.0000000                              NA's :     0.000000
Std Dev.:    3.4242503                           Std Dev.:     4.693202
 SE Mean:    0.8071035                            SE Mean:     1.106198
-----------------------
```

Table 38. ANOVA Model, Percent Top Canopy Points = Treatment + Error

```
                treatment Residuals
 Sum of Squares    1.7778  573.7778
Deg. of Freedom         1        34
Residual standard error: 4.108019
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    1.7778  1.77778 0.1053447 0.7474963
Residuals 34  573.7778 16.87582

Tables of means
Grand mean

 94.556

 treatment
 irrigated   none
 94.778    94.333

Standard errors for differences of means
        treatment
           1.3693
replic.   18.0000
```

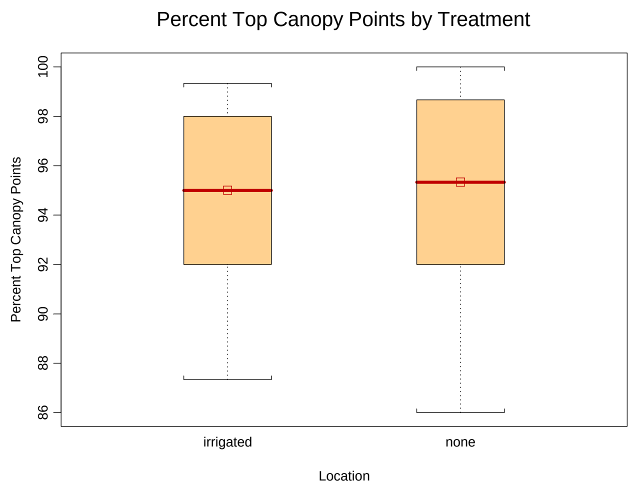

Figure 39. Boxplot of percent top canopy points for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion
The average percent of top canopy points for irrigated and non-irrigated groups is 94.8 and 94.3, respectively. There is no evidence to suggest there is a difference between the percent of top canopy points for irrigated and non-irrigated treatments (p = 0.75).

Question 17. Does Percent Total Litter differ between treatments?
Data

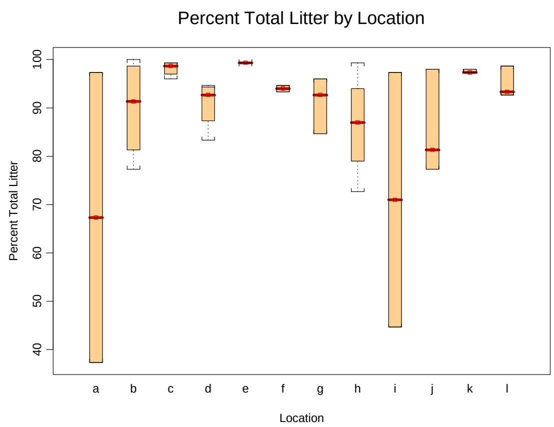

Figure 40. Boxplot of percent total litter for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 39. Percent Total Litter Summary Statistics for Treatments

```
treatment:irrigated
          totlitterpct
     Min:    37.333333
 1st Qu.:    91.833333
    Mean:    90.962963
  Median:    95.333333
 3rd Qu.:    99.000000
     Max:   100.000000
 Total N:    18.000000
   NA's :     0.000000
Std Dev.:    14.777163
 SE Mean:     3.483011
-----------------------
```

```
treatment:none
          totlitterpct
     Min:    44.666667
 1st Qu.:    84.833333
    Mean:    88.629630
  Median:    93.000000
 3rd Qu.:    97.333333
     Max:    99.333333
 Total N:    18.000000
   NA's :     0.000000
Std Dev.:    13.552073
 SE Mean:     3.194254
```

Table 40. ANOVA Model, Percent Total Litter = Treatment + Error

```
                treatment Residuals
 Sum of Squares    49.000  6834.395
Deg. of Freedom         1        34
Residual standard error: 14.17786
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value    Pr(F)
treatment  1    49.000  49.0000 0.243767 0.624673
Residuals 34  6834.395 201.0116
Tables of means
Grand mean
 89.796
 treatment
 irrigated   none
 90.963    88.630
```

```
Standard errors for differences of means
        treatment
            4.726
replic.    18.000
```

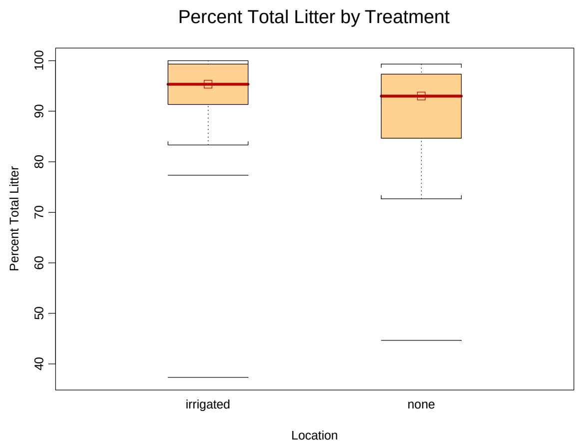

Figure 41. Boxplot of percent total litter for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of total litter for irrigated and non-irrigated groups is 91.0 and 88.6, respectively. There is no evidence to suggest there is a difference between the percent of total litter for irrigated and non-irrigated treatments (p = 0.62).

Question 18. Does Percent Soil Surface differ between treatments?

Data

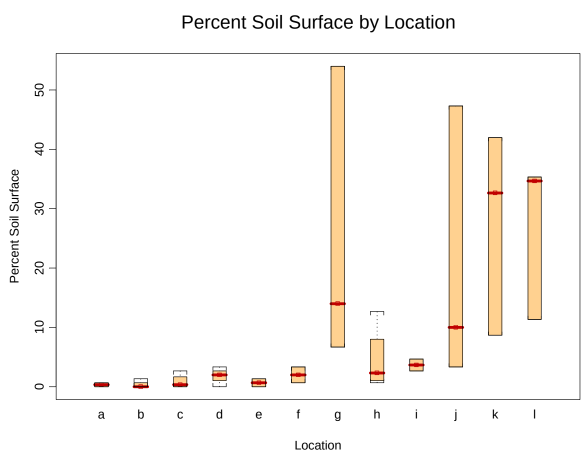

Figure 42. Boxplot of percent soil surface for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 41. Percent Soil Surface Summary Statistics for Treatments

```
treatment:irrigated
                Soil
     Min:  0.0000000
 1st Qu.:  0.0000000
    Mean:  1.0000000
  Median:  0.6666667
 3rd Qu.:  1.8333333
     Max:  3.3333333
 Total N: 18.0000000
   NA's :  0.0000000
Std Dev.:  1.1936652
 SE Mean:  0.2813496
---------------------
```

```
treatment:none
                Soil
     Min:  0.6666667
 1st Qu.:  3.6666667
    Mean: 18.0740741
  Median: 10.6666667
 3rd Qu.: 34.1666667
     Max: 54.0000000
 Total N: 18.0000000
   NA's :  0.0000000
Std Dev.: 17.6825883
 SE Mean:  4.1678260
```

Table 42. ANOVA Model, Percent Soil Surface = Treatment + Error

```
                treatment Residuals
 Sum of Squares  2623.716  5339.679
Deg. of Freedom         1        34
Residual standard error: 12.53193
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value        Pr(F)
treatment  1  2623.716 2623.716 16.70631 0.0002519274
Residuals 34  5339.679  157.049
Tables of means
Grand mean
 9.537

 treatment
 irrigated   none
  1.000    18.074

Standard errors for differences of means
        treatment
           4.1773
replic.   18.0000
```

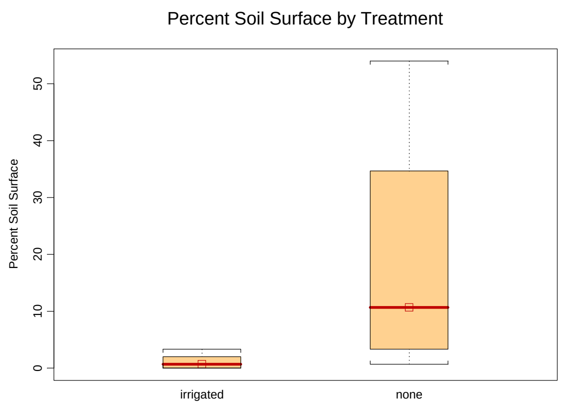

Figure 43. Boxplot of percent soil surface for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Conclusion

The average percent of soil surface for irrigated and non-irrigated groups is 1.0 and 18.1, respectively. There is overwhelming evidence to suggest there is a difference between the percent of soil surface for irrigated and non-irrigated treatments (p = 0.0003).

Question 19. Is Percent Soil Surface Associated with the Number of Years Since Irrigation Stopped?

Table 43. Linear Model, % Soil Surface = $\beta_0 + \beta_1$(Years No Irrigation) + Error

```
Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 2.6365 3.0812     0.8557  0.3982
      years 2.9260 0.9020     3.2438  0.0026

Residual standard error: 13.37 on 34 degrees of freedom
Multiple R-Squared: 0.2363
F-statistic: 10.52 on 1 and 34 degrees of freedom, the p-value is 0.002646

Correlation of Coefficients:
      (Intercept)
years -0.6904
```

Conclusion

There is strong evidence to conclude there is a linear relationship between the amount of percent soil surface and the number of years since irrigation was stopped ($p = 0.003$). For every 1 year that passes since irrigation was stopped there is a 2.93% increase in percent soil surface per 150 ft line transect (Figure 44).

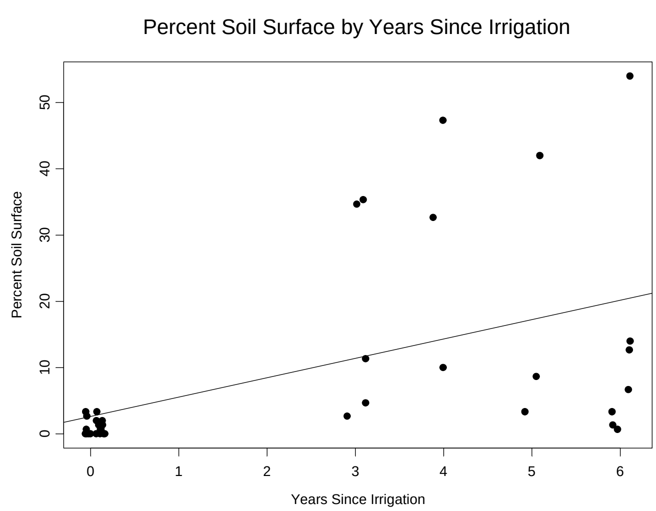

Figure 44. Linear regression of percent soil surface by the number of years since irrigation was stopped. Model: Percent soil surface = 2.64 + 2.93(years) + error.

Annual Production
(One Time Clip: Weight by Species)

Question 1. Does annual production differ between irrigated and non-irrigated treatments for 1 time clipped plots?

Data

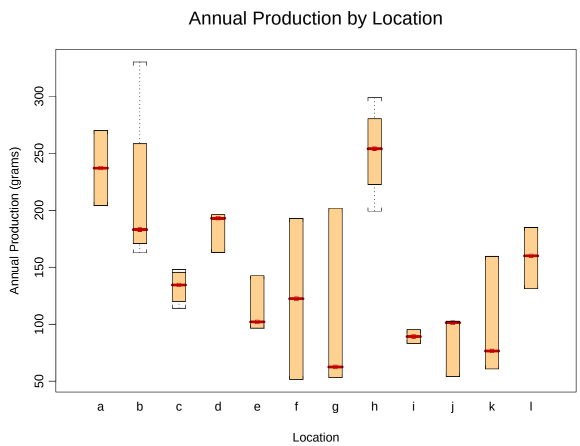

Figure 45. Boxplot of annual production (grams) for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 44. Annual Production (grams) Summary Statistics for Treatments

```
treatment:irrigated                          treatment:none
            totalwt                                      totalwt
     Min:   51.50000                              Min:   53.00000
 1st Qu.: 129.97500                           1st Qu.:   78.20000
    Mean: 166.71111                              Mean: 140.65556
  Median: 162.75000                            Median: 116.75000
 3rd Qu.: 193.00000                           3rd Qu.: 195.62500
     Max: 330.00000                               Max: 298.80000
 Total N:  18.00000                           Total N:  18.00000
   NA's :   0.00000                             NA's :   0.00000
Std Dev.:  64.12210                          Std Dev.:  77.04639
 SE Mean:  15.11372                           SE Mean:  18.16001
--------------------
```

Table 45. ANOVA Model, Annual Production (grams) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares    6110.0  170812.4
Deg. of Freedom         1        34
Residual standard error: 70.87944
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value    Pr(F)
treatment  1    6110.0 6110.028 1.216193 0.277854
Residuals 34  170812.4 5023.895
Tables of means
Grand mean
 153.68
 treatment
 irrigated   none
 166.71    140.66
```

```
Standard errors for differences of means
        treatment
           23.626
replic.    18.000
```

Conclusion
The average annual production for irrigated and non-irrigated groups is 166.7 and 140.7 grams, respectively. There is little evidence to suggest there is a difference between the annual production for irrigated and non-irrigated treatments (p = 0.28).

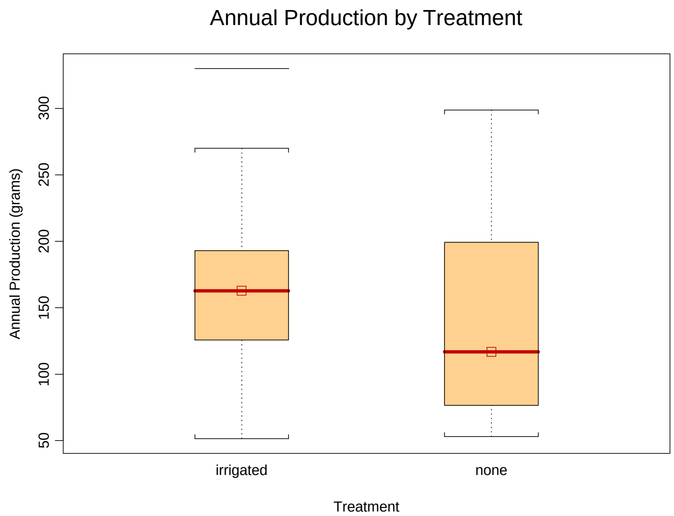

Figure 46. Boxplot of annual production (grams) for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Question 2. Does the number of species differ between irrigated and non-irrigated treatments for 1 time clipped plots?

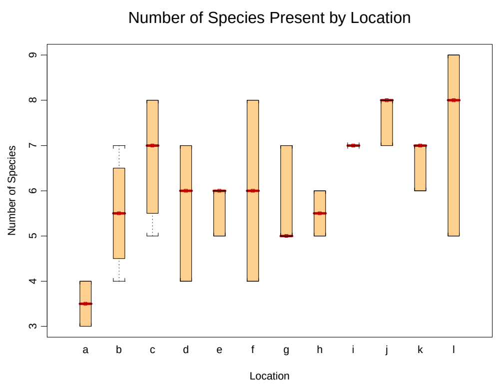

Figure 47. Boxplot of the number of species present for 6 irrigated groups (a-f) and 6 non-irrigated groups (g-i). The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 46. Number of Species Present Summary Statistics for Treatments

```
treatment:irrigated                                     treatment:none
                  spp                                                     spp
     Min:  3.0000000                                         Min:  5.0000000
 1st Qu.:  4.2500000                                     1st Qu.:  5.2500000
    Mean:  5.6666667                                        Mean:  6.5555556
  Median:  6.0000000                                      Median:  7.0000000
 3rd Qu.:  6.7500000                                     3rd Qu.:  7.0000000
     Max:  8.0000000                                         Max:  9.0000000
 Total N: 18.0000000                                     Total N: 18.0000000
   NA's :  0.0000000                                       NA's :  0.0000000
Std Dev.:  1.5339300                                    Std Dev.:  1.2472191
 SE Mean:  0.3615508                                     SE Mean:  0.2939724
--------------------
```

Table 47. ANOVA Model, Number of Species Present = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   7.11111  66.44444
Deg. of Freedom         1        34
Residual standard error: 1.397944
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   7.11111 7.111111 3.638796 0.06492369
Residuals 34  66.44444 1.954248
Tables of means
Grand mean

 6.1111

 treatment
 irrigated   none
 5.6667    6.5556

Standard errors for differences of means
        treatment
          0.46598
replic.  18.00000
```

Conclusion

The average number of species present for irrigated and non-irrigated groups is 5.7 and 6.6, respectively. There is moderate evidence to suggest there is a difference between the number of species present for irrigated and non-irrigated treatments (p = 0.065).

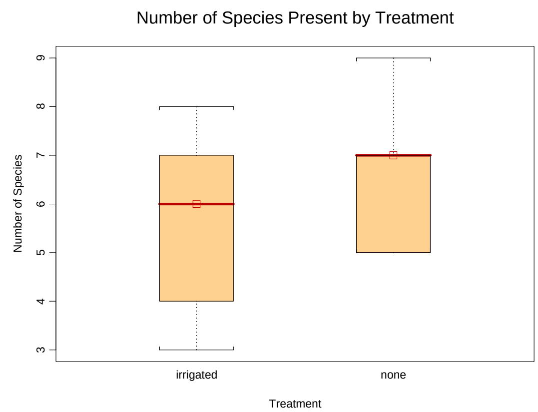

Figure 48. Boxplot of percent soil surface for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Question 3. Is the number of species present associated with amount of annual production, regardless of treatment?

Table 48. Linear Model, Annual Production = $\beta_0 + \beta_1$(Number Species) + Error

```
Coefficients:
                Value Std. Error   t value  Pr(>|t|)
(Intercept)  336.8394    41.7838    8.0615    0.0000
        spp  -29.9710     6.6577   -4.5017    0.0001

Residual standard error: 57.1 on 34 degrees of freedom
Multiple R-Squared: 0.3735
F-statistic: 20.27 on 1 and 34 degrees of freedom, the p-value is 0.00007529

Correlation of Coefficients:
    (Intercept)
spp -0.9737
```

Conclusion

There is overwhelming evidence to conclude there is a linear relationship between the number of species present and the amount of annual production observed in clipped plots ($p = 0.0001$). For every 1 additional species found in a clipped plot there is a 29.97 gram decrease in annual production (Figure 49).

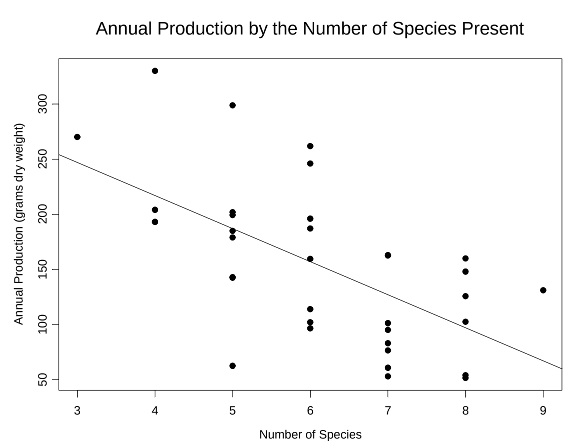

Figure 49. Linear regression of amount of annual production by the number of species present in a clipped plot. Model: Annual Production = 336.8 – 29.97(# species) + error.

Question 4. Is annual production associated with day of year that plots were clipped, regardless of treatment?

Table 49. Linear Model, Annual Production = $\beta_0 + \beta_1$(Day of Year) + Error

```
Coefficients:
                Value Std. Error   t value  Pr(>|t|)
(Intercept) -128.2603  165.4965    -0.7750    0.4437
        day    1.6292    0.9540     1.7078    0.0968

Residual standard error: 69.23 on 34 degrees of freedom
Multiple R-Squared: 0.079
F-statistic: 2.917 on 1 and 34 degrees of freedom, the p-value is 0.09679

Correlation of Coefficients:
    (Intercept)
day -0.9976
```

Conclusion

There is some evidence to conclude there is a linear relationship between the amount of annual production and the day of year clipped (p = 0.097). For every 1 day later in the year that the plot is clipped there is a 1.63 gram increase in annual production (Figure 50).

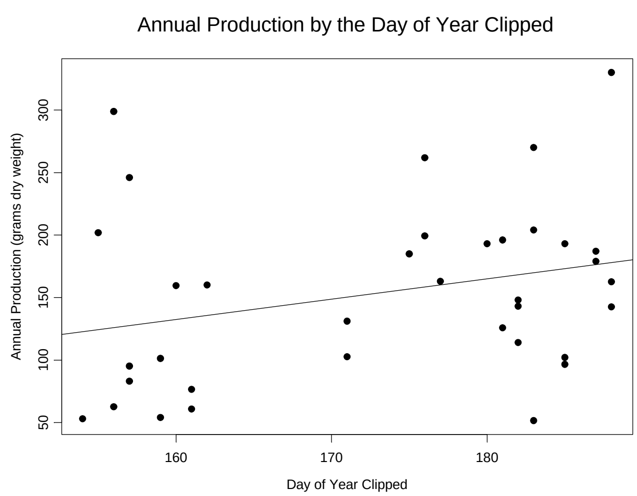

Figure 50. Linear regression of amount of annual production by day of year clipped. Model: Annual Production = -128.26 + 1.63(Day of Year) + error.

Annual Production
(Re-Clip by Date)

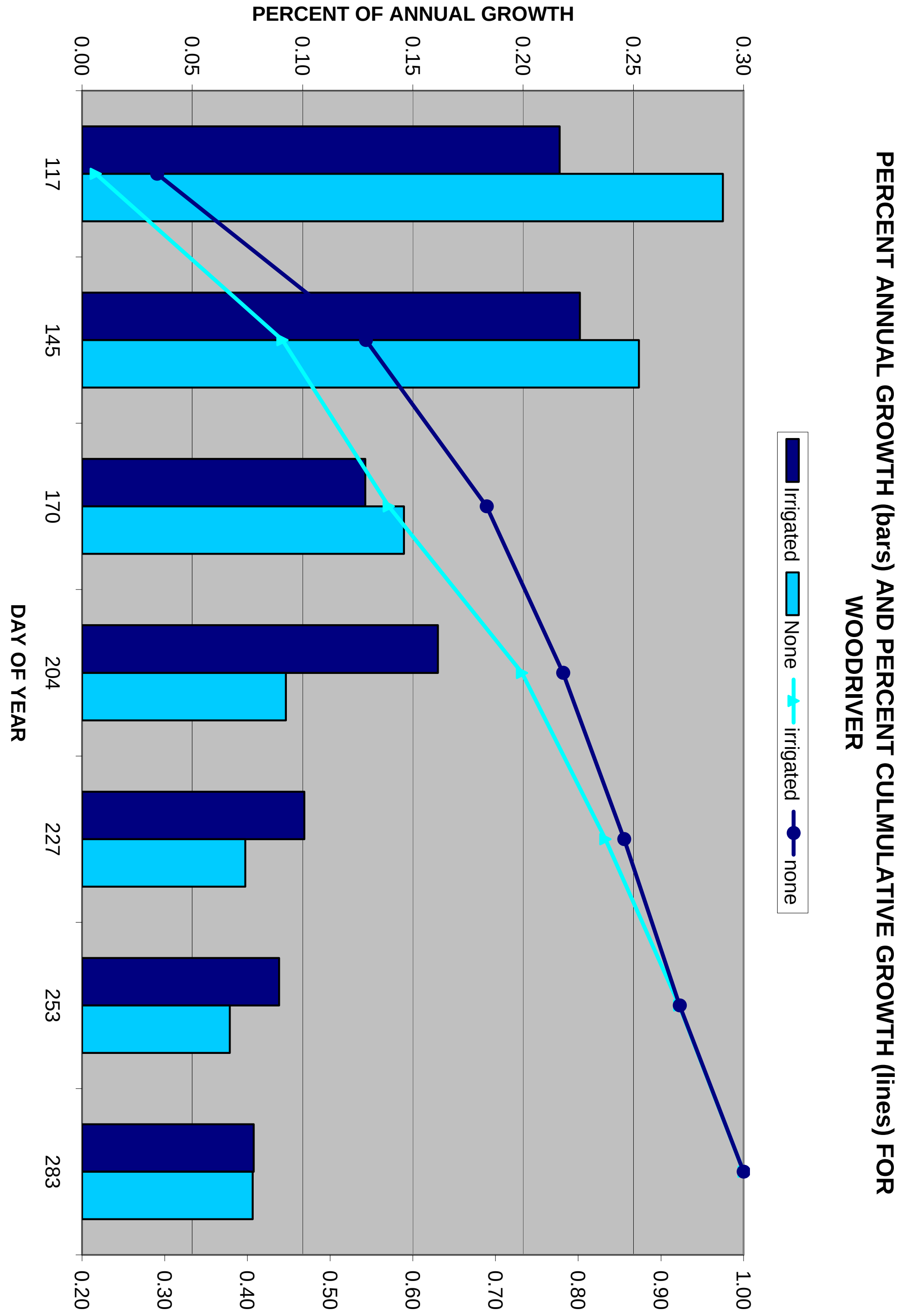

Figure 51. Percent annual of annual growth (bars) and percent culmulative growth (lines) for irrigated and non-irrigated treatments in Wood River, OR.

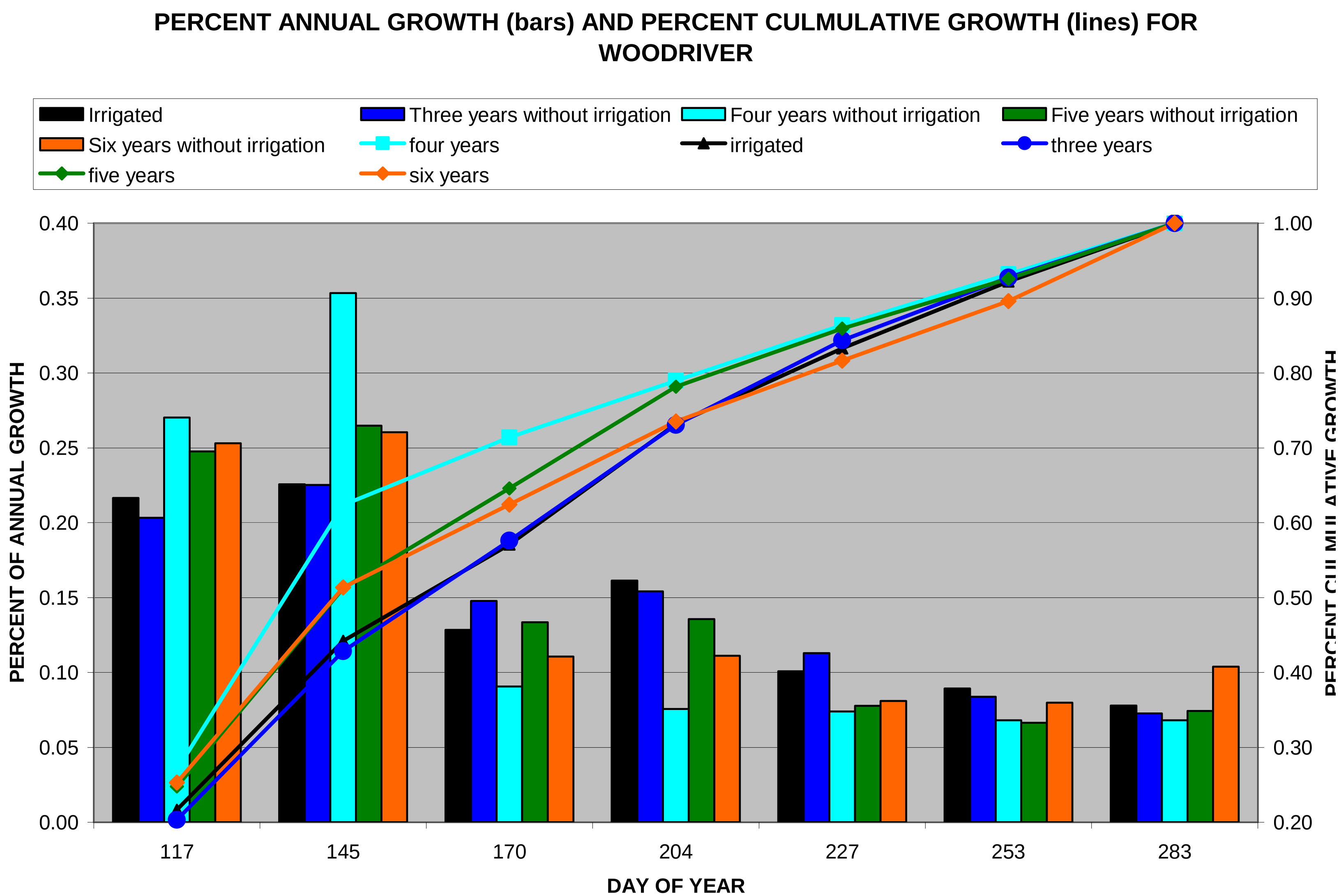

Figure 52. Percent annual of annual growth (bars) and percent culmulative growth (lines) for different irrigation regimes at Wood River, OR.

Question 1. Does Annual Production for Re-clipped plots, beginning on day of year 117 differ between irrigated and non-irrigated treatments?

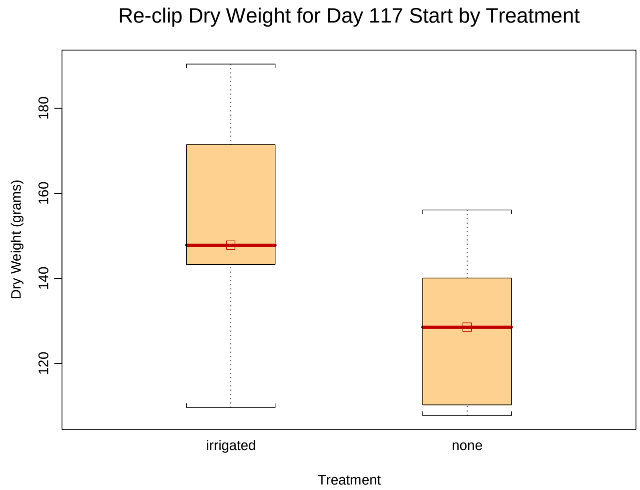

Figure 53. Boxplot of annual production for day of year 117 irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 50. ANOVA Model, Annual Production (Day 117) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares  1614.720  5559.067
Deg. of Freedom         1        10

Residual standard error: 23.57767
Estimated effects are balanced

          Df Sum of Sq  Mean Sq F Value     Pr(F)
treatment  1  1614.720 1614.720 2.90466 0.1191424
Residuals 10  5559.067  555.907

Tables of means
Grand mean

 140.17

 treatment
 irrigated   none
 151.77    128.57

Standard errors for differences of means
        treatment
           13.613
replic.     6.000
```

Conclusion

The average annual production in grams dry weight for irrigated and non-irrigated groups is 151.8 and 128.57, respectively. There is some evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments (p = 0.12).

Question 2. Does Annual Production for Re-clipped plots, beginning on day of year 145 differ between irrigated and non-irrigated treatments?

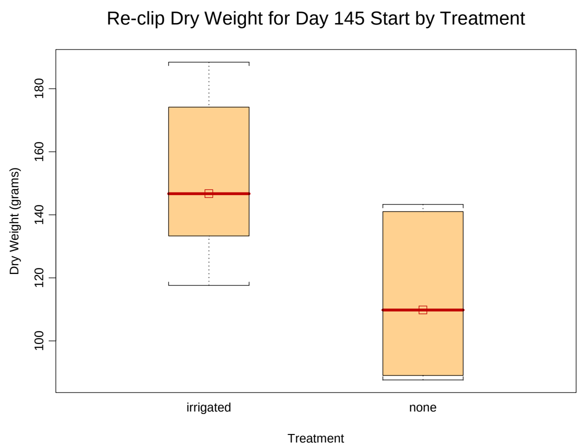

Figure 54. Boxplot of annual production for day of year 145 irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 51. ANOVA Model, Annual Production (Day 145) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares  4271.413  6369.583
Deg. of Freedom         1        10

Residual standard error: 25.23803
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1  4271.413 4271.413 6.705954 0.02696912
Residuals 10  6369.583  636.958

Tables of means
Grand mean

 132.28

 treatment
 irrigated   none
 151.15    113.42

Standard errors for differences of means
        treatment
           14.571
replic.     6.000
```

Conclusion

The average annual production in grams dry weight for irrigated and non-irrigated groups is 151.15 and 113.42, respectively. There is moderate evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments (p = 0.027).

Question 3. Does Annual Production for Re-clipped plots, beginning on day of year 170 differ between irrigated and non-irrigated treatments?

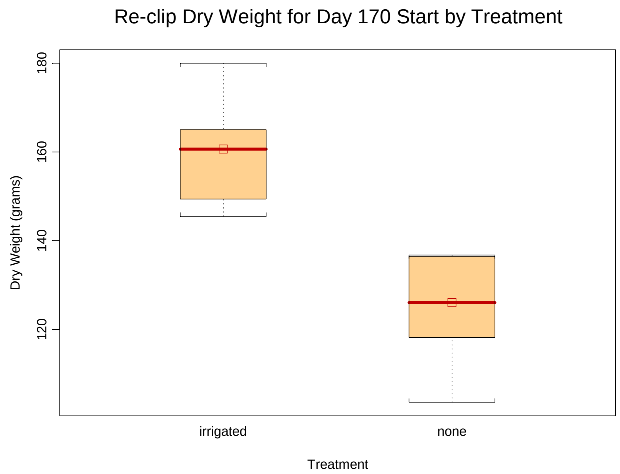

Figure 55. Boxplot of annual production for day of year 170 irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 52. ANOVA Model, Annual Production (Day 170) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares  3816.333  1667.293
Deg. of Freedom         1        10

Residual standard error: 12.91237
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value        Pr(F)
treatment  1  3816.333 3816.333 22.88939 0.0007409346
Residuals 10  1667.293  166.729

Tables of means
Grand mean

 142.37

 treatment
 irrigated   none
 160.20    124.53

Standard errors for differences of means
        treatment
            7.455
replic.     6.000
```

Conclusion

The average annual production in grams dry weight for irrigated and non-irrigated groups is 160.2 and 124.5, respectively. There is overwhelming evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments ($p = 0.0007$).

Question 4. Does Annual Production for Re-clipped plots, beginning on day of year 204 differ between irrigated and non-irrigated treatments?

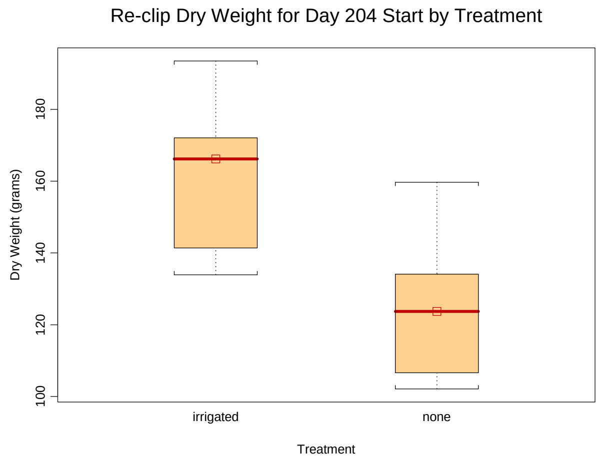

Figure 56. Boxplot of annual production for day of year 204 irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 53. ANOVA Model, Annual Production (Day 204 = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares  4158.963  4717.777
Deg. of Freedom         1        10

Residual standard error: 21.72044
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1  4158.963 4158.963 8.815516 0.01406761
Residuals 10  4717.777  471.778

Tables of means
Grand mean

 143.6

 treatment
 irrigated   none
 162.22    124.98

Standard errors for differences of means
        treatment
            12.54
replic.      6.00
```

Conclusion

The average annual production in grams dry weight for irrigated and non-irrigated groups is 162.2 and 125.0, respectively. There is moderate evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments (p = 0.014).

Question 5. Does Annual Production for Re-clipped plots, beginning on day of year 227 differ between irrigated and non-irrigated treatments?

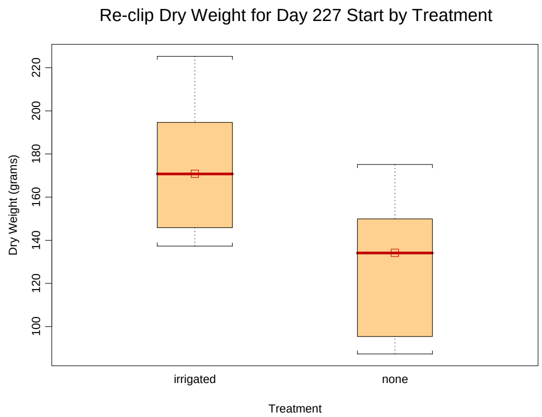

Figure 57. Boxplot of annual production for day of year 227 irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 54. ANOVA Model, Annual Production (Day 227) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   6016.64  11512.84
Deg. of Freedom         1        10

Residual standard error: 33.93058
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   6016.64 6016.641 5.226026 0.04531709
Residuals 10  11512.84 1151.284

Tables of means
Grand mean

 151.72

 treatment
 irrigated   none
 174.12    129.33

Standard errors for differences of means
        treatment
            19.59
replic.      6.00
```

Conclusion

The average annual production in grams dry weight for irrigated and non-irrigated groups is 174.1 and 129.3, respectively. There is moderate evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments (p = 0.045).

Question 6. Does Annual Production for Re-clipped plots, beginning on day of year 253 differ between irrigated and non-irrigated treatments?

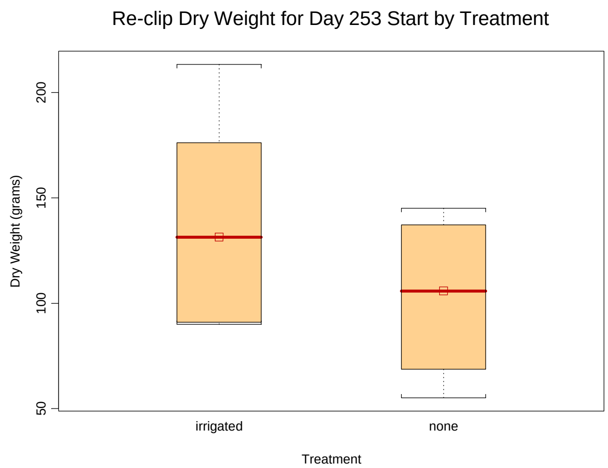

Figure 58. Boxplot of annual production for day of year 253 irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 55. ANOVA Model, Annual Production (Day 253) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   3870.02  18854.51
Deg. of Freedom         1        10

Residual standard error: 43.42178
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1   3870.02 3870.021 2.052571 0.1824607
Residuals 10  18854.51 1885.451

Tables of means
Grand mean

 120.91

 treatment
 irrigated   none
 138.87    102.95

Standard errors for differences of means
        treatment
            25.07
replic.      6.00
```

Conclusion

The average annual production in grams dry weight for irrigated and non-irrigated groups is 138.9 and 103.0, respectively. There is little evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments (p = 0.18).

Question 7. Does Annual Production for Re-clipped plots, beginning on day of year 283 differ between irrigated and non-irrigated treatments?

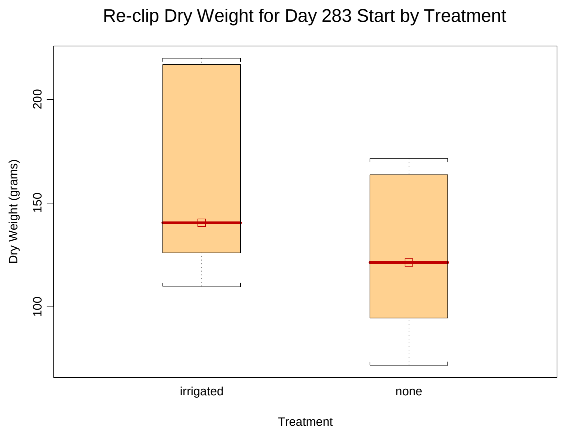

Figure 59. Boxplot of annual production for day of year 283 irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 56. ANOVA Model, Annual Production (Day 283) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   3657.52  18960.27
Deg. of Freedom         1        10

Residual standard error: 43.54339
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1   3657.52 3657.521 1.929045 0.1950161
Residuals 10  18960.27 1896.027

Tables of means
Grand mean

 141.49

 treatment
 irrigated   none
 158.95    124.03

Standard errors for differences of means
        treatment
            25.14
replic.      6.00
```

Conclusion

The average annual production in grams dry weight for irrigated and non-irrigated groups is 159.0and 124.0, respectively. There is little evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments (p = 0.20).

Table 57. Summary Statistics for questions 1 through 7 for irrigated and non-irrigated treatments.

treatment:irrigated

	dry117	dry145	dry170	dry204	dry227	dry253	dry283
Min:	109.70000	117.60000	145.500000	133.900000	137.30000	90.00000	109.90000
1st Qu.:	143.80000	136.37500	151.175000	146.325000	147.10000	97.80000	128.10000
Mean:	151.76667	151.15000	160.200000	162.216667	174.11667	138.86667	158.95000
Median:	147.85000	146.70000	160.650000	166.200000	170.80000	131.35000	140.50000
3rd Qu.:	166.22500	167.60000	164.950000	171.900000	193.67500	168.27500	199.32500
Max:	190.40000	188.40000	180.000000	193.500000	225.30000	213.30000	219.90000
Total N:	6.00000	6.00000	6.000000	6.000000	6.00000	6.00000	6.00000
NA's :	0.00000	0.00000	0.000000	0.000000	0.00000	0.00000	0.00000
Std Dev.:	27.44782	26.09642	12.511275	21.887203	34.66061	49.13678	47.58137
SE Mean:	11.20552	10.65382	5.107707	8.935413	14.15013	20.06000	19.42501

----

treatment:none

	dry117	dry145	dry170	dry204	dry227	dry253	dry283
Min:	107.800000	87.600000	103.600000	102.100000	87.30000	55.10000	71.80000
1st Qu.:	112.800000	93.375000	118.325000	108.575000	104.22500	74.65000	98.70000
Mean:	128.566667	113.416667	124.533333	124.983333	129.33333	102.95000	124.03333
Median:	128.550000	109.800000	126.050000	123.700000	134.15000	105.80000	121.35000
3rd Qu.:	139.275000	134.025000	135.725000	133.800000	146.82500	132.67500	155.70000
Max:	156.100000	143.300000	136.800000	159.700000	175.10000	145.10000	171.40000
Total N:	6.000000	6.000000	6.000000	6.000000	6.00000	6.00000	6.00000
NA's :	0.000000	0.000000	0.000000	0.000000	0.00000	0.00000	0.00000
Std Dev.:	18.932265	24.349408	13.301378	21.552394	33.18449	36.83041	39.09049
SE Mean:	7.729065	9.940604	5.430265	8.798728	13.54751	15.03595	15.95863

Question 8. Does Annual Production for Re-clipped plots, for Non-irrigated treatments differ among start dates?

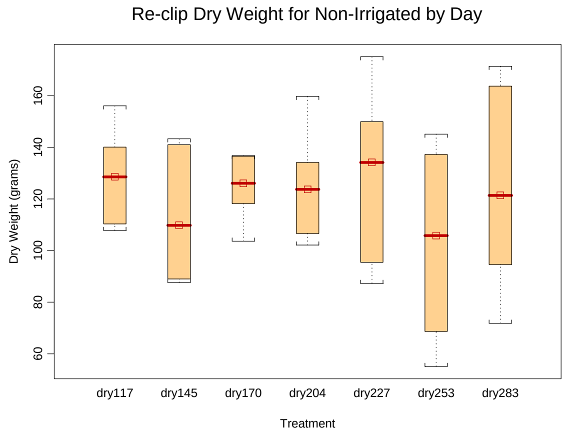

Figure 60. Boxplot of annual production for non-irrigated plots across different re-clipping start dates. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 58. ANOVA Model, Annual Production = Start Date + Error

```
Terms:
                treatment Residuals
 Sum of Squares   3284.79  27892.56
Deg. of Freedom         6        35

Residual standard error: 28.22996
Estimated effects are balanced

          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  6   3284.79 547.4656 0.6869678 0.6613602
Residuals 35  27892.56 796.9304

Tables of means
Grand mean

 121.12

 treatment
 dry117 dry145 dry170 dry204 dry227 dry253 dry283
 128.57 113.42 124.53 124.98 129.33 102.95 124.03

Standard errors for differences of means
        treatment
           16.299
replic.     6.000
```

Conclusion

There is no evidence to suggest there is a difference in mean annual production dry weight for non-irrigated plots with different start dates (p = 0.70).

Question 9. Does Annual Production for Re-clipped plots, for Irrigated treatments differ among start dates?

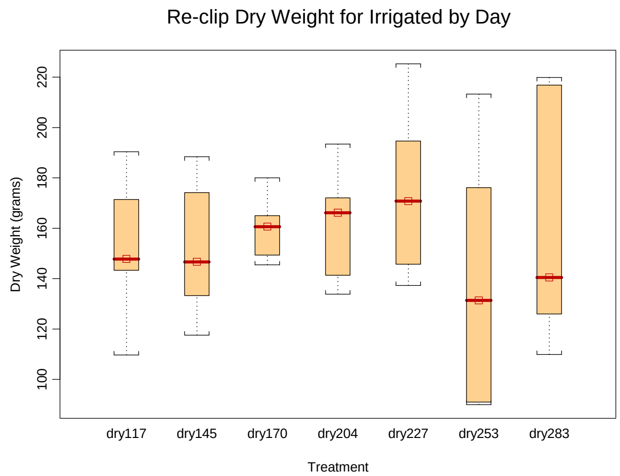

Figure 61. Boxplot of annual production for irrigated plots across different re-clipping start dates. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 59. ANOVA Model, Annual Production = Start Date + Error

```
Terms:
                treatment Residuals
 Sum of Squares   4345.41  39748.77
Deg. of Freedom         6        35

Residual standard error: 33.69984
Estimated effects are balanced

          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  6   4345.41  724.235 0.6377111 0.6992404
Residuals 35  39748.77 1135.679

Tables of means
Grand mean

 156.75

 treatment
 dry117 dry145 dry170 dry204 dry227 dry253 dry283
 151.77 151.15 160.20 162.22 174.12 138.87 158.95

Standard errors for differences of means
        treatment
           19.457
replic.     6.000
```

Conclusion

There is no evidence to suggest there is a difference in mean annual production dry weight for irrigated plots with different start dates (p = 0.70).

Table 60. Summary Statistics for questions 8 through 9 for irrigated and non-irrigated treatments across the different start dates.

```
treatment:dry117
          irrigated       none
     Min: 109.70000 107.800000
 1st Qu.: 143.80000 112.800000
    Mean: 151.76667 128.566667
  Median: 147.85000 128.550000
 3rd Qu.: 166.22500 139.275000
     Max: 190.40000 156.100000
 Total N:   6.00000   6.000000
   NA's :   0.00000   0.000000
Std Dev.:  27.44782  18.932265
 SE Mean:  11.20552   7.729065
------------------------------
treatment:dry145
          irrigated       none
     Min: 117.60000  87.600000
 1st Qu.: 136.37500  93.375000
    Mean: 151.15000 113.416667
  Median: 146.70000 109.800000
 3rd Qu.: 167.60000 134.025000
     Max: 188.40000 143.300000
 Total N:   6.00000   6.000000
   NA's :   0.00000   0.000000
Std Dev.:  26.09642  24.349408
 SE Mean:  10.65382   9.940604
------------------------------
treatment:dry170
           irrigated       none
     Min: 145.500000 103.600000
 1st Qu.: 151.175000 118.325000
    Mean: 160.200000 124.533333
  Median: 160.650000 126.050000
 3rd Qu.: 164.950000 135.725000
     Max: 180.000000 136.800000
 Total N:   6.000000   6.000000
   NA's :   0.000000   0.000000
Std Dev.:  12.511275  13.301378
 SE Mean:   5.107707   5.430265
------------------------------
treatment:dry204
           irrigated       none
     Min: 133.900000 102.100000
 1st Qu.: 146.325000 108.575000
    Mean: 162.216667 124.983333
  Median: 166.200000 123.700000
 3rd Qu.: 171.900000 133.800000
     Max: 193.500000 159.700000
 Total N:   6.000000   6.000000
   NA's :   0.000000   0.000000
Std Dev.:  21.887203  21.552394
 SE Mean:   8.935413   8.798728
------------------------------
treatment:dry227
          irrigated      none
     Min: 137.30000  87.30000
 1st Qu.: 147.10000 104.22500
    Mean: 174.11667 129.33333
  Median: 170.80000 134.15000
 3rd Qu.: 193.67500 146.82500
     Max: 225.30000 175.10000
 Total N:   6.00000   6.00000
   NA's :   0.00000   0.00000
Std Dev.:  34.66061  33.18449
 SE Mean:  14.15013  13.54751
----------------------------
treatment:dry253
          irrigated      none
     Min:  90.00000  55.10000
 1st Qu.:  97.80000  74.65000
    Mean: 138.86667 102.95000
  Median: 131.35000 105.80000
 3rd Qu.: 168.27500 132.67500
     Max: 213.30000 145.10000
 Total N:   6.00000   6.00000
   NA's :   0.00000   0.00000
Std Dev.:  49.13678  36.83041
 SE Mean:  20.06000  15.03595
----------------------------
treatment:dry283
          irrigated      none
     Min: 109.90000  71.80000
 1st Qu.: 128.10000  98.70000
    Mean: 158.95000 124.03333
  Median: 140.50000 121.35000
 3rd Qu.: 199.32500 155.70000
     Max: 219.90000 171.40000
 Total N:   6.00000   6.00000
   NA's :   0.00000   0.00000
Std Dev.:  47.58137  39.09049
 SE Mean:  19.42501  15.95863
```

Annual Production
(One-time by Date)

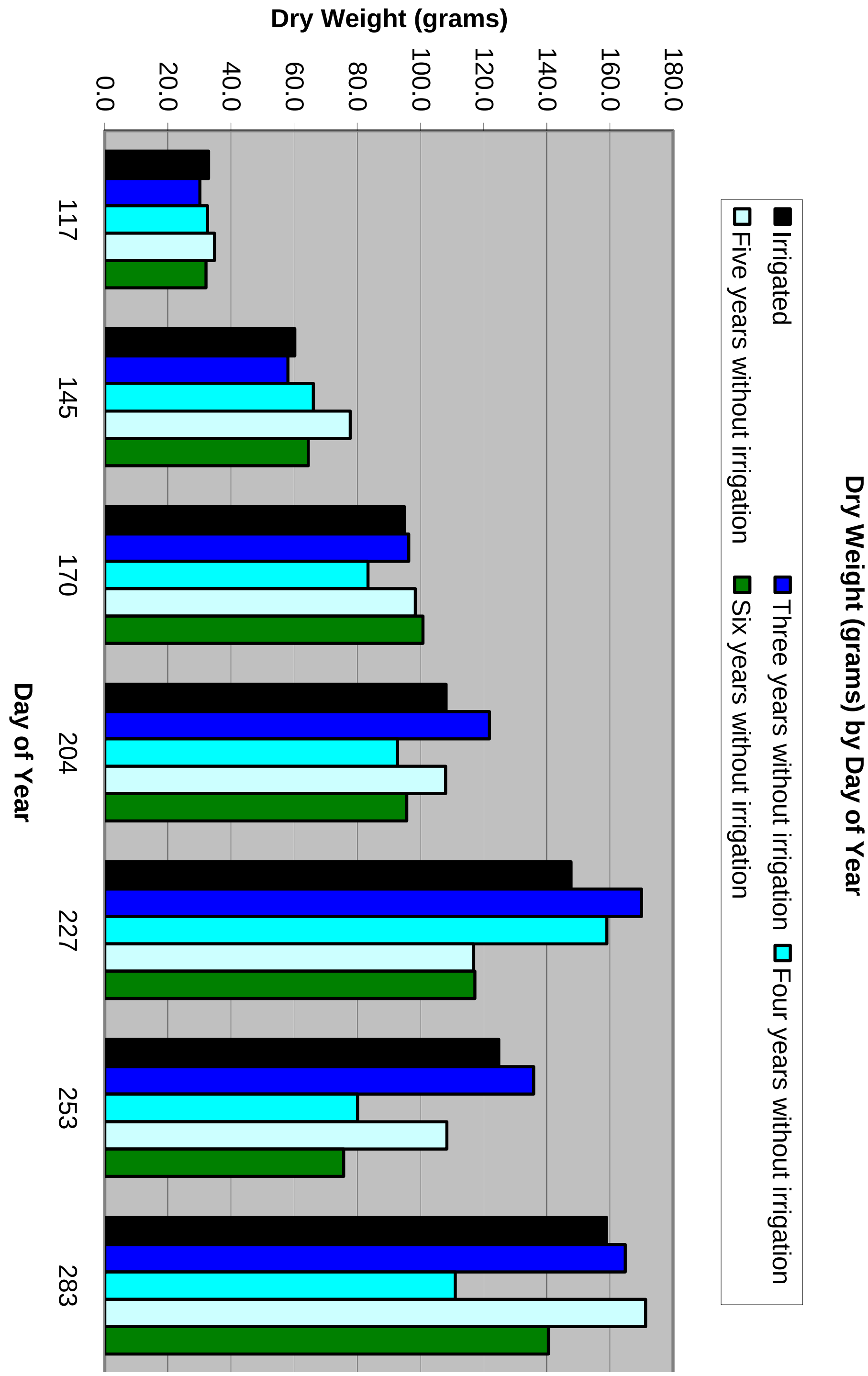

Figure 62. Dry weight in grams for one-time clips by date for irrigated and non-irrigated treatments in Wood River, OR.

Question 1. Does one-time clipping on day of year 117 differ between irrigated and non-irrigated treatments?

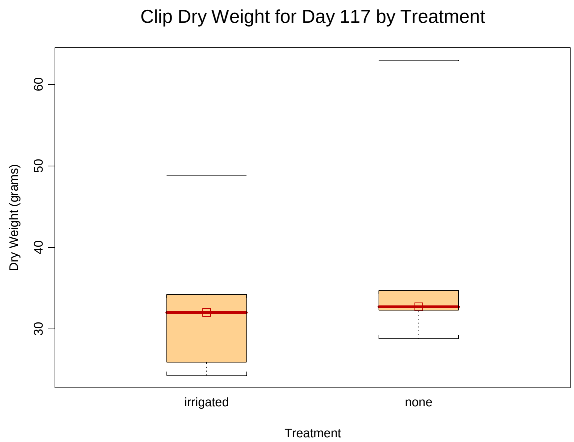

Figure 63. Boxplot of one-time clip dry weight in grams for day of year 117 for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 61. ANOVA Model, Annual Production (Day 117) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares    60.750  1185.967
Deg. of Freedom         1        10

Residual standard error: 10.89021
Estimated effects are balanced

          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    60.750  60.7500 0.5122404 0.4905446
Residuals 10  1185.967 118.5967

Tables of means
Grand mean

 35.117

 treatment
 irrigated   none
 32.867    37.367

Standard errors for differences of means
        treatment
           6.2875
replic.    6.0000
```

Conclusion

The average one-time clipping, in grams dry weight, for irrigated and non-irrigated groups is 32.9 and 37.4, respectively. There is no evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments on day 117 ($p = 0.49$).

Question 2. Does one-time clipping on day of year 145 differ between irrigated and non-irrigated treatments?

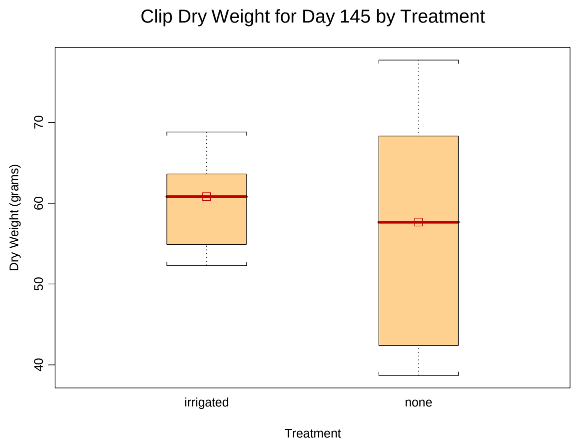

Figure 64. Boxplot of one-time clip dry weight in grams for day of year 145 for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 62. ANOVA Model, Annual Production (Day 145) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares    29.453  1422.213
Deg. of Freedom         1        10

Residual standard error: 11.92566
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value    Pr(F)
treatment  1    29.453  29.4533 0.207095 0.658774
Residuals 10  1422.213 142.2213

Tables of means
Grand mean

 58.633

 treatment
 irrigated   none
 60.200    57.067

Standard errors for differences of means
        treatment
           6.8853
replic.    6.0000
```

Conclusion

The average one-time clipping, in grams dry weight, for irrigated and non-irrigated groups is 60.2 and 57.1, respectively. There is little evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments on day 145 ($p = 0.66$).

Question 3. Does one-time clipping on day of year 170 differ between irrigated and non-irrigated treatments?

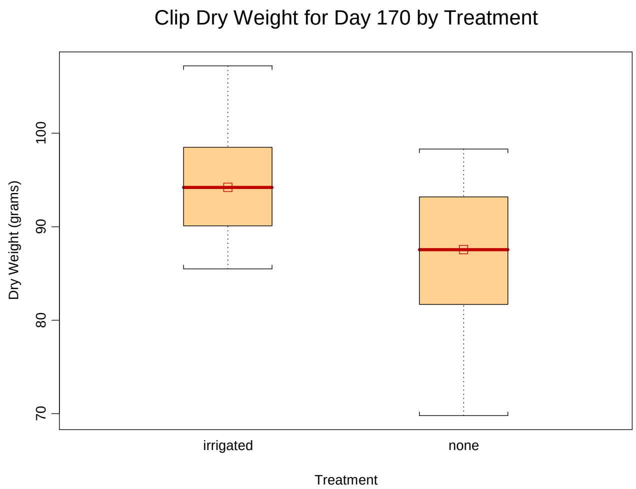

Figure 65. Boxplot of one-time clip dry weight in grams for day of year 170 for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 63. ANOVA Model, Annual Production (Day 170) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares    221.88    800.95
Deg. of Freedom         1        10

Residual standard error: 8.949581
Estimated effects are balanced

          Df Sum of Sq Mean Sq F Value     Pr(F)
treatment  1    221.88 221.880 2.77021 0.1270072
Residuals 10    800.95  80.095

Tables of means
Grand mean

 90.65

 treatment
 irrigated  none
 94.95     86.35

Standard errors for differences of means
        treatment
            5.167
replic.     6.000
```

Conclusion

The average one-time clipping, in grams dry weight, for irrigated and non-irrigated groups is 95.0 and 86.4, respectively. There is some evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments on day 170 ($p = 0.13$).

Question 4. Does one-time clipping on day of year 204 differ between irrigated and non-irrigated treatments?

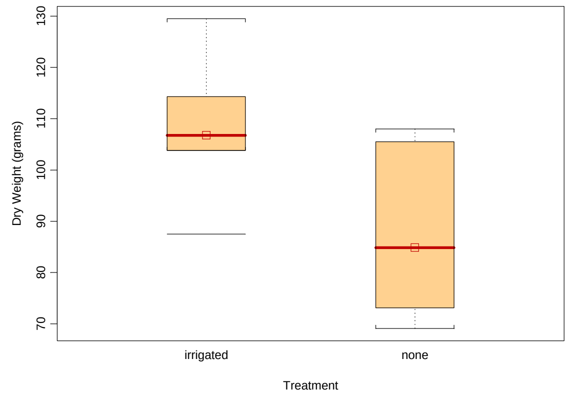

Figure 66. Boxplot of one-time clip dry weight in grams for day of year 204 for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 64. ANOVA Model, Annual Production (Day 204) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares  1264.853  2370.373
Deg. of Freedom         1        10

Residual standard error: 15.39602
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1  1264.853 1264.853 5.336093 0.04350751
Residuals 10  2370.373  237.037

Tables of means
Grand mean

 97.833

 treatment
 irrigated   none
 108.10     87.57

Standard errors for differences of means
        treatment
           8.8889
replic.    6.0000
```

Conclusion

The average one-time clipping, in grams dry weight, for irrigated and non-irrigated groups is 108.1 and 87.6, respectively. There is moderate evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments on day 204 (p = 0.044).

Question 5. Does one-time clipping on day of year 227 differ between irrigated and non-irrigated treatments?

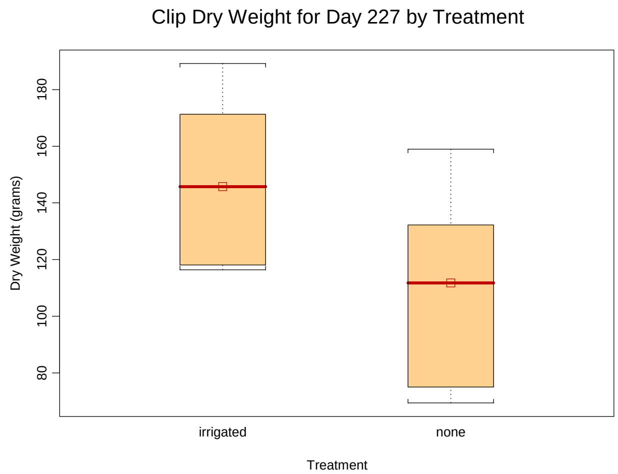

Figure 67. Boxplot of one-time clip dry weight in grams for day of year 227 for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 65. ANOVA Model, Annual Production (Day 227) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   4309.23  11013.13
Deg. of Freedom         1        10

Residual standard error: 33.18604
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   4309.23 4309.230 3.912811 0.07611495
Residuals 10  11013.13 1101.313

Tables of means
Grand mean

 128.8

 treatment
 irrigated   none
 147.75    109.85

Standard errors for differences of means
        treatment
            19.16
replic.      6.00
```

Conclusion

The average one-time clipping, in grams dry weight, for irrigated and non-irrigated groups is 147.8 and 109.9, respectively. There is moderate evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments on day 227 ($p = 0.076$).

Question 6. Does one-time clipping on day of year 253 differ between irrigated and non-irrigated treatments?

Figure 68. Boxplot of one-time clip dry weight in grams for day of year 253 for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 66. ANOVA Model, Annual Production (Day 253) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   3250.52  18231.01
Deg. of Freedom         1        10

Residual standard error: 42.69778
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1   3250.52 3250.521 1.782963 0.2113841
Residuals 10  18231.01 1823.101

Tables of means
Grand mean

 108.34

 treatment
 irrigated   none
 124.80     91.88

Standard errors for differences of means
        treatment
           24.652
replic.     6.000
```

Conclusion

The average one-time clipping, in grams dry weight, for irrigated and non-irrigated groups is 124.8 and 91.9, respectively. There is little evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments on day 253 (p = 0.21).

Question 7. Does one-time clipping on day of year 283 differ between irrigated and non-irrigated treatments?

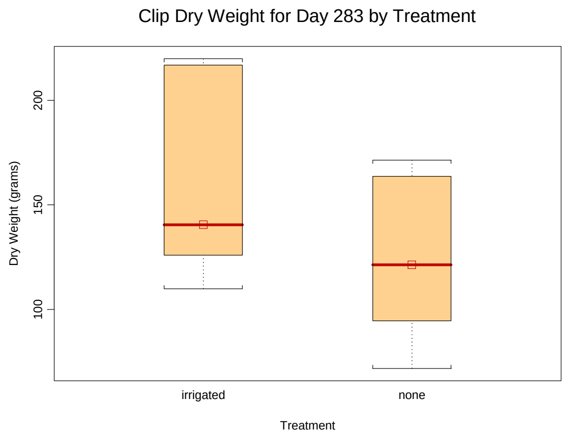

Figure 69. Boxplot of one-time clip dry weight in grams for day of year 283 for irrigated and non-irrigated treatments. The interquartile range is represented in tan, and the red line within the interquartile range is the group median.

Table 67. ANOVA Model, Annual Production (Day 283) = Treatment + Error

```
Terms:
                treatment Residuals
 Sum of Squares   3657.52  18960.27
Deg. of Freedom         1        10

Residual standard error: 43.54339
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1   3657.52 3657.521 1.929045 0.1950161
Residuals 10  18960.27 1896.027

Tables of means
Grand mean

 141.49

 treatment
 irrigated   none
 158.95    124.03

Standard errors for differences of means
        treatment
            25.14
replic.      6.00
```

Conclusion

The average one-time clipping, in grams dry weight, for irrigated and non-irrigated groups is 159.0 and 124.0, respectively. There is little evidence to suggest there is a difference in average annual production for irrigated and non-irrigated treatments on day 283 ($p = 0.20$).

Table 68. Summary Statistics for questions 1 through 7 for irrigated and non-irrigated treatments across the different one-time clip dates.

treatment:irrigated

	dry117	dry145	dry170	dry204	dry227	dry253
Min:	24.300000	52.300000	85.500000	87.500000	116.40000	70.80000
1st Qu.:	27.400000	56.200000	91.075000	104.500000	119.30000	86.85000
Mean:	32.866667	60.200000	94.950000	108.100000	147.75000	124.80000
Median:	32.000000	60.800000	94.200000	106.750000	145.75000	118.40000
3rd Qu.:	33.675000	63.075000	97.475000	112.450000	170.62500	157.37500
Max:	48.800000	68.800000	107.200000	129.500000	189.20000	194.50000
Total N:	6.000000	6.000000	6.000000	6.000000	6.00000	6.00000
NA's :	0.000000	0.000000	0.000000	0.000000	0.00000	0.00000
Std Dev.:	8.707391	5.961879	7.439019	13.732735	32.20837	48.66831
SE Mean:	3.554778	2.433927	3.036967	5.606365	13.14901	19.86875

	dry283
Min:	109.90000
1st Qu.:	128.10000
Mean:	158.95000
Median:	140.50000
3rd Qu.:	199.32500
Max:	219.90000
Total N:	6.00000
NA's :	0.00000
Std Dev.:	47.58137
SE Mean:	19.42501

----

treatment:none

	dry117	dry145	dry170	dry204	dry227	dry253
Min:	28.800000	38.700000	69.800000	69.100000	69.40000	44.30000
1st Qu.:	32.350000	44.125000	82.100000	74.075000	82.90000	65.62500
Mean:	37.366667	57.066667	86.350000	87.566667	109.85000	91.88333
Median:	32.700000	57.650000	87.550000	84.850000	111.75000	94.20000
3rd Qu.:	34.250000	67.725000	92.850000	102.300000	128.37500	122.17500
Max:	63.000000	77.700000	98.300000	108.000000	159.00000	131.00000
Total N:	6.000000	6.000000	6.000000	6.000000	6.00000	6.00000
NA's :	0.000000	0.000000	0.000000	0.000000	0.00000	0.00000
Std Dev.:	12.703333	15.776523	10.239678	16.896351	34.13571	35.74350
SE Mean:	5.186114	6.440738	4.180331	6.897906	13.93585	14.59222

	dry283
Min:	71.80000
1st Qu.:	98.70000
Mean:	124.03333
Median:	121.35000
3rd Qu.:	155.70000
Max:	171.40000
Total N:	6.00000
NA's :	0.00000
Std Dev.:	39.09049
SE Mean:	15.95863

Additional 2007 Statistics

Additional Wood River Analysis for 2007

Forage Quality

1. Is forage quality (fecal analysis) related to annual production and species composition?……………………………………………………………………………………………pg. 80
2. Is there a difference in forage quality (fecal analysis) between irrigated and non-irrigated treatments and is there a relationship with time since irrigation? ……………………………………………………………………………………………pg. 83

Bulk Density

3. Is soil bulk density different between irrigated and non-irrigated exclosures and is bulk density different from time since irrigation? ……………………………pg. 86

Specific Species

4. Does *Poa pratensis* increase in community composition between irrigated and non-irrigated meadows and does it increase or decrease with time since irrigation? ……………………………………………………………………………………pg. 87
5. How does *Carex nebrascensis* (CANE) and *Deschampsia cespitosa* (DECA) community composition change with treatment and time since irrigation? ……………………………………………………………………………… pg. 89
6. How does *Juncus balticus* percentage change with time since irrigation and treatment? ……………………………………………………………………………………pg. 91
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Native and non-native percentages

8. How do natives and non-natives change with treatment and time since irrigation? ……………………………………………………………………………………pg. 96

Functional Groups

9. How does the percentage of species functional groups (grass, grass-like and forb) change with treatment and time since irrigation? ……………………………pg. 100

Wetland status rating

10. Does wetland status rating (OBL, FACW, FAC) change between treatments and time since irrigation? ……………………………………………………………………pg. 107

Gap size and species diversity

11. Is gap size related to species diversity and is the increase in species diversity related to an increase in gap size?……………………………………………………pg. 113

Forage Quality

1. Is forage quality (fecal analysis) related to annual production and species composition?

a. Is crude protein related to total production of the plots (averaged by group)?

```
    *** Linear Model ***
Call: lm(formula = cp ~ grpavgtotal, data = prod.exclo.cp)
Residuals:
    Min      1Q Median     3Q   Max
 -1.723 -0.3568 0.1139 0.3591 1.472
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  9.3921  0.5760    16.3044  0.0000
grpavgtotal  0.0001  0.0001     1.4308  0.1830

Residual standard error: 0.8253 on 10 degrees of freedom
```

```
Multiple R-Squared: 0.1699
F-statistic: 2.047 on 1 and 10 df, the p-value is 0.183
```

Results Summary

There is little evidence to suggest a linear relationship between crude protein and average total production at the plots (p = 0.18).

b. Is crude protein related to the production of grasses at the plots (averaged by group)?

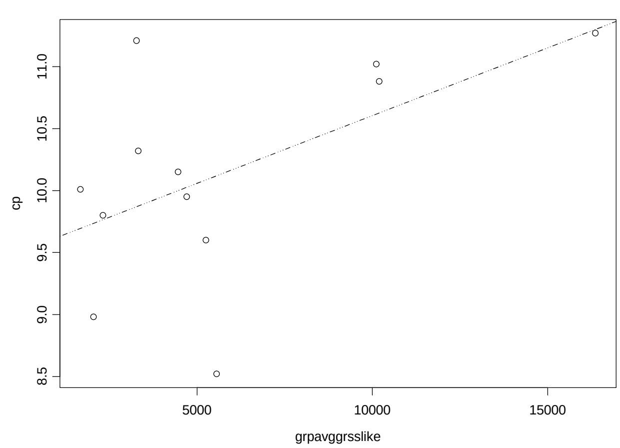
```
*** Linear Model ***
Call: lm(formula = cp ~ grpavggrass, data = prod.exclo.cp)
Residuals:
    Min      1Q Median     3Q    Max
 -1.523 -0.4769 0.0704 0.8249 0.9716
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  10.3903   0.4593    22.6214   0.0000
grpavggrass  -0.0001   0.0001    -0.6500   0.5303

Residual standard error: 0.8873 on 10 degrees of freedom
Multiple R-Squared: 0.04054
F-statistic: 0.4226 on 1 and 10 df, the p-value is 0.5303
```

Results Summary

There is no evidence to suggest a linear relationship between crude protein and average grass production at the plots (p = 0.53).

c. Is crude protein related to the production of grass-likes at the plots (averaged by group)?

```
    *** Linear Model ***
Call: lm(formula = cp ~ grpavggrsslike, data = prod.exclo.cp)
Residuals:
    Min     1Q  Median     3Q   Max
 -1.599 -0.178 0.09327 0.3374 1.341
Coefficients:
                 Value Std. Error t value Pr(>|t|)
   (Intercept)  9.5110  0.3730    25.4964  0.0000
grpavggrsslike  0.0001  0.0001     2.0874  0.0634

Residual standard error: 0.756 on 10 degrees of freedom
Multiple R-Squared: 0.3035
F-statistic: 4.357 on 1 and 10 df, the p-value is 0.0634
```



Results Summary

There is suggestive evidence that a positive linear relationship exists between crude protein and average grasslike production at the plots (p = 0.06), although this relationship may be driven by outliers.

d. Is crude protein related to the production of forbs at the plots (averaged by group)?

```
        *** Linear Model ***
Call: lm(formula = cp ~ grpavgforb, data = prod.exclo.cp)
Residuals:
    Min      1Q Median     3Q   Max
 -1.433 -0.4041 0.1416 0.3902 1.193
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  10.6343   0.5171    20.5646   0.0000
 grpavgforb  -0.0012   0.0011    -1.0829   0.3043

Residual standard error: 0.857 on 10 degrees of freedom
Multiple R-Squared: 0.105
F-statistic: 1.173 on 1 and 10 df, the p-value is 0.3043
```

Results Summary

There is little evidence to suggest a linear relationship between crude protein and average forb production at the plots (p = 0.30).

e. Does total production at the plots vary by time since irrigation ceased and treatment?

```
        *** Linear Model ***
Call: lm(formula = total ~ time, data = production.for.stats)
Residuals:
   Min    1Q Median   3Q   Max
 -7683 -3452  -2363 1797 23236
Coefficients:
                 Value Std. Error    t value   Pr(>|t|)
(Intercept)  9919.1020  1449.2823     6.8441     0.0000
       time  -201.0965   433.6775    -0.4637     0.6458

Residual standard error: 6302 on 34 df
Multiple R-Squared: 0.006284
F-statistic: 0.215 on 1 and 34 df, the p-value is 0.6458
```

Results Summary

There is no evidence to suggest a linear relationship between total production at the plots and time since irrigation ceased (p = 0.64).

```
*** Analysis of Variance Model ***
Short Output:
Call:
   aov(formula = total ~ treatment, data = production.for.stats)
Terms:
                 treatment  Residuals
 Sum of Squares    4597429 1354125241
Deg. of Freedom          1         34
Residual standard error: 6310.881
Estimated effects are balanced

          Df  Sum of Sq  Mean Sq   F Value   Pr(F)
treatment  1    4597429  4597429 0.1154344 0.73613
Residuals 34 1354125241 39827213
```

```
        *Summary Statistics for data in:  production.for.stats ***

 treatment:irrigated                          treatment:nonirrigated
               total                                         total
     Mean:  9813.382                              Mean:  9098.661
  SE Mean:  1776.283                           SE Mean:  1126.971
 LCL Mean:  6065.752                          LCL Mean:  6720.960
 UCL Mean: 13561.012                          UCL Mean: 11476.362
 ----------------------
```

Results Summary

The average production at the irrigated and non-irrigated meadows was 9813 and 9099 lbs/ac, respectively. There is no evidence to suggest a difference in production at the plots between irrigated and non-irrigated meadows (p = 0.74).

f. Does production in the exclosure relate to production at the plots?

```
        *** Linear Model ***
 Call: lm(formula = grpavgtotal ~ exjulyprod, data = prod.exclo.cp)
 Residuals:
    Min    1Q Median   3Q  Max
  -4813 -4340  -1230 4317 6986
 Coefficients:
                   Value  Std. Error     t value    Pr(>|t|)
 (Intercept)  10515.7054   4930.4527      2.1328      0.0587
  exjulyprod     -0.0937      0.4326     -0.2166      0.8329

 Residual standard error: 4711 on 10 degrees of freedom
 Multiple R-Squared: 0.004669
 F-statistic: 0.04691 on 1 and 10 df, the p-value is 0.8329
```

Results Summary

There is no evidence to suggest a linear relationship between production at the plots and production in the exclosures (p = 0.83).

2. Is there a difference in forage quality (fecal analysis) between irrigated and non-irrigated treatments and is there a relationship with time since irrigation?

a. Early Season Analysis

ANOVA to test difference of early season (May-July) DOM:CP between treatments

```
Call: aov(formula = dom.cp ~ treatment, data = SDF1)
Terms:
                treatment Residuals
Sum of Squares   0.06335  29.10487
Deg. of Freedom        1        29
Residual standard error: 1.001806
Estimated effects may be unbalanced
          Df Sum of Sq  Mean Sq    F Value     Pr(F)
treatment  1   0.06335 0.063354 0.06312554 0.8033942
Residuals 29  29.10487 1.003616
   treatment:Irrigated          treatment:Nonirrigated
             dom.cp                           dom.cp
       Mean: 5.8794118              Mean: 5.7885714
    SE Mean: 0.2590714           SE Mean: 0.2441488
   LCL Mean: 5.3302049          LCL Mean: 5.2611200
   UCL Mean: 6.4286186          UCL Mean: 6.3160228
   --------------------
```

Result Summary

The average DOM/CP ratio for early season fecal samples is 5.9 and 5.8 for irrigated and non-irrigated pastures, respectively. There is no evidence to suggest there is a difference between the early season DOM:CP ratio for irrigated and non-irrigated treatments (p = 0.80)

Regression to test if there is a difference over time of early season DOM:CP

```
       *** Linear Model ***
Call: lm(formula = dom.cp ~ time, data = earlyseason)
Residuals:
    Min      1Q Median     3Q   Max
 -2.069 -0.9162 0.2462 0.7905 1.501
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   5.8592   0.2387    24.5502   0.0000
       time  -0.0114   0.0854    -0.1330   0.8951
Residual standard error: 1.003 on 29 degrees of freedom
Multiple R-Squared: 0.0006093
F-statistic: 0.01768 on 1 and 29 df, the p-value is 0.8951
```

Results Summary

There is no evidence to suggest there is a linear relationship between early season DOM:CP ratios and the time (years) since the pastures were last irrigated (p = 0.89).

b. Late Season Analysis

ANOVA to test the difference of late season (Aug-Oct) DOM:CP between treatments

```
Call: aov(formula = dom.cp ~ treatment, data = SDF1)
Terms:
                treatment Residuals
 Sum of Squares   3.69865  34.88466
Deg. of Freedom         1        33
Residual standard error: 1.028159
Estimated effects may be unbalanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   3.69865 3.698650 3.498829 0.07030349
Residuals 33  34.88466 1.057111
       ***  Summary Statistics for data in:  lateseason ***

treatment:Irrigated           treatment:Nnonirrigated
               domcp                          domcp
    Mean:  6.4341667              Mean:  7.0845882
 SE Mean:  0.2296090           SE Mean:  0.2625682
LCL Mean:  5.9497340          LCL Mean:  6.5279684
UCL Mean:  6.9185994          UCL Mean:  7.6412080
---------------------
```

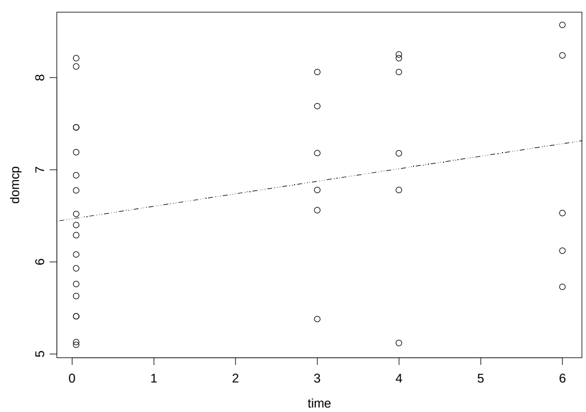
Results Summary

The average late season DOM:CP ratio for irrigated and non-irrigated groups is 6.4 and 7.1, respectively. There is moderate evidence to suggest there is a difference between the DOM:CP ratio between irrigated and non-irrigated treatments (p = 0.07).

Regression to test if there is a difference over time of late season DOM:CP

```
Call: lm(formula = dom.cp ~ time, data = lateseason)
Residuals:
   Min     1Q   Median    3Q   Max
 -1.89 -0.798 -0.07412 0.972 1.736
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  6.4673  0.2379    27.1836  0.0000
       time  0.1358  0.0775     1.7522  0.0890
```

```
Residual standard error: 1.034 on 33 degrees of freedom
Multiple R-Squared: 0.08512
F-statistic: 3.07 on 1 and 33 df, the p-value is 0.08903

***  Summary Statistics for data in:  lateseason ***

time:0.05                     time:4
               domcp                           domcp
    Mean:  6.4341667              Mean: 7.266333
SE Mean:  0.2296090           SE Mean: 0.494607
LCL Mean:  5.9497340          LCL Mean: 5.994905
UCL Mean:  6.9185994          UCL Mean: 8.537761
---------------------         --------------------
time:3                        time:6
              domcp                             domcp
    Mean: 6.9416667               Mean: 7.0380000
SE Mean: 0.3863540            SE Mean: 0.5746077
LCL Mean: 5.9485120           LCL Mean: 5.4426333
UCL Mean: 7.9348213           UCL Mean: 8.6333667
--------------------
```



Results Summary

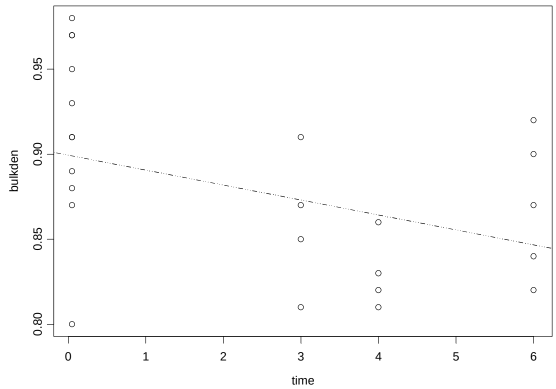
There is some evidence to conclude there is a positive linear relationship between the DOM:CP ratio and time since irrigation ceased (0.09).

Bulk Density

3. Is soil bulk density different between irrigated and non-irrigated exclosures and is bulk density different from time since irrigation?

a. Regression to test if bulk density changes from time since last irrigated

```
Call: lm(formula = bulkden ~ time, data = Fecal.bulkden.summ)
Residuals:
      Min       1Q    Median      3Q     Max
 -0.09897 -0.02897 -0.004237 0.03697 0.08103
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   0.8994   0.0146    61.4152   0.0000
       time  -0.0088   0.0044    -2.0098   0.0563
Residual standard error: 0.05227 on 23 degrees of freedom
Multiple R-Squared: 0.1494
F-statistic: 4.039 on 1 and 23 df, the p-value is 0.05633
```



b. ANOVA to test if bulk density is different between irrigated and non-irrigated exclosures

```
Call:aov(formula = bulkden ~ Treatment, data = Fecal.bulkden.summ)
Terms:
                 Treatment  Residuals
 Sum of Squares 0.01584092 0.05802308
Deg. of Freedom          1         23
Residual standard error: 0.05022691
Estimated effects may be unbalanced
          Df  Sum of Sq    Mean Sq  F Value    Pr(F)
Treatment  1 0.01584092 0.01584092 6.279247 0.019738
Residuals 23 0.05802308 0.00252274
Treatment:Irrigated          Treatment:Nonirrigated
             bulkden                        bulkden
    Mean: 0.90500000             Mean: 0.8546154
 SE Mean: 0.01760251          SE Mean: 0.0104768
LCL Mean: 0.86625713         LCL Mean: 0.8317884
UCL Mean: 0.94374287         UCL Mean: 0.8774424
---------------------
```

Specific Species

4. Does *Poa pratensis* increase in community composition between irrigated and non-irrigated meadows and does it increase or decrease with time since irrigation?

a. Does *Poa pratensis* percentage in the top canopy layer change with treatment and time since irrigation?

Regression to test if % POPR in the top canopy layer changes with time since irrigation

```
Call: lm(formula = popr ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q Median    3Q   Max
 -28.16 -13.81 -2.465 13.67 41.24
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  30.2135   3.9980     7.5572   0.0000
       time  -1.1302   1.1963    -0.9447   0.3515

Residual standard error: 17.38 on 34 degrees of freedom
Multiple R-Squared: 0.02558
F-statistic: 0.8925 on 1 and 34 df, the p-value is 0.3515
```

Results Summary

There is no evidence to suggest there is a linear relationship between the percentage of *Poa pratensis* in the top canopy layer and the time since irrigation ceased (p = 0.35)

ANOVA to test if % POPR is different between treatments

```
Call: aov(formula = popr ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares    528.92  10015.38
Deg. of Freedom         1        34
Residual standard error: 17.16305
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1    528.92 528.9233 1.795577 0.1891354
Residuals 34  10015.38 294.5701
treatment:irrigated           treatment:nonirrigated
               popr                             popr
    Mean: 31.443889               Mean: 23.777778
 SE Mean:  3.790309            SE Mean:  4.285274
LCL Mean: 23.447036           LCL Mean: 14.736640
UCL Mean: 39.440742           UCL Mean: 32.818916
--------------------
```

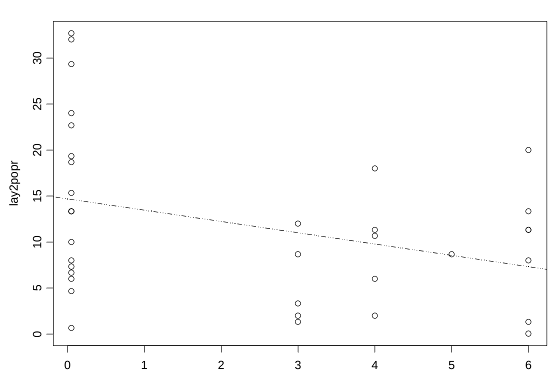
Results Summary

The average top canopy cover for *Poa pratensis* is 31% and 23% for irrigated and non-irrigated pastures, respectively. There is little evidence to suggest a difference between percentage of *Poa pratensis* between irrigated and non-irrigated pastures (p = 0.20).

b. Does *Poa pratensis* percentage in the second layer change with treatment and time since irrigation?

Regression

```
      *** Linear Model ***
Call: lm(formula = lay2popr ~ time, data = april18stats, na.action =
      na.exclude)
Residuals:
    Min    1Q Median    3Q   Max
 -13.95 -7.27  -0.58 4.217 18.05
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  14.6793   1.8892     7.7702   0.0000
       time  -1.2274   0.5653    -2.1713   0.0370

Residual standard error: 8.214 on 34 degrees of freedom
Multiple R-Squared: 0.1218
F-statistic: 4.714 on 1 and 34 df, the p-value is 0.03698
```



Results Summary

There is moderate evidence to suggest a negative linear relationship between percentage of *Poa pratensis* in the second canopy and time since irrigation ceased (p = 0.04).

ANOVA

```
Call: aov(formula = lay2popr ~ treatment, data = april18stats)
Terms:
                treatment Residuals
 Sum of Squares   454.827  2157.480
Deg. of Freedom         1        34
Residual standard error: 7.965884
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   454.827 454.8267 7.167671 0.01134447
Residuals 34  2157.480  63.4553

       ***  Summary Statistics for data in:  april18stats ***
                                            -------------------
treatment:irrigated                         treatment:none
          lay2popr                                    lay2popr
    Mean: 15.407222                             Mean:  8.298333
 SE Mean:  2.271873                          SE Mean:  1.374475
LCL Mean: 10.613989                         LCL Mean:  5.398445
UCL Mean: 20.200456                         UCL Mean: 11.198222
```

Results Summary

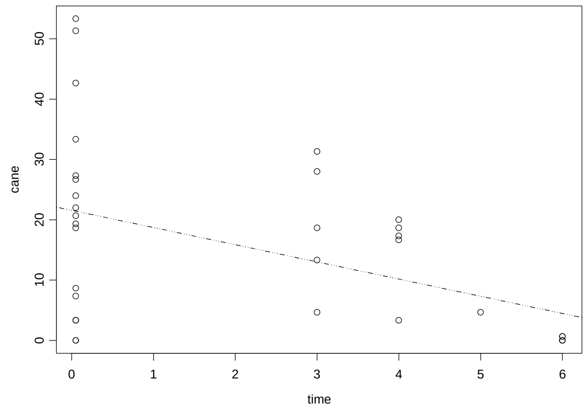
The average percentage of *Poa pratensis* in the second canopy for irrigated and non-irrigated pastures is 15% and 8%, respectively. There is convincing evidence to suggest a difference in percentage of *Poa pratensis* between irrigated and non irrigated pastures in the second canopy (p = 0.01).

5. **How does *Carex nebrascensis* (CANE) and *Deschampsia cespitosa* (DECA) community composition change with treatment and time since irrigation?**

   a. **Does *Carex nebrascensis* percentage in the top canopy layer change with treatment and time since irrigation?**

Regression to test if CANE percentage in the top canopy layer changes with time since irrigation

```
Call: lm(formula = cane ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q Median    3Q   Max
 -21.42 -5.052 -2.366 6.674 31.91
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  21.5656   3.0772     7.0081   0.0000
       time  -2.8512   0.9208    -3.0964   0.0039
Residual standard error: 13.38 on 34 degrees of freedom
Multiple R-Squared: 0.22
F-statistic: 9.587 on 1 and 34 df, the p-value is 0.00391
```



Results Summary

There is convincing evidence to suggest a negative linear relationship between percentage of CANE in the top canopy layer and time since irrigation ceased (p = 0.003).

ANOVA to test if CANE percentage in the top canopy is different between treatments

```
Call: aov(formula = cane ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares   940.240  6863.214
Deg. of Freedom         1        34
Residual standard error: 14.20772
Estimated effects are balanced
          Df Sum of Sq  Mean Sq F Value      Pr(F)
treatment  1   940.240 940.2400  4.6579 0.03806196
Residuals 34  6863.214 201.8592

       ***  Summary Statistics for data in:  Fxn.grp.analysis ***

treatment:irrigated           treatment:none
               cane                          cane
    Mean: 20.110556              Mean:  9.889444
 SE Mean:  4.021761           SE Mean:  2.500848
LCL Mean: 11.625382          LCL Mean:  4.613116
UCL Mean: 28.595729          UCL Mean: 15.165773
---------------------
```

Results Summary

The average percentage of CANE for irrigated and non-irrigated pastures is 20% and 10%, respectively. There is some evidence to suggest a difference between percentage of CANE in the top canopy for irrigated and non-irrigated pastures (p = 0.04).

b. Does *Carex nebrascensis* percentage in the second layer change with treatment and time since irrigation?

Regression

```
      *** Linear Model ***
Call: lm(formula = lay2cane2 ~ time, data = april18stats)
Residuals:
    Min     1Q Median    3Q   Max
 -6.336 -3.117 -1.369 1.111 14.94

Coefficients:
```

```
               Value Std. Error t value Pr(>|t|)
(Intercept)  6.4161  1.2332     5.2029  0.0000
       time -0.5955  0.3690    -1.6138  0.1158

Residual standard error: 5.362 on 34 degrees of freedom
Multiple R-Squared: 0.07115
F-statistic: 2.604 on 1 and 34 df, the p-value is 0.1158
```

Results Summary

There is little evidence to suggest a linear relationship between percentage of *Carex nebrascensis* in the second canopy and time since irrigation ceased (p = 0.11).

ANOVA

```
Call: aov(formula = lay2cane2 ~ treatment, data = april18stats)
Terms:
                treatment Residuals
 Sum of Squares    35.820  1016.587
Deg. of Freedom         1        34
Residual standard error: 5.468056
Estimated effects are balanced

          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1    35.820 35.82022 1.198016 0.2814123
Residuals 34  1016.587 29.89963

       ***  Summary Statistics for data in:  april18stats ***

treatment:irrigated                         treatment:none
          lay2cane2                                   lay2cane2
    Mean:  6.042222                             Mean:  4.047222
 SE Mean:  1.409538                          SE Mean:  1.155589
LCL Mean:  3.068358                         LCL Mean:  1.609144
UCL Mean:  9.016087                         UCL Mean:  6.485301
```

Results Summary

The average percentage of *Carex nebrascensis* in the second canopy for irrigated and non-irrigated pastures is 6% and 4%, respectively. There is no evidence to suggest a difference in percentage of *Carex nebrascensis* between irrigated and non irrigated pastures in the second canopy (p = 0.28).

c. **DECA presence in the top canopy layer was not abundant enough for regression or ANOVA analysis.**

6. **Does *Juncus balticus* percentage change time since irrigation and treatment (irrigated/non-irrigated)?**
   a. **Does *Juncus balticus* percentage in the top canopy change time since irrigation and treatment (irrigated/non-irrigated)?**

Regression

```
       *** Linear Model ***

Call: lm(formula = JUBA ~ time, data = april18stats)
Residuals:
   Min     1Q Median    3Q  Max
 -10.5 -5.896 -1.995 5.329 17.5

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  13.2004   1.7815     7.4096   0.0000
```

```
        time  -0.6337   0.5331    -1.1888   0.2428

Residual standard error: 7.746 on 34 degrees of freedom
Multiple R-Squared: 0.0399
F-statistic: 1.413 on 1 and 34 df, the p-value is 0.2428
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of *Juncus balticus* in the top canopy and time since irrigation ceased (p = 0.24).

ANOVA

```
Call: aov(formula = JUBA ~ treatment, data = april18stats)
Terms:
                treatment Residuals
 Sum of Squares    41.553  2083.442
Deg. of Freedom         1        34
Residual standard error: 7.828007
Estimated effects are balanced

          Df Sum of Sq  Mean Sq   F Value    Pr(F)
treatment  1    41.553 41.55306 0.6781107 0.415977
Residuals 34  2083.442 61.27770

      ***  Summary Statistics for data in:  april18stats ***

treatment:irrigated                          treatment:none
               JUBA                                    JUBA
    Mean: 12.815389                            Mean: 10.666667
 SE Mean:  1.917376                         SE Mean:  1.769831
LCL Mean:  8.770079                        LCL Mean:  6.932649
UCL Mean: 16.860699                        UCL Mean: 14.400684
```

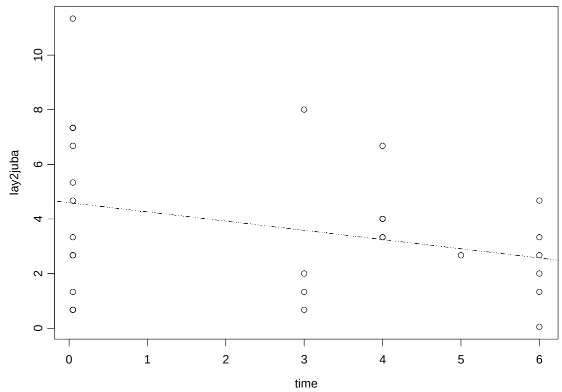
Results Summary

The average percentage of *Juncus balticus* in the top canopy for irrigated and non-irrigated pastures is 13% and 11%, respectively. There is no evidence to suggest a difference in the percentage of *Juncus balticus* in the top canopy for irrigated and non-irrigated pastures (p = 0.41).

b. Does *Juncus balticus* percentage in the second canopy layer change with time since irrigation and treatment?

Regression

```
      *** Linear Model ***
Call: lm(formula = lay2juba ~ time, data = april18stats)
Residuals:
    Min     1Q  Median    3Q   Max
 -3.906 -1.662 0.08647 2.094 6.754
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  4.5930  0.5820     7.8911  0.0000
       time -0.3374  0.1742    -1.9370  0.0611

Residual standard error: 2.531 on 34 degrees of freedom
Multiple R-Squared: 0.09938
F-statistic: 3.752 on 1 and 34 df, the p-value is 0.06109
```



Results Summary

There is suggestive evidence that a negative linear relationship exists between percentage of *Juncus balticus* in the second canopy and time since irrigation ceased (p = 0.06).

ANOVA

```
Call: aov(formula = lay2juba ~ treatment, data = april18stats)
Terms:
                treatment Residuals
 Sum of Squares   21.6845  220.1187
Deg. of Freedom         1        34

Residual standard error: 2.544421
Estimated effects are balanced
          Df Sum of Sq  Mean Sq F Value      Pr(F)
treatment  1   21.6845 21.68454 3.34944 0.07600652
Residuals 34  220.1187  6.47408

       ***  Summary Statistics for data in:  april18stats ***

treatment:irrigated                         treatment:none
           lay2juba                                   lay2juba
    Mean: 4.5922222                             Mean: 3.0400000
 SE Mean: 0.7083238                          SE Mean: 0.4664972
LCL Mean: 3.0977897                         LCL Mean: 2.0557770
UCL Mean: 6.0866548                         UCL Mean: 4.0242230
--------------------
```

Results Summary

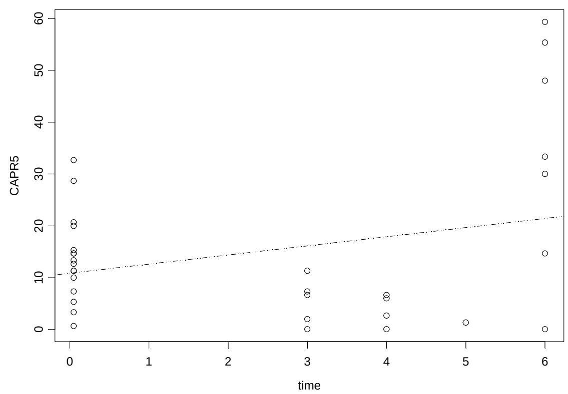
The average percentage of *Juncus balticus* in the second canopy for irrigated and non-irrigated pastures is 5% and 3%, respectively. There is some evidence to suggest a difference in percentage of JUBA between irrigated and non irrigated pastures in the second canopy (p = 0.08).

7. **Does *Carex praegracilis* percentage change with treatment and time since irrigation?**
    a. **Does *Carex praegracilis* percentage in the top canopy change with treatment and time since irrigation?**

Regression

```
         *** Linear Model ***
Call: lm(formula = CAPR5 ~ time, data = april18stats)
Residuals:
```

```
    Min     1Q  Median   3Q   Max
 -21.36 -10.52 -0.2879 5.43 37.92
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) 10.8651  3.3915     3.2036  0.0029
       time  1.7578  1.0149     1.7320  0.0923

Residual standard error: 14.75 on 34 degrees of freedom
Multiple R-Squared: 0.08108
F-statistic: 3 on 1 and 34 df, the p-value is 0.09234
```



Results Summary

There is some evidence to suggest a positive linear relationship between percentage of *Carex praegracilis* in the top canopy and time since irrigation ceased (p = 0.09).

ANOVA

```
Call: aov(formula = CAPR5 ~ treatment, data = april18stats)
Terms:
                treatment Residuals
 Sum of Squares    29.994  8016.294
Deg. of Freedom         1        34
Residual standard error: 15.35491
Estimated effects are balanced

          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    29.994  29.9939 0.1272149 0.7235415
Residuals 34  8016.294 235.7733
       ***  Summary Statistics for data in:  april18stats ***

treatment:irrigated                          treatment:none
              CAPR5                                   CAPR5
    Mean: 14.000000                             Mean: 15.82556
 SE Mean:  1.889792                          SE Mean:  4.75665
LCL Mean: 10.012887                         LCL Mean:  5.78990
UCL Mean: 17.987113                         UCL Mean: 25.86121
-------------------
```

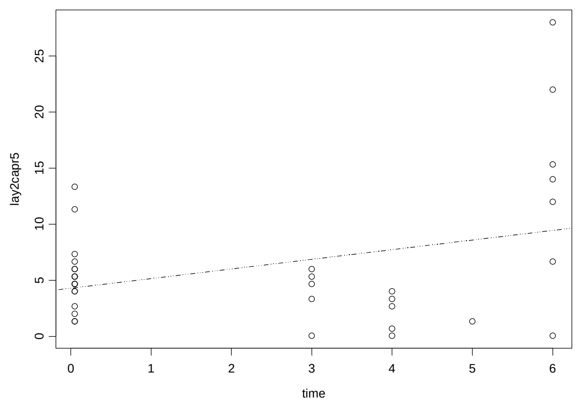
Results Summary

The average percentage of CAPR5 in the top canopy for irrigated and non-irrigated pastures is 14% and 16%, respectively. There is no evidence to suggest a difference in percentage of CAPR5 between irrigated and non irrigated pastures in the top canopy (p = 0.72).

b. Does *Carex praegracilis* percentage in the second layer change with treatment and time since irrigation?

Regression

```
      *** Linear Model ***
Call: lm(formula = lay2capr5 ~ time, data = april18stats)
Residuals:
    Min    1Q  Median    3Q   Max
 -9.392 -3.13 -0.3259 1.842 18.56
Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 4.2829 1.3239     3.2352  0.0027
       time 0.8599 0.3961     2.1707  0.0370
Residual standard error: 5.756 on 34 degrees of freedom
Multiple R-Squared: 0.1217
F-statistic: 4.712 on 1 and 34 df, the p-value is 0.03703
```



Results Summary

There is moderate evidence to suggest a positive linear relationship between percentage of *Carex praegracilis* in the second canopy and time since irrigation ceased (p = 0.04).

ANOVA

```
Call: aov(formula = lay2capr5 ~ treatment, data = april18stats)
Terms:
                treatment Residuals
 Sum of Squares    31.155  1251.557
Deg. of Freedom         1        34
Residual standard error: 6.067166
Estimated effects are balanced
          Df Sum of Sq Mean Sq   F Value     Pr(F)
treatment  1    31.155 31.1550 0.8463617 0.3640651
Residuals 34  1251.557 36.8105

      ***  Summary Statistics for data in:  april18stats ***

treatment:irrigated                            treatment:none
          lay2capr5                                      lay2capr5
    Mean: 5.3327778                               Mean:  7.193333
 SE Mean: 0.7269382                            SE Mean:  1.887225
LCL Mean: 3.7990723                           LCL Mean:  3.211637
UCL Mean: 6.8664832                           UCL Mean: 11.175029
--------------------
```

Results Summary

The average percentage of *Carex praegracilis* in the second canopy for irrigated and non-irrigated pastures is 5% and 7%, respectively. There is no evidence to suggest a difference in percentage of *Carex praegracilis* between irrigated and non irrigated pastures in the second canopy (p = 0.36).

Native and Non-Native

8. How do natives and non-natives change with treatments and time since irrigation?

a. % Native Analysis in top canopy layer

Regression to test if % native species in the top canopy changes with time since irrigation

```
Call: lm(formula = native ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q  Median    3Q  Max
 -38.79 -12.52 -0.7688 12.24 39.7
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  57.8162   4.6227    12.5069   0.0000
       time  -0.9494   1.3833    -0.6863   0.4972
Residual standard error: 20.1 on 34 degrees of freedom
Multiple R-Squared: 0.01367
F-statistic: 0.4711 on 1 and 34 df, the p-value is 0.4972
```

Results Summary

There is no evidence to suggest a linear relationship between the percentage of native species and time since irrigation ceased (p = 0.50).

ANOVA to test if %natives is different between treatments

```
Call: aov(formula = native ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares      0.44  13926.62
Deg. of Freedom         1        34
Residual standard error: 20.23874
Estimated effects are balanced
          Df Sum of Sq  Mean Sq     F Value     Pr(F)
treatment  1      0.44   0.4400 0.001074229 0.9740453
Residuals 34  13926.62 409.6066

treatment:irrigated           treatment:nonirrigated
             native                        native
    Mean: 55.519444              Mean: 55.740556
 SE Mean:  4.466637           SE Mean:  5.055788
LCL Mean: 46.095664          LCL Mean: 45.073775
UCL Mean: 64.943225          UCL Mean: 66.407336
---------------------
```

Results Summary

The average percentage of native species for irrigated and non-irrigated pastures is 56% for both treatments. There is no evidence to suggest a difference between the percentage of native species for irrigated and non irrigated pastures (p = 0.97).

b. Does native species percentage in the second layer change with treatment and time since irrigation?

Regression

```
        *** Linear Model ***
Call: lm(formula = lay2native ~ time, data = layer2and3pct)
Residuals:
    Min     1Q Median    3Q   Max
 -20.09 -8.419  -1.42 9.356 27.92
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) 25.4085  2.8133     9.0315  0.0000
       time  0.2247  0.8419     0.2669  0.7912
Residual standard error: 12.23 on 34 degrees of freedom
Multiple R-Squared: 0.002091
F-statistic: 0.07123 on 1 and 34 df, the p-value is 0.7912
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of native species in the second canopy layer and time since irrigation ceased (p = 0.79).

ANOVA

```
Call: aov(formula = lay2native ~ treatment, data = layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares    75.111  5023.358
Deg. of Freedom         1        34
Residual standard error: 12.15507
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    75.111  75.1111 0.5083806 0.4807061
Residuals 34  5023.358 147.7458

       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                        treatment:none
          lay2native                                 lay2native
    Mean:  24.481481                           Mean:  27.370370
 SE Mean:   2.509998                        SE Mean:   3.180584
LCL Mean:  19.185849                       LCL Mean:  20.659925
UCL Mean:  29.777114                       UCL Mean:  34.080816
--------------------
```

Results Summary

The average percentage of native species in the second canopy for irrigated and non-irrigated pastures is 24% and 27%, respectively. There is no evidence to suggest a difference in percentage of native species between irrigated and non irrigated pastures in the second canopy (p = 0.48).

c. %Non-native analysis in top canopy layer

Regression to test if %non-natives in the top canopy changes with time since irrigation

```
Call: lm(formula = nonnative ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q Median    3Q   Max
 -35.44 -14.55 0.3556 12.73 40.42
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  37.4755   4.4484     8.4246   0.0000
       time  -0.7614   1.3311    -0.5720   0.5711
Residual standard error: 19.34 on 34 degrees of freedom
Multiple R-Squared: 0.009531
F-statistic: 0.3272 on 1 and 34 df, the p-value is 0.5711
```

Results Summary

There is no evidence to suggest a linear relationship between the percentage of non-native species and time since irrigation ceased (p = 0.57).

ANOVA to test if % non-natives in the top canopy is different between treatments

```
Call: aov(formula = nonnative ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares    441.14  12401.22
Deg. of Freedom         1        34
Residual standard error: 19.09821
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1    441.14 441.1400 1.209459 0.2791654
Residuals 34  12401.22 364.7416

treatment:irrigated           treatment:none
          nonnative                     nonnative
    Mean: 39.222778               Mean: 32.221667
 SE Mean:  4.227681            SE Mean:  4.759576
LCL Mean: 30.303151           LCL Mean: 22.179839
UCL Mean: 48.142404           UCL Mean: 42.263495
--------------------
```

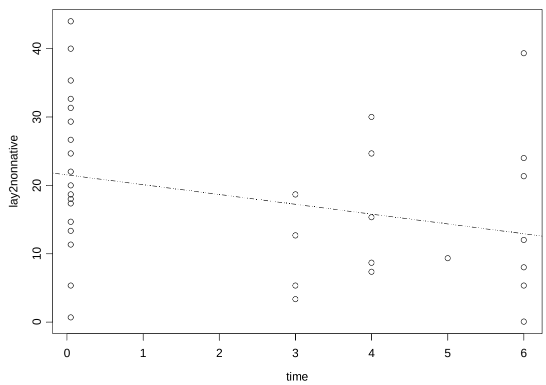
Results Summary

The average percentage of non-native species in irrigated and non-irrigated pastures is 39% and 32%, respectively. There is no evidence to suggest a difference between the percentage of non-native species for irrigated and non irrigated pastures (p = 0.28).

d. Does non-native species percentage in the second layer change with treatment and time since irrigation?

Regression

```
       *** Linear Model ***
Call: lm(formula = lay2nonnative ~ time, data = layer2and3pct)
Residuals:
   Min     1Q Median    3Q   Max
 -20.8 -7.714 -2.128 8.539 26.42
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  21.5337   2.6102     8.2497   0.0000
       time  -1.4374   0.7811    -1.8403   0.0745
Residual standard error: 11.35 on 34 degrees of freedom
Multiple R-Squared: 0.09059
F-statistic: 3.387 on 1 and 34 df, the p-value is 0.07446
```



Results Summary

There is some evidence to suggest a negative linear relationship between percentage of non-native species in the second canopy layer and time since irrigation ceased (p = 0.07).

ANOVA

```
Call: aov(formula = lay2nonnative ~ treatment, data=layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares   664.064  4151.894
Deg. of Freedom         1        34
Residual standard error: 11.05054
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   664.064 664.0643 5.438045 0.02576264
Residuals 34  4151.894 122.1145
       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                        treatment:none
          lay2nonnative                              lay2nonnative
    Mean:     22.518519                        Mean:     13.928704
 SE Mean:      2.737382                     SE Mean:      2.464755
LCL Mean:     16.743147                    LCL Mean:      8.728525
UCL Mean:     28.293891                    UCL Mean:     19.128882
-----------------------
```

Results Summary

The average percentage of non-native species in the second canopy for irrigated and non-irrigated pastures is 22% and 14%, respectively. There is moderate evidence to suggest a difference in percentage of non-native species between irrigated and non irrigated pastures in the second canopy (p = 0.02).

e. Does non-native species percentage in the third layer change with treatment and time since irrigation?

Regression

```
       *** Linear Model ***
Call: lm(formula = lay3nonnative ~ time, data = layer2and3pct)
Residuals:
    Min     1Q  Median    3Q   Max
 -3.018 -1.735 -0.9784 1.644 4.932
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  3.0749  0.5546     5.5442  0.0000
       time -0.1421  0.1660    -0.8563  0.3978
```

```
Residual standard error: 2.412 on 34 degrees of freedom
Multiple R-Squared: 0.02111
F-statistic: 0.7332 on 1 and 34 df, the p-value is 0.3978
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of non-native species in the third canopy layer and time since irrigation ceased (p = 0.40).

ANOVA

```
Call: aov(formula = lay3nonnative ~ treatment, data=layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares    5.0500  196.9484
Deg. of Freedom         1        34
Residual standard error: 2.406782
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    5.0500 5.050008 0.8718032 0.3570406
Residuals 34  196.9484 5.792600

       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated
          lay3nonnative
    Mean:     3.1222222
 SE Mean:     0.6183088
LCL Mean:     1.8177047
UCL Mean:     4.4267397
-----------------------
treatment:none
          lay3nonnative
    Mean:     2.3731481
 SE Mean:     0.5111913
LCL Mean:     1.2946288
UCL Mean:     3.4516675
```

Results Summary

The average percentage of non-native species in the third canopy for irrigated and non-irrigated pastures is 3% and 2%, respectively. There is no evidence to suggest a difference in percentage of non-native species between irrigated and non irrigated pastures in the second canopy (p = 0.36).

Functional Group Analysis

9. How do species functional groups (grass, grasslike and forb) change with treatment and time since irrigation

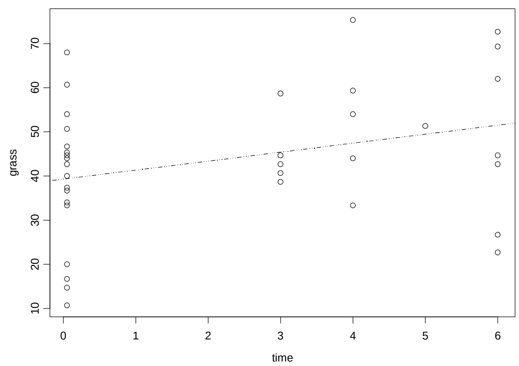
a. %Grass Analysis in the top canopy layer

Regression to test if %grass in the top canopy layer changes with time since irrigation

```
Call: lm(formula = grass ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q   Median    3Q  Max
 -28.83 -6.757 -0.06505 10.69 28.6
Coefficients:
               Value Std. Error t value Pr(>|t|)
(Intercept) 39.2973  3.5374    11.1091  0.0000
       time  2.0346  1.0585     1.9221  0.0630
Residual standard error: 15.38 on 34 degrees of freedom
Multiple R-Squared: 0.09801
F-statistic: 3.694 on 1 and 34 df, the p-value is 0.06301

       ***  Summary Statistics for data in:  Fxn.grp.analysis ***

time:0.05
              grass
    Mean: 38.890000
 SE Mean:  3.687822
LCL Mean: 31.109376
UCL Mean: 46.670624
--------------------
time:3
```

```
            grass
    Mean: 45.070000
 SE Mean:  3.544009
LCL Mean: 35.230253
UCL Mean: 54.909747
--------------------
time:4
           grass
    Mean: 53.19800
 SE Mean:  7.09722
LCL Mean: 33.49296
UCL Mean: 72.90304
-------------------
```

```
time:5
        grass
    Mean: 51.33
 SE Mean:    NA
LCL Mean:    NA
UCL Mean:    NA
----------------
time:6
            grass
    Mean: 48.668571
 SE Mean:  7.547507
LCL Mean: 30.200486
UCL Mean: 67.136657
```



Results Summary

There is some evidence to suggest a positive linear relationship between the percentage of grass in the top canopy and time since irrigation ceased (p = 0.06).

ANOVA to test if %grass in the top canopy layer is different between treatments

```
Call: aov(formula = grass ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares   933.608  7984.181
Deg. of Freedom         1        34
Residual standard error: 15.32413
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   933.608 933.6080 3.975695 0.05423189
Residuals 34  7984.181 234.8289
       ***  Summary Statistics for data in:  Fxn.grp.analysis ***

treatment:irrigated
            grass
    Mean: 38.890000
 SE Mean:  3.687822
LCL Mean: 31.109376
UCL Mean: 46.670624
--------------------
```

```
treatment:none
            grass
    Mean: 49.075000
 SE Mean:  3.534412
LCL Mean: 41.618043
UCL Mean: 56.531957
```

Results Summary

Average grass percentage in the top canopy for irrigated and non-irrigated pastures is 39% and 49%, respectively. There is some evidence to suggest a difference between the percentage of grass for irrigated and non irrigated pastures (p = 0.05).

b. Does grass percentage in the second layer change with treatment and time since irrigation?

Regression

```
        *** Linear Model ***
Call: lm(formula = lay2grass ~ time, data = layer2and3pct)
Residuals:
    Min     1Q   Median    3Q   Max
 -17.21 -7.481 -0.08731 7.813 21.85
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  21.5061   2.4550     8.7600   0.0000
       time  -0.4932   0.7346    -0.6714   0.5065
Residual standard error: 10.67 on 34 degrees of freedom
Multiple R-Squared: 0.01308
F-statistic: 0.4507 on 1 and 34 df, the p-value is 0.5065
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of grass in the second canopy and time since irrigation ceased (p = 0.51).

ANOVA

```
Call: aov(formula = lay2grass ~ treatment, data = layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares     2.420  3923.309
Deg. of Freedom         1        34
Residual standard error: 10.74204
Estimated effects are balanced
          Df Sum of Sq  Mean Sq    F Value     Pr(F)
treatment  1     2.420   2.4198 0.02096995 0.8857159
Residuals 34  3923.309 115.3914
        ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                          treatment:none
          lay2grass                                    lay2grass
    Mean: 20.629630                              Mean: 20.111111
 SE Mean:  2.543148                           SE Mean:  2.520648
LCL Mean: 15.264056                          LCL Mean: 14.793008
UCL Mean: 25.995203                          UCL Mean: 25.429214
-------------------
```

Results Summary

The average percentage of grass in the second canopy for irrigated and non-irrigated pastures is 21% and 20%, respectively. There is no evidence to suggest a difference in percentage of grass between irrigated and non irrigated pastures in the second canopy (p = 0.88).

c. Does grass percentage in the third canopy layer change with treatment and time since irrigation?

Regression

```
        *** Linear Model ***
Call: lm(formula = lay3grass ~ time, data = layer2and3pct)
Residuals:
    Min     1Q  Median    3Q   Max
 -3.253 -2.632 -0.3003 1.534 6.034
Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 3.2990 0.6331     5.2111  0.0000
       time 0.0006 0.1894     0.0032  0.9974
Residual standard error: 2.753 on 34 degrees of freedom
```

```
Multiple R-Squared: 3.105e-007
F-statistic: 0.00001056 on 1 and 34 degrees of freedom, the p-value is
       0.9974
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of grass in the third canopy and time since irrigation ceased (p = 0.997).

ANOVA

```
Call: aov(formula = lay3grass ~ treatment, data = layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares    1.7556  255.8796
Deg. of Freedom         1        34
Residual standard error: 2.743332
Estimated effects are balanced

          Df Sum of Sq  Mean Sq   F Value    Pr(F)
treatment  1    1.7556 1.755625 0.2332786 0.632199
Residuals 34  255.8796 7.525872
       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                        treatment:none
          lay3grass                                  lay3grass
    Mean: 3.0796296                            Mean: 3.5212963
 SE Mean: 0.6432764                         SE Mean: 0.6499257
LCL Mean: 1.7224350                        LCL Mean: 2.1500729
UCL Mean: 4.4368243                        UCL Mean: 4.8925197
-------------------
```

Results Summary

The average percentage of grass in the third canopy for irrigated and non-irrigated pastures is 3%. There is no evidence to suggest a difference in percentage of grass between irrigated and non irrigated pastures in the second canopy (p = 0.63).

d. %Grass-like Analysis in the top canopy layer

Regression to test if %grass-like in the top canopy layer changes with time since irrigation

```
Call: lm(formula = grasslike ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q  Median    3Q   Max
 -28.71 -11.22 -0.7328 6.776 38.62
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  46.7998   4.1474    11.2840   0.0000
       time  -1.8430   1.2411    -1.4850   0.1468
Residual standard error: 18.03 on 34 degrees of freedom
Multiple R-Squared: 0.06091
F-statistic: 2.205 on 1 and 34 df, the p-value is 0.1468
```

Results Summary

There is little evidence to suggest a linear relationship between the percentage of grasslikes in the top canopy and the time since irrigation ceased (p = 0.15)

ANOVA to test if %grass-like in the top canopy layer is different between treatments

```
Call: aov(formula = grasslike ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares   1110.78  10663.64
Deg. of Freedom         1        34
Residual standard error: 17.70979
Estimated effects are balanced
```

```
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   1110.78 1110.778 3.541608 0.06843052
Residuals 34  10663.64  313.637

       ***  Summary Statistics for data in:  Fxn.grp.analysis ***
treatment:irrigated           treatment:none
          grasslike                     grasslike
    Mean:  48.11056               Mean: 37.001111
 SE Mean:   4.64019            SE Mean:  3.649266
LCL Mean:  38.32061           LCL Mean: 29.301834
UCL Mean:  57.90050           UCL Mean: 44.700388
--------------------
```

Results Summary

Average percentage of grasslikes in the top canopy for irrigated and non-irrigated pastures is 48% and 37%, respectively. There is some evidence to suggest a difference between the percentage of grass for irrigated and non irrigated pastures (p = 0.07).

e. **Does the percentage of grass-likes in the second layer change with treatment and time since irrigation?**

Regression

```
       *** Linear Model ***
Call: lm(formula = lay2grasslike ~ time, data = layer2and3pct)
Residuals:
    Min    1Q Median    3Q   Max
 -11.96 -6.63 -1.297 2.984 23.37
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  15.9706   2.0207     7.9035   0.0000
       time  -0.1400   0.6047    -0.2316   0.8183
Residual standard error: 8.786 on 34 degrees of freedom
Multiple R-Squared: 0.001575
F-statistic: 0.05362 on 1 and 34 df, the p-value is 0.8183
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of grass-likes in the second canopy and time since irrigation ceased (p = 0.81).

ANOVA

```
Call: aov(formula = lay2grasslike ~ treatment, data=layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares    37.346  2591.531
Deg. of Freedom         1        34
Residual standard error: 8.730492
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    37.346 37.34568 0.4899626 0.4887061
Residuals 34  2591.531 76.22150

       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                       treatment:none
          lay2grasslike                             lay2grasslike
    Mean:     16.666667                      Mean:     14.629630
 SE Mean:      2.268793                   SE Mean:      1.822535
LCL Mean:     11.879932                  LCL Mean:     10.784417
UCL Mean:     21.453402                  UCL Mean:     18.474842
-----------------------
```

Results Summary

The average percentage of grass-likes in the second canopy for irrigated and non-irrigated pastures is 17% and 15%, respectively. There is no evidence to suggest a difference in percentage of grass-likes between irrigated and non irrigated pastures in the second canopy (p = 0.49).

f. Does grasslike percentage in the third layer change with treatment and time since irrigation?

Regression

```
          *** Linear Model ***
Call: lm(formula = lay3grasslike ~ time, data = layer2and3pct)
Residuals:
    Min    1Q  Median     3Q   Max
 -2.519 -1.77 -0.1534 0.9926 4.764
Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 1.8138 0.4547     3.9889  0.0003
       time 0.1259 0.1361     0.9253  0.3614
Residual standard error: 1.977 on 34 degrees of freedom
Multiple R-Squared: 0.02456
F-statistic: 0.8561 on 1 and 34 df, the p-value is 0.3614
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of grass-likes in the third canopy layer and time since irrigation ceased (p = 0.36).

ANOVA

```
Call: aov(formula = lay3grasslike ~ treatment, data=layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares    1.4534  134.8017
Deg. of Freedom         1        34
Residual standard error: 1.991169
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    1.4534 1.453364 0.3665709 0.5488998
Residuals 34  134.8017 3.964756

       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                        treatment:none
          lay3grasslike                              lay3grasslike
    Mean:     1.9027778                        Mean:     2.3046296
 SE Mean:     0.3780378                     SE Mean:     0.5455418
LCL Mean:     1.1051877                    LCL Mean:     1.1536371
UCL Mean:     2.7003678                    UCL Mean:     3.4556222
-----------------------
```

Results Summary

The average percentage of grass-likes in the third canopy for irrigated and non-irrigated pastures is 2%. There is no evidence to suggest a difference in percentage of grass-likes between irrigated and non irrigated pastures in the second canopy (p = 0.55).

g. %Forbs Analysis in the top canopy layer

Regression to test if %forbs in the top canopy layer changes with time since irrigation

```
Call: lm(formula = forb ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q Median    3Q   Max
 -7.629 -4.064 -1.294 3.583 14.67
Coefficients:
```

```
              Value Std. Error t value Pr(>|t|)
(Intercept)  7.6413  1.2827     5.9573  0.0000
       time -0.2463  0.3838    -0.6417  0.5254
Residual standard error: 5.577 on 34 degrees of freedom
Multiple R-Squared: 0.01197
F-statistic: 0.4118 on 1 and 34 df, the p-value is 0.5254
```

Results Summary

There is no evidence to suggest a linear relationship between the percentage of forbs in the top canopy and the time since irrigation ceased (p = 0.52).

ANOVA to test if %forbs in the top canopy layer is different between treatments

```
Call: aov(formula = forb ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares     0.198  1070.211
Deg. of Freedom         1        34
Residual standard error: 5.610418
Estimated effects are balanced
          Df Sum of Sq  Mean Sq     F Value     Pr(F)
treatment  1     0.198  0.19803 0.006291143 0.9372457
Residuals 34  1070.211 31.47679
treatment:irrigated          treatment:none
              forb                        forb
    Mean: 7.148333               Mean:  7.000000
 SE Mean: 1.076368            SE Mean:  1.529331
LCL Mean: 4.877395           LCL Mean:  3.773394
UCL Mean: 9.419271           UCL Mean: 10.226606
--------------------
```

Results Summary

The average percentage of forbs in the top canopy for irrigated and non-irrigated pastures is 7% for both treatments. There is no evidence to suggest a difference between the percentage of forbs in the top canopy for irrigated and non-irrigated pastures (p = 0.94).

h. Does forb percentage in the second canopy layer change with treatment and time since irrigation?

Regression

```
       *** Linear Model ***

Call: lm(formula = lay2pctforbs ~ time, data = april18stats)
Residuals:
    Min    1Q Median    3Q   Max
 -9.391 -4.64 -1.628 4.559 16.18

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  9.4606  1.3943     6.7852  0.0000
       time -0.3843  0.4172    -0.9211  0.3635

Residual standard error: 6.063 on 34 degrees of freedom
Multiple R-Squared: 0.02435
F-statistic: 0.8485 on 1 and 34 df, the p-value is 0.3635
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of forbs in the second canopy and time since irrigation ceased (p = 0.36).

ANOVA

```
Call: aov(formula = lay2pctforbs ~ treatment, data = april18stats)
```

```
Terms:
                treatment Residuals
 Sum of Squares    22.912  1257.947
Deg. of Freedom         1        34
Residual standard error: 6.082635
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1    22.912 22.91218 0.619274 0.4367685
Residuals 34  1257.947 36.99845

       ***  Summary Statistics for data in:  april18stats ***

treatment:irrigated                        treatment:none
          lay2pctforbs                               lay2pctforbs
    Mean:     9.373333                         Mean:     7.777778
 SE Mean:     1.289464                      SE Mean:     1.564679
LCL Mean:     6.652802                     LCL Mean:     4.476593
UCL Mean:    12.093865                     UCL Mean:    11.078963
```

Results Summary

The average percentage of forbs in the second canopy for irrigated and non-irrigated pastures is 9% and 8%, respectively. There is no evidence to suggest a difference in percentage of forbs between irrigated and non irrigated pastures in the second canopy (p = 0.44).

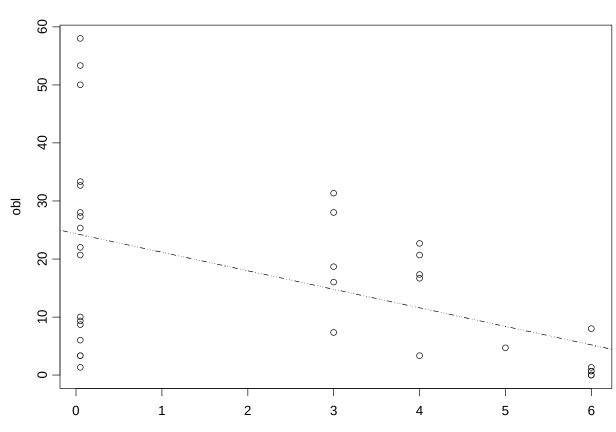
Wetland Status Rating

10. Does wetland status rating (OBL, FACW, FAC) change between treatments and time since irrigation?

a. %Obligate Wetland Spp Analysis in the top canopy layer

Regression to test if %OBL in the top canopy layer changes with time since irrigation

```
Call: lm(formula = obl ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q Median    3Q  Max
 -22.87 -5.752 -2.196 6.432 33.8
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  24.3560   3.1208     7.8044   0.0000
       time  -3.1945   0.9339    -3.4208   0.0016
Residual standard error: 13.57 on 34 degrees of freedom
Multiple R-Squared: 0.256
F-statistic: 11.7 on 1 and 34 df, the p-value is 0.001641
```



Results Summary

There is convincing evidence to suggest a negative linear relationship between the percentage of obligate wetland species in the top canopy and the time since irrigation ceased (p = 0.002).

ANOVA to test if %OBL in the top canopy layer is different between treatments

```
Call: aov(formula = obl ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares  1311.768  7103.657
Deg. of Freedom         1        34
Residual standard error: 14.45445
Estimated effects are balanced
          Df Sum of Sq  Mean Sq F Value      Pr(F)
treatment  1  1311.768 1311.768 6.27847 0.01717285
Residuals 34  7103.657  208.931

       ***  Summary Statistics for data in:  Fxn.grp.analysis ***

treatment:irr obl                            treatment:none obl
    Mean: 23.036111                              Mean: 10.963333
 SE Mean:  4.131947                           SE Mean:  2.478221
LCL Mean: 14.318464                          LCL Mean:  5.734745
UCL Mean: 31.753758                          UCL Mean: 16.19192
--------------------
```

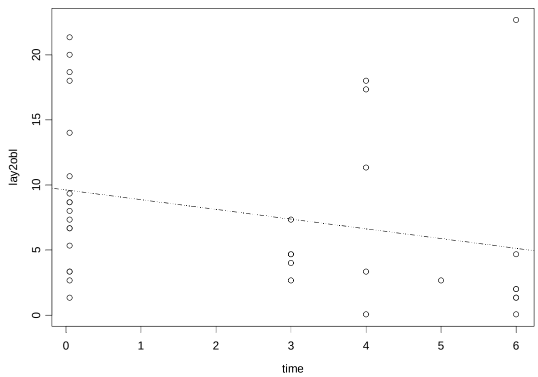
Results Summary

The average percentage of obligate wetland species for irrigated and non-irrigated pastures is 23% and 11%, respectively. There is moderate evidence to suggest a difference between the percentage of obligate wetland species in the top canopy for irrigated and non-irrigated pastures (p = 0.02).

b. Does the percentage obligate wetland species in the second layer change with treatment and time since irrigation?

Regression

```
       *** Linear Model ***
Call: lm(formula = lay2obl ~ time, data = layer2and3pct)
Residuals:
    Min     1Q Median    3Q   Max
 -8.241 -3.797 -2.704 1.926 17.54
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  9.6114  1.4862     6.4673  0.0000
       time -0.7468  0.4447    -1.6793  0.1023
Residual standard error: 6.462 on 34 degrees of freedom
Multiple R-Squared: 0.07659
F-statistic: 2.82 on 1 and 34 degrees of freedom, the p-value is 0.1023
```



Results Summary

There is inconclusive evidence to suggest a linear relationship between percentage of obligate wetland plants in the second canopy layer and time since irrigation ceased (p = 0.10).

ANOVA

```
Call: aov(formula = lay2obl ~ treatment, data = layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares   113.422  1424.116
Deg. of Freedom         1        34
Residual standard error: 6.47192
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1   113.422 113.4225 2.707902 0.1090672
Residuals 34  1424.116  41.8858
       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                     treatment:none
            lay2obl                                lay2obl
   Mean:  9.666667                         Mean: 6.116667
SE Mean:  1.467389                      SE Mean: 1.581373
LCL Mean:  6.570746                     LCL Mean: 2.780261
UCL Mean: 12.762588                     UCL Mean: 9.453072
-------------------
```

Results Summary

The average percentage of obligate wetland species in the second canopy for irrigated and non-irrigated pastures is 10% and 6%, respectively. There is inconclusive evidence to suggest a difference in percentage of obligate species between irrigated and non irrigated pastures in the second canopy (p = 0.11).

c. %Facultative Wet spp Analysis in the top canopy layer

Regression to test if %FACW in the top canopy layer changes with time since irrigation

```
Call: lm(formula = facw ~ time, data = Fxn.grp.analysis)
Residuals:
    Min    1Q Median    3Q   Max
 -26.62 -11.9  1.097 13.43 38.71
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) 30.5166  3.6012     8.4739  0.0000
       time  0.6845  1.0776     0.6352  0.5296
Residual standard error: 15.66 on 34 degrees of freedom
```

```
Multiple R-Squared: 0.01173
F-statistic: 0.4035 on 1 and 34 df, the p-value is 0.5296
```

Results Summary

There is no evidence to suggest a linear relationship between the percentage of facultative wetland species in the top canopy and the time since irrigation ceased (p = 0.53).

ANOVA to test if %FACW in the top canopy layer is different between treatments

```
Call: aov(formula = facw ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares     0.306  8435.238
Deg. of Freedom         1        34
Residual standard error: 15.75104
Estimated effects are balanced
          Df Sum of Sq  Mean Sq     F Value     Pr(F)
treatment  1     0.306   0.3062 0.001234114 0.9721816
Residuals 34  8435.238 248.0952

treatment:irrigated           treatment:none
               facw                             facw
    Mean: 32.185000              Mean: 32.00056
 SE Mean:  2.972005           SE Mean:  4.32820
LCL Mean: 25.914617          LCL Mean: 22.86885
UCL Mean: 38.455383          UCL Mean: 41.13226
--------------------
```

Results Summary

The average facultative wetland species percentage for irrigated and non-irrigated pastures is 32%. There is no evidence to suggest a difference between the percentage of facultative wetland species in the top canopy for irrigated and non-irrigated pastures (p = 0.97).

d. Does facultative wetland species percentage in the second layer change with treatment and time since irrigation?

Regression

```
      *** Linear Model ***
Call: lm(formula = lay2facw ~ time, data = layer2and3pct)
Residuals:
    Min     1Q  Median    3Q   Max
 -12.18 -5.645 -0.8565 3.751 16.48
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) 13.3504  1.7501     7.6284  0.0000
       time  0.2499  0.5237     0.4773  0.6362

Residual standard error: 7.61 on 34 degrees of freedom
Multiple R-Squared: 0.006655
F-statistic: 0.2278 on 1 and 34 df, the p-value is 0.6362
```

Results Summary

There is no evidence to suggest a linear relationship between percentage of facultative wet species in the second canopy layer and time since irrigation ceased (p = 0.64).

ANOVA

```
Call: aov(formula = lay2facw ~ treatment, data = layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares     0.049  1981.975
Deg. of Freedom         1        34
Residual standard error: 7.635011
```

```
Estimated effects are balanced
          Df Sum of Sq  Mean Sq      F Value     Pr(F)
treatment  1     0.049  0.04938 0.0008471409 0.9769505
Residuals 34  1981.975 58.29339

       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                        treatment:none
          lay2facw                                    lay2facw
    Mean: 13.96296                              Mean: 13.888889
 SE Mean:  1.63874                           SE Mean:  1.947197
LCL Mean: 10.50552                          LCL Mean:  9.780662
UCL Mean: 17.42040                          UCL Mean: 17.997115
-------------------
```

Results Summary

The average percentage of facultative wet species in the second canopy for irrigated and non-irrigated pastures is 14%. There is no evidence to suggest a difference in percentage of facultative wet species between irrigated and non irrigated pastures in the second canopy (p = 0.98).

e. %Facultative spp Analysis in the top canopy layer

Regression to test if %FAC in the top canopy layer changes with time since irrigation

```
Call: lm(formula = fac ~ time, data = Fxn.grp.analysis)
Residuals:
    Min     1Q Median    3Q   Max
 -34.92 -14.27  3.202 12.76 34.95
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  36.9629   4.2765     8.6432   0.0000
       time  -0.7641   1.2797    -0.5971   0.5544
Residual standard error: 18.59 on 34 degrees of freedom
Multiple R-Squared: 0.01038
F-statistic: 0.3565 on 1 and 34 df, the p-value is 0.5544
```

Results Summary

There is no evidence to suggest a linear relationship between the percentage of facultative species in the top canopy and the time since irrigation ceased (p = 0.55).

ANOVA to test if %FAC in the top canopy layer is different between treatments

```
Call: aov(formula = fac ~ treatment, data = Fxn.grp.analysis)
Terms:
                treatment Residuals
 Sum of Squares    328.09  11551.45
Deg. of Freedom         1        34
Residual standard error: 18.43227
Estimated effects are balanced
          Df Sum of Sq  Mean Sq   F Value     Pr(F)
treatment  1    328.09 328.0928 0.9656928 0.3326983
Residuals 34  11551.45 339.7487

treatment:irrigated                        treatment:none
               fac                                         fac
    Mean: 38.22222                              Mean: 32.184444
 SE Mean:  4.16764                           SE Mean:  4.514491
LCL Mean: 29.42927                          LCL Mean: 22.659701
UCL Mean: 47.01517                          UCL Mean: 41.709188
-------------------
```

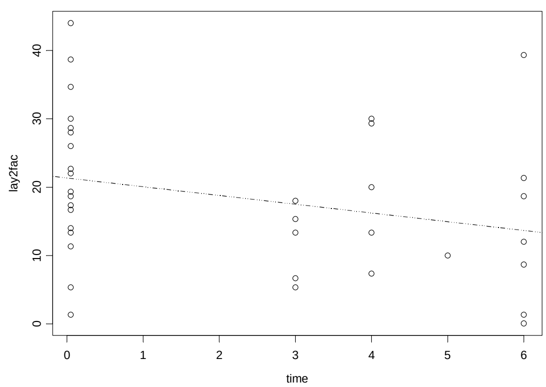
Results Summary

The average percentage of facultative species for irrigated and non-irrigated pastures is 38% and 32%, respectively. There is no evidence to suggest a difference between the percentage of facultative species in the top canopy for irrigated and non-irrigated pastures (p = 0.33).

f. Does the percentage of facultative species in the second layer change with treatment and time since irrigation?

Regression

```
        *** Linear Model ***
Call: lm(formula = lay2fac ~ time, data = layer2and3pct)
Residuals:
    Min     1Q Median    3Q   Max
 -19.94 -7.445 -2.054 6.889 25.68
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  21.3421   2.4934     8.5594   0.0000
       time  -1.2818   0.7461    -1.7180   0.0949
Residual standard error: 10.84 on 34 degrees of freedom
Multiple R-Squared: 0.07988
F-statistic: 2.952 on 1 and 34 df, the p-value is 0.09489
```



Results Summary

There is some evidence to suggest a negative linear relationship between percentage of facultative species in the third canopy layer and time since irrigation ceased (p = 0.09).

ANOVA

```
Call: aov(formula = lay2fac ~ treatment, data = layer2and3pct)
Terms:
                treatment Residuals
 Sum of Squares   413.106  3930.280
Deg. of Freedom         1        34
Residual standard error: 10.75158
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   413.106 413.1056 3.573687 0.06725015
Residuals 34  3930.280 115.5965
       ***  Summary Statistics for data in:  layer2and3pct ***

treatment:irrigated                         treatment:none
            lay2fac                                    lay2fac
    Mean: 21.777778                            Mean: 15.002778
 SE Mean:  2.624946                         SE Mean:  2.440023
LCL Mean: 16.239626                        LCL Mean:  9.854780
UCL Mean: 27.315930                        UCL Mean: 20.150776
-------------------
```

Results Summary

The average percentage of facultative species in the second canopy for irrigated and non-irrigated pastures is 22% and 15%, respectively. There is some evidence to suggest a difference in percentage of facultative species between irrigated and non irrigated pastures in the second canopy (p = 0.07).

Gap

11. Is gap size related to species diversity and is the increase in species diversity related to an increase in gap size?

a. Regression to test if species diversity in all canopy layers changes with time since irrigation

```
Call: lm(formula = sppdiv ~ years, data = gap.spp.diversity)
Residuals:
    Min     1Q  Median    3Q  Max
 -4.185 -1.185 -0.1726 1.852 9.84
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  9.1101  0.4198    21.6993  0.0000
      years  0.0125  0.1256     0.0994  0.9211
Residual standard error: 2.582 on 70 degrees of freedom
Multiple R-Squared: 0.0001411
F-statistic: 0.009876 on 1 and 70 df, the p-value is 0.9211
```

Results Summary

There is no evidence to suggest a linear relationship between species diversity in all canopy and the time since irrigation ceased (p = 0.92).

b. ANOVA to test if species diversity in all canopy layers is different between treatments

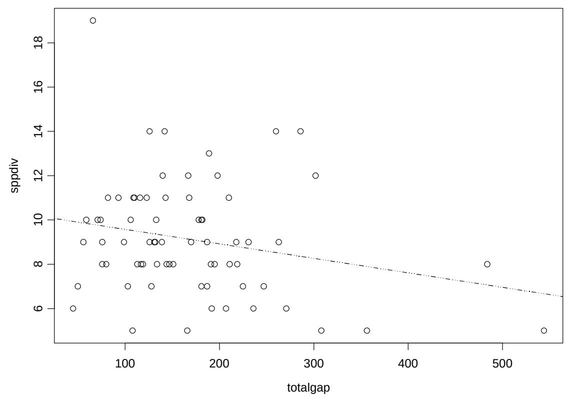
```
Call: aov(formula = sppdiv ~ treatment, data = gap.spp.diversity)
Terms:
                treatment Residuals
 Sum of Squares   20.0556  446.5556
Deg. of Freedom         1        70
Residual standard error: 2.525741
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   20.0556 20.05556 3.143817 0.08056543
Residuals 70  446.5556  6.37937
       ***  Summary Statistics for data in:  gap.spp.diversity ***
90% CL
treatment:irrigated           treatment:none
             sppdiv                        sppdiv
    Mean: 8.6111111              Mean:  9.666667
 SE Mean: 0.3218936           SE Mean:  0.500793
LCL Mean: 8.0672485          LCL Mean:  8.820541
UCL Mean: 9.1549738          UCL Mean: 10.512793
-------------------
```

Results Summary

The average species diversity for irrigated and non-irrigated pastures is 8.6 and 9.7 species, respectively. There is some evidence to suggest a difference between species diversity in all canopy layers for irrigated and non-irrigated pastures (p = 0.08).

c. Regression to test if species diversity is related to gap size

```
Call: lm(formula = sppdiv ~ totalgap, data = gap.spp.diversity)
Residuals:
    Min     1Q  Median    3Q   Max
 -4.519 -1.677 -0.3658 1.409 9.206
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  10.2258   0.6274    16.2983   0.0000
   totalgap  -0.0065   0.0033    -1.9652   0.0534
Residual standard error: 2.513 on 70 degrees of freedom
Multiple R-Squared: 0.05229
F-statistic: 3.862 on 1 and 70 df, the p-value is 0.05336
```

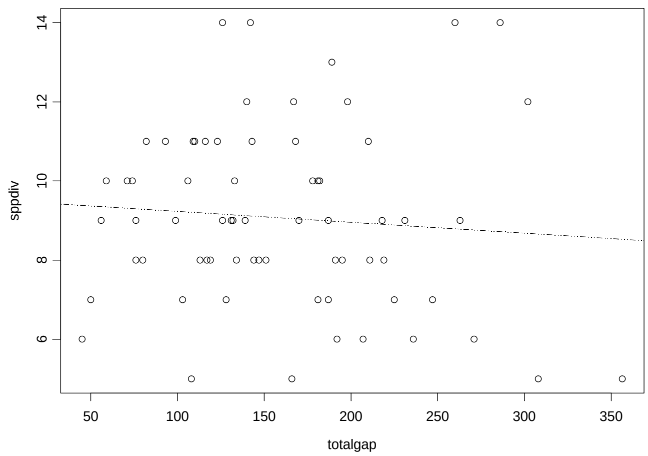


Results Summary

There is moderate evidence to suggest a negative linear relationship between species diversity in all canopy layers and the total gap length (p = 0.05).

d. Species diversity related to total gap length. Regression taking out the outlier lines 2N-5-1, 2N-5-2 and 6N-12-1

```
Call: lm(formula = sppdiv ~ totalgap, data = removed.outliers.gap.spp.div)
Residuals:
    Min     1Q  Median   3Q   Max
 -4.209 -1.286 -0.1455 1.75 5.281
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   9.5056   0.6998    13.5840   0.0000
   totalgap  -0.0027   0.0041    -0.6730   0.5033
Residual standard error: 2.28 on 67 degrees of freedom
Multiple R-Squared: 0.006714
F-statistic: 0.4529 on 1 and 67 df, the p-value is 0.5033
```



Results Summary

There is no evidence to suggest a linear relationship between species diversity in all canopy layers and the total gap length after removing outliers ($p = 0.50$).

Appendix B: 2008 Statistical Summary

1. **Bulk Density**

ANOVA for the exclosures

Formula: bulk density = treatment + error

```
                    treatment  Residuals
 Sum of Squares 0.01584092 0.05802308
Deg. of Freedom          1         23
Residual standard error: 0.05022691
Estimated effects may be unbalanced
          Df  Sum of Sq    Mean Sq  F Value    Pr(F)
treatment  1 0.01584092 0.01584092 6.279247 0.019738
Residuals 23 0.05802308 0.00252274
Tables of means
 treatment
    irrigated nonirrigated
     0.905        0.855
rep 12.000       13.000
```

ANOVA for the bulk density at the meadow plots

Formula: bulk density = treatment + error

```
                treatment Residuals
 Sum of Squares  0.017113  1.521975
Deg. of Freedom        1        70
Residual standard error: 0.1474534
Estimated effects are balanced
          Df Sum of Sq   Mean Sq  F Value     Pr(F)
treatment  1  0.017113 0.0171125 0.787053 0.3780307
Residuals 70  1.521975 0.0217425
Tables of means
 treatment
 irrigated nonirrigated
 0.78417   0.81500
Standard errors for differences of means
        treatment
         0.034755
replic. 36.000000
```

2. **Soil Moisture**

ANOVA for May 2008 soil moisture

Formula: soil moisture = treatment + error

```
                treatment Residuals
 Sum of Squares 0.0220459 0.9449354
Deg. of Freedom        1        70
Residual standard error: 0.1161855
Estimated effects are balanced

          Df Sum of Sq    Mean Sq F Value     Pr(F)
treatment  1 0.0220459 0.02204589 1.63314 0.2054909
Residuals 70 0.9449354 0.01349908
Tables of means
Grand mean
 0.36506
 treatment
 irrigated    none
 0.34756   0.38256
Standard errors for differences of means
        treatment
         0.027385
```

```
replic. 36.000000
```

ANOVA for June 2008 soil moisture
Formula: soil moisture = treatment + error

```
                 treatment Residuals
 Sum of Squares 0.0081188 0.9398600
Deg. of Freedom         1        70
Residual standard error: 0.1158731
Estimated effects are balanced
          Df Sum of Sq    Mean Sq   F Value     Pr(F)
treatment  1 0.0081188 0.00811878 0.6046803 0.4394181
Residuals 70 0.9398600 0.01342657
Tables of means
Grand mean
 0.31916
 treatment
 irrigated    none
 0.32978   0.30854
Standard errors for differences of means
        treatment
         0.027312
replic. 36.000000
```

ANOVA for July 2008 soil moisture
Formula: soil moisture = treatment + error

```
                 treatment Residuals
 Sum of Squares  0.234558  1.281582
Deg. of Freedom         1        70
Residual standard error: 0.1353082
Estimated effects are balanced
          Df Sum of Sq   Mean Sq  F Value        Pr(F)
treatment  1  0.234558 0.2345576 12.81153 0.0006309103
Residuals 70  1.281582 0.0183083
Tables of means
Grand mean
 0.30254
 treatment
 irrigated    none
 0.35962   0.24547
Standard errors for differences of means
        treatment
         0.031892
replic. 36.000000
```

ANOVA for August 2008 soil moisture
Formula: soil moisture = treatment + error

```
                 treatment Residuals
 Sum of Squares  0.629641  1.654272
Deg. of Freedom         1        70
Residual standard error: 0.1537285
Estimated effects are balanced
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
treatment  1  0.629641 0.6296410 26.64306 2.190026e-006
Residuals 70  1.654272 0.0236325
Tables of means
Grand mean

 0.27107
 treatment
 irrigated    none
 0.36458   0.17755
```

```
Standard errors for differences of means
        treatment
         0.036234
replic. 36.000000
```

ANOVA for September 2008 soil moisture

Formula: soil moisture = treatment + error

```
            treatment Residuals
 Sum of Squares 0.5727356 0.9004483
Deg. of Freedom         1        70
Residual standard error: 0.1134176
Estimated effects are balanced
          Df Sum of Sq   Mean Sq  F Value         Pr(F)
treatment  1 0.5727356 0.5727356 44.52392 4.909396e-009
Residuals 70 0.9004483 0.0128635
Tables of means
Grand mean

 0.27739
 treatment
 irrigated    none
 0.36658   0.18820
Standard errors for differences of means
        treatment
         0.026733
replic. 36.000000
```

3. Production

ANOVA for dry weight May 2008

Formula: May dry weight (g) = treatment + error

```
                treatment Residuals
 Sum of Squares  1351.502  1070.700
Deg. of Freedom         1        10
Residual standard error: 10.34747
Estimated effects are balanced
          Df Sum of Sq  Mean Sq F Value       Pr(F)
treatment  1  1351.502 1351.502 12.6226 0.005243478
Residuals 10  1070.700  107.070
Tables of means
treatment
 irrigated   none
 69.717    48.492
Standard errors for differences of means
        treatment
           5.9741
replic.    6.0000
```

ANOVA for dry weight June 2008

Formula: June dry weight (g) = treatment + error

```
                treatment Residuals
 Sum of Squares     0.152  3307.940
Deg. of Freedom         1        10
Residual standard error: 18.18774
Estimated effects are balanced
          Df Sum of Sq  Mean Sq      F Value     Pr(F)
treatment  1     0.152   0.1519 0.0004591225 0.9833264
Residuals 10  3307.940 330.7940
Tables of means
treatment
 irrigated   none
```

```
 85.608   85.383
Standard errors for differences of means
        treatment
           10.501
replic.     6.000
```

ANOVA for dry weight July 2008

Formula: July dry weight (g) = treatment + error

```
                treatment Residuals
 Sum of Squares   1498.57  10792.26
Deg. of Freedom         1        10
Residual standard error: 32.85158
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1   1498.57 1498.567 1.388557 0.2659285
Residuals 10  10792.26 1079.226
Tables of means
 treatment
 irrigated   none
 119.09     96.74
Standard errors for differences of means
        treatment
           18.967
replic.     6.000
```

ANOVA for dry weight August 2008

Formula: May dry weight (g) = treatment + error

```
                treatment Residuals
 Sum of Squares   2948.47  24975.68
Deg. of Freedom         1        10

Residual standard error: 49.97567
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1   2948.47 2948.468 1.180536 0.3027428
Residuals 10  24975.68 2497.568

Tables of means
 treatment
 irrigated   none
 122.78     91.42
Standard errors for differences of means
        treatment
           28.853
replic.     6.000
```

ANOVA for dry weight September 2008

Formula: September dry weight (g) = treatment + error

```
                treatment Residuals
 Sum of Squares   4414.09  12619.20
Deg. of Freedom         1        10
Residual standard error: 35.52351
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
treatment  1   4414.09 4414.085 3.497913 0.09096746
Residuals 10  12619.20 1261.920
Tables of means
 treatment
 irrigated   none
 119.81     81.45
Standard errors for differences of means
```

```
         treatment
             20.51
replic.      6.00
```

ANOVA for dry weight October 2008

Formula: October dry weight (g) = treatment + error

```
                 treatment Residuals
 Sum of Squares    56.117  6641.750
Deg. of Freedom         1        10
Residual standard error: 25.77159
Estimated effects are balanced
          Df Sum of Sq  Mean Sq    F Value     Pr(F)
treatment  1    56.117  56.1169 0.08449109 0.7772401
Residuals 10  6641.750 664.1750
Tables of means
 treatment
 irrigated   none
 89.842    85.517
Standard errors for differences of means
        treatment
           14.879
replic.     6.000
```

4. **Gap**

ANOVA for the average gap size in 2008

Formula: average gap size = treatment + error

```
                 treatment Residuals
 Sum of Squares   2.01696  60.77488
Deg. of Freedom         1        70
Residual standard error: 0.9317792
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1   2.01696 2.016958 2.323115 0.1319699
Residuals 70  60.77488 0.868213
Tables of means
 treatment
 irrigated   none
 4.7163    5.0511
Standard errors for differences of means
        treatment
          0.21962
replic.  36.00000
```

ANOVA for the average number of gaps in 2008

Formula: average number of gaps = treatment + error

```
                 treatment Residuals
 Sum of Squares    813.39  32052.11
Deg. of Freedom         1        70
Residual standard error: 21.3983
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value     Pr(F)
treatment  1    813.39 813.3889 1.776395 0.1869146
Residuals 70  32052.11 457.8873
Tables of means
 treatment
 irrigated   none
 38.556    45.278
Standard errors for differences of means
        treatment
           5.0436
replic.   36.0000
```

ANOVA for the total length of the line (cm) in gaps in 2008

Formula: total length of gaps = treatment + error

```
                treatment Residuals
 Sum of Squares     29606   1191616
Deg. of Freedom         1        70
Residual standard error: 130.4726
Estimated effects are balanced
          Df Sum of Sq  Mean Sq  F Value    Pr(F)
treatment  1     29606 29605.56 1.739141 0.191546
Residuals 70   1191616 17023.09
Tables of means
 treatment
 irrigated   none
 193.39    233.94
Standard errors for differences of means
        treatment
           30.753
replic.    36.000
```

ANOVA for the percent of the line in gaps in 2008

Formula: percent of line in gaps = treatment + error

```
                treatment Residuals
 Sum of Squares  0.046259  1.861901
Deg. of Freedom         1        70
Residual standard error: 0.1630907
Estimated effects are balanced
          Df Sum of Sq    Mean Sq  F Value    Pr(F)
treatment  1  0.046259 0.04625868 1.739141 0.191546
Residuals 70  1.861901 0.02659858
Tables of means
 treatment
 irrigated    none
 0.24174   0.29243
Standard errors for differences of means
        treatment
         0.038441
replic. 36.000000
```

Linear regression of the total centimeters of the line in gaps and time since irrigation ceased

Formula: length of gaps = time since irrigated + error

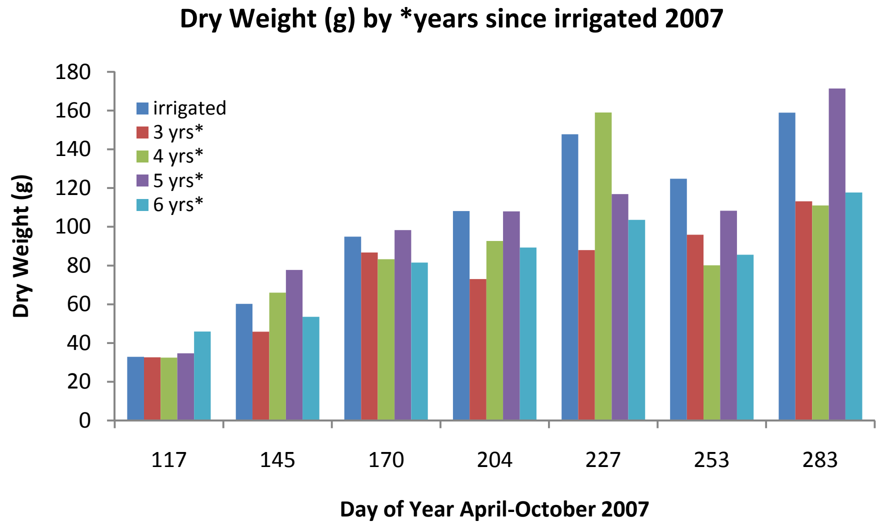
```
   Residuals:
    Min     1Q Median    3Q Max
 -187.6 -105.4 -22.13 80.46 325
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) 193.6877  21.4251     9.0402   0.0000
       time   6.9897   5.2218     1.3386   0.1850

Residual standard error: 130.4 on 70 degrees of freedom
Multiple R-Squared: 0.02496
F-statistic: 1.792 on 1 and 70 degrees of freedom, the p-value is 0.185
```

Appendix C: Species List

Scientific Name	Common Name
Achillea millefolium	common yarrow
Agrostis stolonifera	creeping bentgrass
Alopecurus pratensis	meadow foxtail
Arnica longifolia	spearleaf arnica
Bromus inermis ssp. *inermis*	smooth brome
Carex athrostachya	slenderbeak sedge
Carex nebrascensis	Nebraska sedge
Carex praegracilis	clustered field sedge
Carex utriculata	beaked sedge
Cirsium vulgare	bull thistle
Collomia linearis	tiny trumpet
Danthonia unispicata	onespike danthonia
Deschampsia caespitosa	tufted hairgrass
Eleocharis palustris	common spikerush
Elymus repens	quackgrass
Epilobium	willowherb
Equisetum	horsetail
Fragaria virginiana	Virginia strawberry
Galium	bedstraw
Hordeum brachyantherum	meadow barley
Hypericum formosum	St. Johnswort
Juncus	rush
Juncus balticus	baltic rush
Juncus nevadensis	Sierra rush
Juncus orthophyllus	straightleaf rush
Luzula campestris var. *macrantha*	Pacific woodrush
Medicago lupulina	black medick
Microsteris gracilis	slender phlox
Muhlenbergia asperifolia	scratchgrass
Muhlenbergia filiformis	pullup muhly
Muhlenbergia richardsonis	mat muhly
Penstemon	beardtongue
Phleum pratense	timothy
Poa pratensis	Kentucky bluegrass
Polygonum	knotweed
Potentilla anserina	silver cinquefoil

Scientific Name	**Common Name**
Potentilla gracilis	slender cinquefoil
Potentilla millefolia var. *klamathensis*	Klamath cinquefoil
Ranunculus	buttercup
Ranunculus alismifolius	plantainleaf buttercup
Ranunculus occidentalis	western buttercup
Rumex	dock
Rumex acetosa	garden sorrel
Rumex crispus	curly dock
Sisyrinchium idahoense	Idaho blue-eyed grass
Stellaria longipes	longstalk starwort
Symphyotrichum	aster
Taraxacum officinale	common dandelion
Trifolium	clover
Trifolium longipes	longstalk clover
Trifolium repens	white clover
Veronica	speedwell
Viola adunca	hookedspur violet

Appendix D
Additional graphs



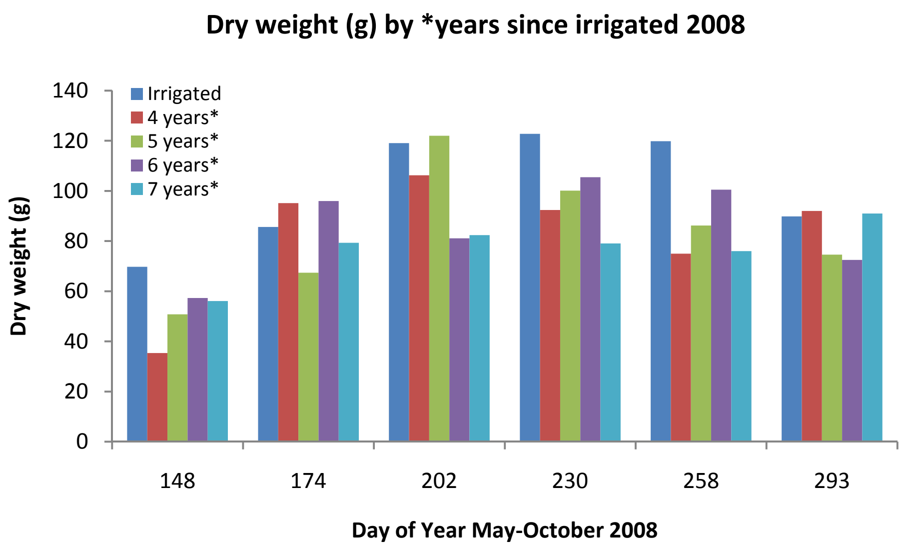
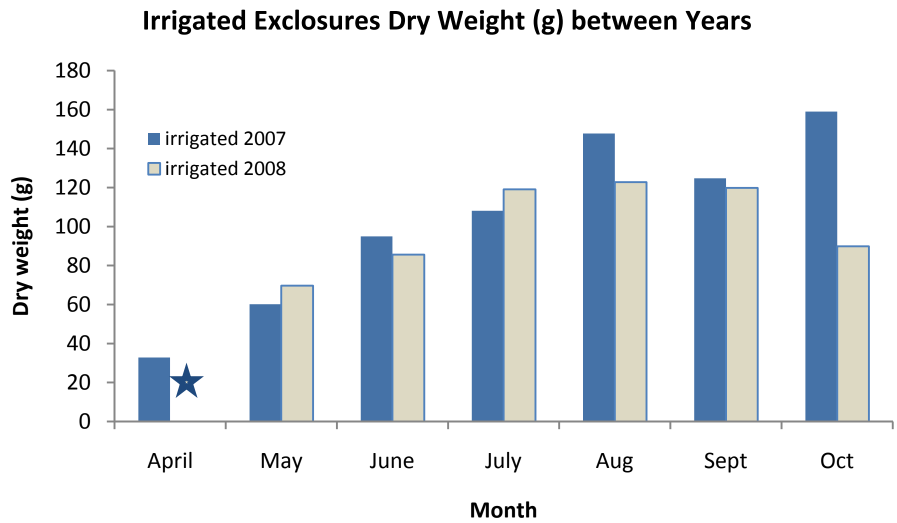


Figure 15. Dry weight (g) between irrigated pastures and non-irrigated pastures, separated by years since irrigated in 2007 and 2008.



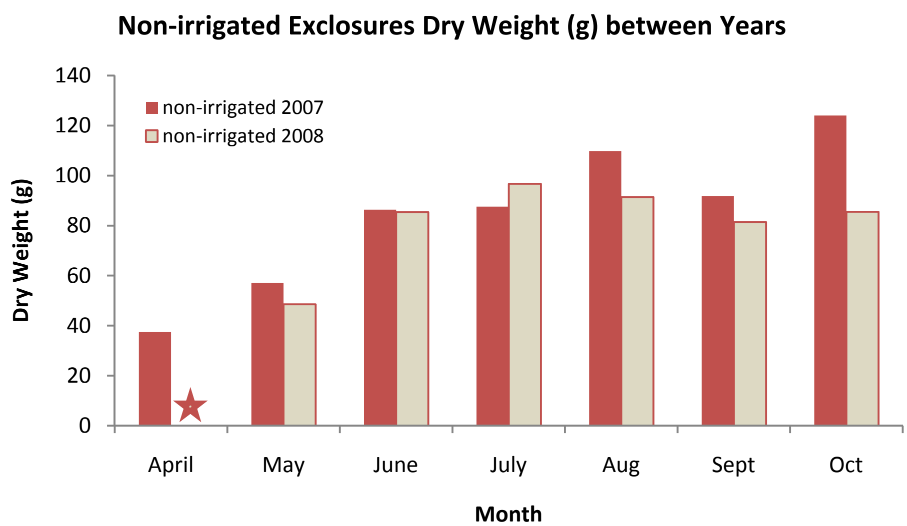


Figure 16. Dry weight (g) year comparison between irrigated exclosures and non-irrigated exclosures.
★no data for April 2008.

Appendix 3

Final Wood River Conservation Effects Assessment Project Report

Introduction to Appendix 3

Appendix 3 contains the final report by the Oregon State University (OSU) team that conducted the Sevenmile and Crooked Creek riparian monitoring. The report details the community typing, greenline, and other monitoring methods used by the OSU riparian monitoring team.



Sevenmile and Crooked Creek Monitoring Summary 2008



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Rangeland Ecology and Management
Oregon State University
December 2008

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Introduction

Permanent vegetation and stream monitoring locations were established to record baseline conditions along Sevenmile Creek and Crooked Creek. Monitoring locations intentionally located within areas that have recently experienced management changes including riparian fencing for grazing control and irrigation water manipulation. Conditions previous to the management changes are unknown, but this study provides detailed vegetation and stream channel data that can be used in future monitoring efforts as a comparison of past condition. A total of six benchmarked monitoring locations were established on Sevenmile Creek and one on Crooked Creek.

Background

Recently, extensive private and institutional efforts have been directed towards innovative approaches to simultaneously improving riparian communities and channel conditions for the benefit of landowners and the aquatic ecosystems in the Wood River Valley (south-central Oregon). Many of these efforts center upon changing management of the riparian corridor along the mainstem of the Wood River and the tributaries of Crooked Creek and Sevenmile Creek. In low-gradient systems like the Wood River, roots of riparian vegetation maintain the integrity of banks and bank-building process, and thus regulate the shape (width, depth, cross-sectional and plan-form morphology) of the river channel. Channel shape, water temperature, and nutrients regulate the conditions for fish and other important aquatic resources. Integrity of the river channel also can affect floodplain groundwater levels, which in turn effect plant community composition and production and channel base flows.

A number of different projects have been initiated on the Wood River system over the last 4 to 5 years including reduction in irrigation withdrawals, riparian corridor and riparian pasture fencing along with changes in grazing practices. In order to understand the impact of management changes on the functionality of the channels and associated riparian systems adequate monitoring using proven scientific methods was installed in 2008.

Objectives

1. Develop a riparian community type classification for the Wood River stream system located in the upper Klamath Basin of southern Oregon.
2. Describe the general physiographic, edaphic, and floristic features of each community type.
3. Describe the fluvial landform and stream channel type associated with the community type.
4. Establish permanent channel cross-section monitoring sites on 7-mile Creek and Crooked Creek.
5. Utilize the community type information for the establishment of a network of vegetation and cross section monitoring.

Location

Sevenmile Creek is located on the western side of the Wood River Valley and flows from a forested system into a low gradient meadow valley (Rosgen valley type X, Rosgen 2007). The riparian area associated with the upstream section, nearest the forest boundary, is composed of deciduous riparian trees and shrubs with scattered conifers. The majority of the riparian area within the valley is composed of graminoids with a patchy shrub component. Sevenmile Creek exhibits a snowmelt influenced hydrograph with peak flows occurring in early spring.

Crooked Creek is located on the east side of the Wood River Valley and flows from a forested system into a lower gradient meadow valley. Crooked Creek originates from a large spring located along the toe slope of the eastside of the Wood River Valley; therefore the hydrograph lacks variability and indicates little snowmelt influence. The composition of the vegetation at Crooked Creek differs from Sevenmile Creek in the amount of obligates and facultative wet classified plants. The difference in vegetation composition between the two channels may be a function of their different hydrographs along with management history.

Community Type Development

Plant communities are an assemblage of plants living and interacting in the same location. Plant communities have no specific successional status (Crow and Clausnitzer 1997). A plant community type is a set of plant communities that have similar species structure and composition. A plant community type represents repeated occurrences of similar plant communities, but do not form a plant association or the plant community is not a climax community type (Crowe and Clausnitzer 1997). Many of the plant communities on Sevenmile Creek would not be considered climax communities because of human disturbances, including grazing, channelization, removal of tree canopy, and irrigation withdrawal. Riparian classifications have been performed in Oregon; however these classifications are based on relatively undisturbed plant communities and the plant communities generally include the adjacent floodplain and not just the greenline plant community. There was a need to identify the plant communities currently on Sevenmile Creek, specifically on the greenline.

Methods

Sites were determined through utilization of the geomorphic information provided by the Klamath Tribes and through field reconnaissance in summer 2007. Late seral and transitional riparian communities were identified and GPS located. Cross-sectional sketches showing the location of fluvial surfaces and both wetland/transitional riparian and adjacent upland plant associations were created. Each fluvial surface with it corresponding plant association represented a vegetation plot. There were a total of 20 vegetation plots sampled (fig. 1).

Vegetation Sampling

1. Each community type chosen for sampling was at least twice as large as the plot in order to avoid sampling ecotones.
2. A minimum sample size of 18 frames per site (35 feet) within homogenous plant community was chosen to insure sampling veracity. Plots were sampled using Daubenmire frames (30 cm by 60 cm).
3. Canopy cover of dominant plants was recorded. Ocular estimates of canopy cover for each of the indicator species within a plot were made to the nearest percent up to 10 % and to the nearest 5% thereafter.
4. Soil was described by morphological features including: current depth of the water table; depth to which 90% of the vascular plant roots reach; depth to and description of redoximorphic features; depth of the surface organic horizon (if present); thickness of the epipedon (surface horizon); depth to the buried stream bed; and parent material.
5. Soil horizon description included: thickness; moist color, percentage and coloring of redoximorphic concentrations and depletions; texture; current moisture status (dry, moist, wet or saturated); percentage and size class of coarse fragments, if present; and amount and diameter classes of roots.
6. Rosgen stream type was visually determined from the geomorphic information provided and recorded for each plot location.
7. Valley landform descriptors (valley shape, gradient, width, side slope gradient and aspect) were recorded at each plot.

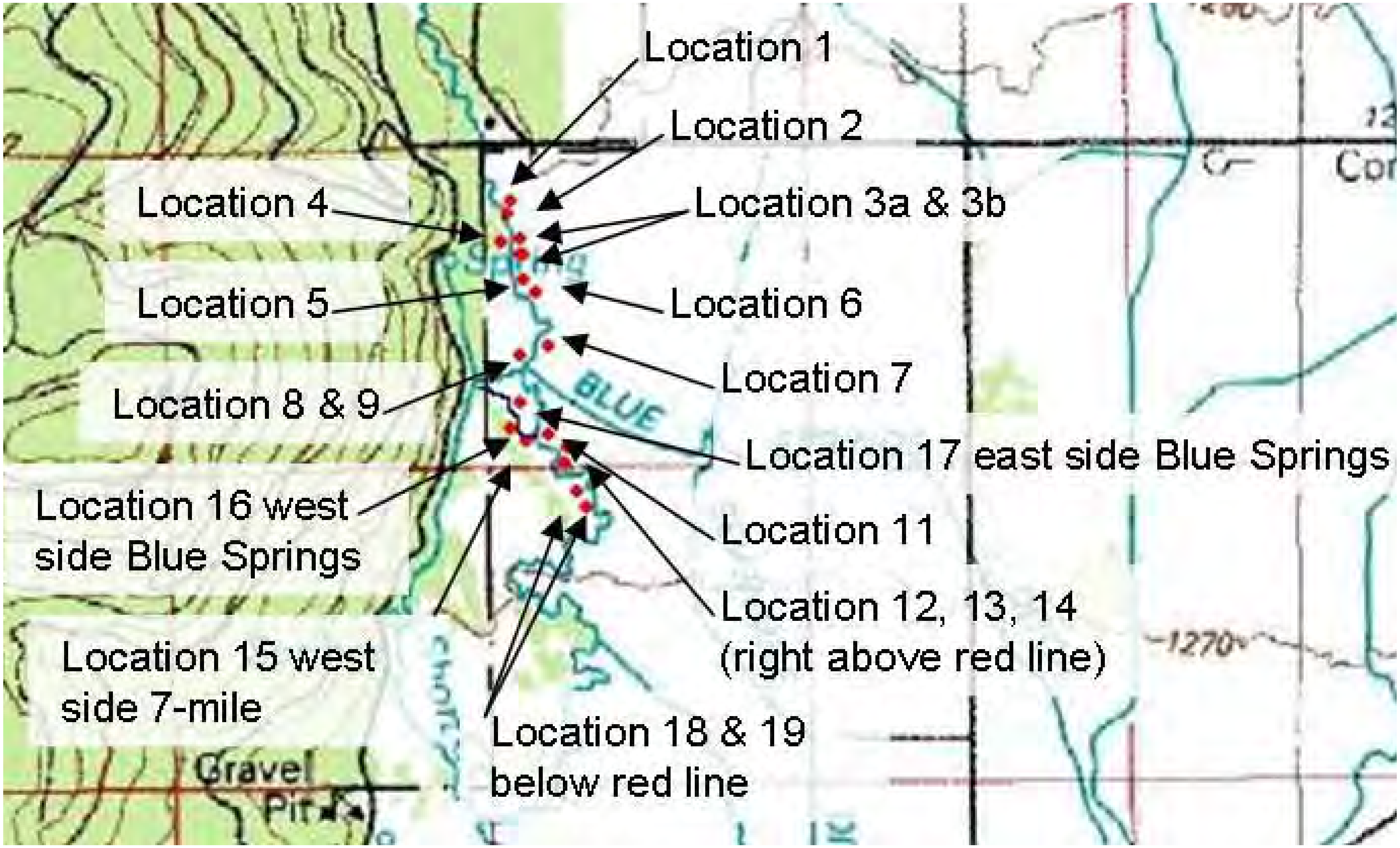

Figure 1. Map of study site locations at Sevenmile Creek. Site locations are indicated in red.

Data Analysis and Summarization

Ordination and classification of data was performed using PCORD (McCune and Grace 2002) to develop concepts of classification group membership, species ecological amplitudes and soil attributes encountered within a series or lifeform group (e.g. herbaceous plots). Appropriate multivariate statistics were applied to groups to determine associations between floristic attributes and stream channel morphology, environmental and soil variables. The results of the multivariate procedures were used to build the final association groups. See Appendix 2 for a detailed description of ordination methods.

Results

Three groups were apparent from the ordination graph based on species structure within each site (fig. 2)

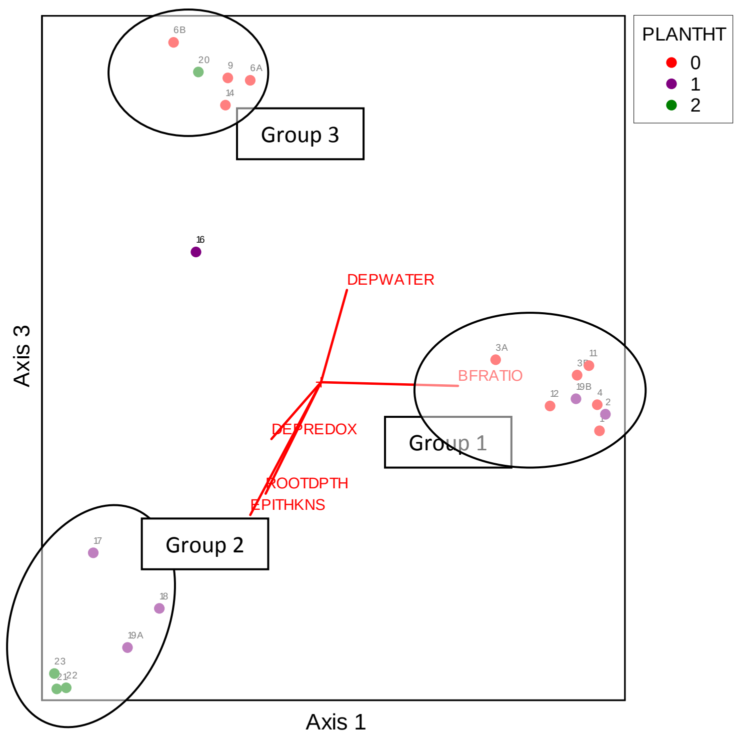

Figure 2. Ordination of 20 sites in plant species space, with joint plot of environmental characteristics. Color of the symbols indicates the height of the plant vegetation at each site (0 = 0.5 m or less, 1 = 0.5 to 1 m, and 2 = 1.1 m or taller). Sites are labeled by alpha-numeric code. Radiating lines indicate the relative strength and direction of correlation of environmental variables with the ordination.

The three groups are separated by differences in the dominant plant species (table 1 and 2). Group 1 is dominated by panicled bulrush (*Scirpus microcarpus*) including a wide varying mix of species. Group 2 is dominated by water sedge (*Carex aquatilis* var. *dives*) with beaked sedge (*Carex utriculata*) as a sub-dominant species. Group 3 is dominated by Nebraska sedge (*Carex nebrascensis*). Group 4, or plot 16, is separated on the graph, therefore does not have a group as one plot cannot represent a group.

Table 1. Plant species data summarization for the groups. Species data are percent cover.

Group 1	SCMI2	ELAC	SALE	POBAT	CACA11	VEAM2	CANE2	GLST	MYLA	JUEN	CAUT	CAPR5	ELPA3	AGST2	VIOLA	JUAR4	HIMO2	EQAR	CAAQ	EP2SPP	PHAR3	SPDO	JUBA	GALIUM	MIMUL
mean	44.12	9.07	6.63	3.16	2.93	2.45	1.50	1.31	1.09	0.77	0.47	0.35	0.32	0.28	0.28	0.28	0.19	0.17	0.16	0.14	0.12	0.12	0.10	0.05	0.04
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
max	100.00	85.00	50.00	45.00	50.00	30.00	25.00	20.00	15.00	20.00	20.00	15.00	10.00	10.00	15.00	15.00	10.00	10.00	15.00	5.00	15.00	10.00	15.00	5.00	5.00

Group 2	CAAQ	CAUT	VIOLA	SCMI2	PHAR3	VEAM2	CANE2	GLST	MYLA	SPDO	SALE	MIMUL	CASI2	GALIUM	JUBA	JUEN	CACA11	HIMO2	EP2SPP
mean	69.91	6.45	1.44	1.03	0.73	0.66	0.63	0.34	0.32	0.25	0.23	0.22	0.13	0.13	0.11	0.06	0.04	0.03	0.01
min	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
max	100.00	45.00	30.00	15.00	50.00	20.00	15.00	15.00	15.00	20.00	10.00	5.00	20.00	10.00	5.00	10.00	5.00	5.00	1.00

Group 3	CANE2	SCMI2	MYLA	VEAM2	PHAR3	JUEN	GLST	CASI2	CAPR5	JUBA	SALE	JUAR4	EQAR	EP2SPP	GALIUM
mean	64.16	3.18	0.91	0.89	0.29	0.28	0.26	0.24	0.19	0.18	0.16	0.10	0.08	0.06	0.01
min	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
max	95.00	35.00	10.00	20.00	15.00	10.00	5.00	10.00	10.00	10.00	10.00	10.00	1.00	5.00	1.00

Group 4	CAUT	CANE2	CASI2	SCMI2	JUBA	SALE	JUAR4	MYLA	VIOLA
mean	35.83	9.10	4.00	2.83	1.27	0.33	0.03	0.03	0.03
min	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
max	60.00	30.00	35.00	15.00	10.00	5.00	1.00	1.00	1.00

Table 2. Environmental data summarization for the groups.

GROUP	SITE	DEPTH TO FREE WATER	PRESENCE OF REDOX	DEPTH TO REDOX (cm)	DEPTH OF ROOTING (cm)	BANK HEIGHT RATIO	THICKNESS OF EPIPEDON (cm)	PERCENT SILT (%)	PLANT HEIGHT (m)	STREAM BANK POSITION	BANKFULL RATIO
NMS Group 1	1	25.00	yes	2.00	75.00	1.04	5.00	65.00	0.50	floodplain	12.06
	2	26.00	yes	2.00	75.00	1.24	2.00	25.00	1.00	floodplain	14.00
	3A	34.00	yes	6.00	34.00	1.00	6.00	25.00	0.50	floodplain	14.83
	3B	22.00	yes	4.00	32.00	1.00	4.00	25.00	0.50	floodplain	14.42
	4	28.00	yes	5.00	33.00	1.00	5.00	25.00	0.50	floodplain	14.60
	11	1.00	no	0.00	38.00	1.23	24.00	20.00	0.50	floodplain	22.07
	12	75.00	yes	3.00	38.00	1.08	28.00	20.00	0.50	terrace	7.89
	19B	11.00	yes	6.00	35.00	0.99	6.00	20.00	1.00	floodplain	8.12
	Average	27.75		3.50	45.00	1.07	10.00	28.13	0.63		13.50
	Range	1-75 cm		0-6 cm	32-75 cm	0.99-1.24	2-28 cm	20-65%	0.5-1 m		7.89-22.07
NMS Group 2	17	4.00	no	0.00	40.00	1.35	16.00	25.00	1.00	streambank	10.00
	18	1.00	no	0.00	75.00	0.99	22.00	20.00	1.00	floodplain	6.34
	19A	11.00	yes	6.00	35.00	0.99	6.00	20.00	1.00	floodplain	8.12
	21	1.00	no	0.00	125.00	1.00	75.00	65.00	2.00	floodplain	8.00
	22	8.00	yes	80.00	140.00	1.00	50.00	40.00	2.00	floodplain	8.00
	23	8.00	yes	80.00	140.00	1.00	50.00	40.00	2.00	floodplain	8.00
	Average	5.50		27.67	92.50	1.06	36.50	35.00	1.50		8.08
	Range	1-8 cm		0-80 cm	35-140 cm	0.99-1.35	6-75 cm	20-65%	1-2 m		6.34-10
NMS Group 3	6A	60.00	yes	5.00	65.00	1.05	5.00	20.00	0.50	streambank	5.50
	6B	60.00	yes	5.00	65.00	1.05	5.00	20.00	0.50	streambank	5.50
	9	30.00	yes	4.00	34.00	1.04	4.00	25.00	0.50	floodplain	6.67
	14	20.00	yes	4.00	3.00	1.01	3.00	20.00	0.50	floodplain	7.13
	20	22.00	yes	8.00	35.00	1.00	8.00	25.00	2.00	floodplain	8.00
	Average	38.40		5.20	40.40	1.03	5.00	22.00	0.80		6.56
	Range	20-60 cm		4-8 cm	3-65 cm	1-1.05	3-8 cm	20-25%	0.5-2 m		5.5-8
NMS Group 4	16	2.00	no	0.00	30.00	1.31	14.00	65.00	1.00	floodplain	11.50

Group 1 represents a *Scirpus microcarpus* dominated community. This community generally occurred on sites that were directly influenced by moving water in the active channel and floodplains. The dominant plant was *Scirpus microcarpus*. *Eleocharis acicularis* (needle spikerush), *Salix* spp. (willows), *Populus* spp. (cottonwood and aspen), and forbs were also present in small amounts. This community will develop and change structure as time progresses. Crowe and others (2004) can be used to identify this community.

Group 2 represents a *Carex aquatilis* var. *dives* dominated community. This community was common on low gradient floodplains on lower Sevenmile and Crooked Creek. The soils were generally deep and the water table remained high through the year (average depth of 5.5 cm). Sitka sedge was the dominant plant in this community, although in some plots, *Carex utriculata* was also present. Willows, Douglas spirea, and forbs were also present in small amounts in this greenline community. The plant communities adjacent to this community were a willow/Sitka sedge community.

Group 3 represents a *Carex nebrascensis* dominated community. This community occurred in areas that had been disturbed along Sevenmile Creek. The average water depth was 38 cm and was lower than the other sampled communities. Nebraska sedge was the dominant plant species within this community. The adjacent plant communities were composed of Baltic rush and Kentucky bluegrass.

All of the communities can be identified with Crowe and others (2004). The procedure created greenline community types. This is different from a community type key, which can aid in determining the community type present. Developing only greenline community types focused the sampling on channel stability and developing a community type document that was not based on reference plant communities but on what was present at the time of sampling. The greenline community types developed aided in monitoring site placement. These types were also identified quantifying greenline vegetation for monitoring.

Monitoring

Methods

The methods used for riparian monitoring in the Wood River valley can be found in, "Monitoring the vegetation resources in riparian areas" (Winward 2000). The only modification made for these sites were in the number of valley cross section. Winward (2000) suggests using five transects and only three were used because of the similarity in valley/floodplain vegetation along each stream.

The monitoring sites were selected based on the vegetation community type work performed the previous season. That initial reconnaissance and intensive sampling provided the necessary information to establish permanent monitoring sites. The sites were selected based on vegetation community composition and potential for change with management.

Greenline

Greenline was the method used to quantify riparian vegetation along the stream edge. Greenline has been defined as the first perennial vegetation that forms a patch or line (6 by 28 inches) that is at least 25% foliar cover of vegetation that is on or near the water's edge (Cowley et al. 2008; Winward 2000). Sampling the greenline can provide information about the ability of the channel to maintain bank stability and buffer the forces of water at high flow. Measurement of the greenline in a specific area over time can provide an indication of the long-term trend for the riparian area.

1. The starting point of each greenline was permanently marked with rebar and a cap on the right bank of the channel, looking downstream.
2. Community types or dominance/sub dominance of the vegetation along the greenline was recorded using a step transect approach (Winward 2000) with enough steps to total a minimum of 363 feet on each side of the channel.

Valley Cross Section

This method quantifies the percent of each community type/species dominance perpendicular to the stream valley (Winward 2000). Measurements taken in future monitoring efforts taken on the same site will provide information on the long-term changes and trend of the species within the site.

1. Three transect locations were chosen based on distance downstream from the beginning of the greenline (each transect is not permanently marked)
2. Each transect was paced instead of using a measuring tape
3. The first transect was located at the beginning of the greenline with the second transect 180 feet downstream from the first and the third transect another 180 feet downstream from the second transect.
4. Each transect is perpendicular to the valley and at 240/60 degrees from magnetic north.
5. Each transect was paced either to a fence line on the east side of the channel or to the conifer trees on the west side of the channel (fig. 3).

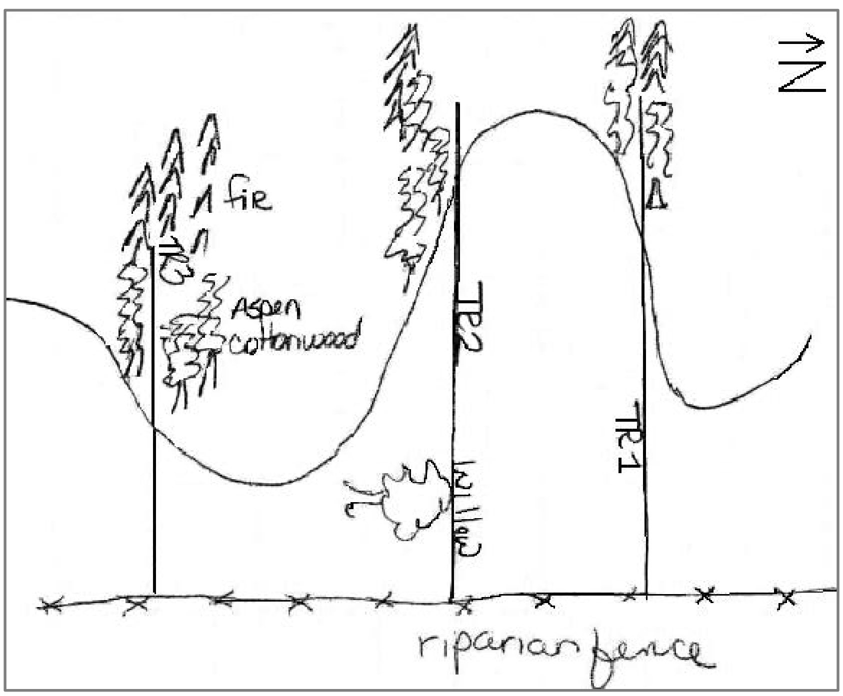

Figure 3. Example of a vegetation cross-section on Sevenmile Creek

Woody Species Regeneration

Woody species regeneration was measured using a 6-foot wide belt along the same transect used for the greenline.

1. The sampler walked along the greenline with the center of a six-foot long pole over the inside edge of the greenline
2. Woody species were recorded as they were encountered within the 6-foot belt transect along with the age class of the species (table 4).

Table 4. Age class of clumped, multiple-stemmed woody species (Winward 2000)

Number of stems at ground surface	Age Class
1	Sprout
2 to 10	Young
>10, >1/2 stems alive	Mature
>10, <1/2 stems alive	Decadent
0 stems alive	Dead

Stream Cross Section

A stream cross sectional survey includes:

1. Each monitoring site was benchmarked with cement and a metal pin placed in the cement. Distances and compass bearings were taken at the benchmark to the cross section and greenline so the site can be found in subsequent years.
2. The endpoints of the cross section were marked using rebar.
3. A measuring tape was then stretched in between the rebar going perpendicular to the channel flow. Elevations were then taken along the tape at any significant change in slope along the tape.
4. At least 20 measurements were taken along the take to accurately characterize a stream channel.
5. Each cross section was located in a straight reach between two channel meander bends.

Data Summarization and Analysis

Three different metrics are used to describe the functionality of the site, 1) successional status, 2) streambank stability, and 3) wetland rating. Detailed descriptions of successional status and streambank stability can be found in Winward (2000) and wetland rating in Burton et al. (2008). The following is a summarization of these metrics.

1. Successional status was weighted by the percent of plants by successional status along the greenline.
2. Streambank stability was based on the ability of a plant species to withstand the erosive forces of water. The data was summarized by weighted average for the greenline transect. Bank stability of over 7 was generally considered adequate to protect the streambank and allow them to function correctly.
3. Wetland rating was a weighted average based on the wetland indicator status. The wetland indicator status was the frequency an individual plant species occurs in saturated soil. This was used for descriptive purposes.

Results

The predominant species found on the greenline were *Scirpus microcarpus, Poa pratensis, Carex nebrascensis, Carex aquatilis* and *Carex utriculata* (Table 2). All the species but *Poa pratensis* are typically found only in riparian areas. They are rhizomatous and can form dense patches of vegetation along stream banks providing good bank stability. *Poa pratensis* is generally found in less saturated conditions than the other dominant riparian species. It is rhizomatous, but not as deep rooting therefore it does not provide the bank stability associated with these obligate wetland rhizomatous species. Generally, the dominant species at sites 1, 2, 5, and 6 are wetland plants that should continue to hold the banks together as long as water remains in the channel year round (Table 5 and 6). Sites 3 and 4 have plant species that are found in drier conditions that do not have the root/rhizome structure to hold the streambanks together as well as sedges and shrubs found at other sites. Reed canarygrass is present along much of Sevenmile Creek and the growth of the patches should be monitored.

Over time if the site continues to develop and progress towards more of a wetter riparian site, the sub-dominant species may begin to increase in cover. It will be critical to monitor the sites again in 3 to 5 years to assess the trend over time. Baseline monitoring only gives a point in time snapshot of the site and observing how it develops over the course of a few years will be important in establishing a positive or negative trend (table 7).

Table 5. Dominant greenline species at each site (any species/groups over 25% total cover)

Site	Dominant Species		
	Scientific Name	**Common Name**	**Total % Cover**
SM- 1	*Scirpus microcarpus*	Panicled bulrush	55.5
SM-2	*Scirpus microcarpus/Salix spp.*	Panicled bulrush/willows	98.1
SM-3	*Poa pratensis/Agrostis stolonifera*	Kentucky bluegrass/Redtop	35.4
	Scirpus microcarpus	Panicled bulrush	27.2
	Carex nebrascensis	Nebraska sedge	25.2
SM-4	*Poa pratensis/Agrostis stolonifera*	Kentucky bluegrass/Redtop	49.1
	Carex nebrascensis	Nebraska sedge	27.1
SM-5	*Carex nebrascensis*	Nebraska sedge	51.5
SM-6	*Carex aquatilis*	Water sedge	53.7
CC-1	*Carex utriculata*	Beaked sedge	55.3

Table 6. Dominant vegetation cross-section species (any species/groups over 10% cover)

Site	Dominant Species		
	Scientific Name	**Common name**	**Total % Cover**
SM-1	*Juncus balticus/Poa pratensis*	Baltic rush/Kentucky bluegrass	15.2
	Populus tremuloides/Poa spp.	Aspen/Bluegrass	12.7
	Carex nebrascensis/ Poa pratensis	Nebraska sedge/Kentucky bluegrass	10.5
SM-2	*Juncus balticus/Poa pratensis*	Baltic rush/Kentucky bluegrass	21.7
	Agrostis stolonifera/Poa pratensis	Redtop/Kentucky bluegrass	19.8
	Bare ground		10.1
SM-3	*Poa pratensis*	Kentucky bluegrass	35.5
	Poa pratensis/Juncus balticus	Kentucky bluegrass/Baltic rush	19.2
	Poa pratensis/Carex nebrascensis	Kentucky bluegrass/Nebraska sedge	12.3
SM-4	*Poa pratensis/Juncus balticus*	Kentucky bluegrass/Baltic rush	21.5
	Poa pratensis	Kentucy bluegrass	20.2
	Poa pratensis/Agrostis stolonifera	Kentucky bluegrass/Redtop	17.6
SM-5	*Poa pratensis*	Kentucy bluegrass	16.6
	Poa pratensis /Dry forb	Kentucy bluegrass/Dry forb	11.3
SM-6	*Poa pratensis/Trifolium* spp	Kentucy bluegrass/Clover	19.2
	Poa pratensis/Trifolium spp	Kentucy bluegrass/Clover	11.0
CC-1	*Poa pratensis/Juncus balticus*	Kentucky bluegrass/Baltic rush	26.3
	Carex nebrascensis/ Poa pratensis	Nebraska sedge/Kentucy bluegrass	18.6
	Poa pratensis/Carex spp.	Kentucky bluegrass/Sedge	12.7
	Carex utriculata	Beaked sedge	10.2

The sites with young willows and bulrush were given an early ecological status because the willows are still developing. With the many young willows at the site, the numbers of willows will drop as they mature and the ecological status will probably change as they mature. Site 2 may experience the most change over time because the vegetation is still developing although the sites that have the most potential for improvement are sites 3 and 4.

Table 7. Greenline monitoring metrics for all monitoring sites.

Site	Stability Rating	Ecological Status	Wetland Status
SM 1	High (7)	Late	Good
SM 2	High (7)	Very Early	Very good
SM 3	Moderate (6)	Mid	Good
SM 4	Low (4)	Mid	Good
SM 5	High (8)	PNC	Very good
SM 6	Excellent (9)	PNC	Very good
CC 1	High (7)	Late	Good

SM = Sevenmile Creek

CC = Crooked Creek

Woody Regeneration

Shrubs would naturally be present in patches along both Sevenmile Creek and Crooked Creek. Willows are fairly well developed in the floodplain of Crooked Creek and they are establishing in the greenline in some sites along Sevenmile Creek (table 9). The shrubs developing along Sevenmile Creek are mainly in the greenline because that is the area that has experienced the most change in recent years. The age class of the woody species should shift upwards as the plants mature and the number of woody plants in the youngest age classes may decrease at some sites as they mature.

Stream Cross Section

The cross sections show that in the downstream section of Sevenmile, on the Popson and Von Schlagell properties, that during high flows, it should have access to the floodplain (Appendix 1.d; table 8). This can also be seen in the vegetation composition on the greenline. The downstream portions of the stream have a higher composition of obligate wetland plants than do the upstream sections and the area directly influenced by the channel outside of the greenline also has the potential for a higher composition of obligate/facultative wet plants. Crooked Creek does not have the same flood capability as Sevenmile because it is a spring fed system that experiences limited snowmelt influence, however, the water remains near bankfull year round, allowing obligate wetland plants to establish along the greenline and floodplain on the left side of the stream.

Table 8. Stream geomorphology metrics for each monitoring site.

Site	Width/Depth	BHR	Max Depth @ BF (m)	Wetted Width (m)	Bankfull Width (m)
SM 1	7.21	1	0.845	4.63	6.09
SM2	12.25	1	0.555	5.14	6.80
SM 3	2.86	1.61	1.125	2.55	3.22
SM 4	3.97	1.3	0.71	2.44	2.82
SM 5	8.94	1	0.68	5.6	6.08
SM 6	4.89	1	1.085	4.55	5.31
CC	9.28	1	1.105	10.21	10.25

Table 9. Woody species regeneration for Sevenmile and Crooked Creek 2008.

SM-Site 1

	Seedling/Sprout		Young/Sapling		Mature		Decadent		Dead	
Species	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Spiraea douglasii	16	55	20	10		5				
Populus balsamifera ssp. trichocarpa	3	24		1						
Salix spp.	8	6	2	9						
Populus tremuloides		58		7						
Amelanchier alnifolia						1				
Symphoricarpos		1				5				
Salix lemmonii	7		7							
Salix lasiandra	3	28		3						
Total	37	172	29	30	0	11	0	0	0	0
Total (L&R)	209		59		11		0		0	

SM-Site 2

	Seedling/Sprout		Young/Sapling		Mature		Decadent		Dead	
Species	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Populus balsamifera ssp. trichocarpa	314	107								
Populus tremuloides	2	1		7						
Alnus incana		1								
Spiraea douglasii	14	22	24	22		4				
Salix lasiandra	878	657	17	9						
Salix lemmonii	82	33								
Total	1290	821	41	38	0	4	0	0	0	0
Total (L&R)	2111		79		4		0		0	

SM-Site 3

	Seedling/Sprout		Young/Sapling		Mature		Decadent		Dead	
Species	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Spiraea douglasii	4	3	2	3	8					
Salix geyeriana				1						
Salix lemmonii	3	11	1							
Salix lasiandra	35	9	3	1	3	2				
Total	42	23	6	5	11	2	0	0	0	0
Total (L&R)	65		11		13		0		0	

SM-Site 4

	Seedling/Sprout		Young/Sapling		Mature		Decadent		Dead	
Species	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Spiraea douglasii	15	1	11	4	4					
Salix lasiandra	1		4							
Alnus incana			1							
Salix geyeriana			2							
Salix lemmonii	1	7		1						
Populus tremuloides	1									
Total	18	8	18	5	4	0	0	0	0	0
Total (L&R)	26		23		4		0		0	

SM-Site 5

	Seedling/Sprout		Young/Sapling		Mature		Decadent		Dead	
Species	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Spiraea douglasii	9	2	25	13	12					
Salix lasiandra	2	1	7	2						
Salix geyeriana		1	2	1						
Salix spp.			3	1						
Populus balsamifera ssp. trichocarpa	2									
Total	13	4	37	17	12	0	0	0	0	0
Total (L&R)	17		54		12		0		0	

SM-Site 6

	Seedling/Sprout		Young/Sapling		Mature		Decadent		Dead	
Species	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Salix lasiandra		2	2							
Spiraea douglasii	6		3	1	8			1		
Salix lemmonii	2									
Salix geyeriana	1									
Total	9	2	5	1	8	0	0	1	0	0
Total (L&R)	11		6		8		1		0	

Crooked Creek - no woody species within a 6-foot belt transect of the greenline. Shrubs were located in the floodplain.

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Appendices

1. Data Sheets
    a. Greenline
    b. Valley Cross Section
    c. Species List/Code definitions
    d. Stream Cross Section
2. Community type ordination methods
3. Maps
    a. Aerial Photo
    b. Site Map
4. GPS points
5. Site Photos

1. Data Sheets

a. Greenline Data Sheets (See Appendix 1.c for community type/species dominance codes)

Site 1

Riparian Greenline Transect Data

Site No. 1

Examiners SEQ, HCC

Location Above 1st diversion, just below FS road

Feet/Step 2ft/step

Date 8.6.08

GPS Point 10T 575866 E 4728155 N

Community Type	Steps (Left)						Steps (Right)						Total Steps	% Comp.
SCMI	34	36					47	9	75				201	56
POTRE/ALPR							11	8	24				43	12
POBAT/POTRE SYMY/SPDO							7						7	2
CAUT/PHAR	30												30	8
POA/AGST2	3	20	7	7									37	10
PHAR	7	10											17	5
PHAR/HYFO PUPA/SPDO/AGST2	12												12	3
PUPA/GLYCERIA/CACA/CAAT JUEN/FORBS	15												15	4
												Grand Total	362	

Site 2

Riparian Greenline Transect Data

Site No. Site 2
Examiners SEQ, HCC
Location Right above 1st weir
Feet/Step 2ft/step
Date 8.5.08
GPS Point 10T 575917 E 4727946 N

Community Type	Steps (Left)						Steps (Right)						Total Steps	% Comp.
SCMI/SHRUB	162	12					181						355	98
GLYCERIA/ELEOCHARIS	7												7	2

Grand Total 362

Site 3

Riparian Greenline Transect Data

Site No. 3
Examiners SEQ
Location Just below 1st diversion/weir
Feet/Step 2ft/step
Date 8.11.08
GPS Point 10T 576038 E 4727636 E

Community Type	Steps (Left)						Steps (Right)						Total Steps	% Comp.
POPR/AGST2/CANE	25	3	1	4	4	5	10	29	6	1	6	5	139	35
	5	12	3				20							
SCMI/CANE							2						2	0.5
SCMI (GRP)	23	6	6	6	4		5	9	5	9	2	12	107	27
							3	8	9					
CAAQ	8						10	3	4	9			34	9
CANE (GRP)	3	10	1	9	22	4	2	20	10				99	25
	15	2	1											
JUEN							5						5	1.3
SALA							4						4	1.0
SPDO	3												3	0.8

Grand Total 393

Species list: POPR, AGST, SPDO, CANE, JUEN, SCMI,
JUBA, PHAR, CAAQ, TRLO, SALA, HOBR, PRUNELLA, STACHYS

Site 4

Riparian Greenline Transect Data

Site No. 4

Examiners SEQ

Location Below Blue Springs pipe/above confluence

Feet/Step 2ft/step

Date 8.11.08

GPS Point 10T 576000 E 4727235 N

Community Type	**Steps (Left)**						**Steps (Right)**						**Total Steps**	**% Comp.**
POPR/AGST2/JUBA	2	12	12	15	4	36	20	4	10	2	19	2	183	49
	3	10					32							
SCMI (GRP)	5						7	2	10	3			27	7
CAREX LANUGINOSA/JUAR							15						15	4
CANE2/CALA							3						3	0.8
CALA							8						8	2
CANE2 (GRP)	7	20	5	7	6	20	14	1	8	5	3	5	101	27
FORB/CAREX/JUNCUS	5						5	1					11	3
CACA							3						3	0.8
SCMI/CANE2/CAUT	22												22	6
											Grand Total		373	

Species list: POPR, AGST, JUAR, PHPR, HYFO, SPDO, PHAR, CANE, ARLO

Site 5

Riparian Greenline Transect Data

Site No. 5
Examiners SEQ, HCC
Location below Blue Springs Ck confluence, above fence
Feet/Step 2ft/step
Date 8.6.08
GPS Point 10T 576065 E 4726990 N

Community Type	Steps (Left)						Steps (Right)						Total Steps	% Comp.
CANE2 (GRP)	50	9	4	50	13		6	12	30	8	10		192	51
SCMI/CAUT							27	25					52	14
SCMI (GRP)	3	6	4				7	3					23	6
CAUT (GRP)	7	10					38	20					75	20
GLYCERIA							2						2	0.5
POPR/JUBA/JUEN/FORB/AGST							22	7					29	8
										Grand Total			373	

Site 6

Riparian Greenline Transect Data

Site No. 6
Examiners SEQ, HCC
Location Below Popson/Von Schlaggel fence
Feet/Step 2 ft/step
Date 5.5.08
GPS Point 10T 576182 E 4726832 N

Community Type	Steps (Left)						Steps (Right)						Total Steps	% Comp.
Carex lanuginosa							2						2	0.5
CALA/CAUT							2						2	0.5
SCMI/CAUT							4	14					18	5
CAAQ (GRP)	74	100					5	4	10	10			203	54
CANE2/VIOLA/TRLO							22	5	13	30			70	19
CAUT (GRP)							5	14	11	37			67	18
CASI							3						3	0.8
SCMI/ELEOCHARIS							3						3	0.8
SALE							1						1	0.3
PUPA/CAAQ/LUPO	9												9	2
										Grand Total			378	

Crooked Creek

Riparian Greenline Transect Data

Site No. Crooked Creek
Examiners SEQ, HCC
Location Agency Ranch
Feet/Step 2ft/step
Date 8.22.08
GPS Point 10T 586883 E 4719724 N

Community Type	Steps (Left)						Steps (Right)						Total Steps	% Comp.
POPR/JUBA	10	10	10	10	10	10	4						92	22
	10	10	8											
SEHY/POPR	6						1						7	2
CAUT/POPR/JUBA	2												2	0.5
CANE2/POPR	10	4											14	3
ALAQ	2												2	0.5
CAUT	10	10	10	10	10	10	2	40	16	10	7	2	226	55
	10	10	3				10	23	16	5	12			
CAPR5/CAUT	10	10	2										22	5
JUBA	2												2	0.5
SEHY/JUBA	2												2	0.5
BEAVER TRAIL/WATER							2	2	1	2	1	1	10	2
							1							
POPR/CAUT							2	3	3	2	3	8	22	5
							1							
TRAIL							3						3	0.7
SEHY/CAUT							2	1					3	0.7
CAUT/AGST2							2						2	0.5
												Grand Total	409	

Notes: Left bank consists of wetland vegetation and many hummocks along the greenline

b. Valley Cross Section

Site 1

Riparian Cross Section Composition

Site No.	1
Examiners	HCC, JCF, SEQ, TKS
Location	Above 1st diversion/weir, most upstream site
Date	8.26.08

	T1					T2					T3						
Community Type	Number Steps					Number Steps					Number Steps					Steps	% Comp
CANE2/POPR	10	6									10	10	2			38	10.47
POPR	10	2				2	1	6								21	5.79
POPR/AGST						5	3	5								13	3.58
ASTER	3															3	0.83
BARE GROUND	3															3	0.83
CAPR5/POPR	4															4	1.10
JUBA/POPR	10	10	5			10					10	10				55	15.15
DAUN	4															4	1.10
DAUN/POPR	10	7														17	4.68
POPR/ASTER	10	1														11	3.03
POPR/FRVI	3															3	0.83
DAUN/AGST	4					12										16	4.41
POPR/VIOLA	1															1	0.28
SALIX/SCMI	2															2	0.55
CASI/VIOLA																0	0.00
SCMI/AGST	6															6	1.65
POTR/AGST	5															5	1.38
AGST/CAREX SPP	2															2	0.55
LWD	3															3	0.83
POPR/POTR(YOUNG)	7										6					13	3.58
SYMPHORICARPOS/POA	2															2	0.55
POTR/AGST/POA	3															3	0.83
POTR/AGST/FRVI	2															2	0.55
CAUT						2										2	0.55
PHAR						2	2				2	4				10	2.75
SALA/POPR						11										11	3.03
POPR/DAUN						19										19	5.23
POTR/POA						5	41									46	12.67
POTR/BARE GROUND						3										3	0.83
POTR/FORB						9										9	2.48
POPR/Cynoglossum											8					8	2.20
JUBA											8					8	2.20
JUBA/CAPR5											10	10				20	5.51
															Grand Total	363	

Notes: Reedcanary grass present at site

Site 2

Riparian Cross Section Composition

Site No. 2

Examiners SEQ, HCC, JCF, TKS

Location Directly upstream of 1st diversion/weir

Photo No

Date 8.26.08

	T1					T2					T3						
Community Type	Number Steps					Number Steps					Number Steps					Steps	% Comp
SCMI/SHRUBS	3	4	1			6					5					19	7.36
GRAMINOID/FORB	3	4														7	2.71
AGST/POPR	6	12	4			10	10	6			3					51	19.77
AGST/FRVI	3															3	1.16
BARE GROUND	2	5	7			3					7	2				26	10.08
JUBA/POPR	13					7					36					56	21.71
PICO/SCMI	7															7	2.71
PICO/POPR	4															4	1.55
ABIES LASIO/POPR	5															5	1.94
JUEN/POBAT						1										1	0.39
JUEN						2										2	0.78
PHAR/POBAT						2										2	0.78
AGST/CANE2						4										4	1.55
AGST/DRY FORB						2										2	0.78
FRVI						1										1	0.39
POPR/DAUN						10										10	3.88
POPR						10	9									19	7.36
JUBA/DAUN						2										2	0.78
ALIN/SCMI						2										2	0.78
SCMI/PHAR											3					3	1.16
SPDO/AGST											1					1	0.39
POPR/EPPA											10	5				15	5.81
STIPA/EPPA											5					5	1.94
CAREX/POPR											6					6	2.33
POPR/PHAR											4					4	1.55
SCMI/FRVI											1					1	0.39
													Grand Total			258	

Notes: Right bank has been diked

Graminoid/forb= CASI, HYFO, JUEN, Buttercup, VIOLA

Dry Forb= Rumex, VIOLA, Penstemon

Site 3

Riparian Cross Section Composition
Site No. 3
Examiners HCC, JCF
Location Above Blue Springs Pipe, below 1st weir
Date 8.26.08

	T1					T2					T3						
Community Type	Number Steps					Number Steps					Number Steps					Steps	% Comp
POPR/CANE2	10	10	5			5					10	3				43	12.32
POPR	10	10	10	10	16	10	10	10	6		10	10	10	2		124	35.53
EPPA/CANE2	2															2	0.57
CANE2	10	7									3					20	5.73
CAPR5/JUBA	3															3	0.86
CAPR5	3										6					9	2.58
POPR/JUBA	8					10	5				10	10	10	10	4	67	19.20
POPR/CAPR5	4					4					1					9	2.58
POPR/AGST	4					3					5					12	3.44
POPR/ALPR						10	1				2					13	3.72
JUBA/CANE2						2					5					7	2.01
POPR/FRVI						10	10	1								21	6.02
DAUN/CAPR5						6										6	1.72
DAUN/JUBA						3										3	0.86
JUBA/FRVI						5										5	1.43
POPR/ACMI											4					4	1.15
ALPR/POGR											1					1	0.29
													Grand Total			349	

Site 4

Riparian Cross Section Composition

Site No. 4

Examiners HCC, JCF, SEQ

Location

Date 8.26.08

	T1					T2					T3						
Community Type	Number Steps					Number Steps					Number Steps					Steps	% Comp
POPR/JUBA	14	23	6	6	7	12	7	8	9	7	10	2				111	21.51
SAMBUCUS	2															2	0.39
POPR/EPILOBIUM	4															4	0.78
POPR	6	9	5			8	10	12			10	10	10	10	14	104	20.16
CANE2/POPR	5	6									10	10	3			34	6.59
EPILOBIUM	2										5					7	1.36
POPR/AGST	6					5	2	4	3	11	20	20	20			91	17.64
DRY FORB/POPR	2	2	9	4							10	10	7			44	8.53
DRY FORB/JUBA	3	3									5					11	2.13
AGST	2	20									3					25	4.84
AGST/POPR	11	7														18	3.49
ALIN	2															2	0.39
MURI/POPR						7										7	1.36
ASTER/JUBA						2										2	0.39
WATER						21										21	4.07
SCMI/JUNCUS						3										3	0.58
CALA/CAPR5						3										3	0.58
CANE2/JUBA											2					2	0.39
AGST/JUBA											2					2	0.39
PHPR/POPR											3					3	0.58
CANE2/AGST											10					10	1.94
CANE2											4					4	0.78
CAPR/POPR											4					4	0.78
MURI											2					2	0.39
													Grand Total			516	

Notes: Dry Forb= TAOF, VIOLA, ASTER, FRVI, ACMI

Site 5

Riparian Cross Section Composition

Site No. 5

Examiners SEQ, HCC, JCF

Location just above Von Schlaggel fence and below Blue Sps Ck confluence

Date 8.26.08

Community Type	T1 Number Steps					T2 Number Steps					T3 Number Steps					Steps	% Comp
POPR/JUBA	8	60									9					77	7.51
POPR/CANE2	7					9					7					23	2.24
CANE2/JUBA	22															22	2.15
CANE2/CAUT	10															10	0.98
CANE2	22	25				8	9	4			3					71	6.93
CANE2/CAPR5	18															18	1.76
CANE2/CACA4	15															15	1.46
CANE2/DECA18	8															8	0.78
DRY FORB	14															14	1.37
FRVI/AGST2	10															10	0.98
DRY GRAM	33										6					39	3.80
CAUT	8															8	0.78
CAPR5/JUBA	4															4	0.39
CAPR5/AGST/CANE	7															7	0.68
JUBA/CAPR5	4															4	0.39
POPR	6					10	10	10	10	6	118					170	16.59
AGST	5	4									2					11	1.07
POPR/FRVI	14	15				6										35	3.41
JUBA/PHPR						6	2									8	0.78
JUBA/POPR						10	4	3	5	14						36	3.51
POGR/FRVI						2										2	0.20
JUBA/DRY FORB						11	3	4	1	14						33	3.22
POPR/DRY FORB						11	11	16	1	18	10	10	10	10	19	116	11.32
MURI						7					2					9	0.88
POPR/DAUN						9	17	36								62	6.05
DAUN/FRVI						6	2									8	0.78
WATER						10	5				10					25	2.44
CAAQ/GLYCERIA						2										2	0.20
POAN/POPR						2										2	0.20
GALIUM/CANE2						1										1	0.10
MIXED SEDGE						6					10	10	9			35	3.41
PHPR/POPR						10	2				10	7				29	2.83
ALPR/POPR						7										7	0.68
CANE2/PHPR						2					1					3	0.29
POPR/AGST						4					8					12	1.17
BARE GROUND											3					3	0.29
AGST/PHAR											1					1	0.10
HOBR/PHPR											4					4	0.39
HOBR/POPR											10	2				12	1.17
MURI/CANE2											2					2	0.20
SALE											6					6	0.59
FRVI											10					10	0.98
DAUN/AGST											50					50	4.88
CANE/PHAR											1					1	0.10
													Grand Total			1025	

Notes: Dry gram= CANE, AGST, MUFI, JUBA, DAUN, ACMI, FRVI
Dry forb= FRVI, ASTER, ACMI, POAN5, POGR, VIOLA

Site 6

Riparian Cross Section Composition

Site No.	6
Examiners	SEQ, TKS, HCC, JCF
Location	Von Schlaggel below fence
Date	8.26.08

Community Type	T1 Number Steps					T2 Number Steps					T3 Number Steps					Steps	% Comp
CAAQ/PHAR						5										5	1.45
CAAQ	6					10	10				3					29	8.43
CACA4/CAAQ						2					5	4				11	3.20
SAGE						4										4	1.16
SPDO						4										4	1.16
CAUT/CANE2	10					7	12									29	8.43
SCMI/CAUT						6										6	1.74
CANE2/AGST	10	7				4					4					25	7.27
POPR/TRIFOLIUM	10	10	10	10	3	8	15									66	19.19
POPR/AGST						13	15									28	8.14
CANE2											3					3	0.87
AGST2											6					6	1.74
DRY GRAM/TRIFOLIUM											38					38	11.05
POPR											3	6	8			17	4.94
SCMI/LUPO											3					3	0.87
CAUT/CAAQ											6	6	6	2		20	5.81
SAGE/CACA4											12					12	3.49
SPDO/CAAQ	2										4	4				10	2.91
CAPR5/POPR	6															6	1.74
CAAQ/DECA18	10	5														15	4.36
ALPR/CANE2	7															7	2.03
														Grand Total		344	

Notes: Dry gram= AGST, POPR, CAPR5

Also present: Calamagrostis in CAAQ/DECA: PHAR: SALE: SALA

Crooked Creek

Riparian Cross Section Composition

Site No.	Crooked Ck
Examiners	SEQ, HCC, TKS
Location	Agency Ranch
Date	8.23.08

Community Type	T1 Number Steps					T2 Number Steps				T3 Number Steps					Steps	% Comp
POPR/JUBA/MESIC FORB	19	44				18				56					137	26.30
CAREX/CANE/PHAR	10														10	1.92
CANE/POPR/JUBA	24					24				49					97	18.62
POPR/CANE/PHAR						21									21	4.03
CAUT	10									30	7	6			53	10.17
POPR/CAUT	4	7	7												18	3.45
POPR/CAREX	8	18				12	21	1		6					66	12.67
SALE/SAGE/POPR	7	5	7	6	16										41	7.87
POPR	16					20									36	6.91
POPR/ELYMUS/SOLIDAGO	7	5				16									28	5.37
BEAVER TRAIL										1					1	0.19
POPR/ELYMUS										13					13	2.50
												Grand Total			521	

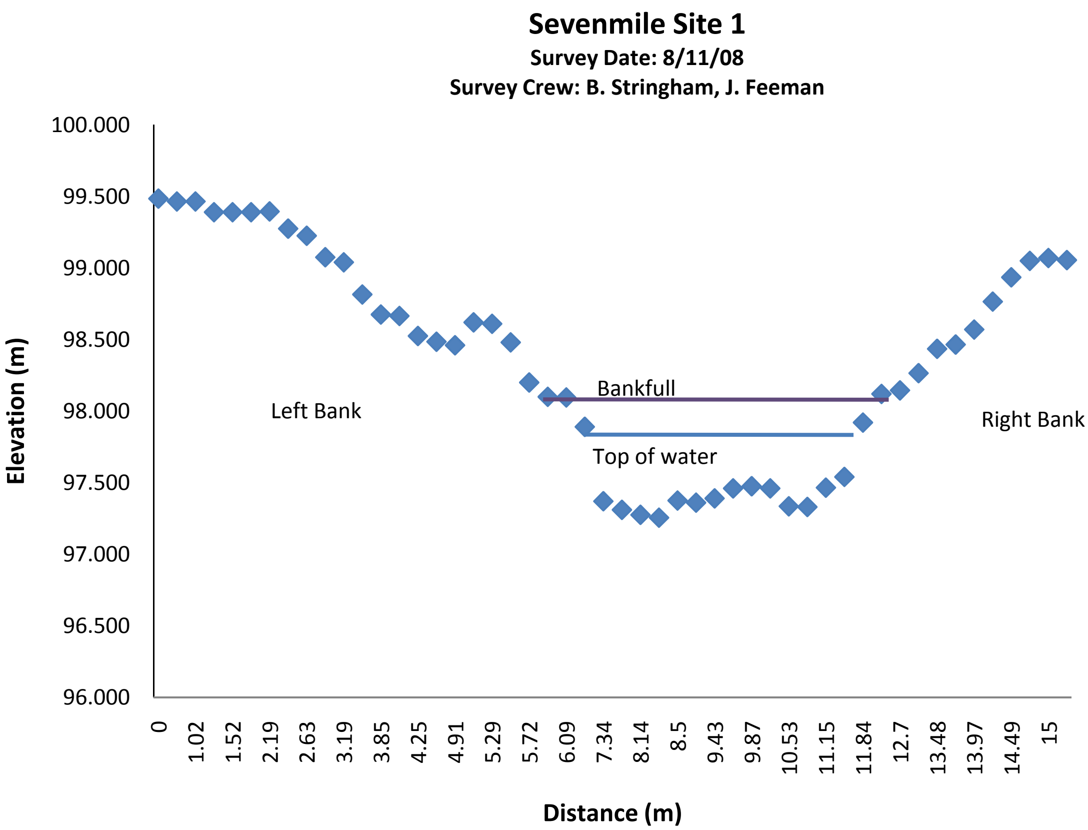
Notes: Mesic forb= SEHY, POAN, EPILOBIUM, LUPINE, ASTER, TAOF, ACMI, POGR

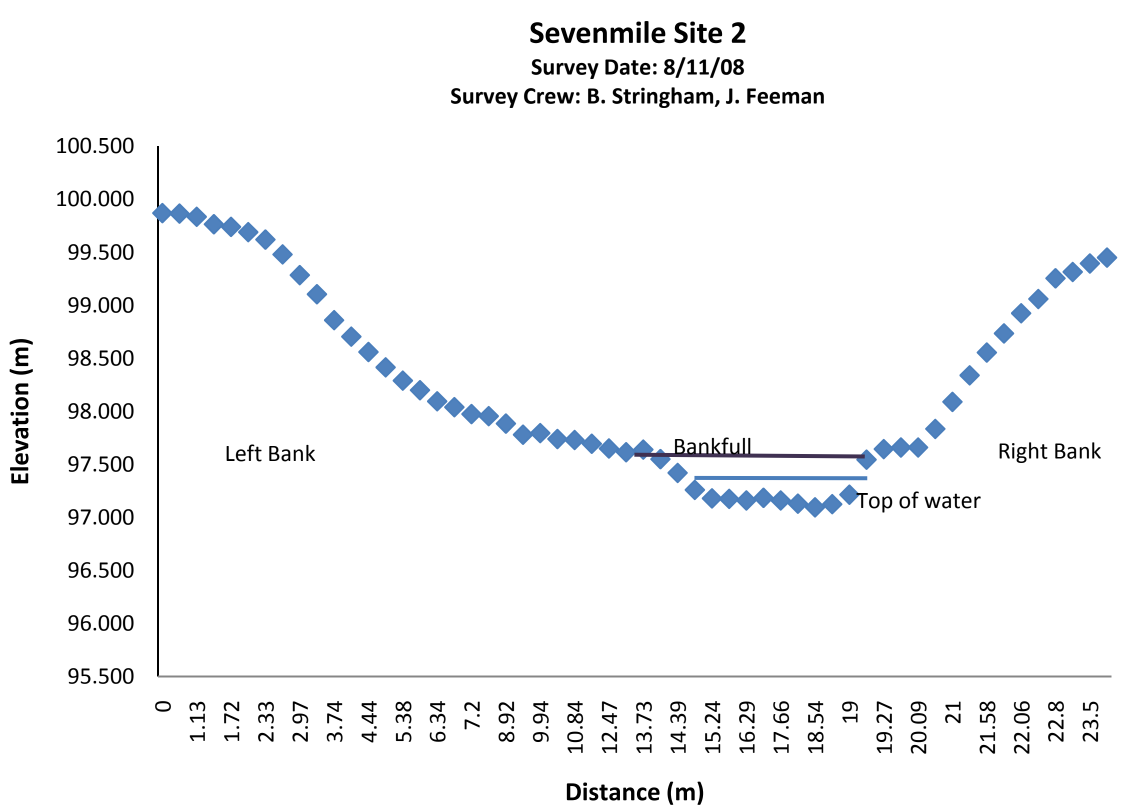
c. Riparian species code definitions

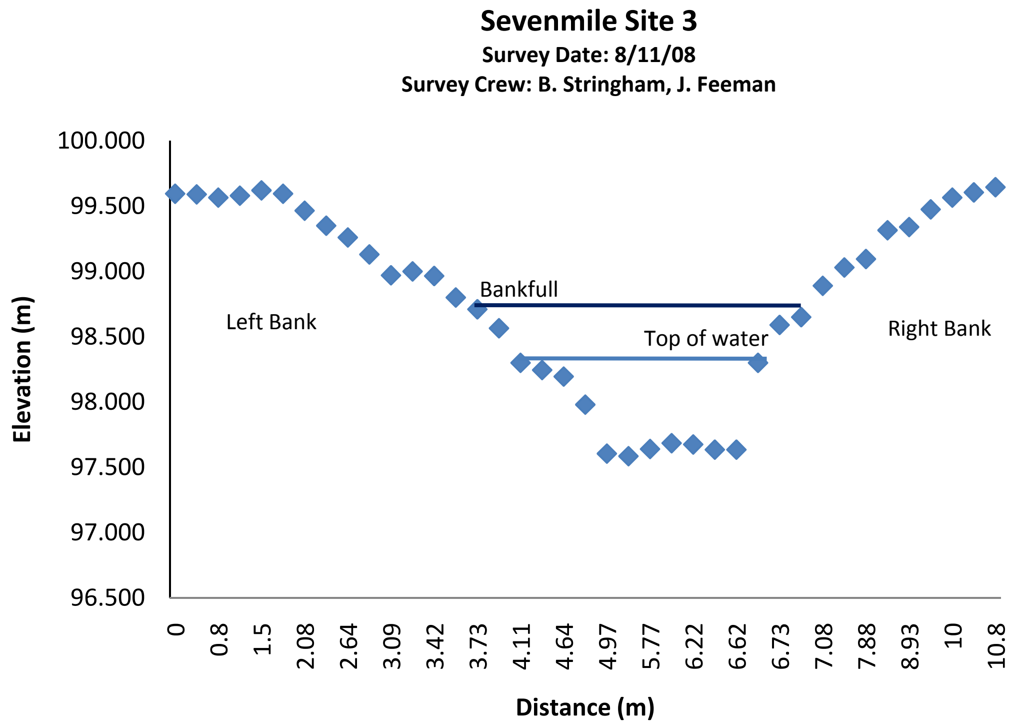
Code	Scientific Name	Common Name
ABLA	*Abies lasiocarpa*	subalpine fir
ACMI2	*Achillea millefolium*	common yarrow
AGST2	*Agrostis stolonifera*	creeping bentgrass
ALAE	*Alopecurus aequalis*	shortawn foxtail
ALIN	*Alnus incana*	alder
ALPR3	*Alopecurus pratensis*	meadow foxtail
ARLO6	*Arnica longifolia*	spearleaf arnica
CAAQ	*Carex aquatilis*	water sedge
CAAR2	*Carex arcta*	northern cluster sedge
CAAT3	*Carex athrostachya*	slenderbeak sedge
CACA4	*Calamagrostis canadensis*	bluejoint reedgrass
CACA11	*Carex canescens*	Silvery sedge
CALA	*Carex lanuginosa*	wolly sedge
CANE	*Calamagrostis neglecta*	slimstem reedgrass
CANE2	*Carex nebrascensis*	Nebraska sedge
CAPR5	*Carex praegracilis*	clustered field sedge
CAREX	*Carex* spp.	sedge
CASI/2	*Carex simulata*	analogue sedge
CAUT	*Carex utriculata*	Beaked sedge
CYNOGLOSSUM	*Cynoglossum* spp.	hound's tongue
DAUN	*Danthonia unispicata*	onespike danthonia
DECA18	*Deschampsia caespitosa*	tufted hairgrass
ELAC	*Eleocharis acicularis*	Needle spikerush
ELECOCHARIS/EP2SPP	*Eleocharis* spp.	spikerush
ELPA3	*Eleocharis palustris*	common spikerush
ELYMUS	*Elymus* spp.	wildrye
EPILOBIUM	*Epilobium* spp.	willowherb
EPPA	*Epilobium paniculatum*	tall annual willowherb
EQAR	*Equisetum arvense*	field horsetail
EQTE	*Equisetum telmateia*	giant horsetail
EQUIS	*Equisetum*	horsetail
FRVI	*Fragaria virginiana*	Virginia strawberry
GALIUM	*Galium* spp.	bedstraw
GAPA	*Galium parisiense*	bedstraw
Glyceria	*Glyceria* spp.	mannagrass
GLST	*Glyceria striata*	Fowl mannagrass
HIMO2	*Hippuris montana*	Mare’s tail
HOBR2	*Hordeum brachyantherum*	meadow barley

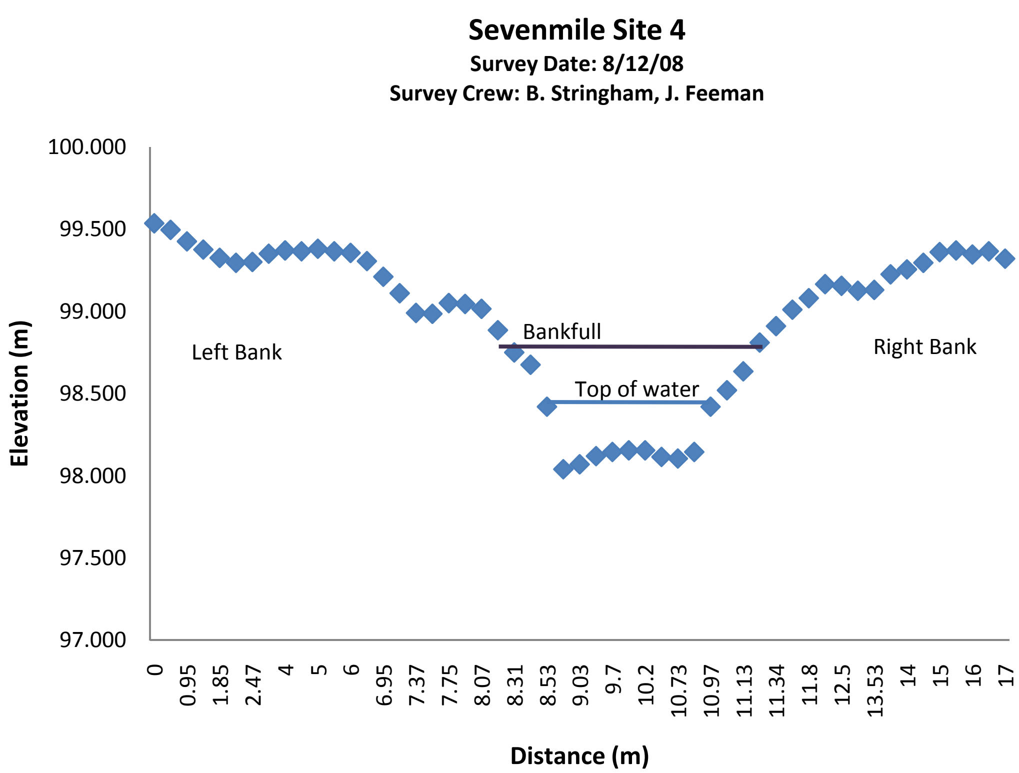
HYFO7	*Hypericum formosum*	St. John's wort
JUAR/4	*Juncus articulatus*	jointleaf rush
JUBA	*Juncus balticus*	baltic rush
JUEN	*Juncus ensifolius*	swordleaf rush
JUNCUS	*Juncus* spp.	rush
JUOR	*Juncus orthophyllus*	straightleaf rush
LUPO	*Lupinus polyphyllus*	bigleaf lupine
LWD		Large woody debris
MIMUL	*Mimulus* spp.	Monkeyflower
MURI	*Muhlenbergia richardsonis*	mat muhly
MYLA	*Mysotis laxa*	forget-me-not
PHAR3	*Phalaris arundinacea*	reed canarygrass
PHPR3	*Phleum pratense*	timothy
PICO	*Pinus contorta*	lodgepole pine
POAN5	*Potentilla anserina*	Silver cinquefoil
POBAT	*Populus balsamifera* spp *trichocarpa*	black cottonwood
POGR9	*Potentilla gracilis*	slender cinquefoil
POPR	*Poa pratensis*	Kentucky bluegrass
POTR5	*Populus tremuloides*	aspen
PUPA	*Puccinellia pauciflora*	false mannagrass
SAGE2	*Salix geyeriana*	Geyer willow
SALA	*Salix lasiandra*	Pacific willow
SALE	*Salix lemmonii*	Lemmon's willow
SAMBUCUS	*Sambucus* spp.	elderberry
SCMI2	*Scirpus microcarpus*	panicled bulrush
SEHY2	*Senecio hydrophilus*	water ragwort
SHRUB		willow, alder, spirea mix
Solidago	*Solidago* spp.	goldenrod
SPDO	*Spiraea douglasii*	rose spirea
SPEU	*Sparganium eurycarpum*	broadfruit bur-reed
Stachys	*Stachys* spp.	Hedgenettle
STIPA	*Stipa* spp.	needlegrass
SYMPHYOTRICHUM (Aster)	*Symphyotrichum* spp.	aster
SYMY	*Symphoricarpos* spp.	snowberry
TAOF	*Taraxacum officinale*	common dandelion
TRIFOLIUM	*Trifolium* spp.	clover
VEAM2	*Veronica americana*	American speedwell
VIOLA (VIAD)	*Viola adunca*	hookedspur violet

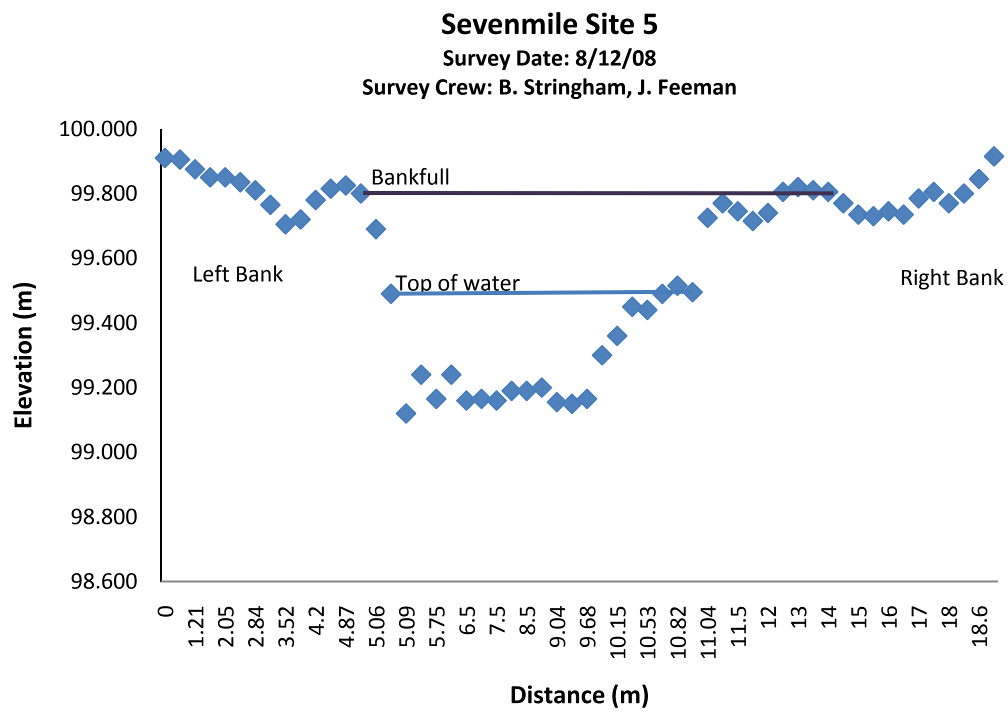
d. Stream Cross Section

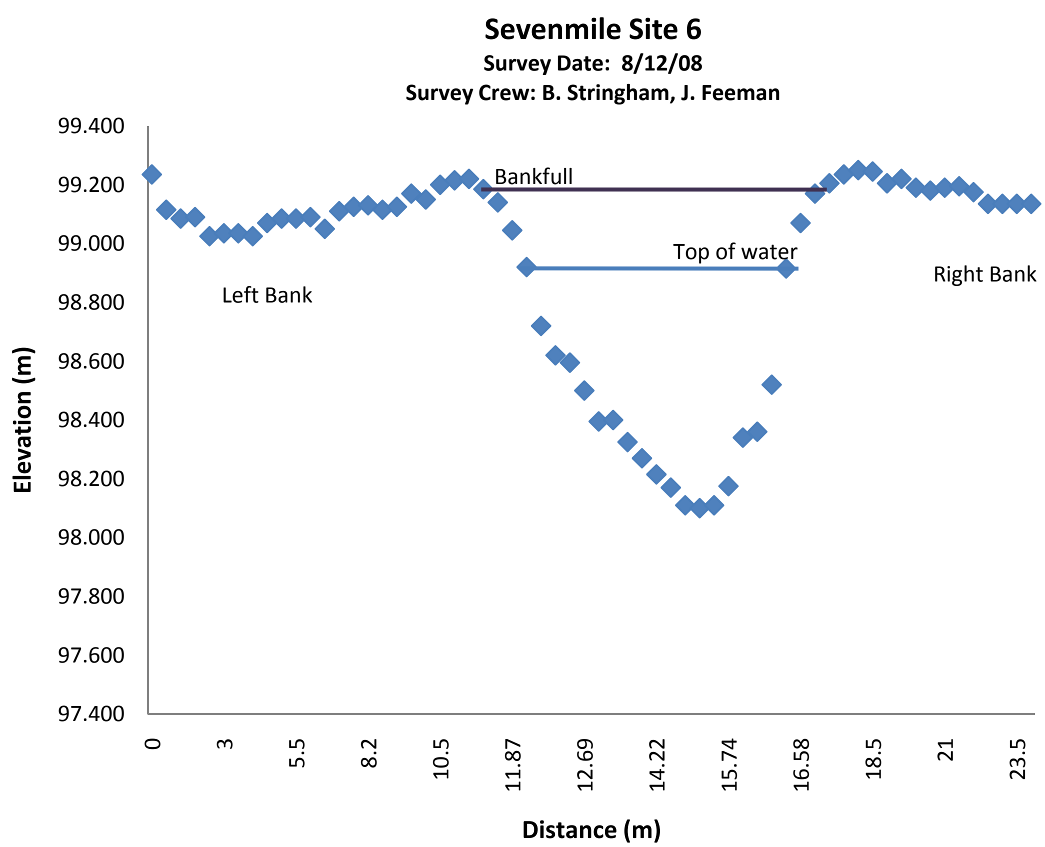


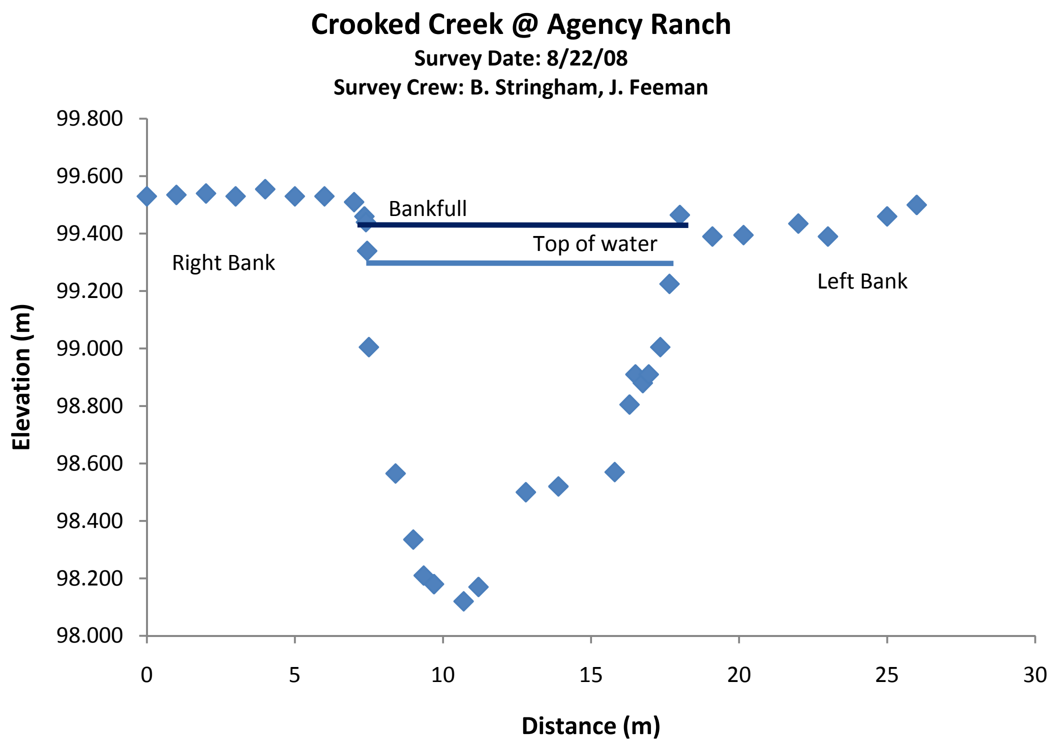



Sevenmile Site 3
Survey Date: 8/11/08
Survey Crew: B. Stringham, J. Feeman
Elevation (m)
100.000
99.500
99.000
98.500
98.000
97.500
97.000
96.500
Left Bank
Bankfull
Top of water
Right Bank
0
0.8
1.5
2.08
2.64
3.09
3.42
3.73
4.11
4.64
4.97
5.77
6.22
6.62
6.73
7.08
7.88
8.93
10
10.8
Distance (m)


Sevenmile Site 4
Survey Date: 8/12/08
Survey Crew: B. Stringham, J. Feeman
Elevation (m)
100.000
99.500
99.000
98.500
98.000
97.500
97.000
Left Bank
Bankfull
Top of water
Right Bank
0
0.95
1.85
2.47
4
5
6
6.95
7.37
7.75
8.07
8.31
8.53
9.03
9.7
10.2
10.73
10.97
11.13
11.34
11.8
12.5
13.53
14
15
16
17
Distance (m)


Sevenmile Site 5
Survey Date: 8/12/08
Survey Crew: B. Stringham, J. Feeman
Elevation (m)
100.000
99.800
99.600
99.400
99.200
99.000
98.800
98.600
Bankfull
Left Bank
Top of water
Right Bank
0
1.21
2.05
2.84
3.52
4.2
4.87
5.06
5.09
5.75
6.5
7.5
8.5
9.04
9.68
10.15
10.53
10.82
11.04
11.5
12
13
14
15
16
17
18
18.6
Distance (m)


Sevenmile Site 6
Survey Date: 8/12/08
Survey Crew: B. Stringham, J. Feeman
Elevation (m)
99.400
99.200
99.000
98.800
98.600
98.400
98.200
98.000
97.800
97.600
97.400
Bankfull
Top of water
Left Bank
Right Bank
0
3
5.5
8.2
10.5
11.87
12.69
14.22
15.74
16.58
18.5
21
23.5
Distance (m)


Crooked Creek @ Agency Ranch
Survey Date: 8/22/08
Survey Crew: B. Stringham, J. Feeman
Elevation (m)
99.800
99.600
99.400
99.200
99.000
98.800
98.600
98.400
98.200
98.000
Bankfull
Top of water
Right Bank
Left Bank
0
5
10
15
20
25
30
Distance (m)

2. Community Type Ordination Methods

C.A. Matney, Oregon State University

Raw Data

In the original data set, there were 510 quadrats by 45 species. Species data were cover values. These 510 quadrats were distributed across 20 sites. In order to maximize the full data set, the data were analyzed in 2 forms: full (510 quadrats) and reduced (20 sites). In the full data analysis, relationships between plant species were sought among the 510 quadrats, regardless of site relationship. In the reduced analysis, relationships between species and plots were sought among the 20 sites. A second reduced data matrix complemented the species data matrix: environmental matrix. The environmental matrix contained environmental data for the 20 sites (10 environmental variables by 20 sites). The environmental matrix was a mix of quantitative and categorical data.

Data Editing

Upon examination of the data, it was apparent there were rare species (species occurring infrequently). The purpose of the overall analyses for the project was to be able to recognize grouping of species and the patterns behind their grouping. If infrequent species are included in the analysis, it creates "noise", and makes it difficult to determine if true groupings are occurring. To reduce noise, species that occurred in 9 or less total quadrats were excluded from the analysis. The remaining data matrix was a 510 quadrat by 26 species matrix. Species cover values within the data matrix ranged widely from "presence" to 100%. Due to the wide variation in values, cover values were reassigned scores (Table 1).

Table 1. Scores assigned to ranges of species cover values.

Cover Value %	0	>0 – 4.9	5 – 9.9	10 – 19.9	20 – 39.9	40 – 59.9	60 – 79.9	80 - 100
Assigned Score	0	1	2	3	4	5	6	7

Full Data Set

The full data set was analyzed using cluster analysis only for the 510 quadrat by 26 species matrix. The matrix was imported into PC-ORD and transposed in order to focus the clustering by species. Many distance measure and linkage method combinations were perfomed. Only 3 suitable outcomes were identified based on percent chaining and overall species grouping. Those 3 methods are: 1.) Wards – Relative Euclidian Distance, 8.41% chaining, 2.) Flexible Beta (-0.25) – Sorensen, 3.54% chaining, 3.) Flexible Beta (-0.25) – Relative Sorensen, 3.10% chaining. Of these, Flexible Beta (-0.25) – Relative Sorensen, 3.10% chaining appeared to offer the best results, but selection of method is somewhat subjective (Figure 1). The dendrogram suggests 3 primary groupings. The other cluster dendrograms can be found below for comparison (Figure 2 and Figure 3). The resulting dendrograma were scaled by Wishart's objective function converted to a percentage of information remaining.

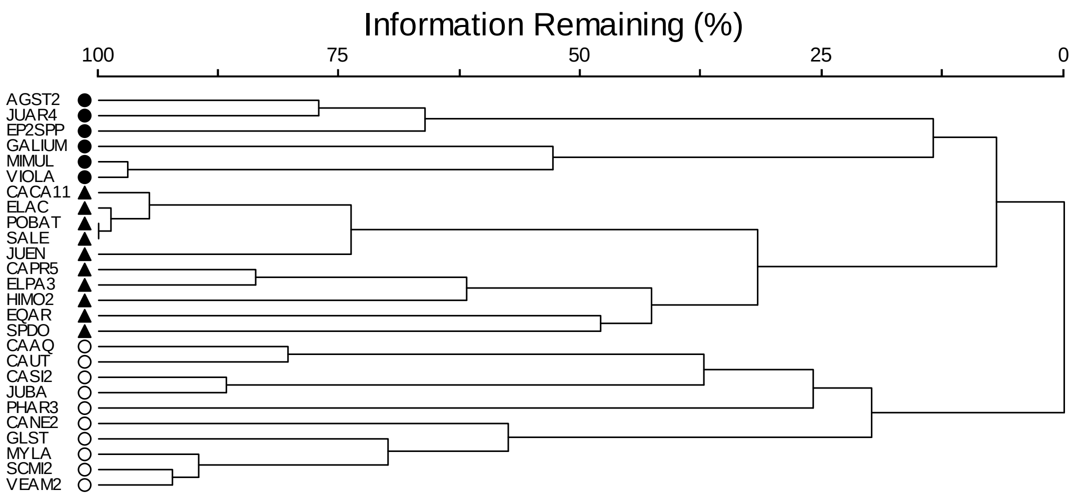


Figure 1. Cluster analysis dendrogram for the full set species data matrix. Method used is the flexible Beta (-0.25) – relative Sorensen. Result is a dendrogram with 3.10% chaining. Character shapes next to species code on the left of the chart depict species assignment among 3 groups, based on a dendrogram split at 13% information remaining.

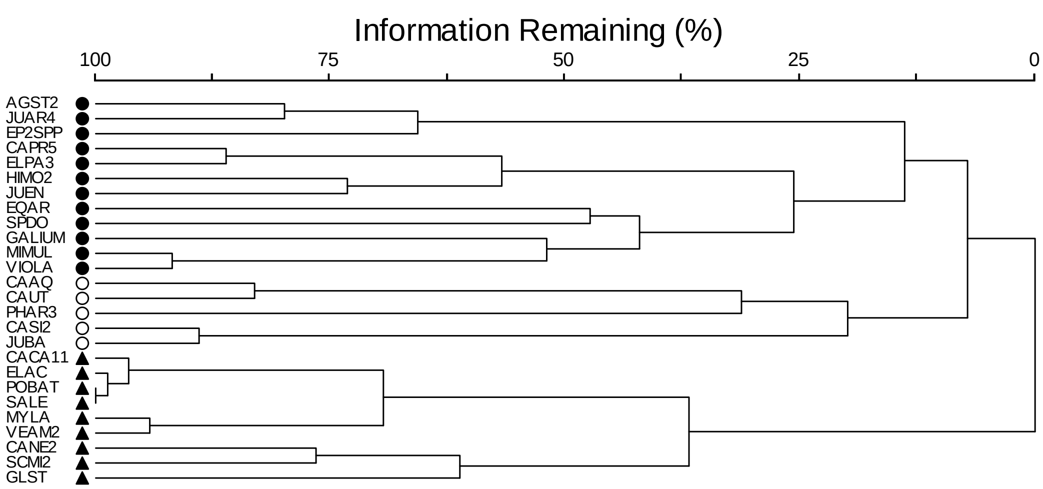


Figure 2. Cluster analysis dendrogram for the full set species data matrix. Method used is the flexible Beta (-0.25) – Sorensen. Result is a dendrogram with 3.54% chaining. Character shapes next to species code on the left of the chart depict species assignment among 3 groups, based on a dendrogram split at 13% information remaining.

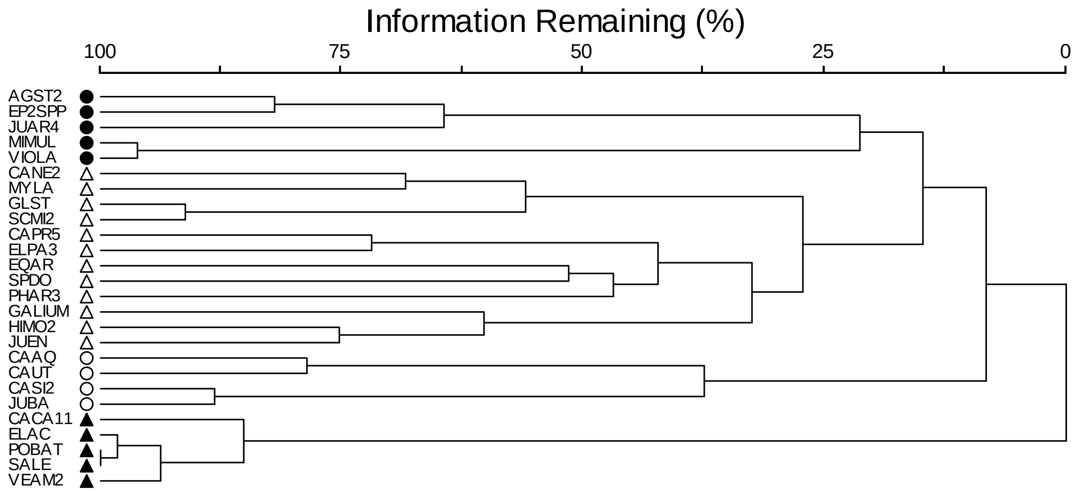


Figure 3. Cluster analysis dendrogram for the full set species data matrix. Method used is the Ward – Relative Euclidian Distance. Result is a dendrogram with 8.41% chaining. Character shapes next to species code on the left of the chart depict species assignment among 4 groups, based on a dendrogram split at 20% information remaining.

Reduced Data Set

In order to reduce the species data from 510 quadrats to a summary cover value for each site by species, averages were calculated. Average site values were determined from the species scores assigned to each quadrat in the full data set analysis. Average species scores in this reduced data set ranged from 0 and 0.001 to nearly 7. In order to reduce the wide variation, values greater than 0, but less than 0.1 were assigned a value of 0.1. This adjustment was desirable since it retained the general structure of the data while reducing the overall disparity of scores between species. After this data adjustment was made, the environmental and species data matrices were imported into PC-ORD and analyzed using Nonmetric Multidimensional Scaling (NMS) Ordination in order to find groups among species and sites as well as determine the relative influence of the environmental data on plant species community structure. NMS provides a graphical depiction of community relationships and environmental variables. The “slow-and-thorough” autopilot mode of NMS in PC-ORD was used, 40 runs with the real data and 50 runs with randomized data for a Monte Carlo test of significance. Sorensen distances were calculated.

An NMS ordination of species by site data matrix yielded a 3-axes solution. The reduction in stress for the NMS ordination solution by adding additional axes is displayed (NMS Screeplot, Figure 4). Variance explained was expressed by the coefficient of determination between Euclidean distances in the ordination space and the Sorensen distances in the original species space. Axes 1 and 3, by themselves, account for 91% (r^2 = 0.91) of the variability in the NMS ordination. Axis 2 accounted for only 6% of the variation. The NMS ordination was rigidly rotated 250° in order to best align the environmental vector bankfull ratio with axis 1. This vector appeared to be among the strongest of the environmental variables. Environmental variables were superimposed on the resulting ordination using a joint plot (Figure 5). A map of the site locations also follows (Figure 6).

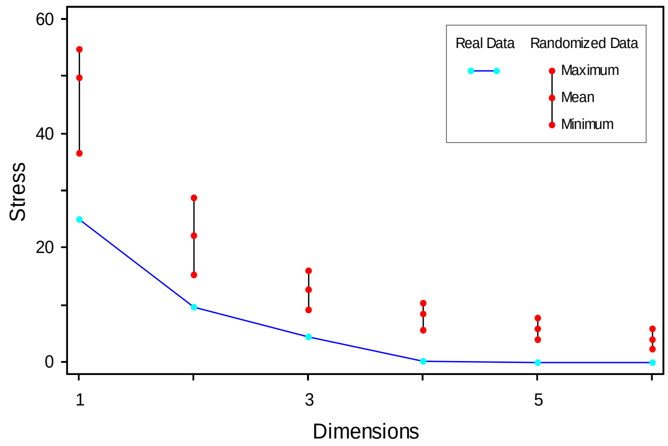


Figure 4. Scree plot for reductions in stress with increasing number of dimensions in the NMS ordination solution.

From the figure below, it is apparent that there are 3 main groups that diverge within the ordination species space, while site 16 is somewhat separate from all others. Generally, this means there are 3 groups that are similar in community species structure. However, it is also possible to identify groupings of species within site space (Figure 7). In Figure 7, it is more difficult to distinguish where one species group ends and where another might begin. But, there are atleast 2 main groups, and more likely 3, depending on where the reader decides to make their bisecting line.

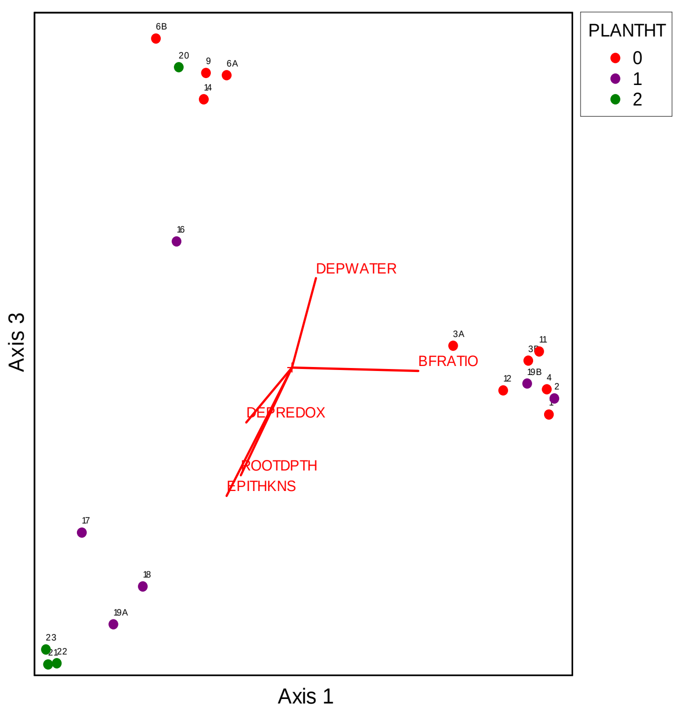


Figure 5. Ordination of 20 sites in plant species space, with joint plot of environmental characteristics. Color of the symbols indicates the height of the plant vegetation at each site (0 = 0.5 m or less, 1 = 0.5 to 1 m, and 2 = 1.1 m or taller). Sites are labeled by alpha-numeric code. Radiating lines indicate the relative strength and direction of correlation of environmental variables with the ordination.

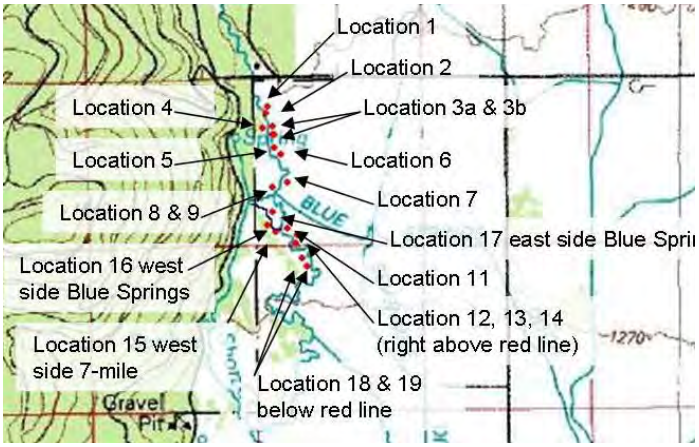


Figure 6. Map of study site locations at Seven Mile Creek. Site locations are indicated in red.

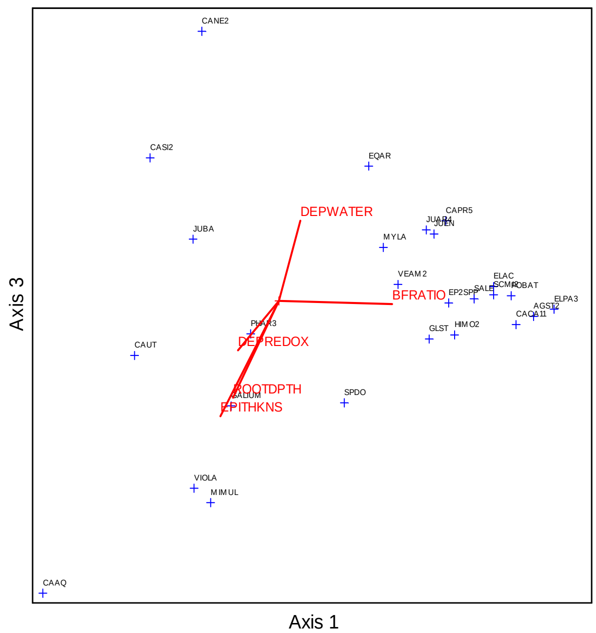


Figure 7. Ordination of 26 plant species in site space, with joint plot of environmental characteristics. Species are labeled by species code. Radiating lines indicate the relative strength and direction of correlation of environmental variables with the ordination.

Conclusion

All though the cluster analysis and the NMS ordination each provide a viewpoint of how plant species group together, it is the agreement between the two techniques that makes for more convincing evidence in deciding whether or not these plant species groups are real or a whether species groupings are just a condition of the mathematical correlation structure that is behind these techniques. Further, these analyses require a great deal of interpretation, and by themselves, their results are not intuitive. When considering all the analyses, it is clear that there are 4 groupings of species that appear from the charts. The exact assignment of a species to a group, however, is dependent on the interpretation of the reader. I am including summarizations of environmental variables based on the groupings that I have delineated (my interpretation) for site groups in species space (from Figure 5). See Tables 2 and 3.

Table 2. Environmental data summarized for 4 groups. Groups were derived from figure 5.

GROUP	SITE	DEPTH TO FREE WATER	PRESENCE OF REDOX	DEPTH TO REDOX (cm)	DEPTH OF ROOTING (cm)	BANK HEIGHT RATIO	THICKNESS OF EPIPEDON (cm)	PERCENT SILT (%)	PLANT HEIGHT (m)	STREAM BANK POSITION	BANKFULL RATIO
NMS Group 1	1	25.00	yes	2.00	75.00	1.04	5.00	65.00	0.50	floodplain	12.06
	2	26.00	yes	2.00	75.00	1.24	2.00	25.00	1.00	floodplain	14.00
	3A	34.00	yes	6.00	34.00	1.00	6.00	25.00	0.50	floodplain	14.83
	3B	22.00	yes	4.00	32.00	1.00	4.00	25.00	0.50	floodplain	14.42
	4	28.00	yes	5.00	33.00	1.00	5.00	25.00	0.50	floodplain	14.60
	11	1.00	no	0.00	38.00	1.23	24.00	20.00	0.50	floodplain	22.07
	12	75.00	yes	3.00	38.00	1.08	28.00	20.00	0.50	terrace	7.89
	19B	11.00	yes	6.00	35.00	0.99	6.00	20.00	1.00	floodplain	8.12
	Average	27.75		3.50	45.00	1.07	10.00	28.13	0.63		13.50
	Range	1-75 cm		0-6 cm	32-75 cm	0.99-1.24	2-28 cm	20-65%	0.5-1 m		7.89-22.07
NMS Group 2	17	4.00	no	0.00	40.00	1.35	16.00	25.00	1.00	streambank	10.00
	18	1.00	no	0.00	75.00	0.99	22.00	20.00	1.00	floodplain	6.34
	19A	11.00	yes	6.00	35.00	0.99	6.00	20.00	1.00	floodplain	8.12
	21	1.00	no	0.00	125.00	1.00	75.00	65.00	2.00	floodplain	8.00
	22	8.00	yes	80.00	140.00	1.00	50.00	40.00	2.00	floodplain	8.00
	23	8.00	yes	80.00	140.00	1.00	50.00	40.00	2.00	floodplain	8.00
	Average	5.50		27.67	92.50	1.06	36.50	35.00	1.50		8.08
	Range	1-8 cm		0-80 cm	35-140 cm	0.99-1.35	6-75 cm	20-65%	1-2 m		6.34-10
NMS Group 3	6A	60.00	yes	5.00	65.00	1.05	5.00	20.00	0.50	streambank	5.50
	6B	60.00	yes	5.00	65.00	1.05	5.00	20.00	0.50	streambank	5.50
	9	30.00	yes	4.00	34.00	1.04	4.00	25.00	0.50	floodplain	6.67
	14	20.00	yes	4.00	3.00	1.01	3.00	20.00	0.50	floodplain	7.13
	20	22.00	yes	8.00	35.00	1.00	8.00	25.00	2.00	floodplain	8.00
	Average	38.40		5.20	40.40	1.03	5.00	22.00	0.80		6.56
	Range	20-60 cm		4-8 cm	3-65 cm	1-1.05	3-8 cm	20-25%	0.5-2 m		5.5-8
NMS Group 4	16	2.00	no	0.00	30.00	1.31	14.00	65.00	1.00	floodplain	11.50

Table 3. Plant species data summarized for 4 groups. Groups were derived from figure 5. Species data are percent cover.

Group 1	SCMI2	ELAC	SALE	POBAT	CACA11	VEAM2	CANE2	GLST	MYLA	JUEN	CAUT	CAPR5	ELPA3	AGST2	VIOLA	JUAR4	HIMO2	EQAR	CAAQ	EP2SPP	PHAR3	SPDO	JUBA	GALIUM	MIMUL
mean	44.12	9.07	6.63	3.16	2.93	2.45	1.50	1.31	1.09	0.77	0.47	0.35	0.32	0.28	0.28	0.28	0.19	0.17	0.16	0.14	0.12	0.12	0.10	0.05	0.04
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
max	100.00	85.00	50.00	45.00	50.00	30.00	25.00	20.00	15.00	20.00	20.00	15.00	10.00	10.00	15.00	15.00	10.00	10.00	15.00	5.00	15.00	10.00	15.00	5.00	5.00

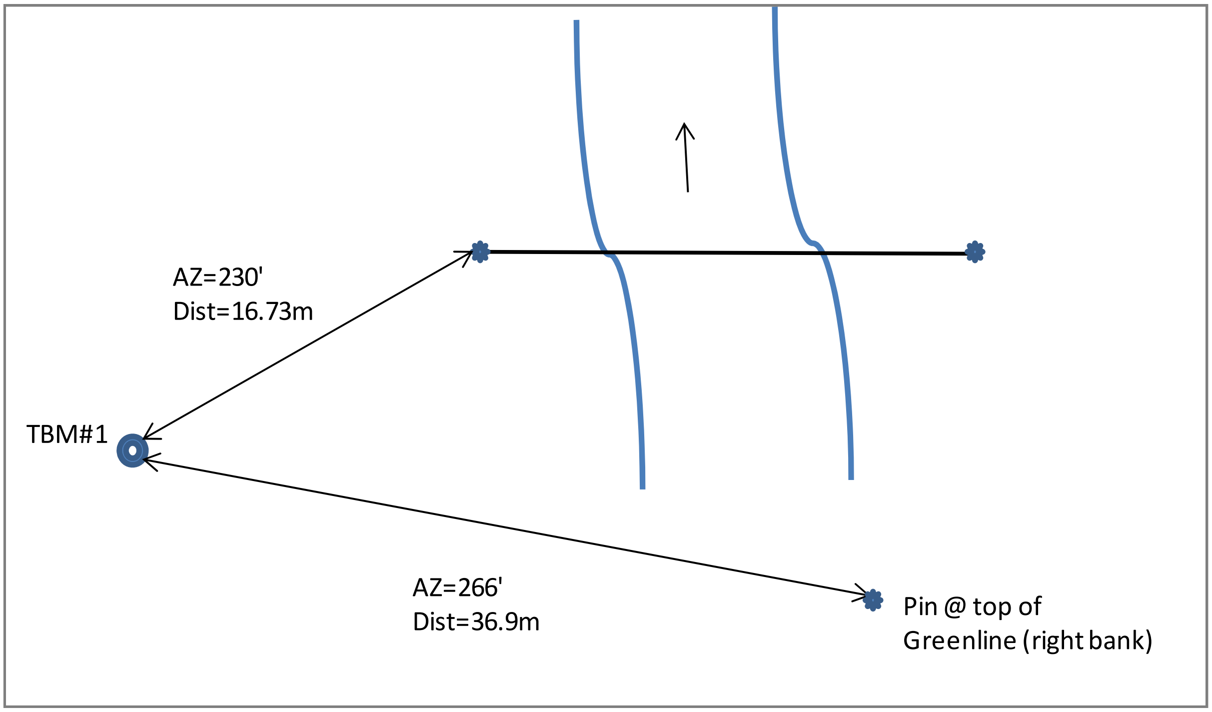
Group 2	CAAQ	CAUT	VIOLA	SCMI2	PHAR3	VEAM2	CANE2	GLST	MYLA	SPDO	SALE	MIMUL	CASI2	GALIUM	JUBA	JUEN	CACA11	HIMO2	EP2SPP
mean	69.91	6.45	1.44	1.03	0.73	0.66	0.63	0.34	0.32	0.25	0.23	0.22	0.13	0.13	0.11	0.06	0.04	0.03	0.01
min	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
max	100.00	45.00	30.00	15.00	50.00	20.00	15.00	15.00	15.00	20.00	10.00	5.00	20.00	10.00	5.00	10.00	5.00	5.00	1.00

Group 3	CANE2	SCMI2	MYLA	VEAM2	PHAR3	JUEN	GLST	CASI2	CAPR5	JUBA	SALE	JUAR4	EQAR	EP2SPP	GALIUM
mean	64.16	3.18	0.91	0.89	0.29	0.28	0.26	0.24	0.19	0.18	0.16	0.10	0.08	0.06	0.01
min	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
max	95.00	35.00	10.00	20.00	15.00	10.00	5.00	10.00	10.00	10.00	10.00	10.00	1.00	5.00	1.00

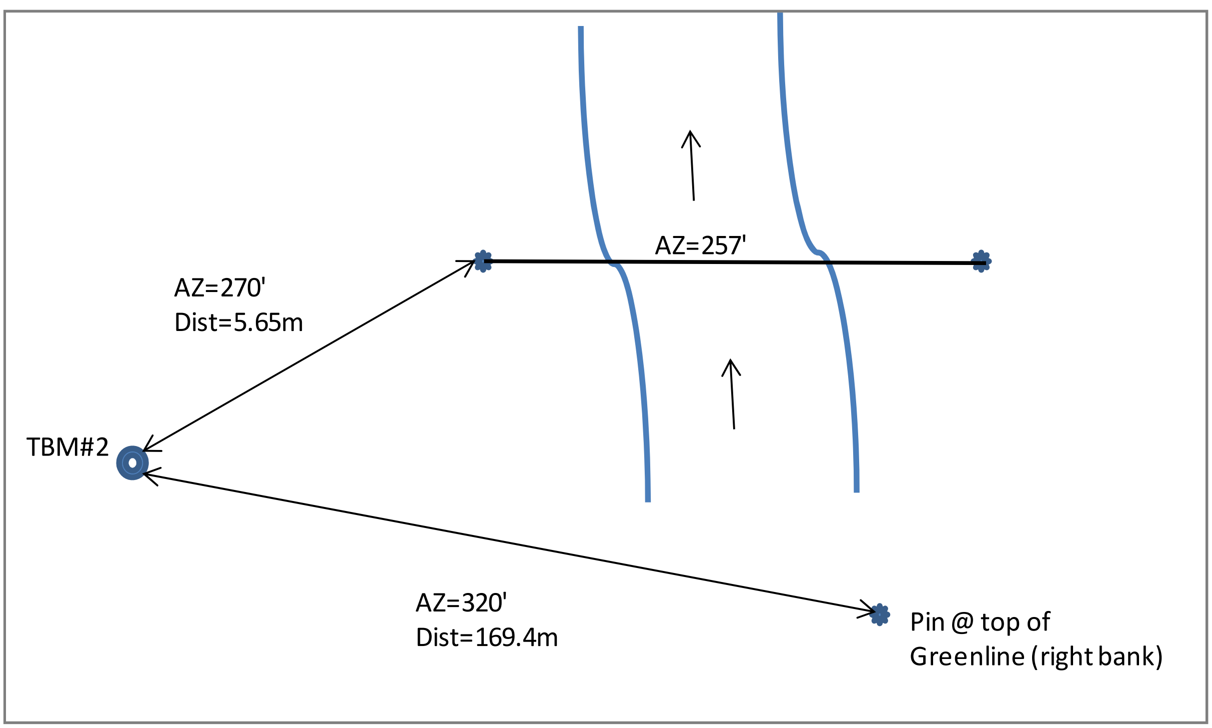
Group 4	CAUT	CANE2	CASI2	SCMI2	JUBA	SALE	JUAR4	MYLA	VIOLA
mean	35.83	9.10	4.00	2.83	1.27	0.33	0.03	0.03	0.03
min	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
max	60.00	30.00	35.00	15.00	10.00	5.00	1.00	1.00	1.00

3. Maps

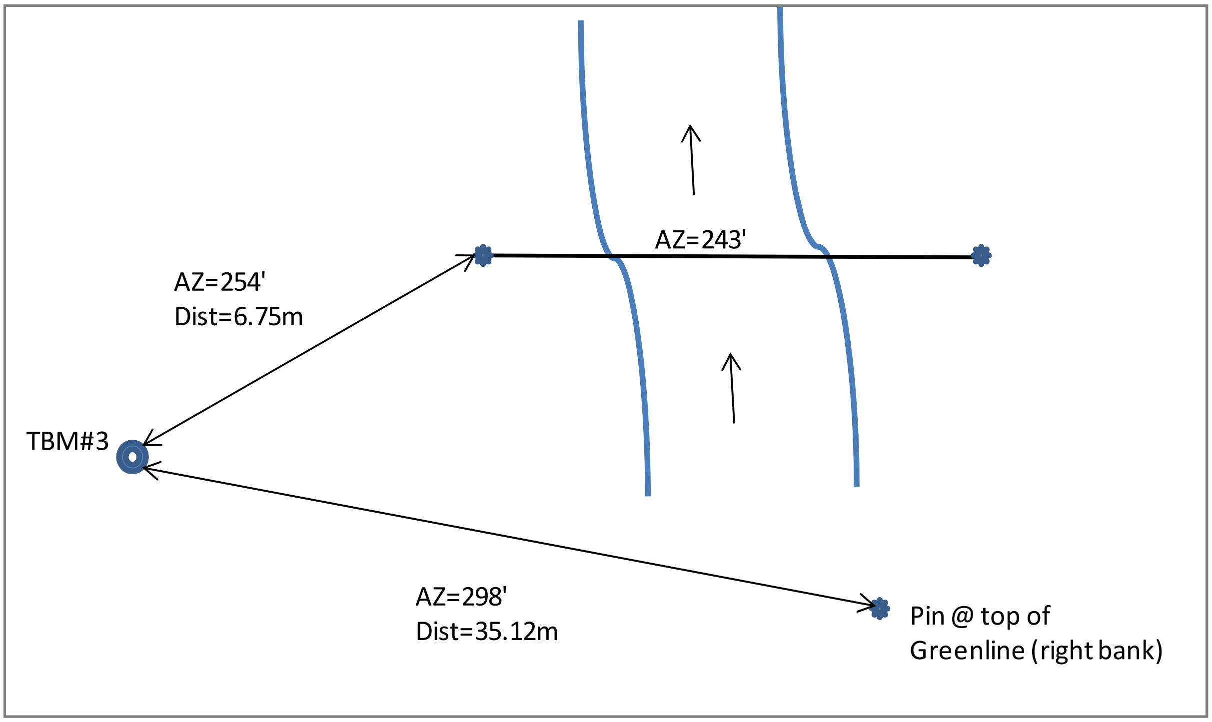
Sevenmile Site 1 Map



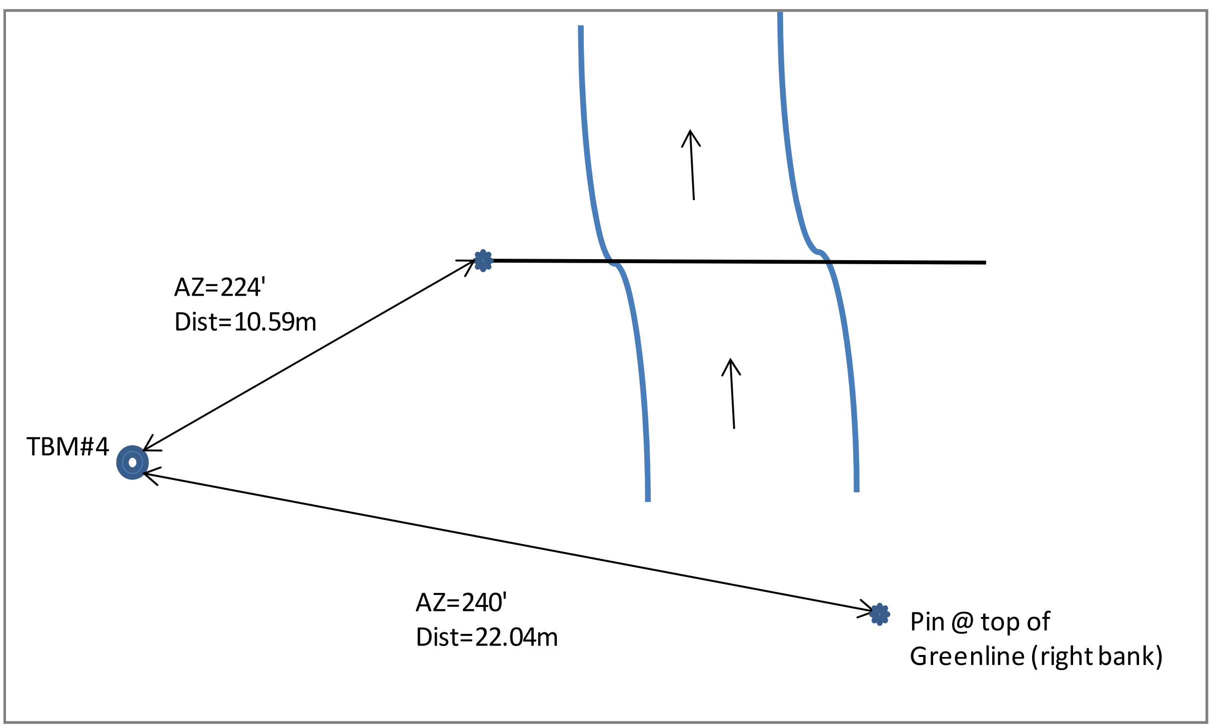
Sevenmile Site 2 Map



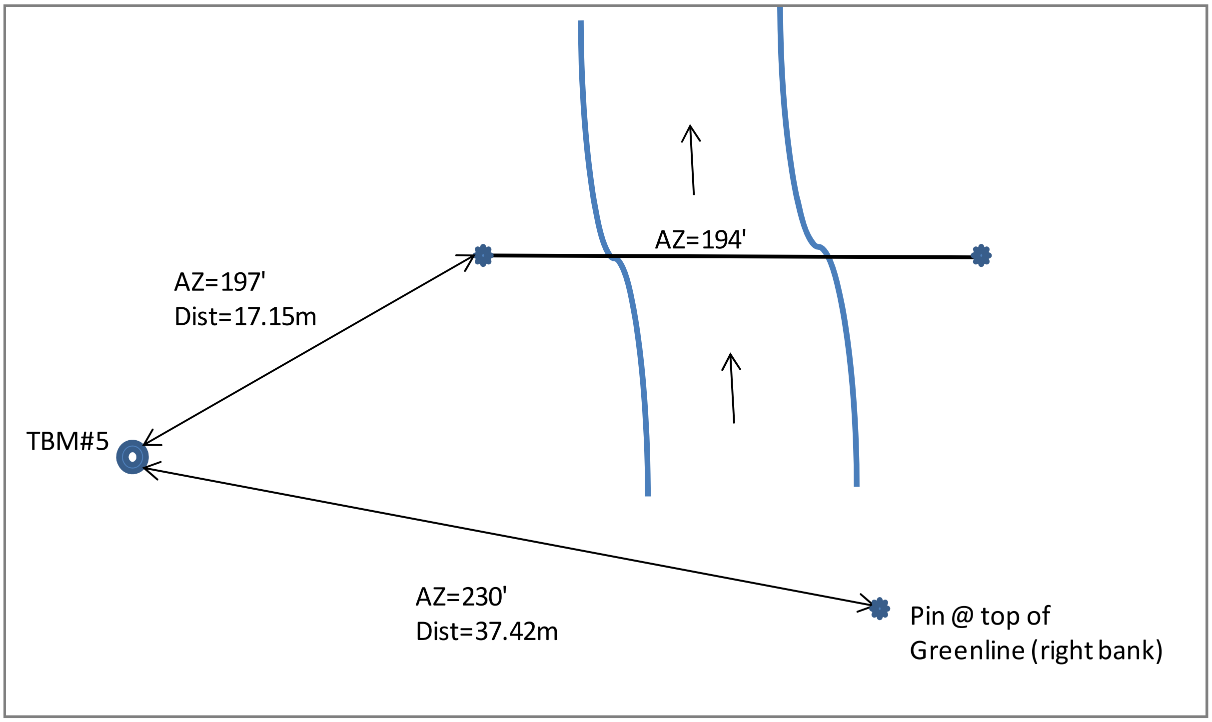
Sevenmile Site 3 Map



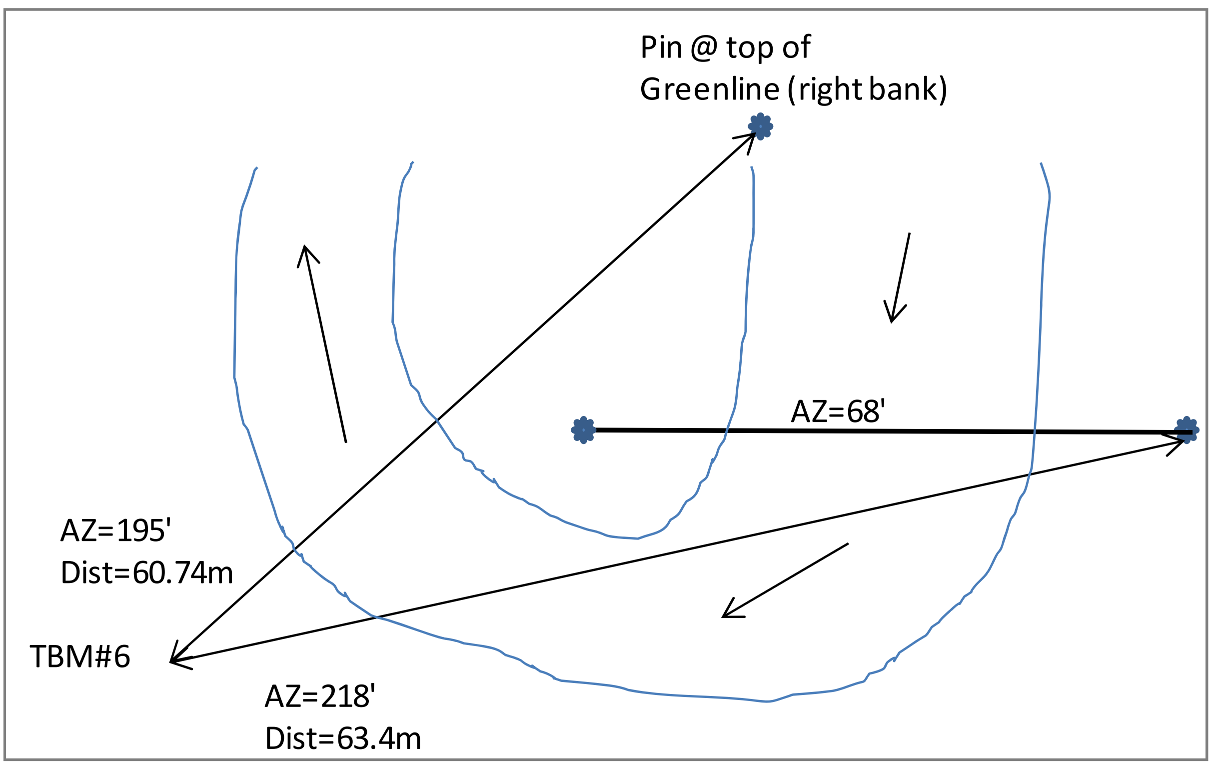
Sevenmile Site 4 Map



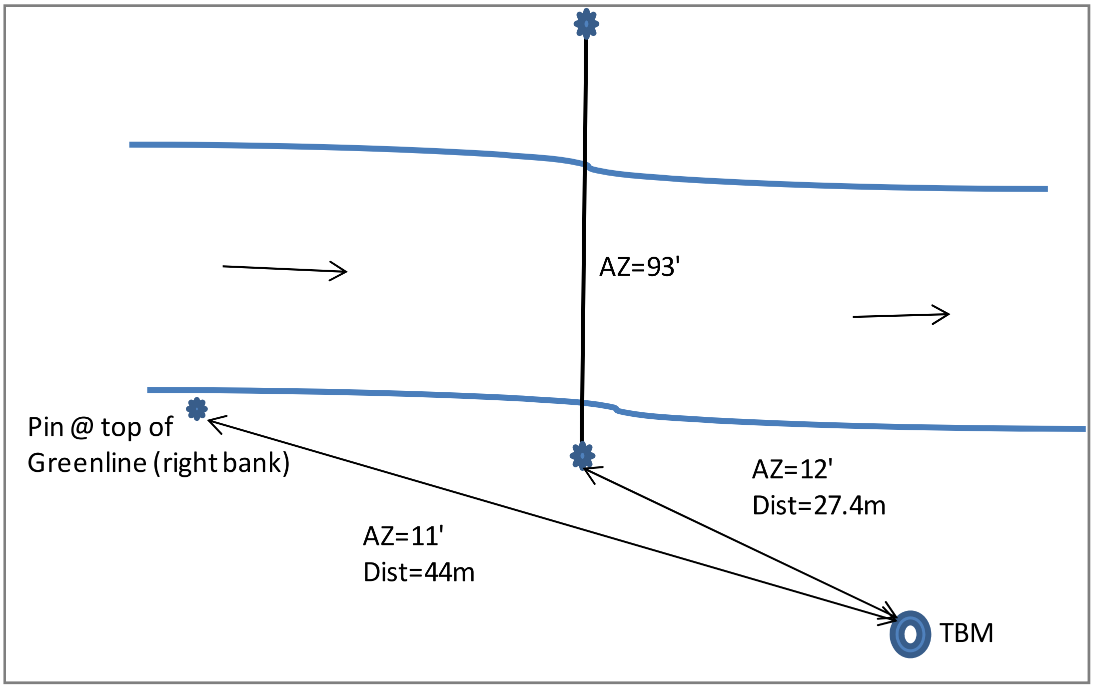
Sevenmile Site 5 Map



Sevenmile Site 6 Map



Crooked Creek Site Map



4. GPS Points

Name	UTM	NAD27		LAT/LON	WGS84
SM BM1	10	575866	E	42.70214	N
		4728155	N	-122.07369	W
SM BM2	10	575917	E	42.70026	N
		4727946	N	-122.07310	W
SM BM3	10	576038	E	42.69745	N
		4727636	N	-122.07166	W
SM BM4	10	576000	E	42.69385	N
		4727235	N	-122.07218	W
SM BM5	10	576065	E	42.69163	N
		4726990	N	-122.07142	W
SM BM6	10	576182	E	42.69020	N
		4726832	N	-122.07001	W
CC BM1	10	586883	E	42.62506	N
		4719724	N	-121.94049	W

BM= Benchmark

5. Photos

All sites photo 1 is looking across stream cross section and photo 2 is looking perpendicular to the stream cross section, unless otherwise noted.

Sevenmile Site 1


Photo 1


Photo 2

Sevenmile Site 2


Photo 1


Photo 2

Sevenmile Site 3

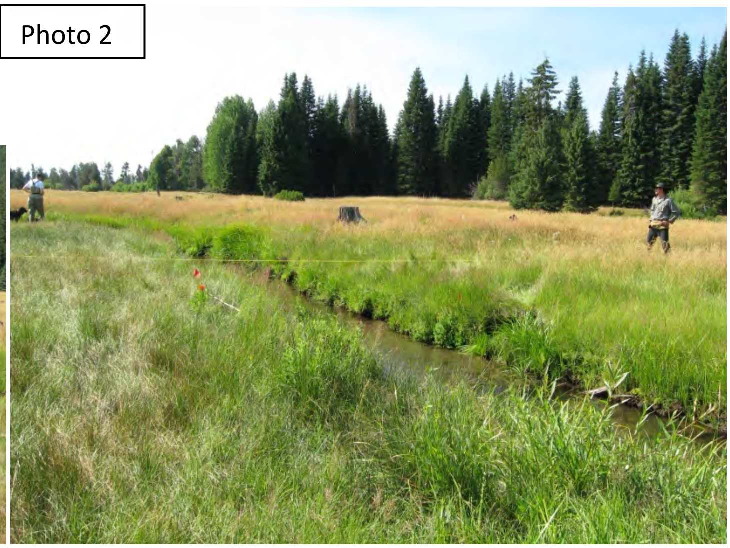

Photo 1


Photo 2

Sevenmile Site 4

Photo 2


Photo 1



Sevenmile Site 5

Photo 1

Photo 2

Sevenmile Site 6

Photo 1

Photo 2

Site 6 photo 3 is an image of the left bank stream cross section pin location. Site 6 photo 4 is an image of the bench mark location on the north side of the property fence. The actual site is located by the standing dead tree in the photo.

Crooked Creek Site Photos

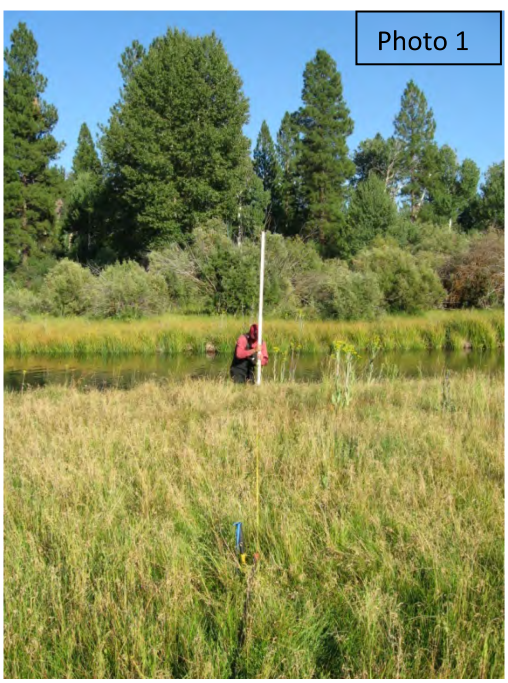
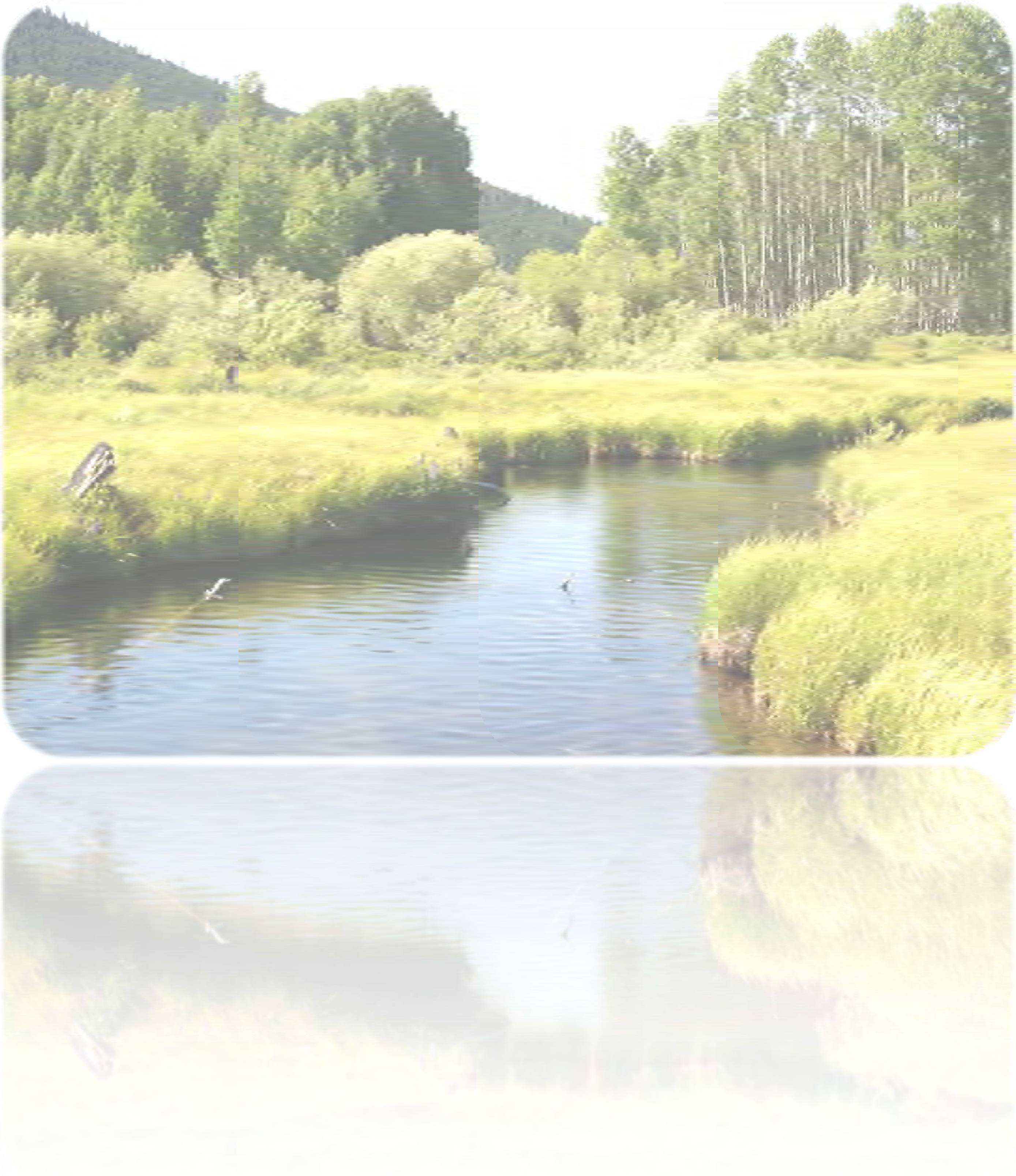


Photo 3

Photo 4

Crooked Creek photo 3 is looking upstream on the right bank photo 4 is the site overview.



Appendix 4

Final Wood River Conservation Effects Assessment Project Report

Introduction to Appendix 4

Appendix 4 contains two parts. Appendix 4, Part 1 contains a report from the Oregon State University (OSU) team's Chanda Engel, who examined specific pasture production questions (that is, dry matter percentage and yield).

Part 2 of the appendix is a copy of Chanda Engel's report on forage quality using wet chemistry methods. Ms. Engel's wet chemistry work was undertaken as a check on the Near Infrared Reflectance Spectroscopy (NIRS) forage quality piece of the Wood River CEAP study.

Appendix 4

Final Wood River Conservation Effects Assessment Project Report

Part 1

Summary of Wood River CEAP Forage Dry Matter Percentage and Yeild: Outside the Exclosures (grazed areas) for the Year 2008

By Chanda L. Engel
OSU Klamath Basin Research and Extension Center

Forage Yeild --Statistical Analysis

The percentage forage dry matter (% DM) and forage dry matter yield (lb/acre), for the grazed areas (outside of the exclosures) of the wood river pastures clipped in 2008, were analyzed by repeated measures using the MIXED procedure of SAS, as described by Littell et al. (1998). All covariance structures were modeled in the initial analysis. The indicated best fit covariance structures, Toeplitz and Compound Symmetry, were used for analyzing the forage dry matter percent and forage dry matter yield, respectively. The model for both included treatment (irrigated or non-irrigated), time (month, May through October), and treatment x time. When a significant ($P \leq 0.05$) effect was detected, for any of the main effects and interactions, LSMeans were separated by the PDIFF option of SAS.

Effect of Treatment

The main effect of treatment answers the question: *Are there differences in forage moisture (% dry matter) and forage yield (lb/acre of available forage dry matter) due to the two water management treatments, Irrigated (Irr) or Non-irrigated (NonIrr), in the presence of grazing?*

Both forage dry matter (DM) Percent and forage DM yield varied significantly ($P < 0.01$) by water management treatment in the grazed areas of the wood river pastures. Both the percentage DM and forage DM yeild were greater ($P \leq 0.01$) for the NonIrr than the

Irr treatment pastures (50.97 and 42.36 ± 1.12%, and 2878.63 and 2304.0 ± 115.2 lb/acre, respectively; Figure 1A and 2A).

Effect of Time

The main effect of time answers the question: *Does forage moisture (% dry matter) and forage yield (lb/acre of available forage dry matter) change over time, from May through October, in the presence of grazing?*

Both forage dry matter (DM) Percent and forage DM yield varied significantly ($P < 0.01$) over time. The forage DM percentage increased ($P \leq 0.05$) linearly over time, from may (29.6 ± 1.94%) through July (44.2 ± 1.94%), remained similar ($P > 0.05$) through September, and increased ($P < 0.01$) in October (64.0 ± 1.94%; Figure 3A). Forage DM yield (lb/acre) increased ($P < 0.01$) from May (1561.5 ± 199.5 lb/acre) to June (3079.9 ± 199.5 lb/acre), remained similar ($P > 0.05$) through August (3090.3 ± 199.5 lb/acre) and declined ($P = 0.03$) in both September (2501.7 ± 199.5 lb/acre) and October (1885.5 ± 199.5 lb/acre; Figure 4A).

Effect of Treatment x Time

The interaction of treatment with time answers the question: *Does forage moisture (% dry matter) and forage yield (lb/acre of available forage dry matter), change similarly over time (the growing season May through October) among water management treatments (Irr compared to NonIrr)?*

There was no significant ($P = 0.26$) interaction of irrigation treatment over time for forage DM yield (Figure 5A). However, forage DM percentage was different ($P < 0.01$) over time. The change in forage DM percent was similar between Irr and NonIrr treatments from may through July, however from August through October the NonIrr pastures had a steeper increase (*$P < 0.01$)* over time compared to Irr (Figure 6A).

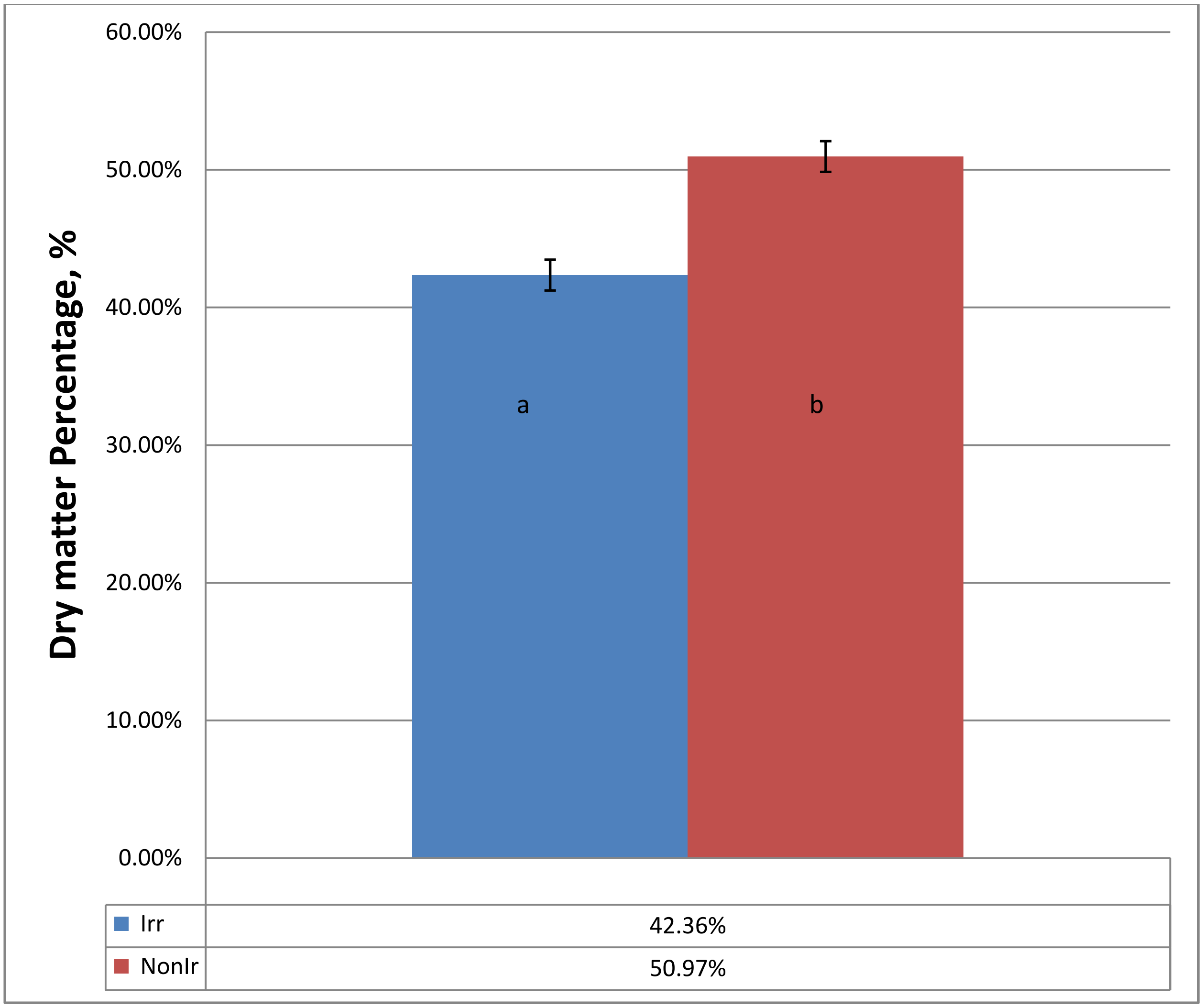


Figure 1A. The main effect of irrigation treatment, irrigated (Irr) or non-irrigated (NonIrr), on forage dry matter percent in the presence of grazing, for pastures clipped in the Wood River basin in 2008. Means (± SEM; 1.12%) with different letters are different (*P* < 0.01).

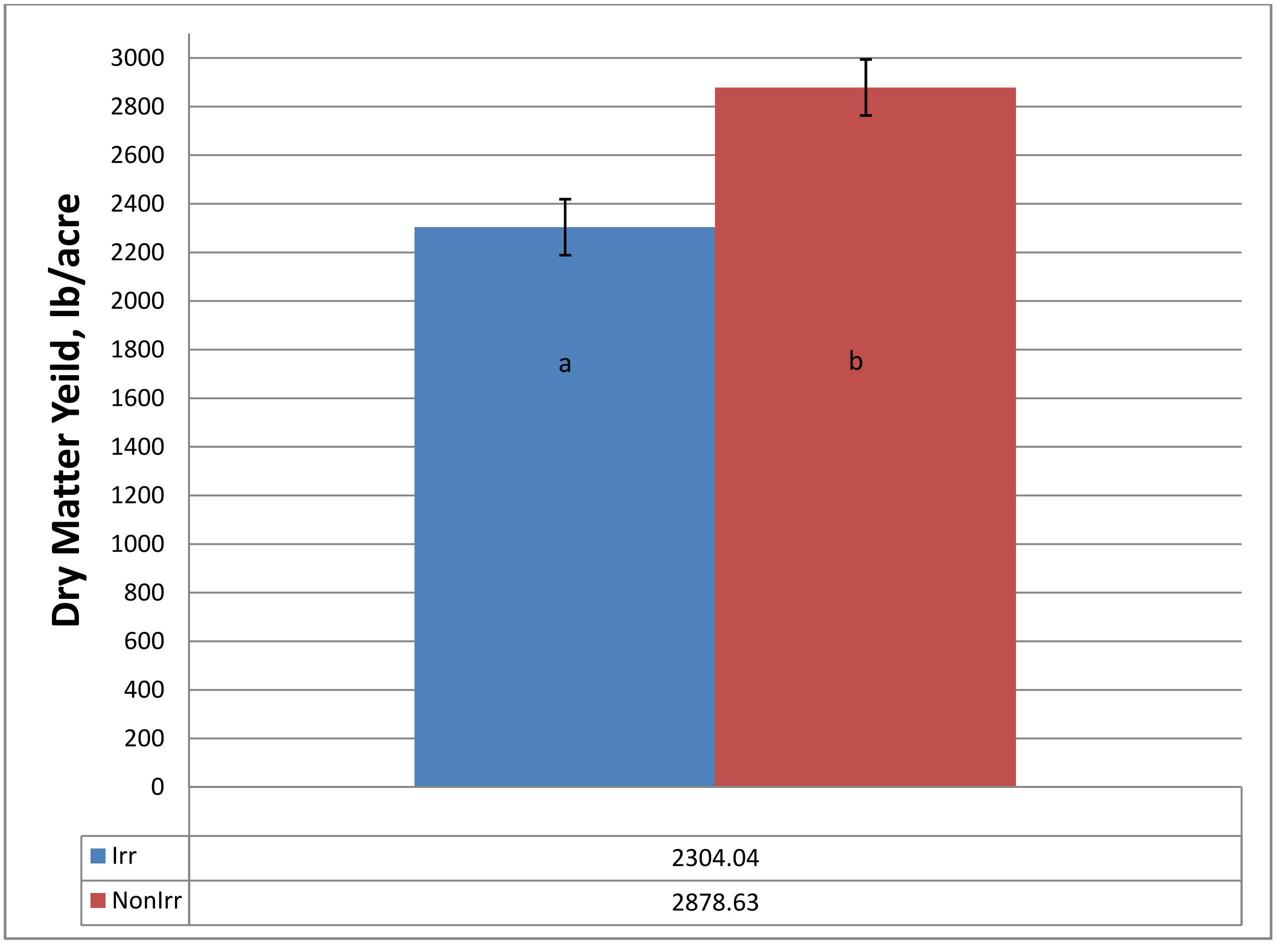
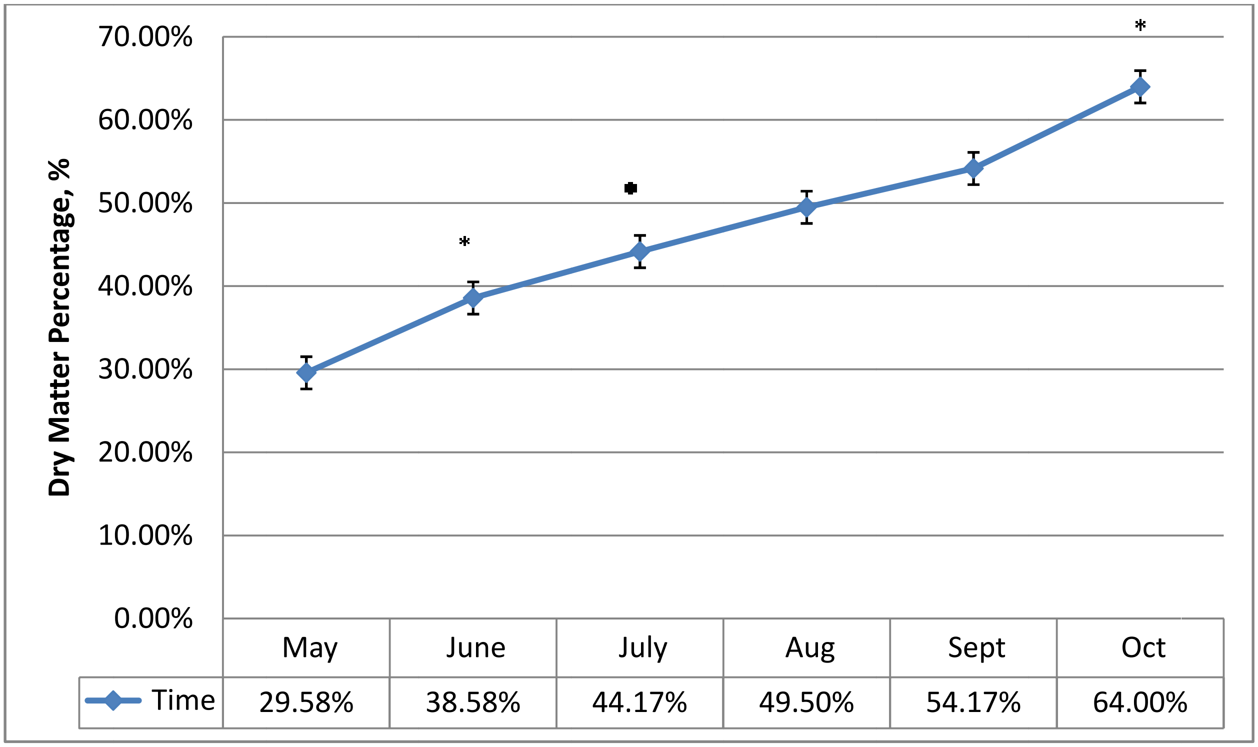


Figure 2A. The main effect of irrigation treatment, irrigated (Irr) or non-irrigated (NonIrr), on forage dry matter yield (lb/acre) in the presence of grazing, for pastures clipped in the Wood River basin in 2008. Means (± SEM; 115.2 lb/acre) with different letters are different (*P* < 0.01).

61 

62 Figure 3A. The main effect of time (May through October), on forage dry matter percent, in the presence of grazing, for pastures clipped in the Wood River basin in 2008. Means (± SEM; 1.94%) with asterisks (*), above the value, are different (*P ≤ 0.05*) than the preceding month.

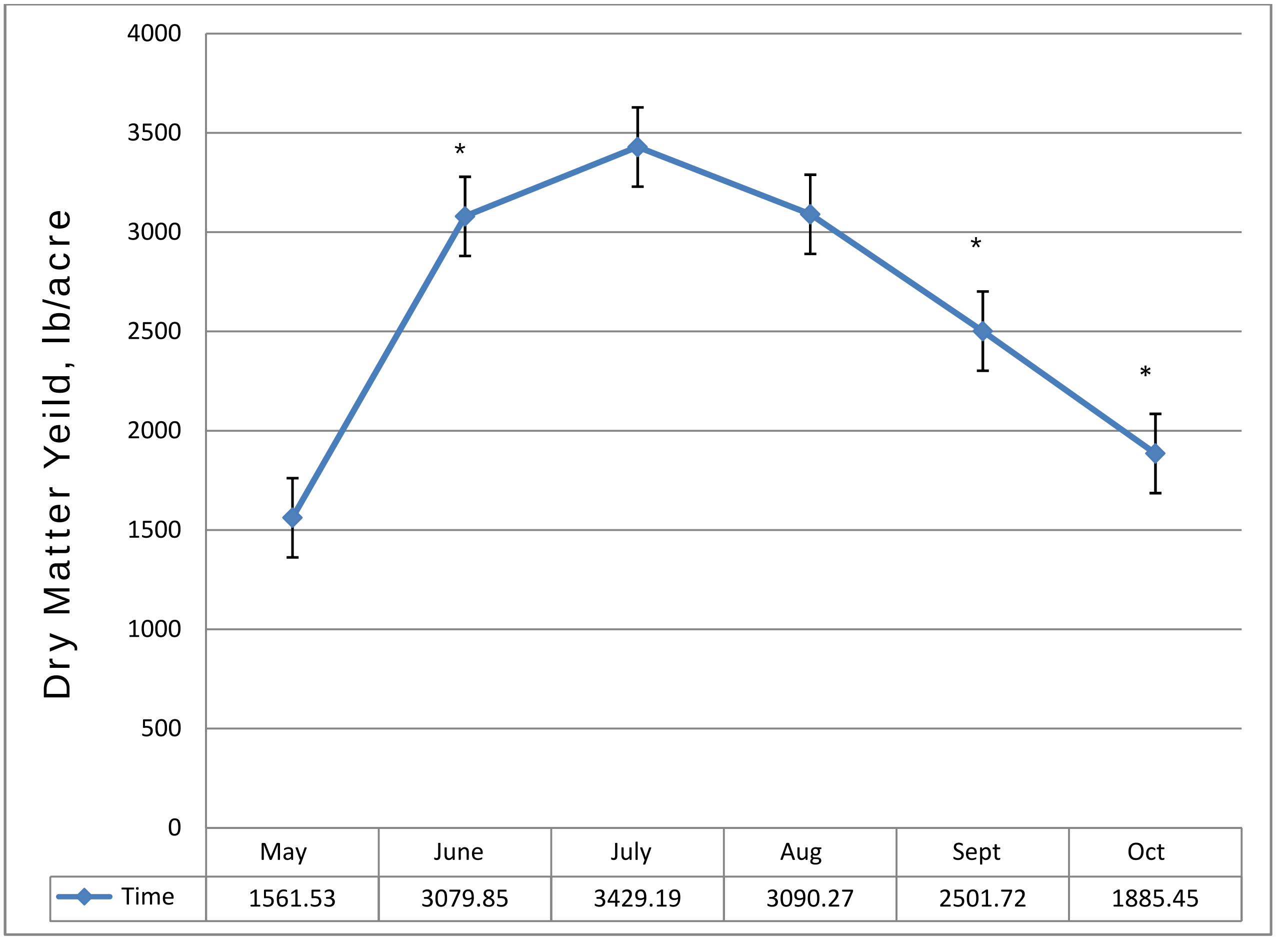
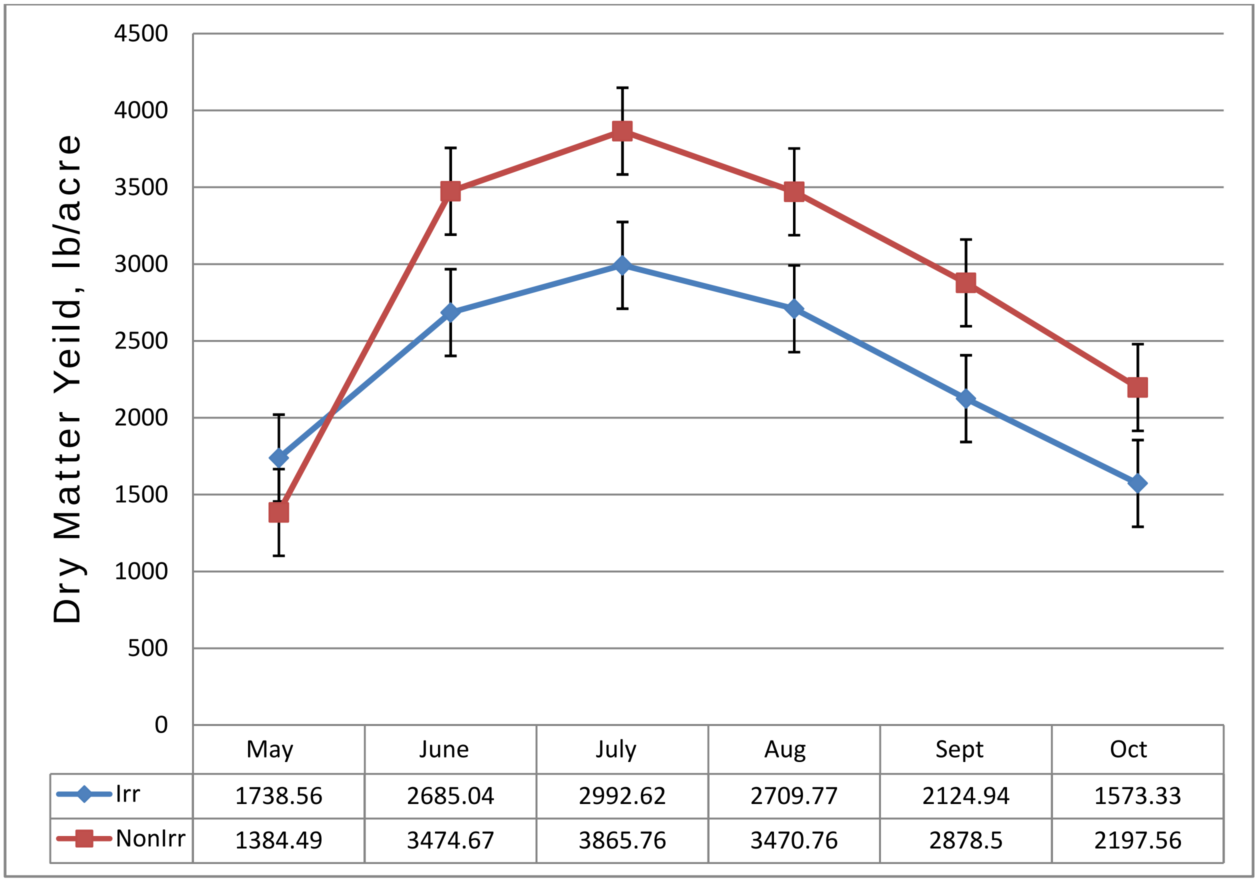
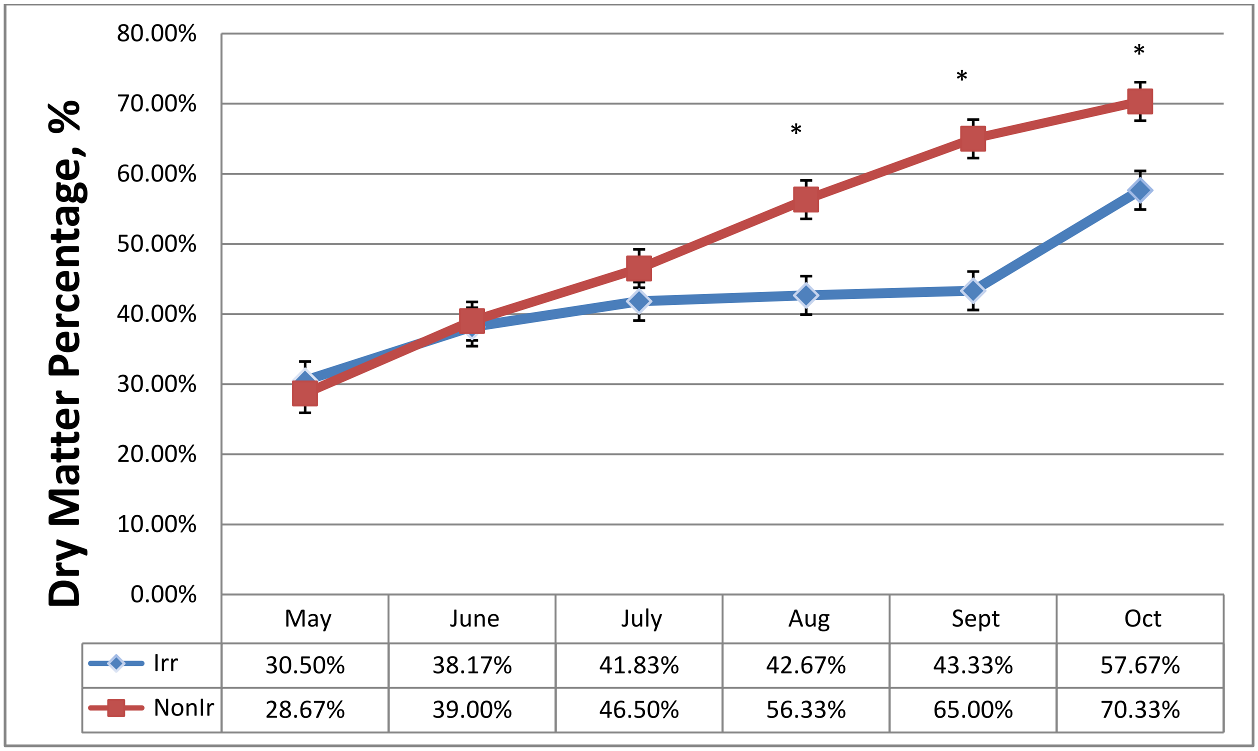


Figure 4A. The main effect of time (May through October), on forage dry matter yield (lb/acre), in the presence of grazing, for pastures clipped in the Wood River basin in 2008. Means (± SEM; 199.5 lb/acre) with asterisks (*), above the value, are different (*P* ≤ *0.05*) than the preceding month.



	May	June	July	Aug	Sept	Oct
Irr	1738.56	2685.04	2992.62	2709.77	2124.94	1573.33
NonIrr	1384.49	3474.67	3865.76	3470.76	2878.5	2197.56

Figure 5A. The interaction of treatment, irrigated (Irr) or non-irrigated (NonIrr), with time, month (May through October), on forage dry matter yield (lb/acre), in the presence of grazing, for pastures clipped in the Wood River basin in 2008. Between Irr and NonIrr treatments, means (± SEM; 282.19 lb/acre) with asterisks (*), above the value, are different (*P ≤ 0.05*).



	May	June	July	Aug	Sept	Oct
Irr	30.50%	38.17%	41.83%	42.67%	43.33%	57.67%
NonIr	28.67%	39.00%	46.50%	56.33%	65.00%	70.33%

Figure 6A. The interaction of treatment, irrigated (Irr) or non-irrigated (NonIrr), with time, month (May through October), on forage dry matter percent, in the presence of grazing, for pastures clipped in the Wood River basin in 2008. Between Irr and NonIrr treatments, means (± SEM; 2.74%) with asterisks (*), above the value, are different (*P ≤ 0.05*).

Appendix 4

Final Wood River Conservation Effects Assessment Project Report

Part 2

Summary of Wood River CEAP Wet Chemistry Forage Quality Data, for both Inside (ungrazed) and Outside (grazed) the exclosures, for the Year 2008

By Chanda L. Engel
OSU Klamath Basin Research and Extension Center

Wet Chemistry Data --Statistical Analysis

The Wood River wet chemistry forage quality data for 2008 was analyzed by ANOVA as a 2 x 2 factorial using the GLM procedures of SAS with the main effects of Location (n = 2, inside or outside the exclosure) and treatment (n = 2; irrigated or Non-irrigated). The model, with 23 df, included the independent variables: Location, treatment, time (n = 6 months; May, June, July, August, September, and October), location x treatment, location x time, treatment x time, and location x treatment x time. Pasture group (n = 12, outside exlosure and n = 15, inside exclosure) was the experimental unit, and the residual experimental error, with 138 df, was the error term. When a significant ($P \leq 0.05$) effect was detected, for any of the main effects and interactions, LSMeans were separated by the PDIFF option of SAS.

Forage quality parameters measured and included in this analysis are crude protein [CP, % of Dry Matter (% of DM)], Acid Detergent Fiber (ADF, % of DM), Neutral Detergent Fiber (NDF, % of DM), Neutral Detergent Fiber disappearance at 48 hrs (NDFd48, % of NDF), Invitro True Dry Matter Disappearance at 48 hrs (IVTDMD, % of DM), and Ash (% of DM). Calculated quality parameters include Total Digestible Nutrients [TDN; TDN = 88.9-(ADF*.779); % of DM].

Effect of Location

The main effect of location answers the question: *Are there differences in forage quality due to the absence (inside the exclosure; IN) of grazing or the presence (outside the exclosure; OUT) of grazing?*

All forage quality parameters were significantly ($P < 0.001$) different between the IN and OUT locations. Inside the enclosures' had lower CP (9.28 ± 0.16 %), IVTDMD (72.95 ± 0.42 %), NDFd (56.49 ± 0.62 %), and TDN (59.69 ± 0.18 %); compared to OUT (10.41 ± 0.18, 75.58 ± 0.47, 59.72 ± 0.69, and 61.81 ± 0.20%; respectively; Figure 1). The ADF, NDF, and Ash were greater (37.50 ± 0.23 and 34.77 ± 0.25%, 61.91 ± 0.40 and 60.28 ± 0.45%, and 9.88 ± 0.19 and 8.79 ± 0.21%; respectively) IN compared to OUT, respectively.

<u>Effect of Treatment</u>

The main effect of treatment answers the question: *Are there differences in forage quality due to the two water management treatments, Irrigated (Irr) or Non-irrigated (NonIrr)?*

There was no effect ($P > 0.05$) of treatment for ADF, NDF, Ash, or TDN (36.33 and 35.94 ± 0.24%, 61.44 ± 0.42 and 60.75 ± 0.43%, 9.10 ± 0.20 and 9.57 ± 0.21%, and 60.60 ± 0.18 and 60.90 ± 0.19%; Irr and NonIrr, respectively; Figure 2). However, Irr had greater ($P < 0.01$) CP (10.38 ± 0.17%) and lower ($P < 0.01$) NDFd48 (56.66 ± 0.64%) and IVTDMD (73.27 ± 0.44%) compared to Non-Irr (9.31 ± 0.18%, 59.55 ± 0.66%, 75.25 ± 0.46%; CP, NDFd48, and IVTDMD, respectively).

Effect of Time

The main effect of time answers the question: *Does forage quality change over time, from May through October?*

Forage quality varied significantly *(P*< 0.01) over Time for all forage quality parameters with the exception of Ash (*P > 0.05;* Figure 3*)*. Wood River pastures had a CP content of 14.30 ± 0.30% in May which declined (*P* < 0.01) through July to 9.08 ± 0.30%. From July to September CP was similar (*P* ≥ 0.41) and then declined again in October (7.55 ± 0.30%; *P* < 0.01; Figure 4).

From May through June ADF was similar (*P* = 0.10), then increased (*P* < 0.01) from 33.68 ± 0.42% in June, to 35.97 ± 0.42% in July, and 37.32 ± 0.42% in August (Figure 5). ADF in September was similar (*P* = 0.88) to August. From August to October ADF increased (*P* < 0.01) to 39.74 ± 0.42%. The percent NDF was similar (*P* = 0.06; 56.25 ± 0.73%) in May and June and then increased (*P* = 0.01) in July (61.00 ± 0.73%) where it remained (*P* ≥ 0.09) through September (Figure 5). Then in October the percentage NDF increased (*P* < 0.01) to 65.46 ± 0.73%.

The NDFd is a measure of the digestibility of the NDF at 48hrs. The NDFd percentage started out in May at 61.55 ± 1.13% and remained similar (*P* ≥ 0.07) through July (Figure 5). In August the NDFd declined to 57.14 ± 1.13% and further to 51.98 ± 1.13% in September, where it remained (*P* = 0.17) through October.

ADF is used to calculate TDN, which is a measure of available energy. TDN is negatively correlated with ADF, as ADF increases TDN decreases. Thus it makes sense that the effects on TDN would inversely mirror ADF. The percent calculated TDN started at 63.42 ± 0.33% in May and remained similar ($P = 0.10$) through June (Figure 6). Then declined ($P \leq 0.02$) in both July (60.88 ± 0.33%) and August (59.83 ± 0.33%), remained similar ($P = 0.88$) in September and then declined further in October (57.94 ± 0.33%; $P < 0.01$). Another method for measuring available energy is through Invitro digestion, which uses a simulated rumen environment. Invitro true dry matter disappearance can be considered a measure of the energy value of a feedstuff. The Wood River samples started out with an IVTDMD of 78.09 ± 0.78% in May, remained similar ($P = 0.67$) through June and decreased ($P \leq 0.01$) July through September (69.86 ± 0.78%; Figure 6).

<u>Effect of Location x Treatment</u>

The interaction of location with treatment answers two questions: *1. Is there a difference in forage quality due to Irr or NonIrr water management treatments in the absence of grazing (IN)? 2. Is there a difference in forage quality due to Irr or NonIrr water management in the presence of grazing (OUT)?*

Water management treatments IN, did not differentially ($P \geq 0.55$) influence the CP (9.74 ± 0.22 and 8.82 ± 0.24%), NDFd (55.22 ± 0.84 and 57.76 ± 0.90%), IVTDMD (71.66 ± 0.58 and 74.23 ± 0.62%), or Ash (9.66 ± 0.26 and 10.10 ± 0.28%) forage quality parameters, for Irr and NonIrr, respectively. However, water management, IN, did influence the percent fiber (ADF and NDF), and thus the calculated percent TDN (*P* < 0.01; Figure 7). Both the ADF and NDF were greater (38.34 ± 0.31 and 36.66 ± 0.33%, and 63.20 ± 0.54 and 60.62 ± 0.58%; *P* ≤ 0.003*)* IN for Irr compared to NonIrr, respectively. Thus, TDN was lower (*P* = 0.003; 59.03 ± 0.24 and 60.34 ± 0.26%) IN for Irr and NonIrr, respectively.

Water management treatment OUT, did not have any significant (*P* > 0.05) influence on any of the forage quality parameters between Irr and NonIrr (11.02 and 9.81 ± 0.26%, 34.32 and 35.22 ± 0.36%, 59.68 and 60.88 ± 0.97%, 74.88 and 76.28 ± 0.67%, 62.16 and 61.46 ± 0.28%, 8.55 and 9.04 ± 0.30%; CP, ADF, NDF, NDFd, IVTDMD, TDN, and Ash, respectively; Figure 8).

<u>Effect of Treatment x Time</u>

The interaction of treatment with time answers the question: *Does forage quality change similarly over time (the growing season May through October) among water management treatments (Irr compared to NonIrr)?*

Whether pastures were managed with (Irr) our without (NonIrr) irrigation water, over the growing season, did not (*P* > 0.28) appear to affect the way forage quality changed over time for NDFd (Figure 9), IVTDMD (Figure 10), or Ash parameters. However, water management did appear to influence (*P* ≤ 0.01) the changes in CP, ADF, NDF, and TDN over the growing season (Figure 11, 12, and 10, respectively). The percent CP at the start of the growing season in May was greater (*P* = 0.007) for NonIrr compared to

Irr (15.13 ± 0.42 and 13.48 ± 0.43%, respectively). The percent CP decreased similarly (*P* ≥0.10) from June to July for Irr compared to NonIrr. However, from July through October, the percentage CP declined (*P* ≤ 0.01) more rapidly for the NonIrr pastures than the Irr pastures (Figure 11). Both ADF and NDF fiber values were greater (*P* ≤ 0.05) in May (33.86 ± 0.58 and 31.55 ± 0.60%; 57.73 ± 1.02 and 54.78 ± 1.05%, respectively) and lower in October (38.76 ± 0.58 and 40.72 ± 0.60%; 63.27 ± 1.02 and 67.66 ± 1.05%,respectively) for Irr compared to NonIrr, respectively. Thus, inversely TDN was lower (*P* = 0.01) in Irr than NonIrr pastures in May (62.52 ± 0.45 and 64.32 ± 0.47%, respectively) and greater (*P* = 0.02) in October (58.70 ± 0.45 and 57.18 ± 0.47%, respectively; Figure 10).

<u>Effect of Location x Time</u>

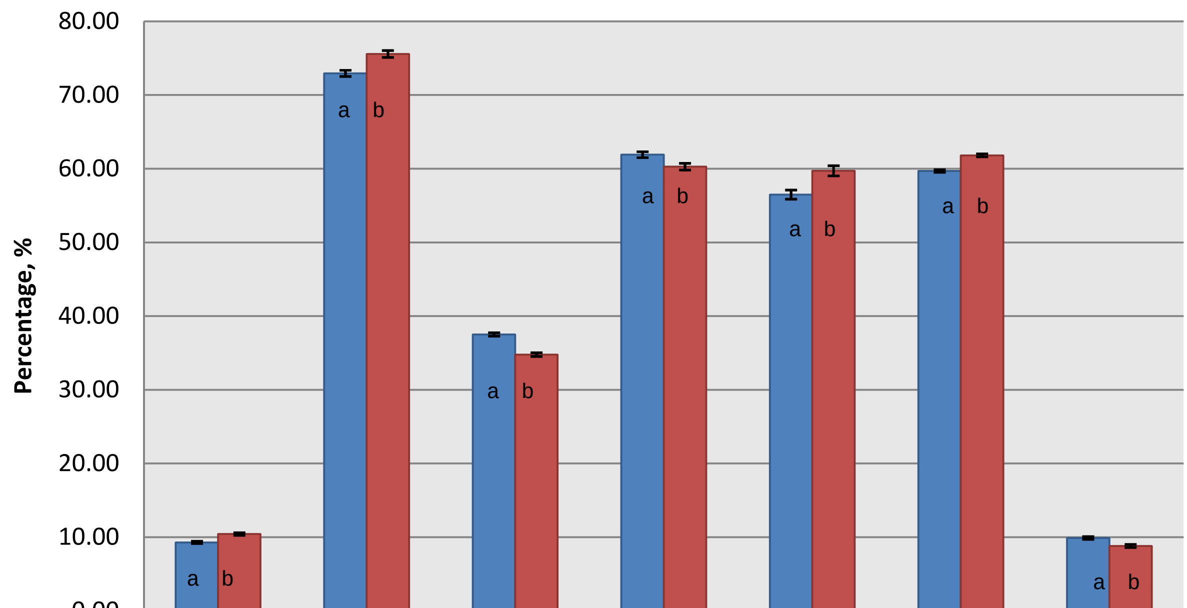
The interaction of location with time answers the question: *Does forage quality change similarly over the growing season (time) in the presence (OUT) or absence (IN) of grazing?*

Whether pastures were grazed (OUT) or not grazed (IN) did not have any effect (*P* ≥ 0.07) on the changes in forage quality over time (May through October) for CP (Figure 13), ADF, NDF, NDFd (Figure 14), TDN, or IVDTDMD (Figure 15).

<u>Effect of Location x Treatment x Time</u>

The interaction of location (IN or OUT) with treatment (Irr or NonIrr) and Time (May through October), answers the question: *Does forage quality change similarly over time* *in the prescence or absence of grazing and among the two water management treatments?*

There were no significant ($P \geq 0.64$) interactions detected for any of the forage quality parameters, thus water management and grazing do not appear to interact to affect changes in forage quality over the growing season (Figure 16, 17, 18 and 19).



	CP	IVTDMD	ADF	NDF	NDFd	TDN	Ash
in	9.28	72.95	37.50	61.91	56.49	59.69	9.88
out	10.41	75.58	34.77	60.28	59.72	61.81	8.79

Figure 1. Effect of location, inside (in) or outside (out) of the exclosure, on forage quality parameters. Means (± SEM), within each quality parameters, with different letters are different ($P < 0.05$)

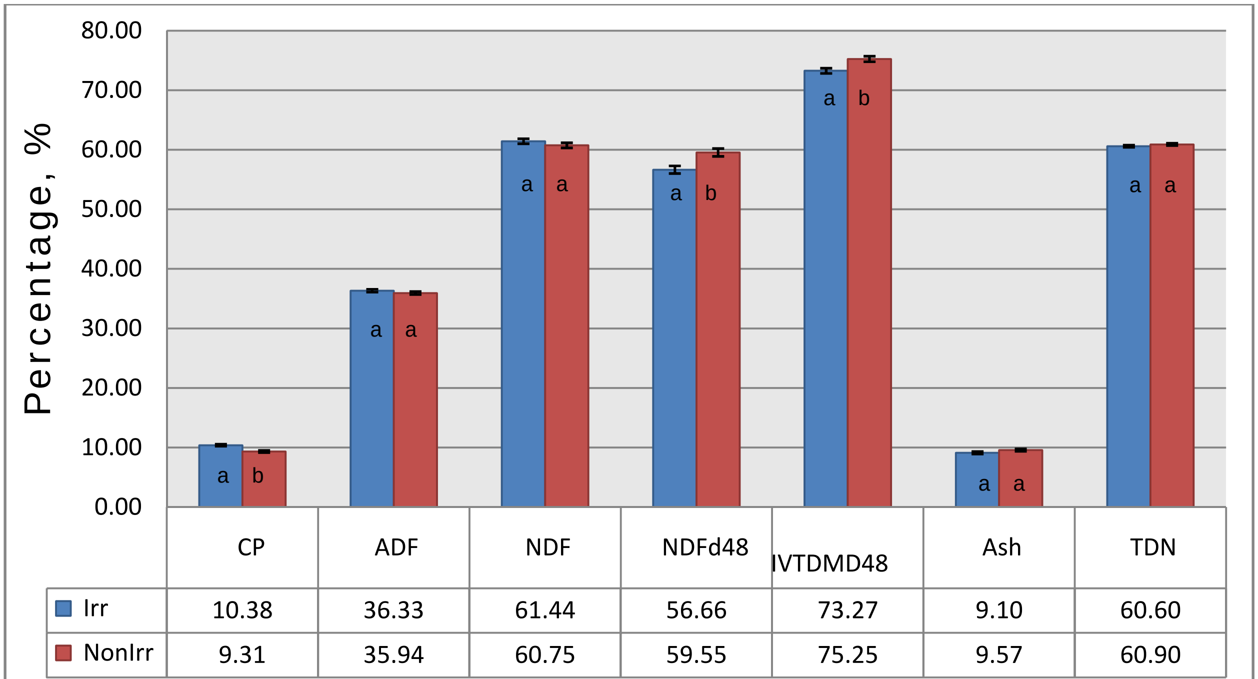


Figure 2. Effect of water management (means ± SEM; irrigation or non irrigation), on forage quality parameters. Means (± SEM), within each quality parameter, with different letters are different (*P* < 0.01)

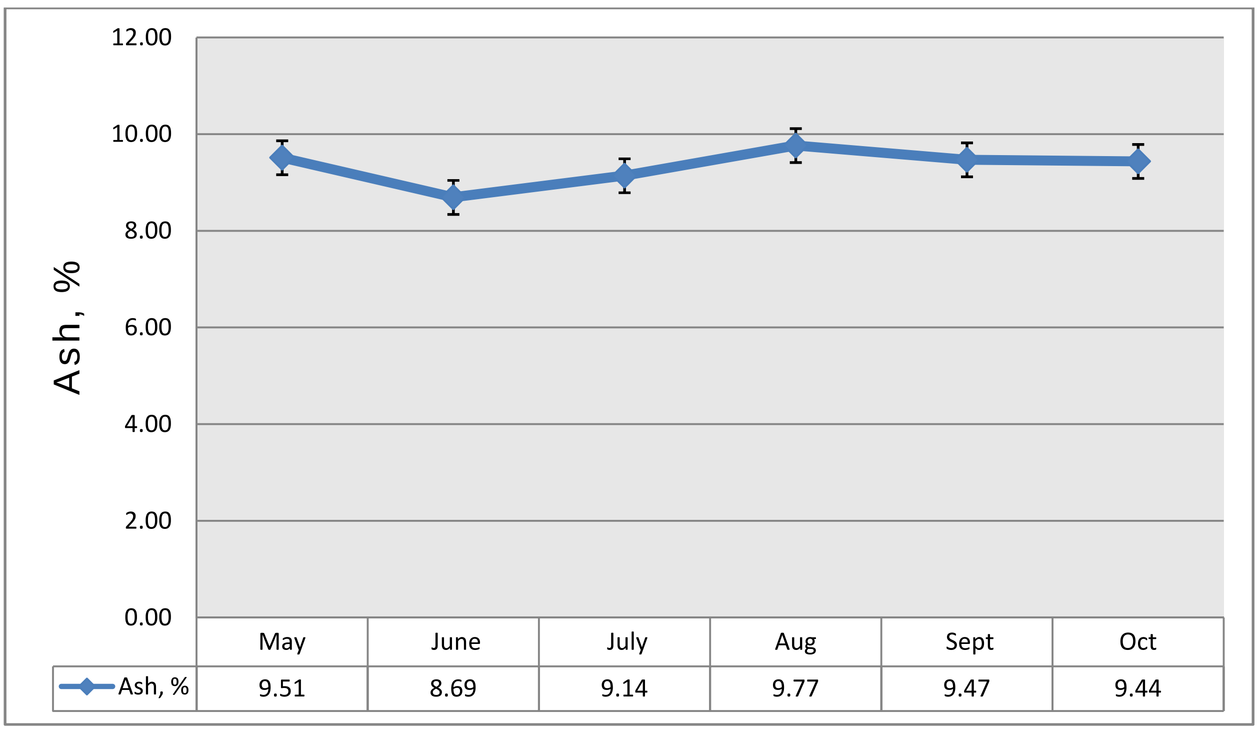


Figure 3. The main effect of time (month of clipping) on percentage (± SEM) Ash, from clipped samples, during the 2008 growing season, in the Wood River basin.

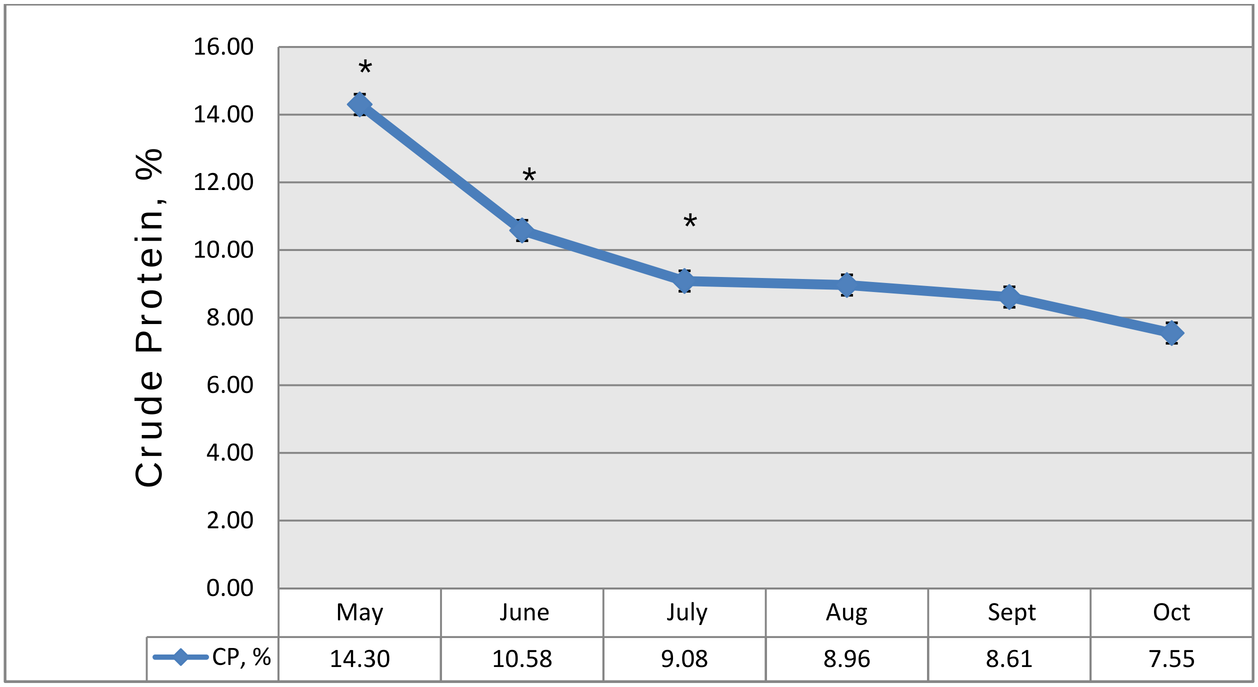
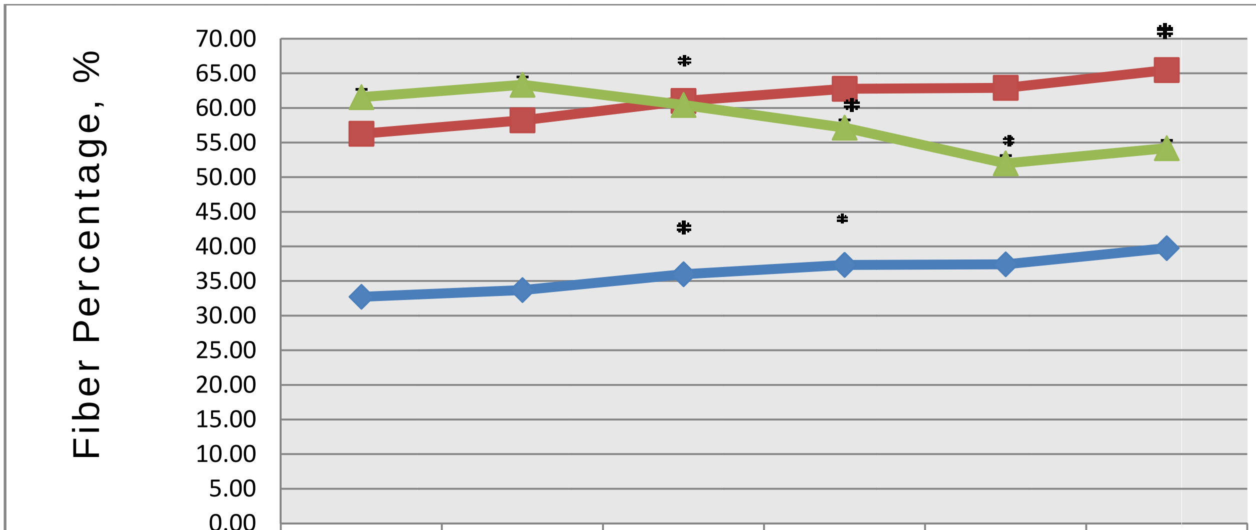


Figure 4. The main effect of time (month of clipping) on percentage (± SEM) Crude Protein (CP), from clipped samples, during the 2008 growing season, in the Wood River basin. Months with asterisks (*) above the value are different (*P* ≤0.05) than the preceding month.



	May	June	July	Aug	Sept	Oct
ADF, %	32.71	33.68	35.97	37.32	37.41	39.74
NDF, %	56.25	58.19	61.00	62.76	62.90	65.46
NDFd, % of NDF	61.55	63.34	60.42	57.14	51.98	54.18

Figure 5. The main effect of time (month of clipping) on percentage (± SEM) fiber (acid detergent fiber, ADF; neutral detergent fiber, NDF; neutral detergent fiber digestibility, NDFd), from clipped samples, during the 2008 growing season, in the Wood River basin. Months with asterisks (*) above the value are different ($P \leq 0.05$) than the preceding month.

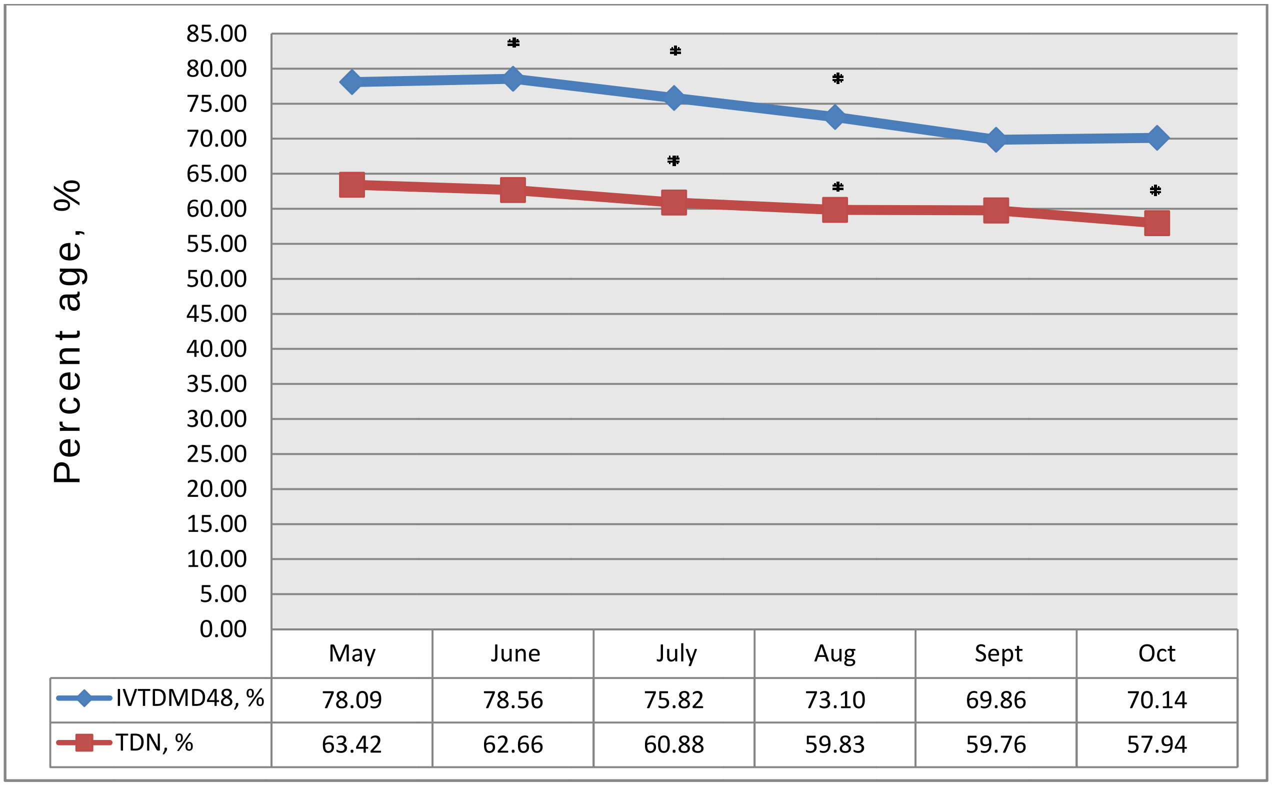
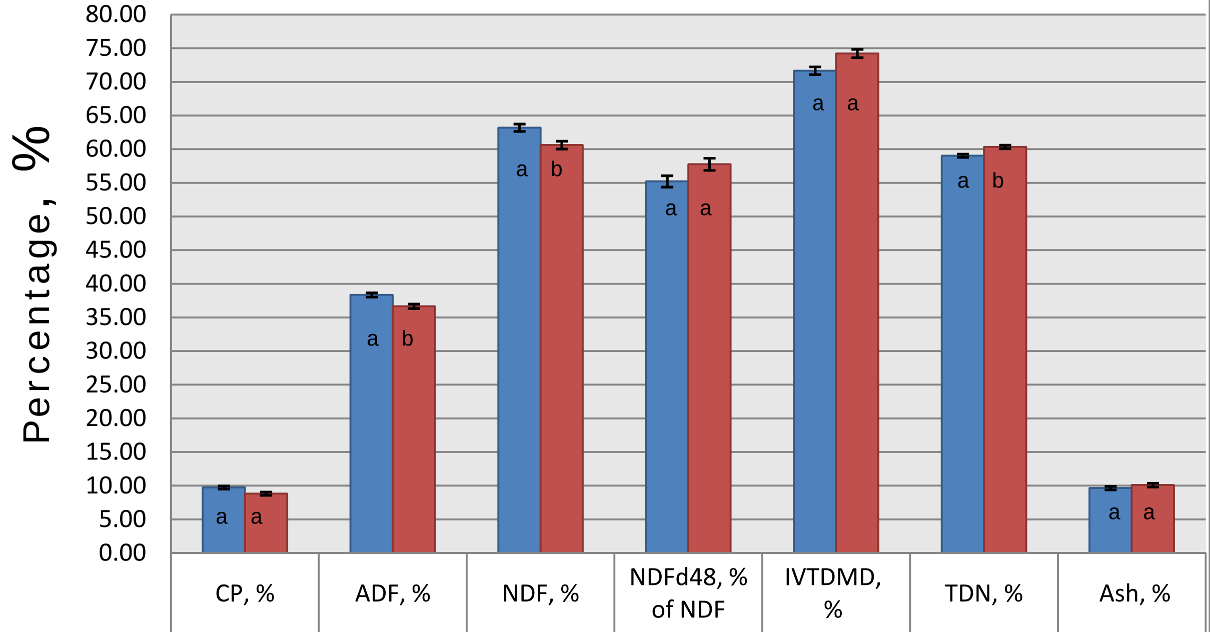
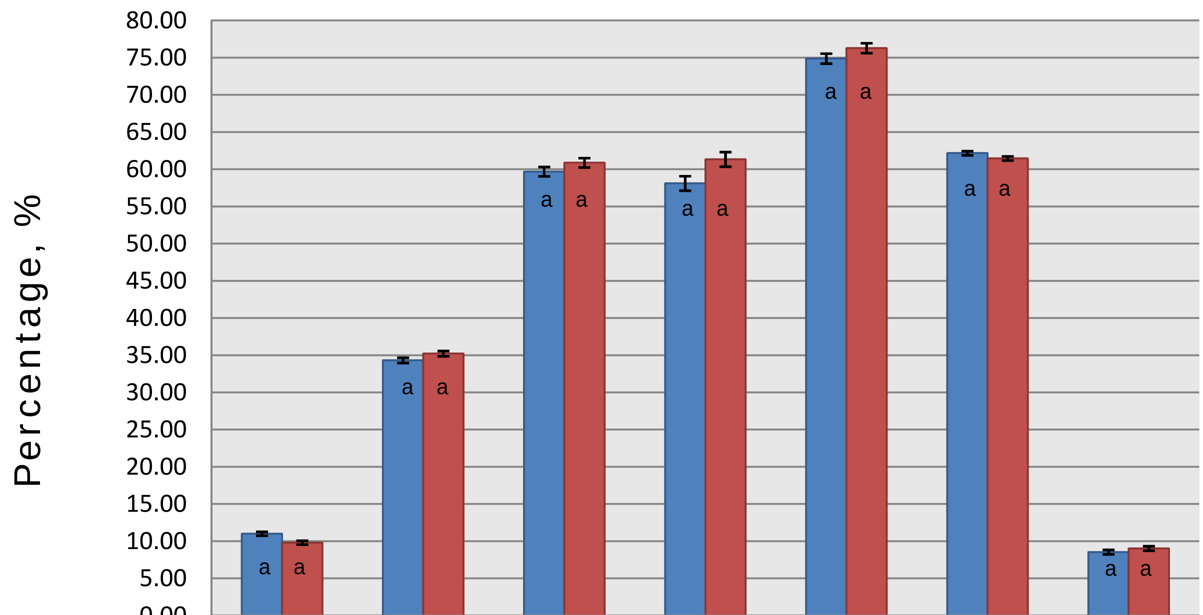


Figure 6. The main effect of time (month of clipping) on percentage (± SEM) invitro true dry matter disappearance at 48hr (IVTDMD48) and calculated total digestible nutrients (TDN) from clipped samples, during the 2008 growing season, in the Wood River basin. Months with asterisks (*) above the value are different (*P* ≤0.05) than the preceding month.



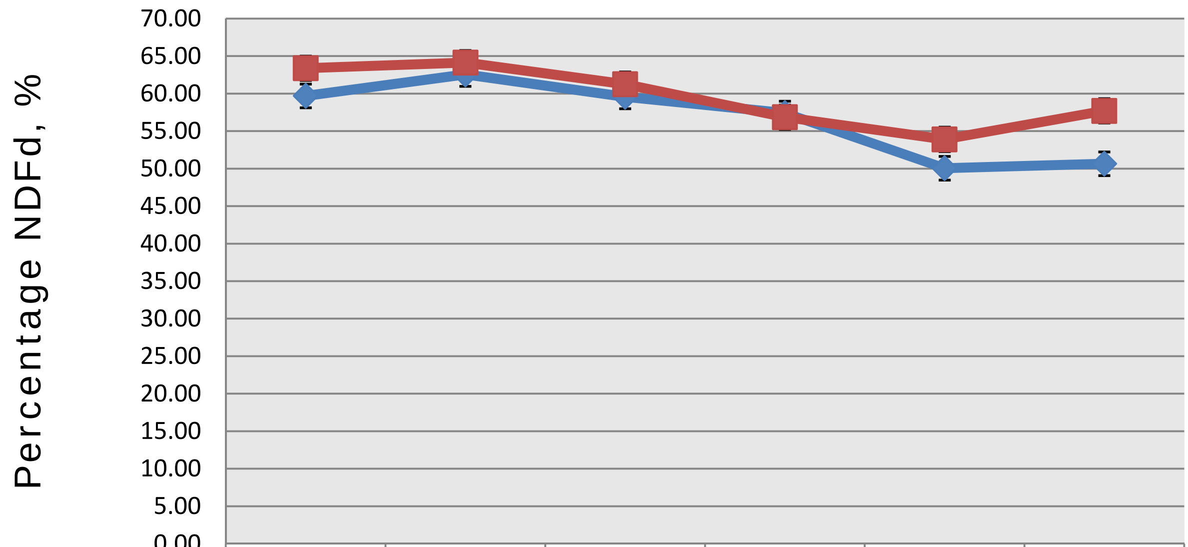
	CP, %	ADF, %	NDF, %	NDFd48, % of NDF	IVTDMD, %	TDN, %	Ash, %
in Irr	9.74	38.34	63.20	55.22	71.66	59.03	9.66
in NonIrr	8.82	36.66	60.62	57.76	74.23	60.34	10.10

Figure 7. The effect of treatment, irrigated (Irr) or non irrigated (NonIrr), by location, Inside the exclosure (In), on forage quality for clipped samples, during the 2008 growing season, in the Wood River basin. Means (± SEM), within each quality parameter, with different letters are different ($P \leq 0.05$).



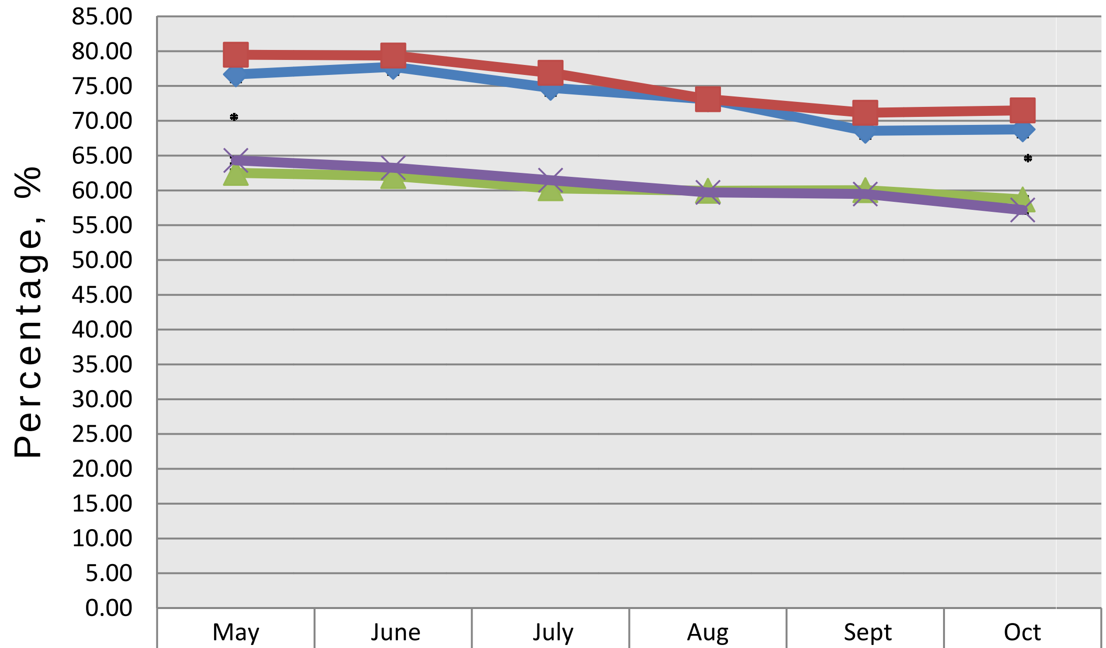
	CP, %	ADF, %	NDF, %	NDFd48, % of NDF	IVTDMD, %	TDN, %	Ash, %
out Irr	11.02	34.32	59.68	58.10	74.88	62.16	8.55
out NonIrr	9.81	35.22	60.88	61.33	76.28	61.46	9.04

Figure 8. The effect of treatment, irrigated (Irr) or non irrigated (NonIrr), by location, outside the exclosure (out), on forage quality for clipped samples, during the 2008 growing season, in the Wood River basin. Means (± SEM), within each quality parameter, with different letters are different (*P* ≤ 0.05).



	May	June	July	Aug	Sept	Oct
Irr NDFd	59.70	62.55	59.57	57.42	50.06	50.65
Non Irr NDFd	63.40	64.14	61.27	56.87	53.91	57.71

Figure 9. The interaction of treatment, irrigated (Irr) or non-irrigated (NonIrr), with time (month), on percentage Neutral detergent fiber digestibility (NDFd), for clipped samples, during the 2008 growing season, in the Wood River basin. Between Irr and NonIrr, for each forage quality parameter, months with asterisks (*) above the value are different ($P \leq 0.05$).



	May	June	July	Aug	Sept	Oct
Irr IVTDMD	76.68	77.75	74.74	73.10	68.57	68.78
Non Irr IVTDMD	79.50	79.38	76.90	73.10	71.15	71.49
Irr TDN	62.52	62.07	60.30	59.95	60.04	58.70
Non Irr TDN	64.32	63.25	61.46	59.71	59.48	57.18

Figure 10. The interaction of treatment, irrigated (Irr) or non-irrigated (NonIrr), with time (month), on percentage invitro true dry matter disappearance (IVTDMD) and total digestible nutrients (TDN), for clipped samples, during the 2008 growing season, in the Wood River basin. Between Irr and NonIrr, for each forage quality parameter, months with asterisks (*) above the value are different (*P* ≤0.05).

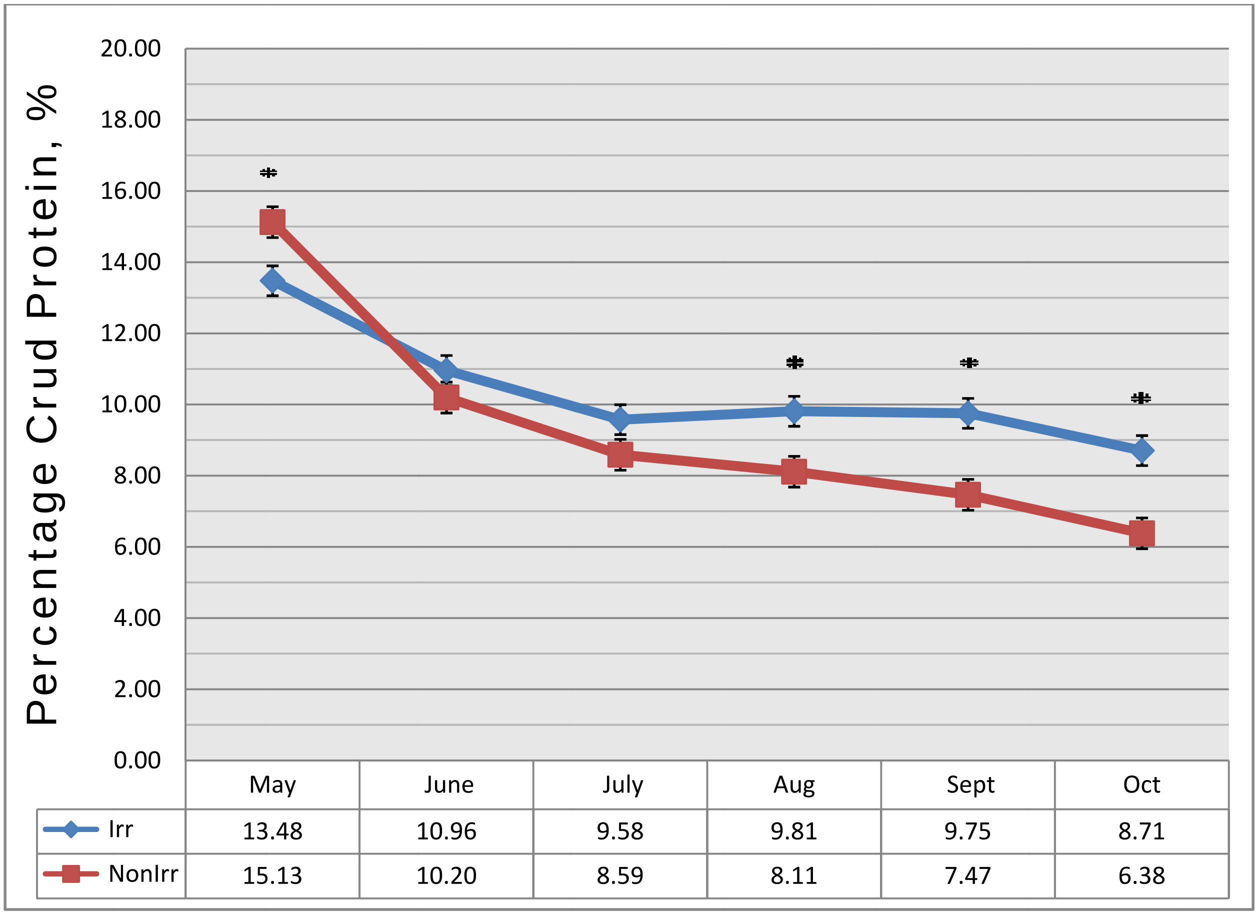
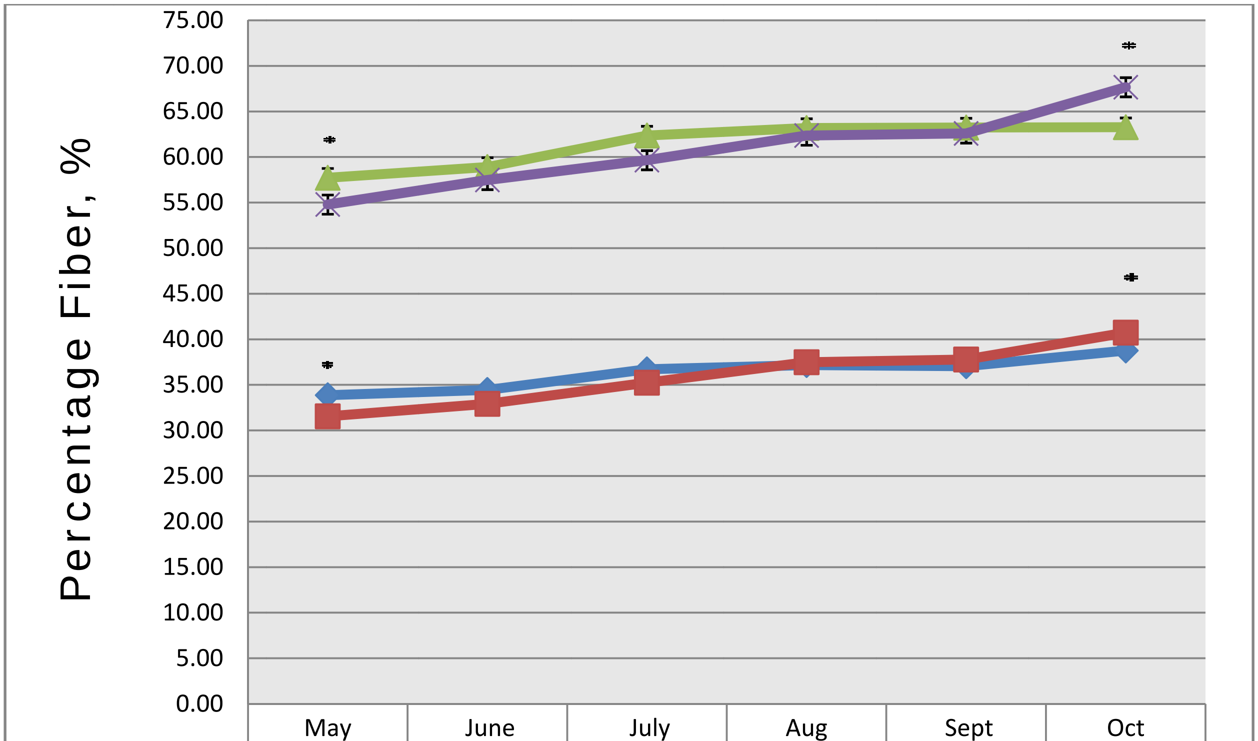


Figure 11. The interaction of treatment, irrigated (Irr) or non-irrigated (NonIrr), with time (month), on the percentage crude protein (CP), for clipped samples, during the 2008 growing season, in the Wood River basin. Between Irr and NonIrr, for each forage quality parameter, months with asterisks (*) above the value are different (*P* ≤0.05).



	May	June	July	Aug	Sept	Oct
Irr ADF	33.86	34.44	36.71	37.17	37.05	38.76
Non Irr ADF	31.55	32.92	35.22	37.47	37.77	40.72
Irr NDF	57.73	58.90	62.35	63.17	63.22	63.27
Non Irr NDF	54.78	57.48	59.65	62.35	62.58	67.66

Figure 12. The interaction of treatment, irrigated (Irr) or non-irrigated (NonIrr), with time (month), on the percentage acid detergent fiber (ADF) and neutral detergent fiber (NDF), for clipped samples, during the 2008 growing season, in the Wood River basin. Between Irr and NonIrr, among forage quality parameters, months with asterisks (*) above the value are different ($P \leq 0.05$).

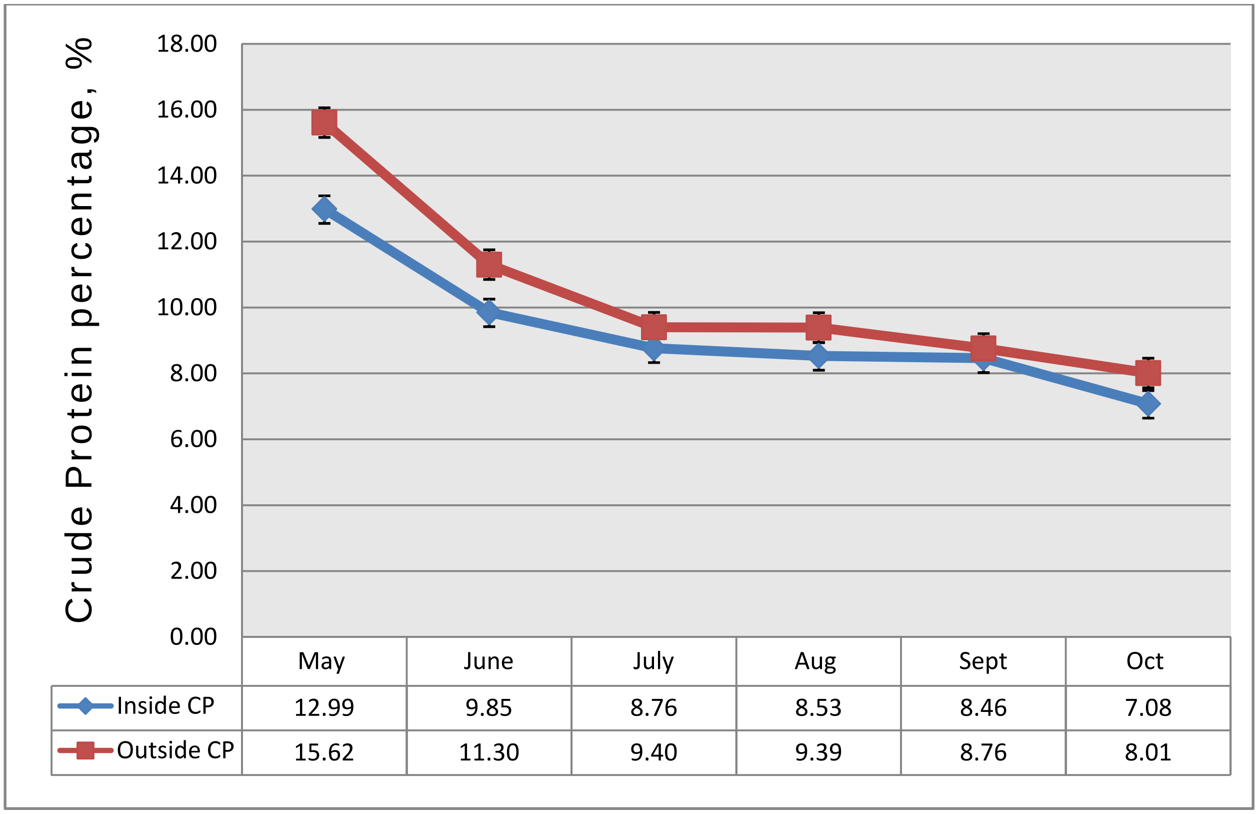
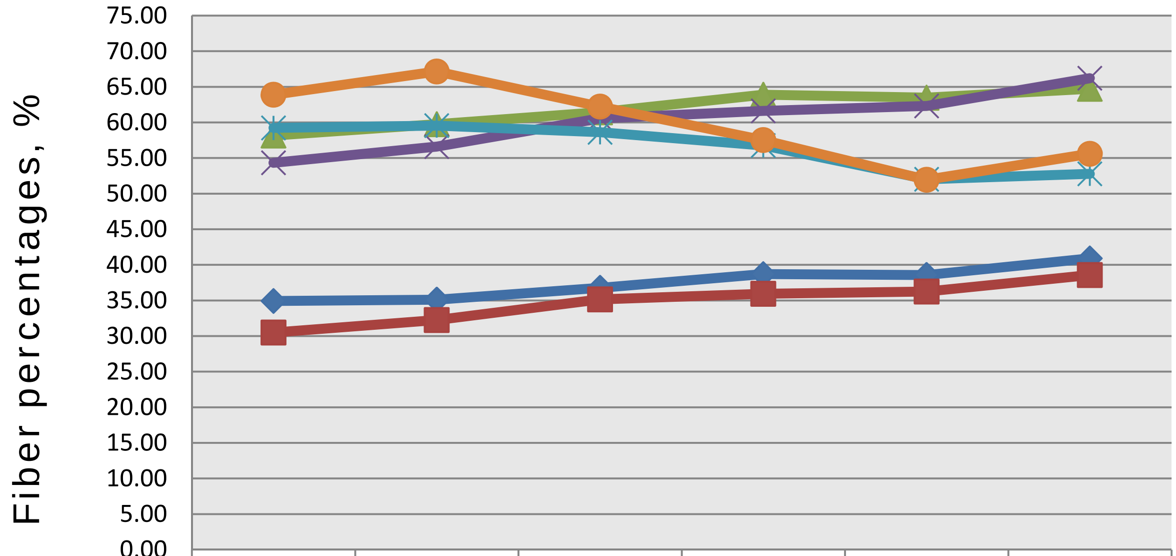
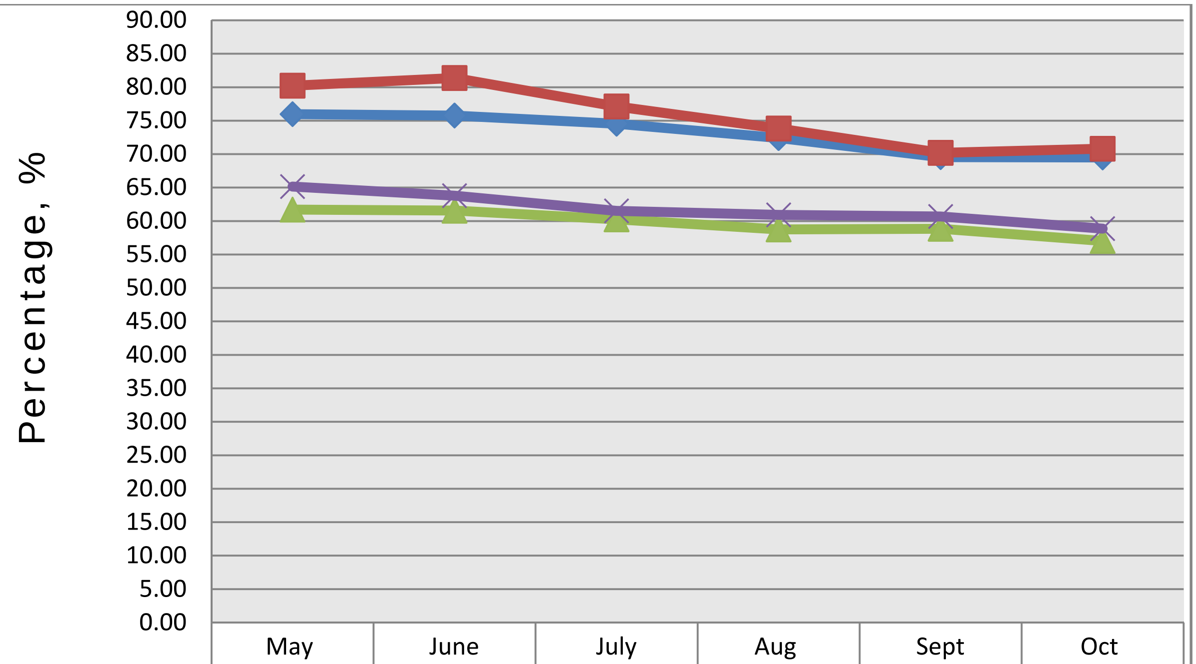


Figure 13. The interaction of location, Inside (ungrazed) or outside (grazed) of the exclosure, with time (month), on the percentage crude protein (CP), for clipped samples, during the 2008 growing season, in the Wood River basin.



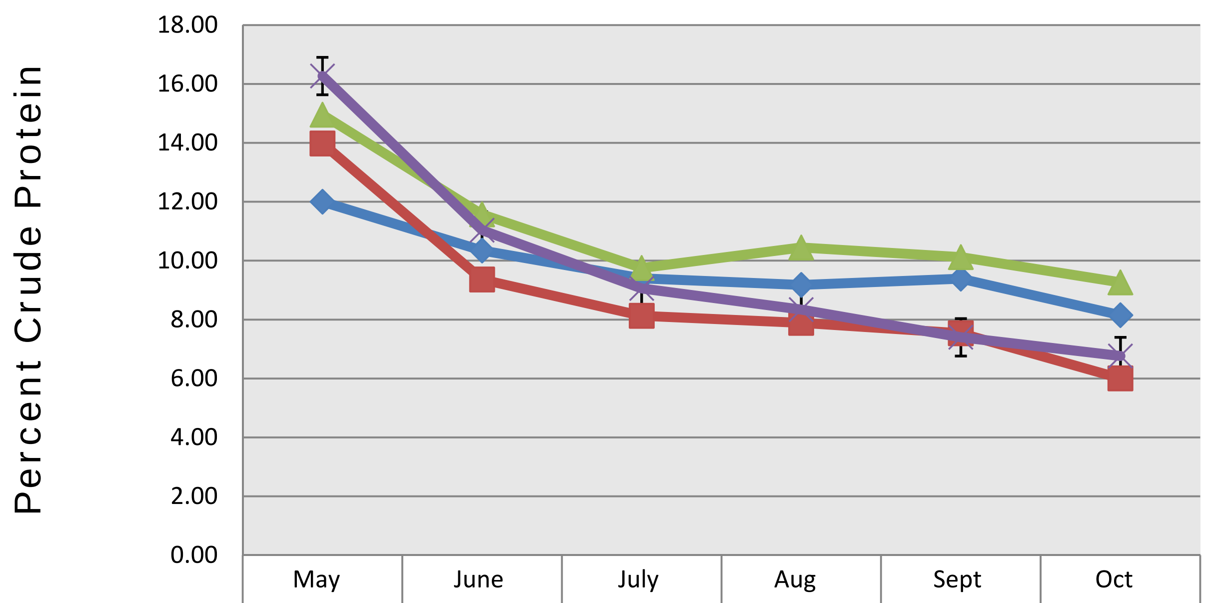
	May	June	July	Aug	Sept	Oct
Inside ADF	34.92	35.11	36.78	38.71	38.58	40.91
Outside ADF	30.49	32.25	35.16	35.93	36.24	38.57
Inside NDF	58.17	59.77	61.43	63.89	63.47	64.72
Outside NDF	54.34	56.61	60.57	61.63	62.33	66.21
Inside NDFd	59.22	59.54	58.61	56.76	52.02	52.78
Outside NDFd	63.88	67.15	62.23	57.52	51.94	55.58

Figure 14. The interaction of location, Inside (ungrazed) or outside (grazed) of the exclosure, with time (month), on the percentage acid detergent fiber (ADF), neutral detergent fiber (NDF), neutral detergent fiber digestibility (NDFd), for clipped samples, during the 2008 growing season, in the Wood River basin.



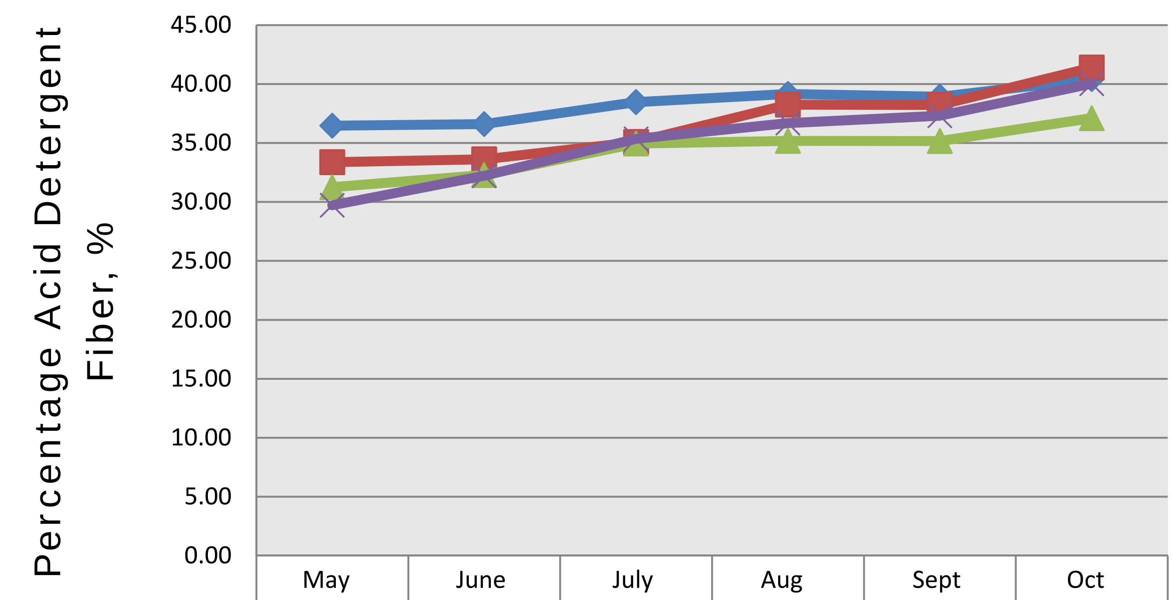
	May	June	July	Aug	Sept	Oct
Inside IVTDMD	75.97	75.76	74.53	72.39	69.54	69.48
Outside IVTDMD	80.21	81.37	77.11	73.81	70.18	70.79
Inside TDN	61.69	61.55	60.25	58.75	58.85	57.03
Outside TDN	65.15	63.78	61.51	60.91	60.67	58.86

Figure 15. The interaction of location, Inside (ungrazed) or outside (grazed) of the exclosure, with time (month), on the percentage invitro true dry matter disappearance (IVTDMD) and total digestible nutrients (TDN), for clipped samples, during the 2008 growing season, in the Wood River basin.



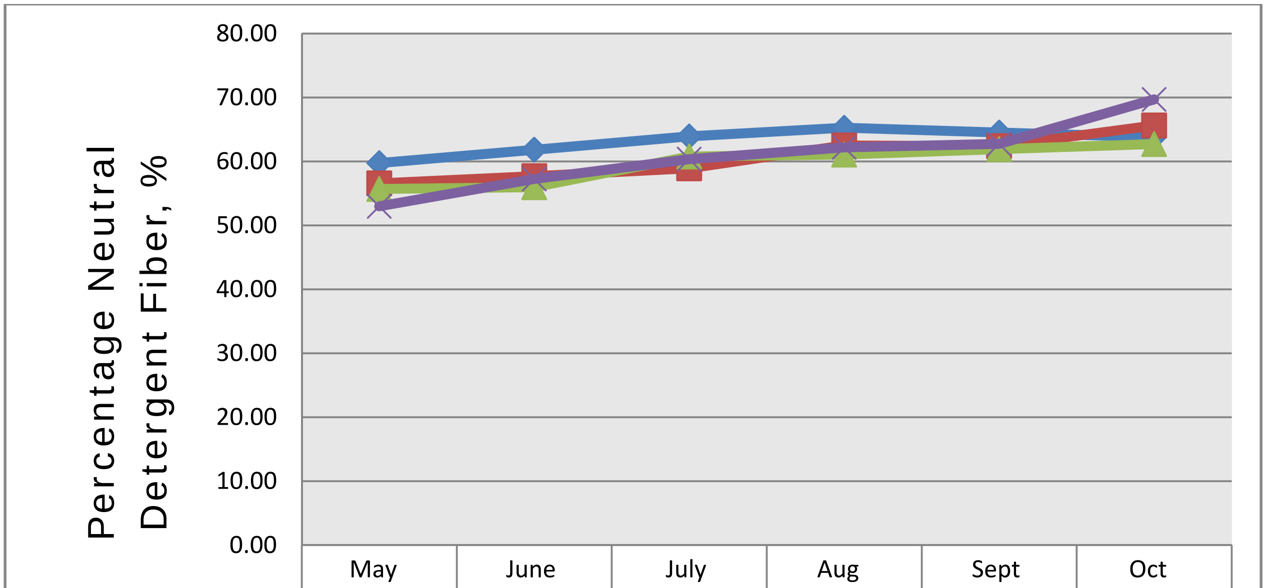
	May	June	July	Aug	Sept	Oct
In- Irr-CP	12.00	10.34	9.40	9.18	9.39	8.15
In-Non Irr-CP	13.98	9.36	8.13	7.89	7.53	6.00
Out-Irr-CP	14.96	11.58	9.75	10.45	10.12	9.27
Out Non Irr-CP	16.27	11.03	9.05	8.34	7.40	6.76

Figure 16. The interaction of location, Inside (In; ungrazed) or outside (Out; grazed) of the exclosure, with treatment, irrigated (Irr) or non-irrigated (NonIrr), over time (month), on the percentage crude protein (CP), for clipped samples, during the 2008 growing season, in the Wood River basin.



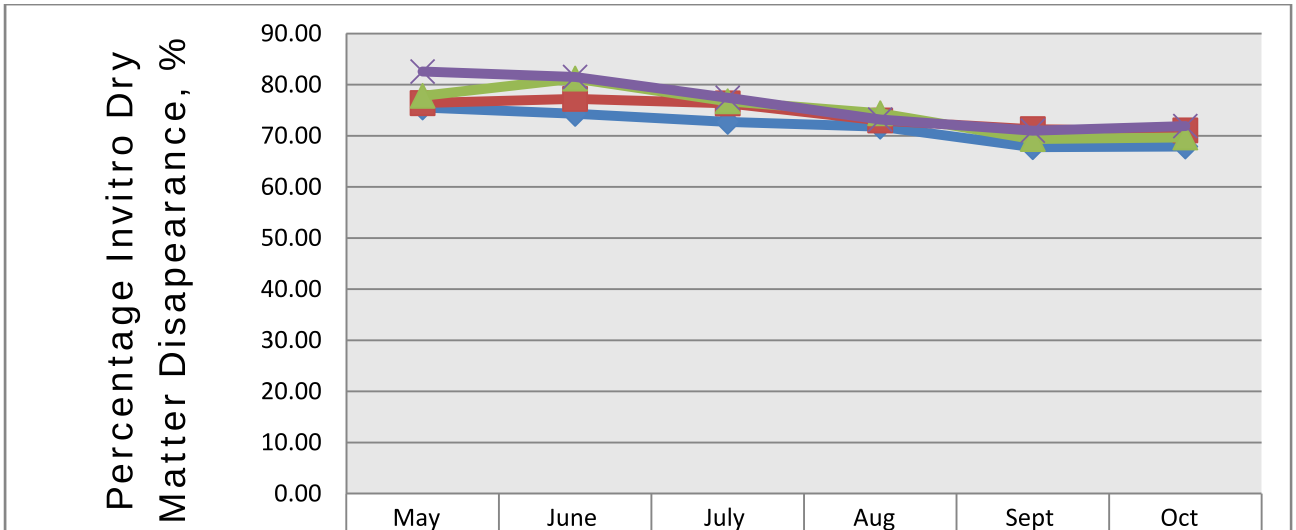
	May	June	July	Aug	Sept	Oct
In-Irr-ADF	36.47	36.61	38.47	39.16	38.93	40.42
In-Non Irr-ADF	33.37	33.62	35.09	38.26	38.23	41.41
Out-Irr-ADF	31.25	32.28	34.95	35.18	35.17	37.11
Out-Non Irr-ADF	29.72	32.22	35.36	36.69	37.31	40.03

Figure 17. The interaction of location, Inside (In; ungrazed) or outside (Out; grazed) of the exclosure, with treatment, irrigated (Irr) or non-irrigated (NonIrr), over time (month), on the percentage acid detergent fiber (ADF), for clipped samples, during the 2008 growing season, in the Wood River basin.



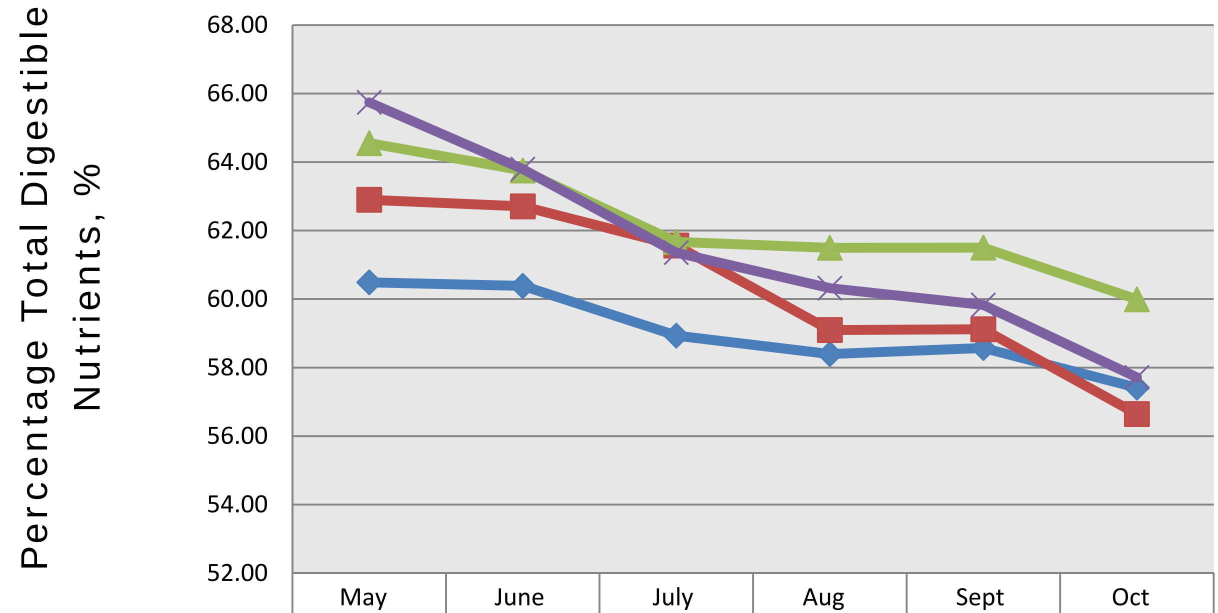
	May	June	July	Aug	Sept	Oct
In-Irr-NDF	59.76	61.85	63.94	65.29	64.54	63.81
In-Non Irr-NDF	56.57	57.69	58.93	62.50	62.41	65.62
Out-Irr-NDF	55.69	55.96	60.77	61.06	61.91	62.72
Out-Non Irr-NDF	52.99	57.27	60.37	62.19	62.74	69.69

Figure 18. The interaction of location, Inside (In; ungrazed) or outside (Out; grazed) of the exclosure, with treatment, irrigated (Irr) or non-irrigated (NonIrr), over time (month), on the percentage neutral detergent fiber (NDF), for clipped samples, during the 2008 growing season, in the Wood River basin.



	May	June	July	Aug	Sept	Oct
In-Irr-IVTDMD	75.53	74.30	72.71	71.78	67.77	67.89
In-Non Irr-IVTDMD	76.40	77.22	76.35	73.00	71.31	71.08
Out-Irr-IVTDMD	77.83	81.21	76.77	74.42	69.37	69.67
Out-Non Irr-IVTDMD	82.60	81.53	77.46	73.19	70.99	71.91

Figure 19. The interaction of location, Inside (In; ungrazed) or outside (Out; grazed) of the exclosure, with treatment, irrigated (Irr) or non-irrigated (NonIrr), over time (month), on the percentage invitro true dry matter disappearance (IVTDMD), for clipped samples, during the 2008 growing season, in the Wood River basin.



	May	June	July	Aug	Sept	Oct
In-Irr-TDN	60.49	60.38	58.93	58.40	58.57	57.41
In-Non Irr-TDN	62.90	62.71	61.56	59.10	59.12	56.65
Out-Irr-TDN	64.55	63.76	61.67	61.50	61.51	60.00
Out-Non Irr-TDN	65.75	63.80	61.36	60.32	59.83	57.72

Figure 20. The interaction of location, Inside (In; ungrazed) or outside (Out; grazed) of the exclosure, with treatment, irrigated (Irr) or non-irrigated (NonIrr), over time (month), on the percentage total digestible nutrients (TDN), for clipped samples, during the 2008 growing season, in the Wood River basin.

Appendix 5

Final Wood River Conservation Effects Assessment Project Report

Introduction to Appendix 5

Appendix 5 is a copy of a report prepared by the Oregon State University (OSU) Department of Biological and Ecological Engineering’s Hydrologic Science Team detailing their work in crop production and irrigation modeling in the Wood River Valley. The modeling work, using MIKE SHE and DAISY, was based upon the data generated in the other components of this CEAP study.

Wood River Basin Crop Production and Irrigation Modeling using DAISY and MIKE SHE for Conservation Effects Assessment Program

Submitted to the Natural Resources Conservation Service November 20, 2009

Submitted by:
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1 Introduction

Much of the attention in the Wood River Basin (WRB) over the last five years has focused on reducing water demand by curtailing irrigation accompanied with reductions in cattle grazing intensity. Considerable public funds have been expended to compensate ranchers for lost income through water banking and grazing forbearance programs. Late in 2006 NRCS initiated a CEAP study in the WRB to determine the effects of these programs on forage production and animal unit carrying capacity.

NRCS selected six irrigated and six non-irrigated pastures for monitoring the effects of water banking and grazing forbearance programs. Grazing forbearance on the non-irrigated sites resulted in reduction of herd sizes by 30 to 50% of animal units customarily stocked on irrigated sites. Monitoring began during the 2007 growing season and continued through the 2008 growing season. Each site had vegetation transects to measure plant composition, exclosures to measure crop growth and productivity, and continuous data loggers to measure the shallow water table elevation.

These data were used to construct and calibrate numerical models for pasture production (DAISY) and soil hydrology (MIKE SHE). These models where used to simulate intermediate levels of irrigation to develop curves describing crop production as a function of irrigation level. From these data animal unit carrying capacity can be described as a function of irrigation level. Economic analysis can then be performed to determine the lost production value due to decreased irrigation, and a fair cost can be assigned to the water banking program. Optimal program levels can also be determined.

This report will describe the numerical crop production and soil hydrology modeling performed as part of the CEAP by the Hydrologic Science Team at Oregon State University under the supervision of Dr. Richard Cuenca.

2 Methods

2.1 Field Sites

A total of 12 field groups were selected, consisting of 6 irrigated groups (1I, 2I, 3I, 4I, 5I, and 6I) and 6 non-irrigated groups (1N, 2N, 3N, 4N, 5N, and 6N) distributed throughout the WRB. All irrigated sites were fully irrigated; there were no sites with reduced irrigation levels. Three vegetation transects and one vegetation exclosure were established at each site. Water table and soil moisture sensors connected to data loggers were placed within the exclosures. Fecal and forage quality data were also taken within each grouping. A digital elevation model (DEM) of the WRB with 1-m horizontal cell resolution was obtained via LiDAR.

2.2 Data Collection

2.2.1 Plant Production and Composition

Three transects and one exclosure were established for each field group. Transects were approximately 150 ft (45.72 m) long and oriented North-South. The exclosures were 1.94 ft^2 (0.180 m^2). Samples were collected about every 2 feet (0.61 m) along the transects once a month from April to October. Exclosure samples were taken concurrently. For each sampling location the following data/observations were taken:

1) Monthly productions via clippings and re-clippings
2) Distance between rooted plants
3) Species composition by percent cover
4) Presence of invasive species, especially bull thistle

2.2.2 Forage Quality (Plant and Fecal Sampling)

Each month six forage samples from each field group were taken and analyzed using wet chemistry techniques for crude protein (*CP*), acid detergent fiber (*ADF*), neutral detergent fiber (*NDF*), in vitro dry matter digestibility (*IVDMD*), and in vitro neutral detergent fiber digestibility (*IVNDFD*). These analyses were designed to estimate total and digestible fiber present in the forage so that a nutrition balance of the livestock could be made. Fecal samples were also taken and analyzed with near infrared reflectance spectroscopy (NIRS). NIRS samples are easier and cheaper to collect and analyze than the wet chemistry samples. NIRS is also advantageous in that it directly samples what the animal ingested and the sampler does not have to attempt to clip forage in the same proportions that an animal would graze. Stubble height was also recorded when collecting plant and fecal samples.

2.2.3 Grazing Management

Visits to the field groups were made each month from April to October to estimate grazing characteristics. Observations were made for animal breed, average weight, average age, and sex (lactating, pairs). Estimates of amount of remaining forage and rate of plant regrowth were made visually. These observations were confirmed with the land owner when possible. The typical grazing system practiced in the WRB was continuous. Cattle were kept in large pastures and grazed freely.

2.2.4 Soil Hydrology

Soil hydrology data were collected within the exclosures of all of the sites. Water table elevation in the shallow aquifer was collected using pressure transducers installed between depths of 1.4 m (4.5 ft) to 2.0 m (6.5 ft). Data were collected at hourly intervals. For the non-irrigated sites the water table dropped below the pressure transducers during the summer months. Soil water content was also collected using factory calibrated Time Domain Reflectrometry (TDR) probes The factory calibration settings are unsuitable for the volcanic andisols soils of the WRB because they have unique physical properties for their texture class, such as low bulk density, high porosity, and large specific surface area [Miyamoto *et al.*, 2003].

2.2.5 Soil Physical Properties

Soil moisture retention curves and bulk density were obtained from NRCS NSSC Soil Survey Laboratory Characterization Data for a sample taken near Fort Klamath (Pedon ID 67OR035013). Saturated hydraulic conductivity was obtained from an NRCS report that used an amoozemeter for *in situ* measurement. In addition, undisturbed soil cores were taken within field groups 3I, 4I, 6I, 2N, 4N, and 6N ranging in depth from 5 cm to 70 cm. The cores were then analyzed for soil moisture retention. Due to the length of time required to run this analysis and the suitability of the NRCS NSCC data, the soil core data have not been used in the simulations.

The soil hydraulic parameters used with MIKE SHE and DAISY were estimated based on these soil hydraulic data. Among different formulations implemented in MIKE SHE and DAISY, this study selected the van Genuchten [1980] and the Mualem [1976] formulations, which can be described as:

$$\theta(\psi) = \theta_r + \frac{(\theta_s - \theta_r)}{\left[1 + |\alpha\psi|^n\right]^m} \quad [1]$$

$$K(\psi) = Ksat \frac{\left[\left(1 + |\alpha\psi|^n\right)^m - |\alpha\psi|^{n-1}\right]^2}{\left[1 + |\alpha\psi|^n\right]^{m(l+2)l}} \quad [2]$$

$$m = 1 - \frac{1}{n}$$ [3]

where θ, θ_r and θ_s are the actual, residual and saturated water contents (cm^3/cm^3), ψ is the pressure head (cm), α is related to the inverse of the air-entry pressure (1/cm), *Ksat* is the saturated hydraulic conductivity (cm/hr), *n* (> 1) is the measure of the pore-size distribution (-), *l* is the pore connectivity and tortuosity factor (-).

2.2.6 Meteorological Data

Daily meteorological data including mean daily air temperature (*T*), precipitation (*P*), global radiation (R_s), and alfalfa based reference evapotranspiration (ET_R) were obtained from the Agency Lake AgriMet Station (AGKO) located at the southern end of the WRB,. MIKE SHE and DAISY requires the use of potential (grass based) evapotranspiration (ET_0) that can be calculated from ET_R as:

$$ET_0 = 0.83 ET_R$$ [4]

2.2.7 Digital Elevation Model

Klamath Basin Rangeland Trust (KBRT) provided a digital elevation model (DEM) of the WRB generated using LiDAR data collected from flights flown on 09/26/2004 and 09/27/2004 by Watershed Sciences, Inc. of Corvallis, OR.

2.3 Irrigation Simulation using MIKE SHE

2.3.1 Description of MIKE SHE

The European Hydrological System (SHE) was developed in the 1980's as a joint effort by the Institute of Hydrology, Societe Grenobloise d'Etudes et d'Applications Hydrauliques (SOGREAH), and the Danish Hydraulics Institute (DHI). These three have since developed SHE independently, and MIKE SHE is the DHI version of the model. MIKE SHE is one of many models that DHI has developed that are included in their MIKE Zero modeling package. MIKE SHE simulates the land phase of the hydrological cycle including ground water, soil moisture, overland (non-channelized) flow, precipitation and irrigation, and evapotranspiration.

MIKE SHE is a fully distributed, physically based model. It is very versatile with a modular structure that can be easily suited to project needs. MIKE SHE has been used to model scales from a one-dimensional soil profile to the 80,000 km^2 Senegal Basin [Andersen *et al.*, 2001; Andersen *et al.*, 2002]. The modules available in MIKE SHE include Overland Flow, Rivers and Lakes (requires MIKE 11) Unsaturated Flow, Evapotranspiration, Saturated Flow, and Advection-Dispersion for Water Quality. Each module is flexible, giving the user control over how the model is run. For example, the unsaturated flow module can be run using Richards Equation, gravity flow, and two-layer model that will be selected based on the user's requirements for accuracy and computational efficiency. Furthermore, MIKE SHE allows selection from two retention curve functions, three hydraulic conductivity functions and tabulated values for the fitting parameters. It is possible to set up very complex models but computational resources and time requirements become major factors in using MIKE SHE, especially when running 3-dimensional models over large areas or at fine spatial resolutions.

2.3.2 Conceptual Model of WRB Field-Scale Water Balance

Figure 1 provides a schematic of the simulated water balance. For clarity, regular font indicates that the values have been measured, **bold** font indicates that the values are unknown, and *italic* font indicates that the values are calculated during the simulation.

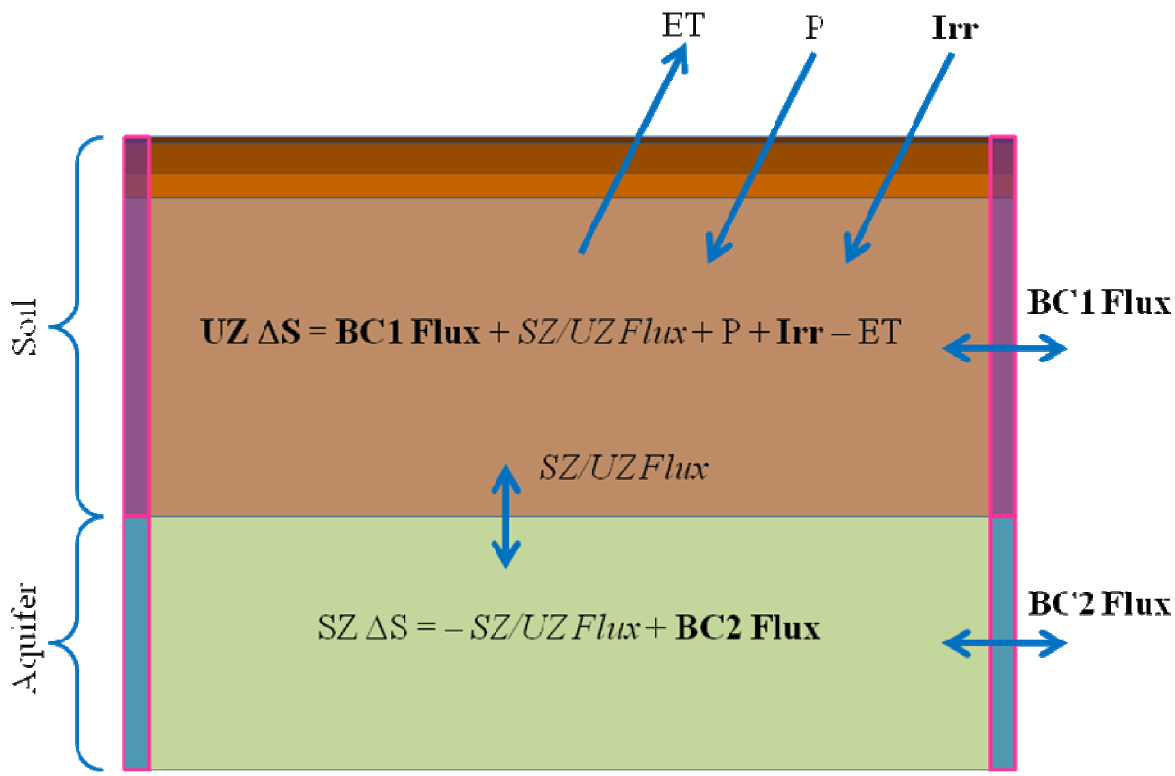

Figure 1: Conceptual model of pasture water balance in WRB set-up in MIKE SHE

where:

- *ET* Evapotranspiration

- *P* Precipitation
- *Irr* Irrigation
- *BC*1*Flux* Soil Boundary Condition Flux Rate
- *BC*2*Flux* Aquifer Boundary Condition Flux Rate
- *UZ* ∆*S* Change of Storage in the Unsaturated Zone (UZ)
- *SZ* ∆*S* Change of Storage in the Saturated Zone (UZ)
- *SZ*/*UZFlux* Flux between UZ and SZ, positive up

Consider the equations for *UZ* ∆*S* and *SZ* ∆*S* where:

$$UZ\ \Delta S = BC1Flux + SZ/UZFlux + P + Irr - ET \qquad [5]$$

$$SZ\ \Delta S = -SZUZFlux + BC2Flux \qquad [6]$$

$$SZUZFlux = f(UZ\ \Delta S, SZ\ \Delta S, BC1Flux, BC2Flux, P, Irr, ET) \qquad [7]$$

BC1Flux, *BC2Flux* and *Irr* are all unknown making solutions to the above equations non-unique. However in these sites the hydraulic conductivity of the soil is much less than the hydraulic conductivity in the aquifer, so the *BC*1*Flux* can be assumed to be negligible compared to the *BC*2*Flux* and approximated as 0. In the non-irrigated sites *Irr* = 0, therefore the above equations are simplified to:

$$UZ\ \Delta S = SZ/UZFlux + P - ET \qquad [8]$$

$$SZ\ \Delta S = -SZUZFlux + BC2Flux \qquad [9]$$

$$SZUZFlux = f(UZ\ \Delta S, SZ\ \Delta S, BC2Flux, P, ET) \qquad [10]$$

These equations can be solved for *BC*2*Flux* by comparing *SZ* ∆*S* to its measured values represented by water table elevations. In the simulations, the *BC*2*Flux* term was varied to achieve the highest model efficiencies. Conceptually the *BC*2*Flux* is manifested as sub-irrigation where water comes in from the shallow aquifer and rises to the root zone to become available to plants.

BC2Flux and *Irr* are unknown for irrigated sites so neither can be solved for explicitly. The irrigated site domain is set up to be a small portion within the irrigated management area and the water table will either be the same as the surrounding area, or be controlled by the water level within adjacent ditches. Therefore there is no head gradient to drive flux between the model domain and the surrounding area and the *BC2Flux* term can be assumed to be equal to 0. The resulting simplified equations are:

$$UZ\ \Delta S = SZ/UZFlux + P + Irr - ET \quad [11]$$

$$SZ\ \Delta S = -SZUZFlux \quad [12]$$

$$SZUZFlux = f(UZ\ \Delta S, SZ\ \Delta S, BC1Flux, BC2Flux, P, Irr, ET) \quad [13]$$

Irr can be solved by adjusting it to match the observed or desired water table dynamics. This approach worked for most irrigation application levels, however when there was only one irrigation application in the season the water table drops to the point where the *BC2Flux* term is needed to maintain water table levels. In this case the *BC2Flux* term was adjusted so that the water table recession curves were consistent with those observed in the non-irrigated simulations.

2.3.3 Irrigation Scenarios

8 irrigation scenarios were simulated to look at how various irrigation management practices can affect water table dynamics and thus crop production. The scenarios varied by irrigation frequency that ranged from weekly irrigation throughout the growing season to no irrigation, and are listed in Table 1. Each irrigation event is modeled as a "full irrigation" where enough water is applied to bring the water table to the surface. This study assumes that Lv2 (bi-weekly irrigation) is the common irrigation practice in the WRB and that Lv6 (non-irrigated) is the irrigation practice in the water bank and grazing forbearance programs. Crop production field data collected for irrigated and non-irrigated pastures correspond to Lv2 and Lv6 respectively.

Table 1. List of 8 irrigation scenarios used in this study. The irrigation season is assumed from 5/1 to 9/30 in each year.

Level	Frequency
Lv1	Weekly
Lv2	Bi-weekly
Lv3	Monthly
Lv4	Bi-monthly
Lv5j	Once (7/1)
Lv5a	Once (8/1)
Lv5s	Once (9/1)
Lv6	None

2.3.4 Model Set-Up, Non-Irrigated Site

The 4N field group was used to simulate the non-irrigated soil hydrology. 4N was chosen because it is centrally located, representative of most of the WRB, and easily delineated. Watered conveyances were chosen to delineate the simulation because they represent easily definable boundary conditions. Model efficiency was assessed by comparing the simulated water table against the measured water table from 4/28/2007 to 12/31/2007

2.3.4.1 Simulation Specification

Simulations were run over a three-year period from 01/01/2006 to 12/31/2008. Simulations were started on the first of the year because saturated initial conditions can be assumed. A multi-year simulation was used to validate the model over different precipitation and evapotranspiration records. At the beginning of the simulations there can be erratic behavior caused by errors in the initial conditions that lead to rapid adjustments in the model. A "Spin-Up" period is therefore useful. In this case the simulation was started about 16 months prior to the measured water table record.

2.3.4.2 Model Domain and Grid

The model domain was defined by creating a shapefile in ArcGIS using photo and DEM base layers to delineate watered conveyances bounding the field site. Under the non-irrigation management small ditches are not watered and so the boundary has to be defined by large canals and streams resulting in a large domain. The 4N domain consists of 511 grid cells each measuring 50 m x 50 m (164.0 ft x 164.0 ft) for a total size of 127.75 ha (315.7 ac). Large grid cells were chosen for this site to reduce computation time and because there is no overland flow from irrigation that requires fine scale topographic resolution for accurate simulation.

2.3.4.3 Topography

Elevation from the LiDAR DEM was coarsened to 5-m horizontal cell resolution using the Spatial Analyst Raster Calculator in ArcGIS 9.3 and then converted to a point shapefile to be used in MIKE SHE. MIKE SHE uses the point data and applies a bilinear interpolation algorithm to assign an elevation to each of the model grid cells. Elevations ranged from 1,269.7 m (4,165.7 ft) at the north end of the domain to 1,266.4 (4,154.9 ft) at the south end of the domain resulting in a slope of about 0.25%.

2.3.4.4 Climate

The climate data used in the simulation include daily precipitation and potential evapotranspiration records. These data were obtained for 2004 to 2008 from the Agency Lake AgriMet Station in in/day and converted to mm/day.

2.3.4.5 Land Use

Land use included vegetation characteristics that are used to calculate evapotranspiration and were assumed constant year-round. This assumption is not accurate due to winter dormancy, but during the period of interest from April to October the active continuous grazing results in relatively constant vegetation levels. The potential evapotranspiration is very low during the winter period. Inaccuracies in vegetation characteristics result in small changes in evapotranspiration during this period and do not affect the model during the period of interest. Parameters are listed in Table 2.

Table 2. Vegetation and evapotranspiration parameters

LAI **(-)**	**2**
Rood Depth (mm)	**1000**
Canopy Interception (-)	**0.05**
***C*1 (-)**	**0.3**
***C*2 (-)**	**0.2**
***C*3 (mm/day)**	**20**
Aroot **(1/m)**	**1**

*C*1, *C*2, *C*3, and *Aroot* are parameters used in the Kristensen and Jensen method for calculating ET used by MIKE SHE [Kristensen and Jensen, 1975].

2.3.4.6 Overland Flow

Overland Flow is not used in the non-irrigated set-up.

2.3.4.7 Unsaturated Flow

MIKE SHE treats the Unsaturated Zone (*UZ*) and the Saturated Zone (*SZ*) dynamically and switches between the two modules based on the head elevation of the saturated zone; therefore, *UZ* and *SZ* have to be defined coincidentally.

The simulations used the van Genuchten retention curve model (Eq. [1]) with the Mualem constraint (Eq. [2]). Vertical matrix water flows are simulated by the Richards equation. The *UZ* is constructed using soil profile definitions based on NRCS NSSC Soil Survey Laboratory Characterization Data (see section 2.2.5). These soils have a fairly shallow top soil layer with the C horizon extending to 2 to 3 m (6 to 10 ft) below the surface. Below the C horizon is a shallow aquifer to a depth of about 10 m (33 ft) according to well logs from the area. The shallow aquifer is characterized using typical values for medium sand [Todd and Mays, 2005]. Well logs in the area indicate that the shallow aquifer is built up through a series of frequent depositional events followed by soil formation as would be expected in an active volcanic area. This likely caused the series of thin non-continuous layers of pumice and sand intermixed with layers of silty sand and clay. The depth and order of these layers are inconsistent amongst well logs and therefore they are probably not continuous through the extent of the model. Because of the difficulty in characterizing the local shallow aquifer, and because the non-continuous character of the layers means that there are no layers impeding water flow, medium sand was chosen as an intermediate material to characterize the entire shallow aquifer. Below the shallow aquifer is a clay layer that serves as an aquitard between the shallow aquifer and the deeper aquifer below, resulting in no flux between the shallow and deep aquifers. Soil horizon depths are determined by analyzing local well logs. The 4N Soil profile is shown in Table 3.

Table 3. Soil profile horizons and depths for 4N

Horizon	Top Depth	Bottom Depth
	m	
A1	0.00	0.05
A2	0.05	0.25
A/C	0.25	0.50
C	0.50	2.50
R (Aquifer)	2.50	10.00

MIKE SHE also requires vertical discretization much like the domain grid cells used for horizontal discretization. A finer vertical discretization results in more precise simulations, but can also lead to increased computation time, especially in the *UZ* when Richard's Equation is used. The vertical discretization for 4N is shown in Table 4.

Table 4. Vertical discretization and calculation layers for 4N.

Top Depth	Bottom Depth	Cell Height	No of Cells
m			
0	0.05	0.025	2
0.05	0.25	0.05	4
0.25	0.5	0.05	4
0.5	2.5	0.1	20
2.5	10	0.5	15
		Total Cells	45

The 511 horizontal grid cells are each divided into 45 vertical cells resulting in 22,995 computational cells. There is finer resolution at the surface where the soil hydrology will respond quickly to moisture inputs and outputs. At depth, the response is lagged and so a coarser resolution is adequate, especially below the permanent water table where there are no *UZ* calculations.

2.3.4.8 Saturated Zone

The saturated zone (*SZ*) governs water movement under saturated conditions and can be made up of multiple layers, each with unique values of horizontal and vertical hydraulic conductivity, specific yield, and specific storage.

The model was divided into 2 layers, the soil layer and the aquifer layer. Parameters assigned to the layers are shown in Table 5. Geologic layer parameters define the physical properties of the layers, computation layers define the initial and boundary conditions used by the numerical engine.

Table 5. Parameters used to characterize the saturated zone in 4N.

Parameter	Soil	Aquifer
Geologic Layers		
Lower Level (m)	-2	-10
Horizontal *Ksat* (m/s)	5*10-8	3*10-5
Vertical *Ksat* (m/s)	5*10-8	3*10-5
Specific Yield (-)	0.1	0.1
Specific Storage (1/m)	1*10-5	0.001
Computation Layers		
Initial potential head (m)	-0.5	-0.5
Outer Boundary Condition	Zero-Flux	Flux
Internal Boundary Condition	None	None

The Outer Boundary Condition for the aquifer layer is defined as Flux meaning that water can either enter or exit from the model domain through this boundary at a specified rate. A previous study of evapotranspiration in irrigated vs. non-irrigated sites in the WRB in 2005 showed that the total evapotranspiration between irrigated (802 mm) and non-irrigated (689mm) sites only differed by 15.1%. This is an indication that there was a water source in the non-irrigated sites, most likely sub-irrigation from the shallow aquifer. Nearby irrigated sites that maintain a high local water table may contribute to the flux into non-irrigated sites by providing a source of water and a head gradient to transport the water. The Flux boundary condition is consistent with the conceptual model of the hydrology in the WRB.

The Boundary Flux is likely variable throughout the year, with the highest flux occurring during the late summer when the water table is lowest and almost no flux occurring in the winter when the water table height across the WRB is elevated in all regions. Three flux scenarios were simulated: constant, seasonal, and monthly. The constant scenario used a constant flux into the model domain year round. The seasonal scenario used a flux value for March through June and a different flux value for the rest of the year. The monthly scenario used a different flux value for each month. Flux values for each scenario were adjusted manually to achieve the best model efficiency.

2.3.5 Model Set-Up, Irrigated Sites

The 3I field group was used to simulate the irrigated soil hydrology. 3I was chosen because it is centrally located and near 4N so the two sites make a good study pair. There was no attempt to recreate the measured water table record that was influenced by irrigation frequencies and rates that are unknown. Model efficiency was assessed by comparing the simulated water table against the measured water table for a long recession period in the water table record from 04 Sep 2007 to 30 Sep 2007, during this period it can be assumed that there are no irrigation inputs. Water table recession curves between the simulated and measured water table data were also compared qualitatively during other periods.

Unless otherwise noted, the model set-up for the irrigated site is the same as the non-irrigated site. Please see the corresponding subsections under section 2.3.4 Model Set-Up, Non-Irrigated Sites for more information.

2.3.5.1 Simulation Specification

Simulations were run over a four-year period from 01 Jan 2005 to 31 Dec 2008 to obtain multiple crop production vs. depth of irrigation curves. The minimum time step for irrigated conditions was reduced to 6 min to prevent the numerical engine from crashing when using Richards equation due to rapid changes in soil moisture content.

2.3.5.2 Model Domain and Grid

To match the plant production model, the irrigated site was set up as a 1-dimensional (1-D) model at the point of water table observation. The 1-D model was also used for the model set-up because simulations could be run rapidly.

A 3-dimensional domain was set-up to simulate flood irrigation; however the 1-D model had better performance in simulating water table and irrigation. This domain consisted of 1,793 grid cells that are 5 m x 5 m (16.4 ft x 16.4 ft) each resulting in a total area of approximately 4.5 ha (11.1 ac). The finer resolution is required to accurately represent flood irrigation.

2.3.5.3 Topography

Elevations from the LiDAR DEM were coarsened to 2-m horizontal cell resolution using the Spatial Analyst Raster Calculator in ArcGIS 9.3 and then converted to a point shapefile to be used in MIKE SHE. MIKE SHE uses the point data and applies a bilinear interpolation algorithm to assign an elevation to each of the model grid cells. Elevations ranged from 1,266.5 m (4,155.2 ft) at the north end of the domain to 1,265.2 m (4,150.9 ft) at the south end of the domain resulting in a slope of about 0.4%.

2.3.5.4 Climate

See section 2.3.4.4

2.3.5.5 Land Use

For Vegetation characteristics and *ET* parameters see section 2.3.4.5.

Irrigation is specified in this module by defining the irrigation command area and irrigation demand. The irrigation command area defines where and how irrigation will be applied within the model domain. In the 1-D simulation, water is applied as sheet irrigation over the grid cell. For sheet irrigation the application area must also be defined because in 3-D applications water would be applied at the application area and allowed to flow to neighboring cells via overland flow.

Irrigation demand controls the amount of water applied. A maximum rate and duty can be specified, but in these simulations they were not set to be a limiting factor. Eight different irrigation levels were investigated with various application frequencies. Application lasted 24 hours and for each application enough water was applied to raise the water table to the ground surface as is commonly observed in the WRB. Irrigation can start as early as 01 April and the last irrigation can occur as late as 01 October depending on the annual climate variations. The irrigation levels and timing are summarized in Table 6.

Table 6. Irrigation timing for each level, irrigation duration is 24 hours. The irrigation season is assumed from 5/1 to 9/30 in each year.

Level	Frequency (Approx)	Application Dates
Lv1	Weekly	1, 7, 15, 22, of each month
Lv2	Bi-Weekly	1, 15 of each month
Lv3	Monthly	1 of each month
Lv4	Bi-Monthly	5/1, 7/1, and 9/1
Lv5j	Once	7/1
Lv5a	Once	8/1
Lv5s	Once	9/1
Lv6	None	

2.3.5.6 Overland Flow

Overland flow is required for sheet application of irrigation and uses roughness coefficient, detention storage, and initial water depth as parameters. A roughness coefficient Manning's number ($m^{1/3}s^{-1}$) of 20 is used, the max within the range of high grass pasture [Chow, 1959]. The Manning's number here is the reciprocal of what is typically reported as the Manning's n or Manning's coefficient, hence lower numbers indicate a rougher surface and values generally range from 5 to 50 for floodplains. Detention storage was set at 50 mm (2 inches). This is the depth of water on the surface that must be surpassed for flow to be initiated and represents small scale undulations and holes on the surface, such as hoof prints, that can store water. If the detention storage is too low the water will leave the field too quickly and will not infiltrate into the soil. Initial water depth was set at 0 m.

2.3.5.7 Unsaturated Flow

The soil and geology are very similar to the 4N site, see section 2.3.4.7. Layer depths are from local well logs and differ from the 4N set-up. The horizon depths and vertical discretization are shown in the Tables 7 and 8.

Table 7. Soil profile horizons and depths for 3I.

Horizon	Top Depth	Bottom Depth
	m	
A1	0	0.15
A2	0.15	0.5
A/C	0.5	0.6
C	0.6	2.5
R (Aquifer)	2.5	10

Table 8. Vertical discretization and calculation layers for 3I.

Top Depth	Bottom Depth	Cell Height	No of Cells
m			
0	0.15	0.025	6
0.15	0.5	0.05	7
0.5	0.6	0.05	2
0.6	2.5	0.1	19
2.5	10	0.5	15
		Total Cells	49

2.3.5.8 Saturated Zone

The saturated zone (*SZ*) is set up similarly to the 4N site. Parameters are shown in Table 9.

Table 9. Parameters used to characterize the saturated zone in 3I.

	Soil	Aquifer
Geologic Layers		
Lower Level (m)	-2.5	-10
Horizontal *Ksat* (m/s)	5*10-6	3*10-5
Vertical *Ksat* (m/s)	5*10-6	3*10-5
Specific Yield (-)	0.1	0.1
Specific Storage (1/m)	1*10-5	0.01
Computation Layers		
Initial potential head (m)	-0.16	-0.16
Outer Boundary Condition	Zero-Flux	Flux
Internal Boundary Condition	None	None

For Irrigation Levels 1 to 4 the Aquifer Boundary Condition Flux was set to 0. For Levels 5 and 6 the Aquifer Boundary Condition Flux was adjusted so that the water table drawdown was similar to what was observed in 4N.

2.4 Crop Production Simulation using DAISY

2.4.1 Description of DAISY

DAISY [Hansen *et al.*, 1990] is a soil-vegetation-atmosphere transfer (SVAT) model to simulate one-dimensional water balance, heat balance, solute balance and crop production in various agroecosystems. The model estimates maximum plant productivity (Y_{max}) as a function of carbohydrate production rate through photosynthesis (light distribution) in each development stage (*DS*) (e.g., germination = 0, flowering = 1, and maturation = 2), then estimates actual plant productivity after accounting for stress factors (i.e. water and nitrogen deficiencies). In this study, because 1) fertilizer application is generally not practiced and 2) nitrogen fixing plant (e.g. legumes) population is small (≤ 7% at irrigated sites and 0% at non-irrigated sites), nitrogen availability is assumed to be limited in the WRB. Thus, water and nitrogen are considered as stress factors of the pasture system in this study.

DAISY estimates gross photosynthesis as a function of light distribution based on Beer's law [Hansen, 2000]. Carbohydrate produced as a result of photosynthesis is consumed first for maintenance respiration, then for growth respiration. If any carbohydrate remains it contributes to net production. Partitioning of the net production among plant components (e.g., root, stem, leaf and storage organs) is determined as a function of development stage (*DS*). DAISY estimates *DS* as a function of temperature (*T*) and day length (*DL*) to determine physiological age of each crop (emergence: 0, vegetative: ~1, and reproductive: ~2).

$$DS = f(T, DL) \qquad [14]$$

The effects of temperature on *DS* are crop specific. In this study the default parameter set for the temperature effect on *DS* was used.

DAISY estimates water stress based on the assumption that transpiration as well as CO_2 assimilation is governed by stomatal responses. It is also assumed that stomata are open when intercepted water is evaporated from the leaf surfaces. The water limited photosynthesis (F_w) is estimated based on these assumptions as:

$$F_w = F_p \frac{AET}{ET_c} \qquad [15]$$

where F_p is the potential photosynthesis, *AET* is the actual evapotranspiration (≤ ET_c) and ET_c is the crop evapotranspiration under standard conditions. Crop evapotranspiration (ET_c) can be obtained as:

$$ET_c = K_c ET_o \qquad [16]$$

where K_c is the crop coefficient.

The water limited photosynthesis (F_w) in Eq. [15] is further limited by nitrogen availability. The nitrogen limited gross photosynthesis (F_n), after accounting for the water limited photosynthesis (F_w), is expressed as:

$$F_n = F_w \frac{N_c^a - N_c^n}{N_c^c - N_c^n} \qquad [17]$$

where N_c^a is the nitrogen content of the crop, N_c^c is the critical nitrogen value, and N_c^n is the non-function nitrogen content of the crop, which is crop specific. If N_c^a falls below N_c^c, then nitrogen stress occurs.

DAISY simulates *AET* as it simulates root growth, soil water flow, and changes in leaf area index (*LAI*) with growth and re-growth after grazing. DAISY has been linked with MIKE SHE to simulate *AET* due to its relatively comprehensive and theoretical evapotranspiration model, and the ability to update plant characteristics during the model run. However, the link was not used in this study for the following three reasons:

1. The link did not work: The link is designed to be established through the OpenMI environment to simulate water flows in unsaturated zone. However, the connection of DAISY remained broken until 25 Feb 2009.
2. The vertical spatial resolution for DAISY is higher than that for MIKE SHE in the hydrologic modeling study.
3. One of the most important hydrologic processes in this study is saturated water flow (groundwater table) and is not linked. Therefore, the groundwater table data have to be provided manually even if the link was established.

For these reasons, the link between DAISY and MIKE SHE was not used. This study used the open source version of DAISY 4.61 obtained from: http://code.google.com/p/daisy-model/.

2.4.2 Irrigation and Rest Period Scenarios

After the crop, soil hydraulic and nitrogen availability related parameters were calibrated the 8 scenarios were run with a 10-day rest period. This study defines "rest period" in the model as the period between two grazing events with the grazing event taking place in one day. In continuous grazing cattle are allowed to migrate within a large pasture and will intensely graze a small area then move on, giving the area a rest period before the cattle return. Higher stocking rates will lead to increased grazing intensity and a decreased rest period. It was considered that the grazing intensity in the WRB can be best represented by a 10-day rest period. The 8 irrigation scenarios were also run with a 30-day rest period to assess effects of the longer rest period on the pasture systems. The analysis was done based on the results from 16 simulations (8 irrigations x 2 rest periods) during the April to October growing season from 2005 to 2008.

2.4.3 Groundwater Table

DAISY imported and used the groundwater table elevation simulated by MIKE SHE for calibration and simulation runs. This study had to simulate flood irrigation by adjusting water table elevation. DAISY is designed to simulate flood irrigation by using a built-in function (irrigate_surface). However, the version of DAISY used in this study imposed water stress and suppressed plant growth whenever water was applied over the ground, therefore crop productivity decreased with frequent irrigation. In our preliminary study, DAISY reduced simulated pasture production by 36 % when the model switched the irrigation scenario from Lv6 (none) to Lv2 (bi-weekly), which contradicted the field observation data. This problem appears to suggest that there is a bug in the code for water stress estimation (Eq. [16]). To manage the problem, flood irrigation was simulated not by using the built-in function (irrigate_surface), but by raising the water table to near surface. Cattle manure was assumed 100 % dry for the same reason, which was schedule to be applied twice a month to simulate deposition of urine and feces from cattle. The expected error caused by this temporal solution in estimating crop water use should be negligible because crop water use was estimated by MIKE SHE which was set to simulate flood irrigation. Under flooded conditions AET and ET_c are temporarily increased by increasing surface evaporation [Allen *et al.*, 1998; Allen, 2005]. AET is maximized and becomes equal to ET_c so the AET/ET_c term in Eq. [16] is equal to one resulting in F_w being equal to F_p. AET is also maximized and becomes equal to ET_c by raising the groundwater table and saturating the root zone, therefore in this case F_w is also equal to F_p. Because water stress (F_w) is equal under both conditions, there is no difference in crop production.

2.4.4 Soil Hydraulic Data

The parameters in Eqs. [1] through [3] were first estimated from the laboratory data and then calibrated to match the simulated and observed pasture productivity at the non-irrigated sites in 2007 and 2008. Table 10 summarizes the values used in the DAISY model setup.

Table 10. Hydraulic properties used to describe the soil profile in the Wood River Basin.

Horizon	Depth			*Ksat*	θ_s	^θ_{fc}	^^θ_{wp}	θ_r	α	*n*	*l*
	m			cm/hr	cm^3/cm^3				1/cm	-	-
A1	0	-	0.04	0.050	0.618	0.511	0.117	0.083	0.003	1.745	0.50
A2	0.04	-	0.24	0.065	0.489	0.453	0.094	0.075	0.002	2.000	0.50
A/C	0.24	-	0.40	0.025	0.415	0.314	0.068	0.035	0.004	1.601	0.50
C	0.40	-	3.00	0.060	0.403	0.317	0.053	0.026	0.003	1.691	0.50
R	3.00	-	15.00	0.100	0.430	0.045	0.045	0.045	0.145	2.680	0.50

^ soil water content at h = 300 cm
^^ soil water content at h = 15000 cm

2.4.5 Weather Data

Table 11 summarizes the schedule and corresponding weather data used for calibration and simulation. The weather dataset for both calibration and simulation consists of the 2001-2008 weather data looped twice (total 16 years). The weather data in the first loop were dated 1993-2000 in the input file for convenience. The spin up period was scheduled to stabilize the vegetation and biochemistry (C and N) in the model. The model field was initialized (plowing, fertilizing and sowing) in the first year (1993). The pasture systems were grazed monthly and irrigated bi-weekly for this period. DAISY was set to record the simulation results only for the calibration and the simulation periods for the analysis. Grazing was scheduled on the same date as the field observation and irrigated bi-weekly for the calibration period. Grazing and irrigation for the simulation period were scheduled as described in Section 2.3.3.

Table 11. Schedule used for the calibration and simulation with DAISY, and used weather data. The values 01 – 08 correspond to 2001 – 2008.

Loop	Loop 1	Loop 2							
†Schedule	1993 - 2000	01	02	03	04	05	06	07	08
‡Used Data	2001 - 2008	01	02	03	04	05	06	07	08
Calibration	Spin up							Calibration	
Simulation	Spin up					Simulation			

† label date in the input file.
‡ original date.

2.4.6 Crop Parameters

Bi-weekly irrigation was used to calibrate the crop parameters in the calibration phase. This calibration was done to match the observed re-clip data in the irrigated fields in 2007 and 2008 (see the list below). DAISY provides the "grass.dai" parameter set as the default crop parameters for grass (for hay) agroecosystem. The parameters listed below were calibrated to match the observed irrigated pasture productivity (Table 12).

- *Qeff* — Quantum efficiency at low light [$(gCO_2/m^2/h)/(W/m^2)$]
- *Fm* — Maximum assimilation rate [$gCO_2/m^2/h$]
- *TempEff* — Temperature factor for assimilate production [dimensionless]
- *DSRate*1 — Development rate in the vegetative stage [dimensionless]
- *DSRate*2 — Development rate in the reproductive stage [dimensionless]
- *TempEff*1 — Temperature effect, vegetative stage [dimensionless]
- *PhotEff*1 — Photoperiod effect, vegetative stage [dimensionless]
- *Partit* — Fraction of the assimilate for growth goes to roots at a given development stage [dimensionless]

Table 12. Observed irrigated and non-irrigated pasture productivity.

Month	2007			2008		
	DOY	Irrigated	Non-Irrigated	DOY	Irrigated	Non-Irrigated
		—— kg/ha ——			—— kg/ha ——	
April	117	1846	2098			
May	145	1921	1822	148	6468	5206
June	170	1088	977	174	1301	1460
July	204	1424	660	202	1045	467
August	227	1102	619	230	612	279
September	253	760	508	258	504	195
October	283	693	577	293	258	135

2.4.7 Nitrogen Availability

It was assumed that the low productivity in the late season (September and October) of 2007 and 2008 was caused by low nutrient (nitrogen) availability. The pasture system in the WRB is dominated by cool season grasses (e.g. Kentucky bluegrass and Nebraska sedge). Cool season grasses grow best when the air temperature is between 60 °F and 75 °F (15.6 °C and 23.9 °C) [Beard, 1973], and thus are productive in the spring and fall. The observed data show high production in spring 2007 and 2008, but not in the fall. In fact, the data show continuous decline of productivity throughout the season at both irrigated and non-irrigated sites.

Nitrogen is a primary plant nutrient and often limits pasture productivity. Nitrogen becomes available for the growth of plants through nitrogen fixation by legumes, nitrogen fertilizer application, manure application, and through the mineralization of soil organic matter. There was no significant nitrogen input to these sites since no nitrogen fertilizer application was practiced, and small legume composition was present only in irrigated sites. The pasture systems had to recycle nitrogen from manure and soil organic matter, which is assumed enough to support spring growth, but not to sustain summer and fall growth. This nitrogen deficiency appears to explain the low productivity of summer and fall in 2008 after vigorous production in April and May. The application of dry manure was scheduled twice a month to simulate the return of manure to the land. This rate was decreased over the season to simulate and control nitrogen availability in the pasture.

2.4.8 Grazing

DAISY does not have a built-in function for grazing, but “grazing” can be mimicked by simulating “clipping hay” with the “combined” option. This option allows specifying how much vegetation is left after clipping by removing which parts of vegetation (combined: leaf, stem, and dead). The field observation data was obtained by clipping vegetation near the ground at about 3 cm height. To calibrate the model from this data "down to 3 cm base height" was used (Figure 2). With any lower base height, pasture could not survive. In the WRB cattle graze to about 10 cm height. To simulate grazing "down to 10 cm base height" was used. This base height was determined based on interviews with farm managers and is consistent with the recommended height (i.e. 5 to 15 cm or 2 to 6 inches) [Rinehart, 2006]. For the calibration timing of clipping is matched to the observation date. For the simulations 10-day and 30-day rest periods were used. The model reduced *DS* to 0.2 after clipping and grazing. Between *DS* = 0.20 and 0.25, the assimilation of growth going to roots was limited (*Partit* = 0.25) to promote aboveground growth.

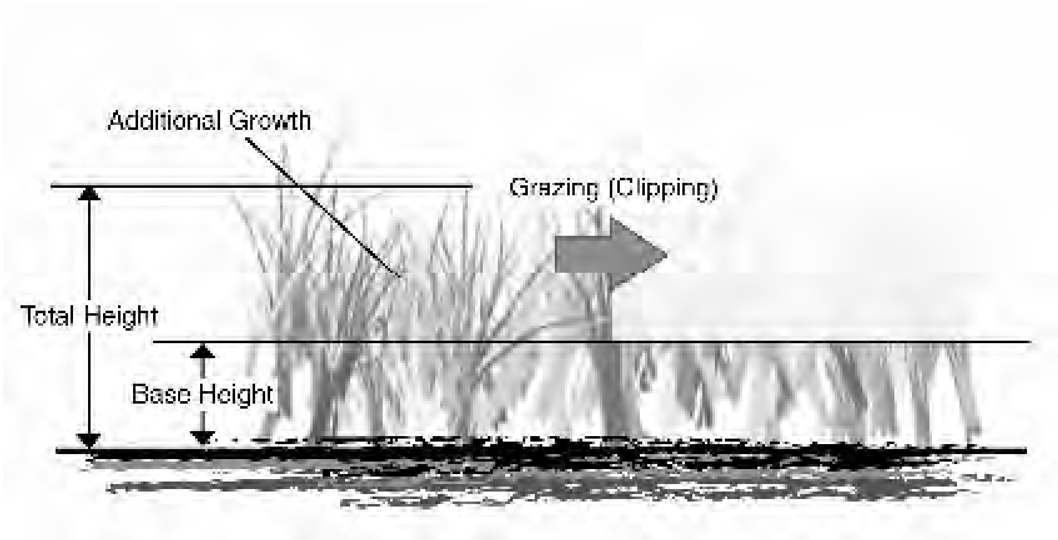

Figure 2. Description of grazing (clipping) specified in this study. Grazing was scheduled when development stage reached specified value or with specified rest period, and removed all biomass above the base height.

2.5 Data Analysis

Results of the simulations were evaluated using coefficient of determination (R^2) and Nash Sutcliffe correlation coefficient (*NS*) as described in Equations 18 and 19. NS can range from 1 to -∞ where 1 indicates a perfect fit, a value of 0 means that the model performs the same as taking the mean of the observed data, and negative values mean that the model performs worse than taking the mean of the observed values.

$$R^2 = 1 - \frac{\sum (Y_{est} - Y_{obs})^2}{\sum (Y_{obs} - \mu_{obs})^2} \qquad [18]$$

$$NS = \frac{\sum Y_{est} - Y_{obs}}{\sum Y_{obs} - \mu_{obs}} \quad [19]$$

where Y_{est} and Y_{obs} are the estimated and observed values, respectively, and μ_{obs} is the average of the observed values. In addition, sample standard deviation (STDEV) was used to describe deviation of values from the mean.

$$STDEV = \sqrt{\frac{\sum (Y_{obs} - \mu_{obs})^2}{N - 1}} \quad [20]$$

where N is the number of observations. In addition, to assess deviation of two data sets (e.g. over- or under-estimation), the Students *t*-test was used with significance level of 0.05 [Ramsey and Schafer, 2002]. We also used percentage change to describe the relative change between the value associated with the reference condition (Lv2) and the value associated with a target condition.

$$\Delta = \frac{V_T - V_R}{V_R} \quad [21]$$

where Δ is the percent change, V_T is the value associated with the reference condition, and V_R is the value associated with a target condition.

3 Results and Discussion

3.1 DAISY Model Performance

Model performance for DAISY was assessed by comparing the observed vs. simulated crop production data for 2007 and 2008. Figure 3 shows the time-series of the results and Figure 4 is a plot of simulated vs. observed values.

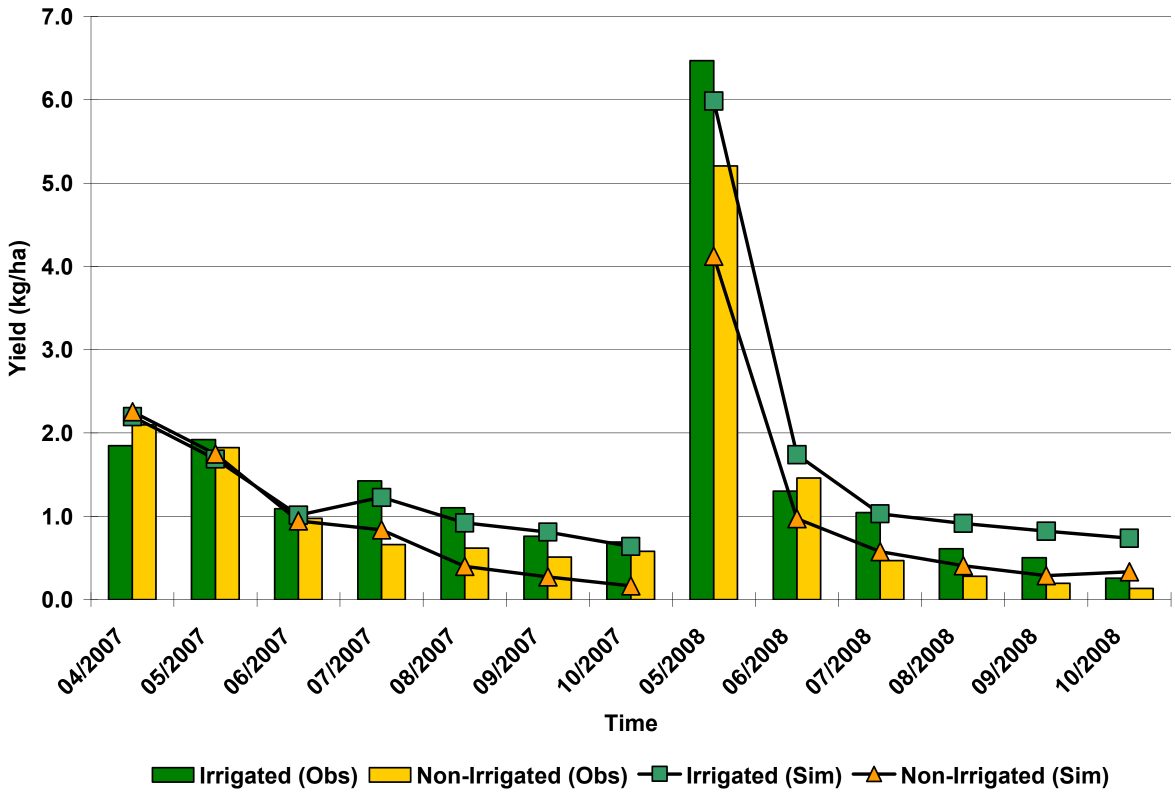

Figure 3: Simulated and observed crop production for 2007 and 2008.

The results show a good fit between the model output and observed values of monthly production. These values plot along the 1:1 line in Figure 4, indicating good model performance. The R^2 coefficient of determination forces through the origin for the Irrigated data is 0.96 and the R^2 for the non-irrigated data is 0.92.

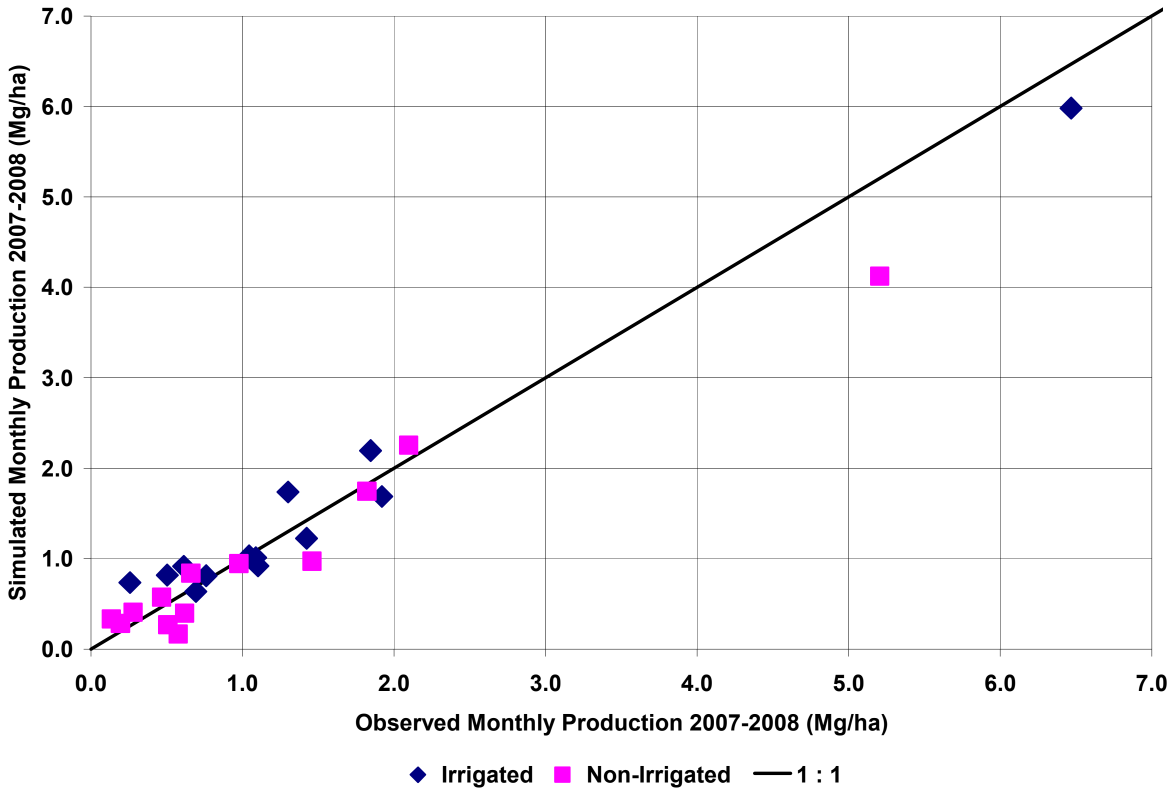

Figure 4: 2007 and 2008 simulated vs. observed values for irrigated and non-irrigated pastures

3.2 MIKE SHE Model Performance

Model performance for MIKE SHE was assessed by comparing observed vs. simulated water table data for site 4N which are shown as a time series in Figure 5. Three different scenarios for the aquifer boundary condition flux term were tested, constant, monthly, and seasonal, as discussed in section 2.3.4.8. The flux values were calibrated over the 2007 period and the same flux values were used for each year in multi-year simulations. 2008 data were used to validate the 2007 results. Nash-Sutcliffe efficiency and R^2 fits are reported in Table 13 for the calibration and validation. The efficiencies are also reported for the growing season from 01 April to 31 October, because this if the period of interest. The amount of data within this period is limited for the non irrigated sites because the water table fell below sensor depth through most of the summer.

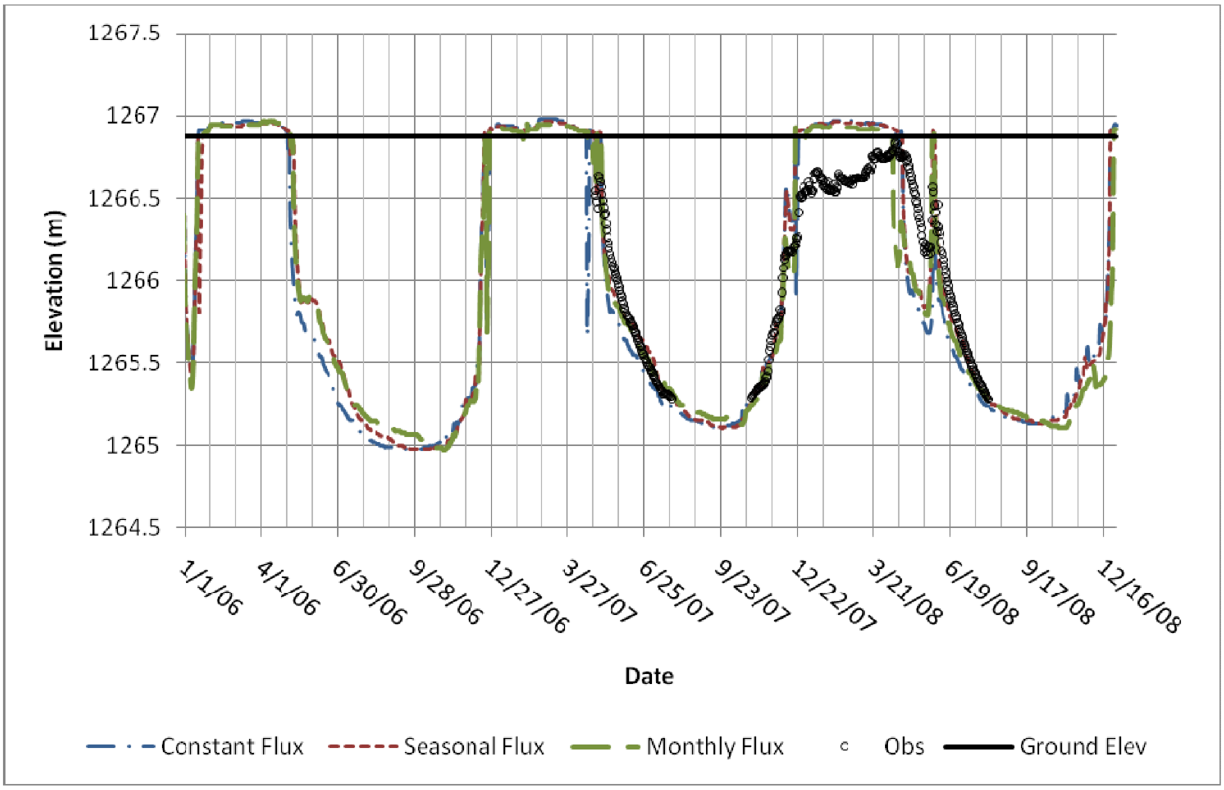

Figure 5: 4N 2006 to 2008 simulated and observed water table elevation.

Table 13. Goodness of fit parameters for the calibration period (2007) and validation period (2008).

Parameter	Constant Flux		Seasonal Flux		Monthly Flux	
	Calibration Period 2007	Validation Period 2008	Calibration Period 2007	Validation Period 2008	Calibration Period 2007	Validation Period 2008
Nash-Sutcliffe	.731	.415	.773	.573	.796	.515
Nash-Sutcliffe†	.763	.503	.893	.725	.887	.597
R^2	.846	.762	.871	.799	.871	.735
$R^{2\dagger}$	.868	.779	.895	.802	.899	.769

† these parameters were calculated for 01 April to 31 October.

The model performs well for all three scenarios based on the R^2 and Nash-Sutcliffe efficiency values. Small gains are seen for more detailed seasonal and monthly variable flux terms during the calibration period, but the seasonal flux term performs better than the monthly flux term during the validation period. In each case the fit over the validation period is worse than the calibration period due to natural annual variations. The calibration would be more representative of a typical year if it could take place over a longer period. The differences in fit to the observed data are considered acceptable since there was only a single year each for calibration and validation. The constant flux scenario was chosen for use in the irrigated scenarios that required an aquifer boundary flux (Lv5j, Lv5a, Lv5s and Lv6) because it performed well and is much simpler than the other scenarios. Monthly and seasonal variation in flux could change from year to year, however we do not have water table data for every simulated year to calculate the flux. Therefore a constant flux is more applicable for multi-year simulations. Using constant flux, which was chosen to fit water table data primarily during the growing season, resulted in too much water in the system over the winter months and the profile remaining saturated over the entire winter. Since 1) the WRB pastures are vacant during the winter, and 2) this period does not represent a large portion of the total plant production, inaccuracies during this period were deemed relatively unimportant.

Due to the good performance of the model at 4N a similar setup was used for 3I. For 3I the actual irrigation management is unknown, therefore we could not attempt to reconstruct the measured water table data. Short periods of water table recession were compared when it was expected that irrigation was not occurring (Figures 6 and 7).

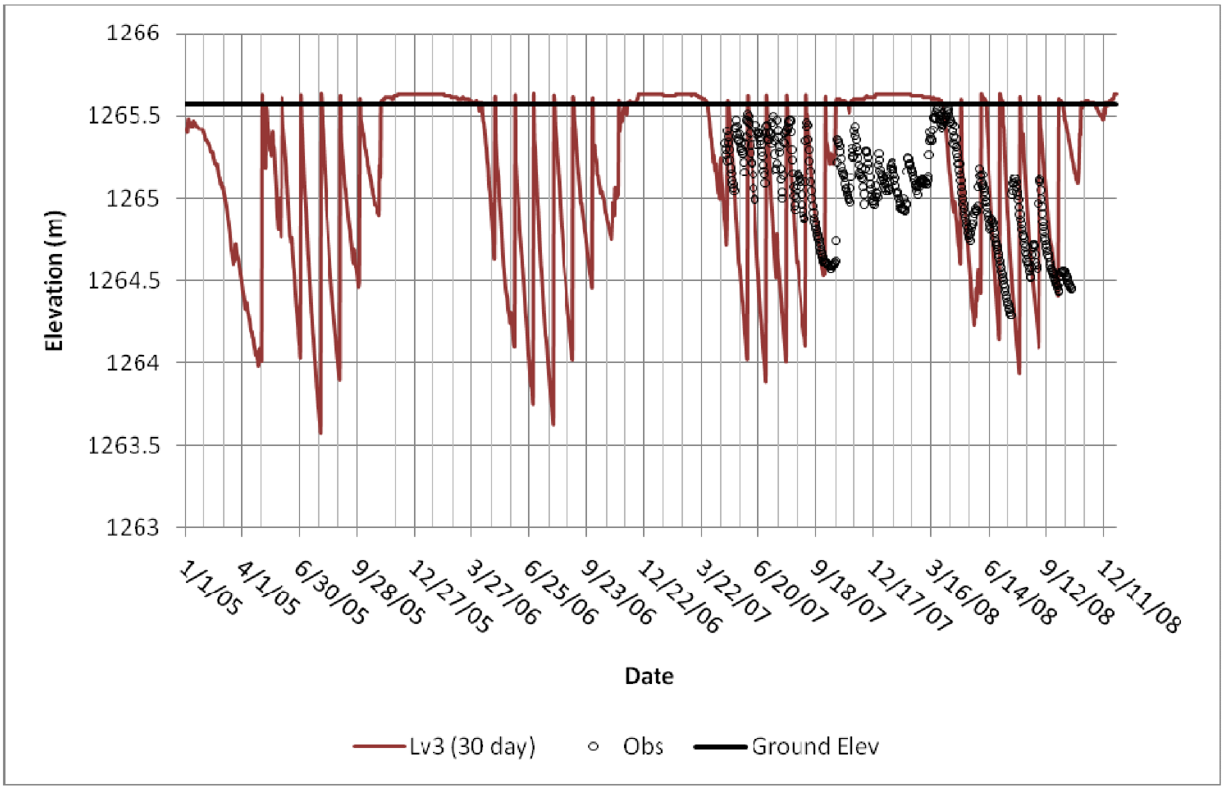

Figure 6: Four-year simulation for Irrigation Lv3 (every 30 days), poor correlation and low Nash-Sutcliffe efficiency result because recreating the actual water table elevation was not attempted.

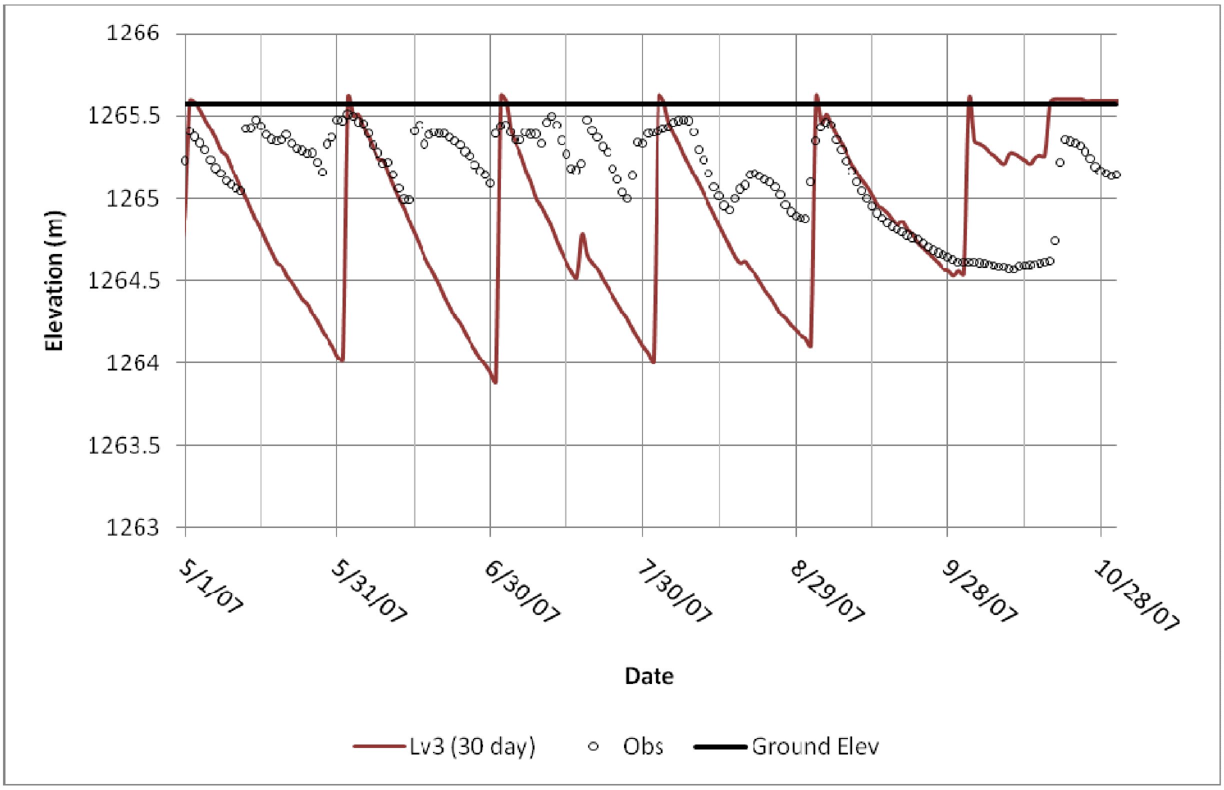

Figure 7: Irrigation Lv3 (every 30 days) from May 2007 to October 2007. Note water table recessions beginning June 2 and September 4.

The actual irrigations were not accounted for in the simulation, rather the irrigation was simplified to happen at regular intervals over a 24-hour period. On 02 June 2007 and 04 September 2007 the modeled irrigation and actual irrigation timing coincide to achieve a saturated profile, followed by a period of no irrigation and water table recession. This gives an opportunity to compare the simulated and observed water table elevations. The measured and simulated recession curves fit very well for the period following irrigation until the next irrigation occurs. The Nash Sutcliffe efficiency for 02 June 2007 to 14 June 2007 is 0.878 and the Nash Sutcliffe Efficiency for 04 September 2007 to 30 September 2007 is 0.954. It is otherwise noted that the shape of the observed water table recession is similar to the simulated water table recession during other periods, even though the recessions do not occur at the same time.

3.2.1 Crop Production and Depth of Water Applied

Tables 14 (SI Units) and 15 (US Units) summarize the irrigation and plant production results from MIKE SHE and DAISY with a 10-day rest period that represents the typical grazing management in the WRB. *Irr* is the total water applied during the growing season including irrigation and precipitation, and $Prod_{10}$ is the total monthly plant production with a 10-day rest period. Note that while $Prod_{10}$ changed less than 25% between the irrigation scenarios, *Irr* varied significantly (approximately 9-fold). Therefore, much of water applied is used to fill the soil profile without contributing to crop production. Among them, *Irr* for Lv1, Lv2, Lv3, and Lv4 are all very similar and likewise $Prod_{10}$ is very similar. This indicates that enough moisture to maintain near full production is maintained in the soil profile over a 60-day period (especially during the most productive spring season), and that additional return with more frequent irrigations is diminishing. *Irr* and $Prod_{10}$ are very similar between Lv5j, Lv5a, and Lv5s. This indicates that the timing of a once-a-season irrigation is not important. These data are also presented in Figures 8, 9, and 10.

Table 14. Total water applied and plant production with 10-day rest period during the growing season (May-October), SI units.

Level	— 2005 —		— 2006 —		— 2007 —		— 2008 —	
	Irr	$Prod_{10}$	***Irr***	$Prod_{10}$	***Irr***	$Prod_{10}$	***Irr***	$Prod_{10}$
	(mm)	**(kg/ha)**	**(mm)**	**(kg/ha)**	**(mm)**	**(kg/ha)**	**(mm)**	**(kg/ha)**
Lv1	**909**	**5620**	**844**	**6140**	**905**	**4830**	**812**	**6090**
Lv2	**916**	**5450**	**813**	**5980**	**862**	**4700**	**834**	**5880**
Lv3	**876**	**5100**	**734**	**5650**	**847**	**4360**	**810**	**5660**
Lv4	**948**	**4730**	**830**	**5330**	**907**	**4120**	**858**	**5240**
Lv5j	**348**	**4570**	**398**	**5190**	**487**	**3880**	**438**	**5070**
Lv5a	**468**	**4560**	**398**	**5170**	**487**	**3850**	**438**	**5050**
Lv5s	**468**	**4450**	**398**	**5050**	**487**	**3720**	**438**	**4970**
Lv6	**108**	**4230**	**38**	**4860**	**127**	**3560**	**78**	**4770**

Table 15. Total water applied and plant production with 10-day rest period during the growing season (May-October), US units.

Level	— 2005 —		— 2006 —		— 2007 —		— 2008 —	
	Irr	*Prod*$_{10}$	*Irr*	*Prod*$_{10}$	*Irr*	*Prod*$_{10}$	*Irr*	*Prod*$_{10}$
	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)	(in)	(lb/ac)
Lv1	35.8	5019	33.2	5483	35.6	4313	32.0	5438
Lv2	36.1	4867	32.0	5340	33.9	4197	32.8	5251
Lv3	34.5	4554	28.9	5045	33.3	3893	31.9	5054
Lv4	37.3	4224	32.7	4760	35.7	3679	33.8	4679
Lv5j	13.7	4081	15.7	4635	19.2	3465	17.2	4528
Lv5a	18.4	4072	15.7	4617	19.2	3438	17.2	4510
Lv5s	18.4	3974	15.7	4510	19.2	3322	17.2	4438
Lv6	4.3	3777	1.5	4340	5.0	3179	3.1	4260

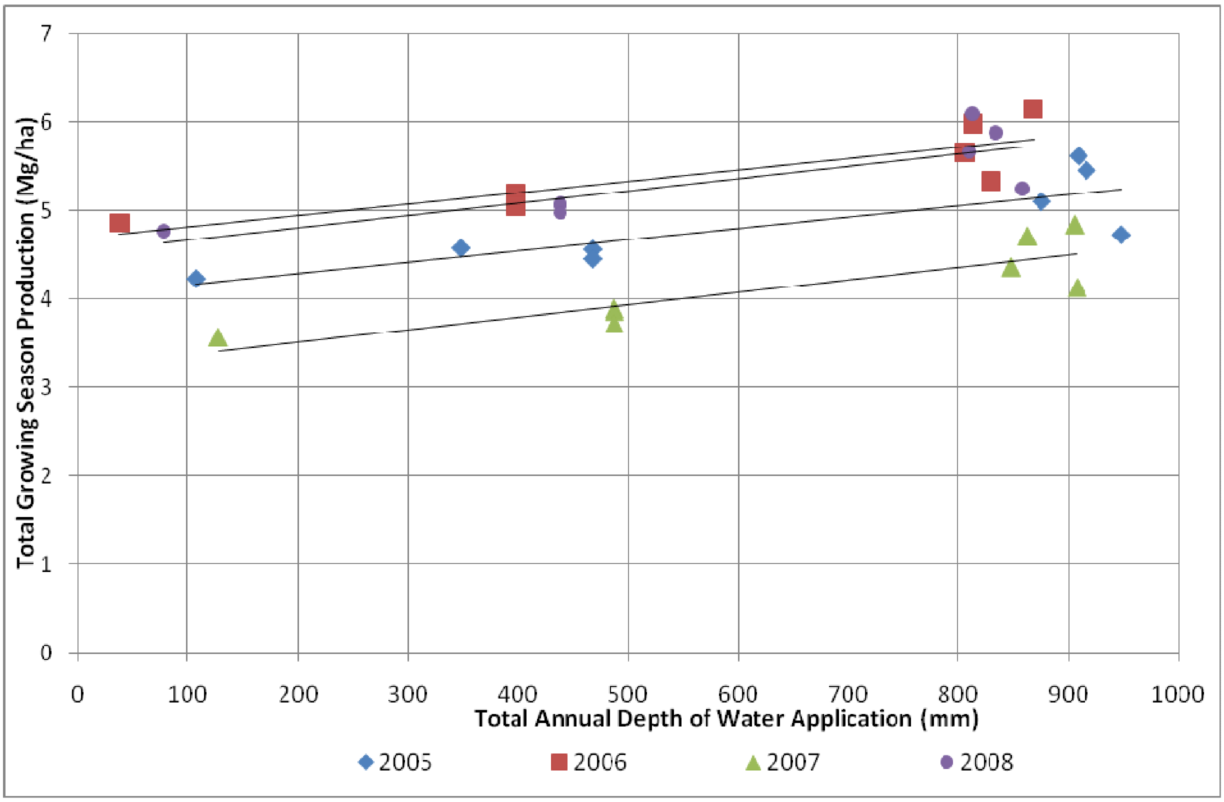

Figure 8: Crop production vs. irrigation depth for 2005 to 2008 with rest period = 10 days.

Figure 8 shows the change in crop production in response to different irrigation levels for four years in the WRB. The points are clumped into three distinct groups. The group at the right (750 to 950 mm) represents irrigation scenarios Lv1, Lv2, Lv3, and Lv4. The group in the middle (350 to 500 mm) represents irrigation scenarios Lv5j, Lv5a, and Lv5s. The group at the left (50 to 150 mm) represents irrigation scenario 6. One of the reasons why the irrigation levels are so similar within these groups is because the 1-D MIKE SHE model assumes 100% uniformity and efficiency of the irrigation application with no waste. During an actual flood irrigation there will be areas that are over-irrigated to obtain the same water table dynamics as the observation point used in the simulation. These over-irrigated areas can represent wasted water and loss of production due to extended saturated conditions. Reducing the number of irrigation events will lead to more efficient use of water if we assume that each irrigation event results in a given amount of water wasted.

It is convenient to take the average of each of the groups mentioned above for the monthly crop production curves because there is little difference between treatments within these groups. Figure 9 shows the monthly production for 2005 to 2008 of all the irrigation scenarios and Figure 10 shows monthly production averaged within the grouped irrigation levels mentioned above.

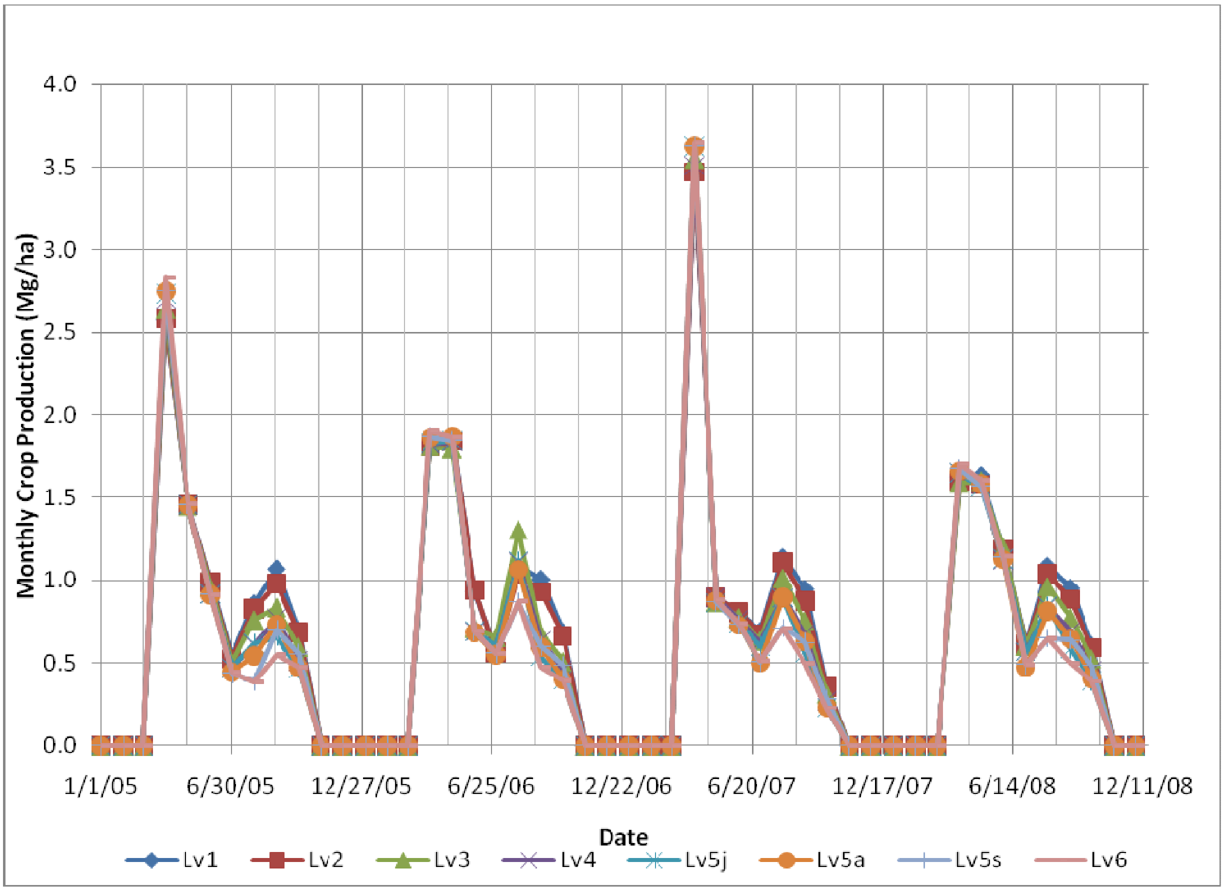

Figure 9: Four-year (2005-2008) simulated monthly crop production for rest period = 10 days

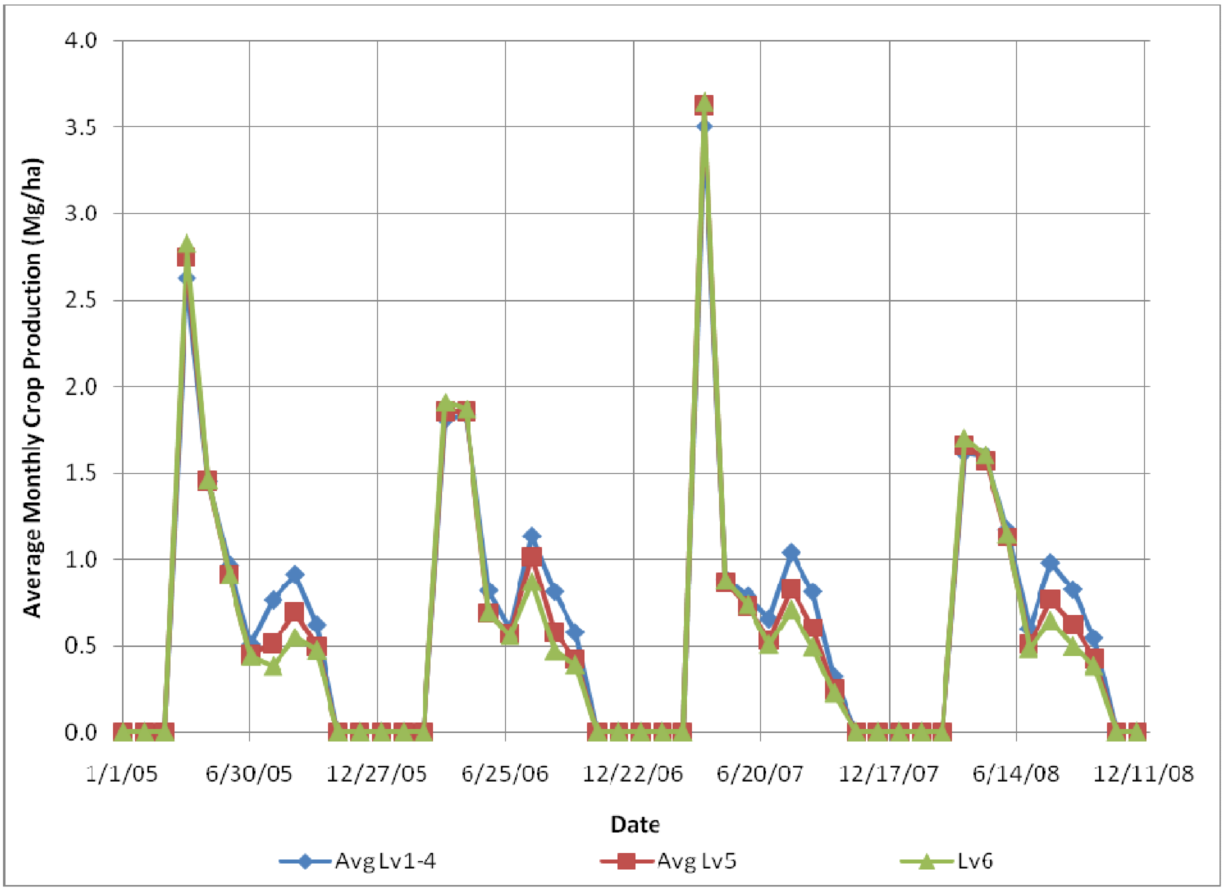

Figure 10: Monthly crop production for 2005 to 2008 averaged within grouped levels of irrigation for rest period = 10 days

Figures 8, 9 and 10 show that there is a small decrease in crop production with reduced irrigation levels. The total annual production during the growing season (May to October) is shown in the Table 16, averaged within the irrigation groups as in Figure 10.

Table 16. Average monthly production for each irrigation group with the 10-day rest period (*Prod*$_{10}$). Note that the STDEV between years (bottom) is larger than the STDEV between irrigation groups (right).

	Avg Lv1-4	Avg Lv5	Lv6	†% change	STDEV
	kg/ha (lb/ac)			%	kg/ha (lb/ac)
2005	5224 (4660)	4528 (4039)	4228 (3772)	-19.1	511 (456)
2006	5775 (5152)	5135 (4581)	4860 (4335)	-15.9	470 (419)
2007	4504 (4017)	3818 (3406)	3560 (3176)	-20.9	488 (435)
2008	5718 (5101)	5029 (4486)	4766 (4251)	-16.7	492 (439)
Average	5305 (4733)	4628 (4128)	4353 (3883)	-17.9	
STDEV	589 (525)	601 (536)	597 (533)		

† percent change from Avg. Lv1-4 to Lv6.

The percent change column is the difference between Avg Lv-1-4 and Lv6 (full irrigation and non-irrigation) and ranges from 16.7 % to 20.9 % with the 10-day rest period. The similar standard deviation between irrigation levels (≈ 600 kg/ha) shows that pasture systems with short rest periods are influenced by precipitation (and other environmental factors) that are highly variable from year to year. The standard deviation between the four years (average 470 kg/ha) is smaller, but significant. This confirms that the pasture systems in the WRB are highly influenced by the environmental factors.

3.2.2 Crop Production and Rest Period

Another set of simulations was done with a 30-day rest period using the same meteorological and field hydrological data to assess the effect of longer rest periods (shifting from continuous grazing to rotational grazing) on the pasture system in the WRB.

Tables 17 (SI Units) and 18 (US Units) summarize the irrigation and plant production results from MIKE SHE and DAISY with the 30-day rest period. *Prod*$_{30}$ is the total monthly plant production with the 30-day rest period.

Table 17. Total water applied and plant production with 30-day rest period during the growing season (May-October) - SI units.

	— 2005 —		— 2006 —		— 2007 —		— 2008 —	
Level	***Irr***	***Prod*$_{30}$**	***Irr***	***Prod*$_{30}$**	***Irr***	***Prod*$_{30}$**	***Irr***	***Prod*$_{30}$**
	(mm)	**(kg/ha)**	**(mm)**	**(kg/ha)**	**(mm)**	**(kg/ha)**	**(mm)**	**(kg/ha)**
Lv1	**901**	**6130**	**836**	**6060**	**897**	**5940**	**812**	**6620**
Lv2	**911**	**5980**	**808**	**5880**	**857**	**5840**	**834**	**6460**
Lv3	**878**	**5610**	**736**	**5520**	**850**	**5470**	**810**	**6080**
Lv4	**956**	**5290**	**837**	**5260**	**915**	**5210**	**858**	**5810**
Lv5j	**350**	**5160**	**401**	**5120**	**491**	**5080**	**438**	**5690**
Lv5a	**471**	**5160**	**401**	**5170**	**490**	**5020**	**438**	**5620**
Lv5s	**471**	**5060**	**401**	**5030**	**491**	**4890**	**438**	**5480**
Lv6	**108**	**4880**	**38**	**4870**	**127**	**4760**	**78**	**5330**

Table 18. Total water applied and plant production with 30-day rest period during the growing season (May-October) - US units.

	— 2005 —		— 2006 —		— 2007 —		— 2008 —	
Level	***Irr***	***Prod*$_{30}$**	***Irr***	***Prod*$_{30}$**	***Irr***	***Prod*$_{30}$**	***Irr***	***Prod*$_{30}$**
	(in)	**(lb/ac)**	**(in)**	**(lb/ac)**	**(in)**	**(lb/ac)**	**(in)**	**(lb/ac)**
Lv1	**35.5**	**5474**	**32.9**	**5412**	**35.3**	**5304**	**32.0**	**5912**
Lv2	**35.9**	**5340**	**31.8**	**5251**	**33.7**	**5215**	**32.8**	**5769**
Lv3	**34.6**	**5010**	**29.0**	**4929**	**33.5**	**4885**	**31.9**	**5429**
Lv4	**37.6**	**4724**	**33.0**	**4697**	**36.0**	**4653**	**33.8**	**5188**
Lv5j	**13.8**	**4608**	**15.8**	**4572**	**19.3**	**4536**	**17.2**	**5081**
Lv5a	**18.5**	**4608**	**15.8**	**4617**	**19.3**	**4483**	**17.2**	**5019**
Lv5s	**18.5**	**4519**	**15.8**	**4492**	**19.3**	**4367**	**17.2**	**4894**
Lv6	**4.2**	**4358**	**1.5**	**4349**	**5.0**	**4251**	**3.1**	**4760**

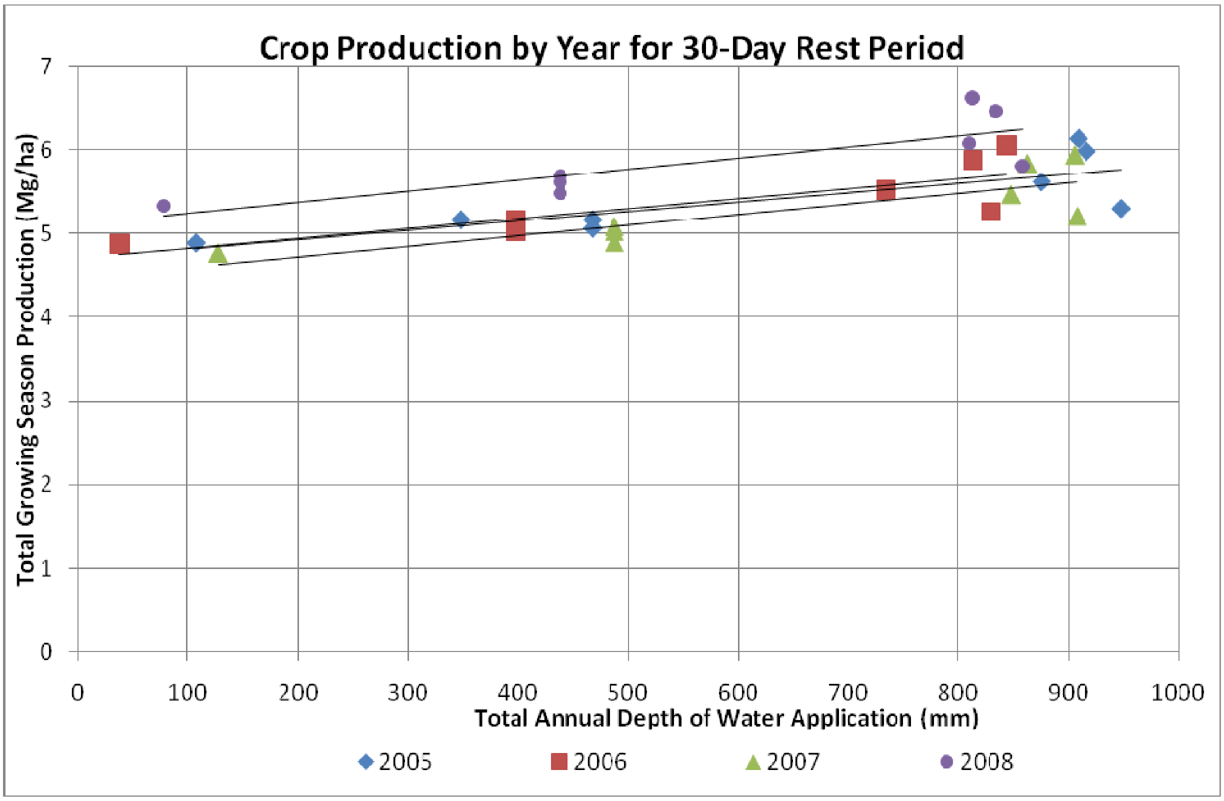

Figure 11: Crop production vs. irrigation depth for 2005 to 2008 with rest period = 30 days.

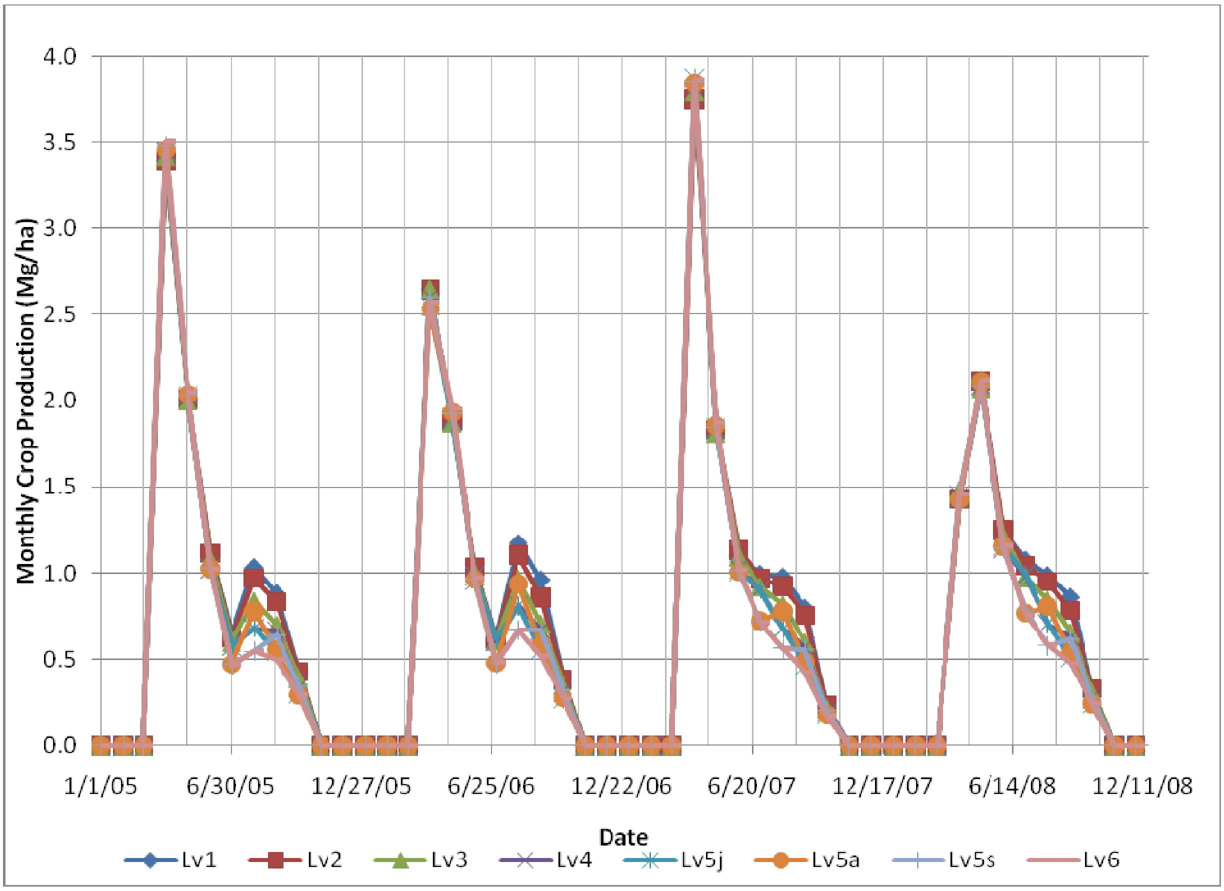

Figure 12: Four-year (2005-2008) simulated crop production for rest period = 30 days

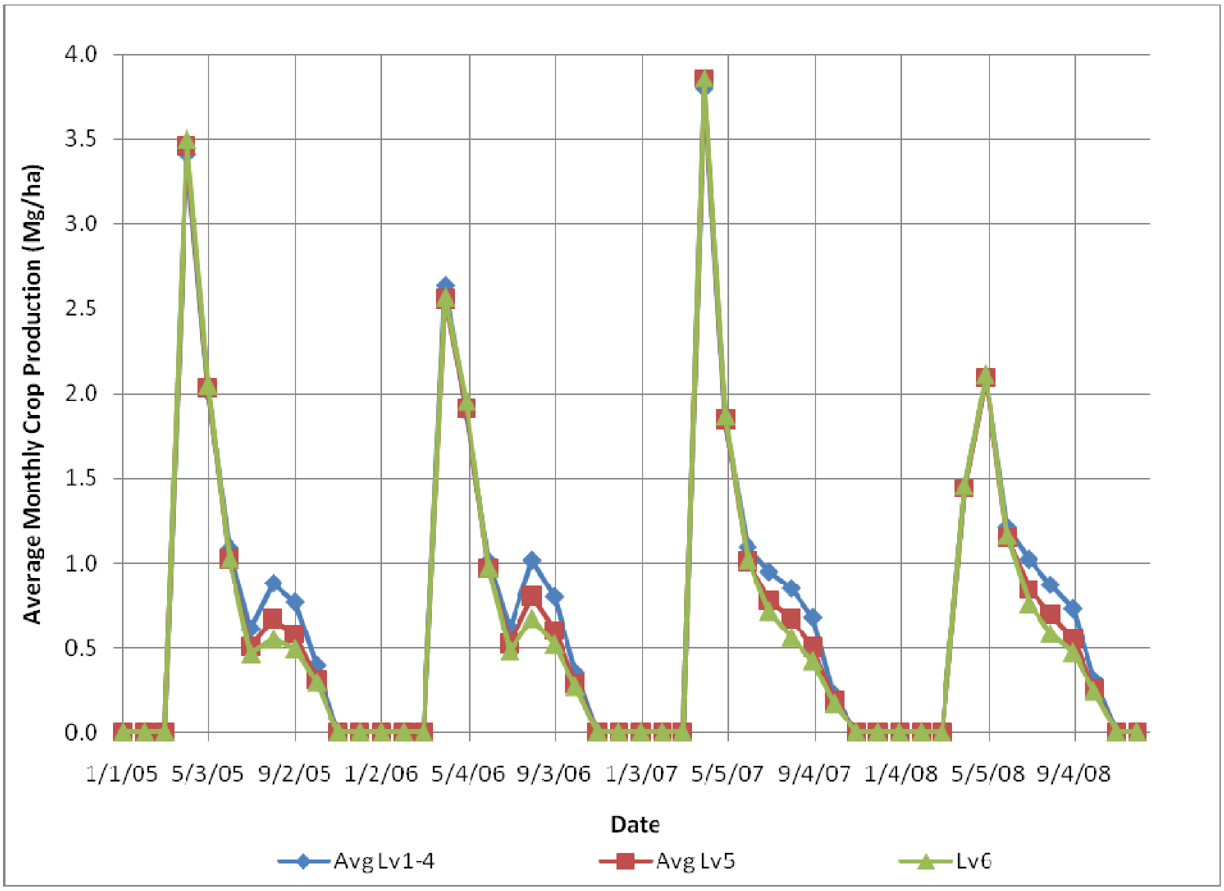

Figure 13: Monthly crop production for 2005 to 2008 averaged within grouped levels of irrigation for rest period = 30 days

The parameterization of MIKE SHE was for short grass with constant *LAI*, which is similar to the condition simulated by DAISY with a 10-day rest period. To assess changes in grass height (*LAI*) and root growth as a function of different rest periods a correction multiplier (ΔIrr) was calculated based on the simulated changes in actual evapotranspiration rate by DAISY with different rest periods (Irr_{30}/Irr_{10}). Estimated ΔIrr ranged between 0.9893 to 1.0101, or about ± 1%, meaning that the irrigation demand was roughly equal for both rest periods, therefore the same depth of water application was used. The 30-day rest period pasture was more productive, had increased LAI and root depth, and therefore water demand for photosynthesis and transpiration is increased. The increased LAI also means that less ground is exposed and the evaporation from bare soil should decrease. In this case the balance between increased transpiration and decreased evaporation keeps the evapotranspiration and consumptive use roughly constant.

Table 19. Average monthly production for each irrigation group in the 30-day rest period (*$Prod_{30}$*). Note that the STDEV between years (bottom) is smaller than the STDEV between irrigation groups (right).

	Avg. Lv1-4	Avg. Lv5	Lv6	†% Change	STDEV
	kg/ha (lb/ac)			%	kg/ha (lb/ac)
2005	5753 (5131)	5127 (4573)	4885 (4357)	-15.1	448 (399)
2006	5678 (5065)	5106 (4555)	4874 (4347)	-14.2	414 (369)
2007	5615 (5008)	4998 (4459)	4763 (4249)	-15.2	440 (392)
2008	6241 (5567)	5598 (4993)	5333 (4757)	-14.6	467 (417)
Average	5822 (5193)	5207 (4645)	4964 (4427)	-14.7	
STDDEV	285 (254)	266 (238)	252 (225)		

† percent change from Avg. Lv1-4 to Lv6.

The lower standard deviation between years with a 30-day rest period (≈ 270 kg/ha) compared to that with a 10-day rest period (≈ 600 kg/ha) shows that pasture systems with longer rest periods are influenced less by environmental factors and more by irrigation levels. With the 30-day rest period the pasture productivity is more consistent from year to year than with the 10-day rest period (Figures 8 and 11)).

3.2.3 Further Consideration of the Simulation Results

Although our overall simulation results are consistent with the observations there are some deviations which should be addressed. The range of the percent change with the 30-day rest period is less variable and smaller than the findings of the *Wood River Valley Vegetation Monitoring Summary 2007-2008* which reported a change of about 20% in total crop production (18% and 24% in 2007 and 2008, respectively). The vegetation monitoring was done with rest period of 23-35 days, thus the observation results should be equivalent to the simulation result with 30-day rest period. The deviation of the simulation result from the observed data can be attributed to timing of re-clipping and the water-nutrient relationship. Grass was not clipped in April 2008, resulting in exceptionally high yield in May 2008. The calibration process could be forced to over-weight the spring (April-May) production because of the significantly larger values. Although overestimation of crop productivity in one or two months may sound insignificant, April and May production comprise approximately 57% of annual productivity (53% and 61% in Irrigated and Non-Irrigated Sites, respectively), and this potential problem should not be neglected.

The above argument for the two rest periods was based on the assumption that the model, which was calibrated using the observation data with approximately 30-day rest period, can correctly capture the root growth as a function of different rest periods. There are two opposing viewpoints on response of root growth to different rest periods. Generally it is assumed that grazing induces a decline in root growth [Belsky, 1986; Jameson, 1963]. However, some recent field and simulation studies [Frank *et al.*, 2002; McNaughton *et al.*, 1998] have shown that is not always the case. Our simulation results show that root biomass slightly increased with a shorter rest period. Unfortunately, we did not have observation data to validate the result.

Our simulations were done with the same dry manure application rate for all simulated years (2005-2008) and irrigation levels (Lv1-Lv6) because sufficient data to model nitrogen dynamics in the fields for all years and irrigation levels were not available. DAISY simulation results suggest that nitrogen availability in the pasture systems in the WRB (no external nitrogen sources) is not sufficient to support full productivity throughout the growing season. This nitrogen deficiency could explain the lower observed yield in 2008 (June-October). Using the same manure application in all years means there is a similar seasonal trend of nitrogen availability which could force underestimation of differences in productivity between years. Also, if nitrogen was a major limiting factor, the effect of irrigation treatment on pasture productivity in the WRB was not fully appreciated.

4 Conclusions

This modeling study as well as the *Wood River Valley Vegetation Monitoring Summary 2007-2008* [Stringham and Quistberg, 2008] both show that there is a small, but appreciable decrease in pasture production between the irrigated and non-irrigated treatments. Crop production variation between years (STDEV = 490 kg/ha with 10-day rest period) is similar to the variation between the irrigated and non-irrigated treatments (STDEV = 596 kg/ha with 10-day rest period) making it difficult to separate the influence of annual variability from the influence of irrigation level. However this modeling study and previous studies of consumptive use show that irrigated pastures are more productive. When considering years individually there is a consistent reduction in productivity in the non-irrigated sites (average 17.9 % with 10-day rest period, 14.7 % with 30 day rest period).

DAISY was used to assess pasture productivity as a function of irrigation (8 scenarios) and rest period (10-day and 30-day). Because DAISY had a problem with simulating flood irrigation and estimating water stress, we could not use the built-in function for flood irrigation. We used the simulated groundwater information provided by MIKE SHE and moved the groundwater table to mimic flood irrigation. Because 1) this study uses crop water demand (*AET*) estimated by MIKE SHE and 2) DAISY can simulate crop productivity correctly as long as the root depth is saturated ($AET/ET_c = 1$), this solution would not cause any error in our results.

We also simulated all irrigation levels with the same nutrient availability. The high moisture content of the pasture forages in a well-watered system results in a very wet and nitrogen rich manure that is readily decomposable by soil organisms [Bellows, 2001]. Thus, more nitrogen can be recycled and become available in pasture systems with more frequent irrigation. For better appreciation of the effect of irrigation management on pasture productivity, an additional comprehensive nutrient study is recommended.

The current 1-D modeling to find irrigation levels was used because it is consistent with the 1-D modeling performed by DAISY. Flood irrigation in MIKE SHE adds ponded water to the surface and for 1-D modeling flood irrigation will have a high efficiency, which is why we see very similar depths of application for irrigation levels 1 to 4 in the simulation. These depths of application are close to the consumptive use. For actual flood irrigations in the WRB the efficiency will be fairly poor, meaning that for each irrigation event there will be areas of over-application where excess water is applied. Frequent irrigations (level 1 or 2) should have a higher depth applied than less frequent irrigation (level 3 or 4), but the total depth applied is similar for all of these levels and averages 860mm (33.9 in). The extensive drainage network and highly transmissive soils in the WRB means that excess water from over-application is readily returned to the channel network, does not subtract significantly from in-stream flows, and does not increase consumptive use within this range (Level 1 to 4). Differences in application depth between the irrigation groupings noted in Figures 8 and 11 do affect the crop productivity and hence the consumptive use. Level 5 irrigation (Levels 5j, 5a and 5s) averages 440mm (17.3in) applied. While this represents a 420mm (16.5in) reduction of applied water it is unclear whether the consumptive use is reduced similarly. To model irrigation level 5, the *BC2Flux* term, which represents sub-irrigation input from adjacent areas, has to be included and must be greater than zero.

Cattle migrating freely in a large pasture will graze a subarea and move on, giving the subarea a chance to rest before returning. The rest period duration for continuous grazing will depend on the stocking rate and pasture productivity. The simulated 10-day rest period with the 10-cm base height was used to approximate the continuous grazing system that is currently used in the WRB. For the cool season grasses a 10-day rest period is probably sufficient to keep the growth rates of the grasses at optimal rates during spring and fall, although two to three weeks would be more ideal [Blanchet *et al.*, 2003]. A longer rest period of about 6 weeks is ideal during the summer months. Less than this and the grasses will be stressed over the summer months and take longer to reach optimal growth stages for the fall growing season [Rinehart, 2006]. Severely curtailing cattle stocking rates during the summer is not practical, therefore a 30-day rest period was simulated because it was considered to 1) represent an improvement of overall pasture production, 2) be able to support a consistent stocking rate throughout the season, and 3) increases in management costs will be small.

A 30-day rest period requires an increase in management costs over continuous grazing because of the time needed to move cattle and the capital required for fencing and maintenance. The pasture productivity for the 30-day rest period is higher than that of the 10-day rest period as seen in Figures 8 and 11. Another key feature of the 30-day rest period is that the year to year variation is much lower. Pasture productively will remain high in what would be poor years under the 10-day rest period, such as 2007, if the 30-day rest period is adopted. The 30-day rest period for 2007 was about 30% more productive than the 10-day rest period for all irrigation levels. In 2006, a good year, there was no difference in productivity between the rest periods. Our study results indicate that the advantage of using a 30-day rest period in grazing management is to be able to have consistent productivity from year to year and to mitigate environmental factors that would cause productivity to drop for a given year.

One possible affect of the current patchwork of irrigated and non-irrigated fields in the WRB is that the irrigated fields may contribute to maintaining a higher water table across the WRB making sub-irrigation from the shallow aquifer to the non-irrigated sites possible. If more landowners become program participants, resulting in significant amounts of land being taken out of irrigation, there may be basin-wide implications due to a lower water table.

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Appendix 6

Final Wood River Conservation Effects Assessment Project Report

Introduction to Appendix 6

Appendix 6 contains the final Aquatic Habitat monitoring report prepared by Graham Matthews & Associates (GMA). The Aquatic Habitat component of this Wood River CEAP study was undertaken to repeat the baseline monitoring work GMA undertook in 2003 at the behest of the Klamath Basin Rangeland Trust. The 2008 monitoring work undertaken by GMA allowed for the measurement of changes in fish habitat on Sevenmile and Crooked Creeks after five years of conservation work in the area.

WOOD RIVER VALLEY AQUATIC HABITAT STUDY 2008 MONITORING REPORT

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WOOD RIVER VALLEY AQUATIC HABITAT STUDY
2008 MONITORING REPORT

1.0 INTRODUCTION

The Wood River Valley is located within the Upper Klamath Basin on the eastern slopes of the Cascade Mountains in South Central Oregon. The Wood River Valley once contained over 60,000 acres of wetlands; however, throughout the last century most of its marshes have been eliminated and many of its stream systems have been modified as a result of diking, draining, channelization, irrigation diversion and other activities primarily associated with agricultural management practices. By 1989 the wetland area had been reduced to about 44,000 acres (Carlson 1993). In addition to the reduction of wetland habitat, the hydrology and channel form within many of the important creeks and rivers, such as Sevenmile Creek, Crooked Creek, and the Wood River have been significantly impacted and modified by these management actions.

In 2002, the Klamath Basin Rangeland Trust (KBRT) developed a new land and water management plan for the Wood River Valley, and began a pilot project to evaluate the feasibility and effectiveness of the new plan. The goal of the program is to increase the quantity and quality of water in the Klamath Basin by conserving irrigation water in the Wood River Valley, while restoring pastures and wetlands to maximize ecological value. The primary means to accomplish this goal was eliminating irrigation diversions for project lands, thus leaving this water instream, providing important ecological benefits and increased flows for downstream use. Other actions include various cattle management strategies, including substantial reductions in cattle numbers, riparian fencing, and active stream restoration.

Extensive monitoring of the project lands was begun in 2002, including surface water, water quality, fish habitat, and stream condition. Initial thoughts on the potential timeframe until changes caused by KBRT management were detectable suggested a 5-10 year period. Now that over five years have passed since initiation of the KBRT program, it is appropriate to evaluate changes. This current monitoring and comparison to 2002/2003 data has been funded by the USDA Natural Resources Conservation Service.

1.1 Previous Work

Baseline conditions were established in 2002 and 2003 (Pacific Groundwater Group, et al 2003, Kann and Reedy 2004) for fish habitat and geomorphic conditions of Crooked Creek and Sevenmile Creek (Figure 1), two streams affected by management actions of KBRT. Additional monitoring work has occurred on Crooked Creek since the late 1990s, primarily associated with planning and implementation of stream restoration work on the Root Ranch.

1.2 Scope and Objectives

This report describes the monitoring objectives, methods, results, and analyses. Most of the methods were established in the 2003 Fisheries Habitat Monitoring Report (Kann and Reedy 2004) and the basics will not be reiterated here unless methods were altered or new methods added. The results are compared to those from 2003 to evaluate general trends for predictive purposes. Figures follow the body of the report. Tables are included in the text. Photo point comparisons are included in appendices.

The primary objective of the present study was to measure changes in fish habitat and fish numbers on Crooked Creek and fish habitat on Sevenmile Creek after five years of the KBRT program. Monitoring efforts included repeating surveys of geomorphic conditions, fish habitat, and fish abundance.

2.0 SEVENMILE CREEK STUDY AREA

2.1 Sevenmile Monitoring Locations

Sevenmile Creek was delineated into seven contiguous segments for the 2003 study (Kann and Reedy 2004) differentiated by hydrologic and morphological characteristics. Three of those segments (Figure 2) were selected for detailed measurements and one reach from each (Reaches 2, 5, and 6) was chosen which contained at least 1000 linear feet of stream, 30 or more habitat units and conditions that were representative of the overall segment. 2008 monitoring in reaches 2, 5, and 6 consisted of repeating survey methods used in 2003 and comparing results to determine changes.

2.2 Sevenmile Monitoring Methods

2.2.1 Geomorphic Survey Methods

Channel mapping focused on repeating the survey methods from 2003 with some minor changes. Mapping was performed with survey-grade real time kinematic (RTK) GPS (Trimble 4700/4800) almost exclusively and focused on surveying tops and toes of banks, water surface elevations and thalweg (deepest part of channel). Ten cross sections had been surveyed in 2003 but were based on the top, toe, riveredge, and thalweg points only and were not monumented in the field. In 2008, the endpoints were approximately located using the coordinates from 2003 and resurveyed in a more traditional manner with considerable more detail. Cross section changes were difficult to determine between the 2003 and 2008 surveys since the survey methods were so different (one fairly crude (2003), and one fairly detailed (2008) but they should serve to detect geomorphic changes in the future.

The baseline parameters of depth, width, and width to depth ratio were established in 2003 for geomorphic monitoring and were repeated for 2008 with some changes to the widths and width to depth ratios. In 2003, the mapping data was used to generate channel widths from the left edge of the water to the right edge every 100 feet and then generating width to depth ratios using those widths and depths below the water surface. These parameters were felt to be non-standard geomorphic measurements and, since both widths and depths were dependant on discharge, difficult to repeat during later monitoring. Thus, for the 2008 effort, a more standard bankfull channel width was generated every 50’ (along the 2003 thalweg line) between the tops of banks, while depths for width to depth ratios were calculated from the top of the bank surface to the thalweg depth. These same width and width to depth ratios were generated from the 2003 survey data at the same 50’ locations along the 2003 thalweg for comparison.

In 2003, depths were generated using AutoCAD by comparing a digital terrain model (DTM) from the tops, toes and thalweg points and to a DTM built from water surface elevations. The difference between the two surfaces equals the depth along the thalweg and points (with elevation equal to depth) were generated every foot along the thalweg. Since water stage was higher in 2003 than during the August, 2008 survey period, it was felt that the 2008 top, toe and thalweg DTM was best compared to the 2003 water surface DTM to generate standardized depths along the thalweg to properly compare changes between the two years. 2008 widths, depths, and width to depth ratios were compared to the equivalent 2003 parameters for each reach.

2.2.2 Habitat Typing Methods

Fish habitat typing used the same methods from 2003 but delineated habitat units using more accurate survey-grade RTK GPS rather than the handheld units used in 2003. Habitat units were typed as either lateral pools, straight pools, glides, or riffles and the quality was determined based on combined depth and cover factors. The presence and number of large wood pieces and rootwads were counted for each unit and the composition of the streambed substrate was estimated as the percentage of cover by various sediment size classes and aquatic vegetation. The length of undercut banks and eroding stream banks was measured for each unit using the RTK GPS. Habitat types measured in 2008 were sorted and compared to the 2003 habitat types.

2.2.3 Photo Point Monitoring

Photo points were established in representative locations in 2003 and marked with 5/8" rebar topped with yellow plastic caps stamped "PHOTOPOINT". These were relocated where possible, and at each location, 3 or more photographs were taken of the stream reach in an upstream, across and downstream orientation to duplicate the 2003 efforts and visually compare the photos to detect changes.

2.3 Sevenmile Monitoring Results

Planform 2008 survey maps of the three reaches along Sevenmile Creek are shown in Figures 3, 4, and 5 for Reaches 6, 5, and 2 respectively, presented in a downstream direction. The maps are overlain on a 2005 orthophoto and show top, toe, and thalweg point groups connected by line work, as well as cross section, control point, and photo point locations.

2.3.1 Longitudinal Profile and Cross Section Results

Lest the water surface levels in the longitudinal profiles and cross sections for Reaches 5 and 6 confuse, it must be pointed out that the 2003 surveys were conducted in October after the irrigation season while the 2008 surveys were completed in mid July at a lower streamflow.

The Reach 6 longitudinal profile (Figure 6) documents a noticeable thalweg deepening as evidenced in Table 1. The downstream end of Reach 6 has steepened as virtually all of the higher points of the channel (not technically riffles) in the lower 800 feet of the reach have dropped in elevation in 2008. The average bed slope has increased from .0023 to .0026, while the water surface slope has remained the same. The number and depth of pools has also increased. Data in Table 1 show that the mean channel depth has increased by 0.33 feet, primarily in the lower half of the reach, and that the percent of channel thalweg deeper than 4 feet has doubled from 0.76% to 1.53%. The thalweg length increased by 57 feet, or 0.38%, from 2003 to 2008, although this change could be an artifact of survey methods.

The Reach 5 longitudinal profile (Figure 7) has experienced a similar drop in elevation at the "riffles" in its lower section. The mean bed slope of this quite low-gradient reach has more than doubled from .0002 to .0005, while the water surface slope remained the same at .0004. Four pools deepened, while three filled in a little. Overall, though, there was essentially no change in mean depth (Table 1). The percentage of the channel thalweg greater than 4 feet deep decreased from 8.9% to 5.4%.

There is little change in the longitudinal profile of Reach 2 (Figure 8) except several of the deeper pools have filled in and some bed features in the upper half of this reach have shifted around somewhat, resulting in a thalweg length 65 feet (4%) longer than in 2003. Overall, mean channel depth declined from 4.68 feet to 4.44 feet.

Comparison of the cross sections (Figures 9a, 9b, and 9c) from all three reaches do not provide any useful trends since they were generated in much different manners between the two study periods. The following section on channel geometry involves analysis of reach-wide depths, widths, and width to depth ratios, which reveal changes over time better than the present cross sections. Future monitoring can take more advantage of the improved cross section survey methods.

2.3.2 Channel Geometry Results

Table 1 summarizes the 2003 and 2008 widths, depths from water surface, width to (channel) depth ratio, and thalweg length. Some of the parameters from 2003 are different than reported in the 2003 report, due to differing methods in determining channel widths, width to depth ratio, and using slightly different channel lengths. The differences represent results using methods that should be more repeatable in future monitoring efforts.

Table 1: *Width, Depth, Length and W/D Ratio Summary for Sevenmile Creek Reaches 2, 5, and 6 for 2003 and 2008.*

REACH	YEAR	THALWEG LENGTH (ft)	MEAN DEPTH (ft) [1]	DEPTH Std.Dev.	MEAN WIDTH (ft) [2]	WIDTH Std.Dev.	MEAN WIDTH TO DEPTH RATIO [3]	W/D Std.Dev.	PERCENT THALWEG > 4' DEEP
2	2003	1487	4.68	1.54	60.43	10.39	8.20	1.98	64.40
2	2008	1552	4.44	1.30	59.54	10.98	7.98	2.34	58.36
5	2003	2157	2.75	0.83	27.04	7.18	10.16	5.12	8.87
5	2008	2174	2.78	0.68	19.30	3.34	6.47	1.96	5.44
6	2003	1580	2.11	0.72	26.90	7.82	6.19	2.01	0.76
6	2008	1637	2.44	0.70	23.05	7.84	5.00	2.03	1.53

1) Depths calculated every 1’ along thalweg based on 2003 water surface survey.
2) Bankfull channel widths determined every 50’.
3) Width to depth ratio uses bankfull channel widths and matching bankfull channel thalweg depths every 50’.

Figures 10 through 15 chart the distribution and changes of depths, widths, and width to depth ratios for the three reaches over the monitoring period from 2003 to 2008. Figures 10, 12, and 14 are box and whisker plots, where the outsides of the box are 25 and 75 percentile values, the line through the box is the 50% value or median, the blue diamond is the mean, and the whiskers are the maximum and minimum values. Figures 11, 13, and 15 are frequency plots, showing the relative frequency of computed values that have been divided into various bins.

In 2003, Reach 6 and Reach 5 both had mean bankfull channel widths around 27 feet and in both the channel width has decreased: to 23 feet in Reach 6 and 19 feet in Reach 5 (Table 1 and Figure 10). Photo comparison also demonstrates this channel narrowing which is likely a result of reduced or eliminated grazing pressure, encroaching vegetative growth, and consequently less bank erosion. Reach 2 had a slight (less than 1 foot) decrease in mean channel width. Figure 11 shows the shift in the frequency histogram towards narrower widths in Reach 6 and 5. This is particularly noticeable for Reach 5, where 63% now are in the 20 foot width bin, while only 15% had been in 2003.

Overall, depths still increase downstream from Reach 6 to Reach 2 (Table 1 and Figure 12). Pools >3' deep are important for large adult trout (KBRT 2003) and the percentage of thalweg depths greater than or equal to 3' deep has increased in Reach 5 (80% to 88%) and 6 (52% to 72%) since 2003 (Figure 13). Depths increased in Reach 6, remained essentially constant in Reach 5, and declined slightly in Reach 2, over the study period.

The width to depth ratios follow accordingly with the narrowing of Reach 6 and 5 (Table 1 and Figure 14). The mean ratio has dropped slightly from 6 to 5 in Reach 6 but significantly from 10 to 6.5 in Reach 5 indicating a narrower, deeper channel in 2008. In addition, the range of width to depth ratio values was much greater (Figure 14) in Reach 5 in 2003 compared to 2008. 73% of the ratio values are now in the 6 and 8 bins (Figure 15).

The most downstream Reach 2 is still the deepest and widest of the three study reaches. Mean depth has decreased slightly and the percentage of depths >4' has dropped 6% to 58%. There has been very little change in channel width and width to depth ratio.

2.3.3 Habitat Typing Results

The results of habitat typing are presented in Table 2 and Figures 16 and 17. The most significant changes in fish habitat between 2003 and 2008 occurred in Reach 6 where large woody debris (LWD) increased substantially, rising from 2.8 to 18.9 pieces per 1000 feet (Table 2). This large wood presence resulted in glides (50% of the habitat units in 2003, but only 29% in 2008) changing into lateral scour pools (formerly 31%, now 52%) (Figure 16). Pool numbers increased sharply from 19 to 32 and their quality also increased from 2 to 2.5. Bank stability improved as evidenced by a doubling of the percentage of undercut banks and a large decrease in the percentage of bank erosion (Table 2). Coupled with less erosion is a coarsening of the substrate, as gravel and sand now dominate with a large reduction in silt and aquatic vegetation. Figure 17 shows that in Reach 6, gravel substrate increased from 2.8 to 22%, while combined silt and aquatic vegetation dramatically declined from 54.6 to 15.6%.

Table 2. Habitat Summary for Sevenmile Creek Reaches 2, 5, and 6 for 2003 and 2008.

Reach	Sample Year	Habitat Units	Number of Pools	Mid-Channel Length (ft)	Mean Pool Quality	Mean Pool Max. Depth (ft)	Percent Undercut Bank[1]	Percent Eroding Bank[1]	Large Wood per 1000 Ft.
2	2003	17	10	1461	2.11	na	1.9	17.8	16.4
2	2008	15	9	1461	3.33	6.8	6.3	19.1	4.1
5	2003	35	19	1997	2.6	4.5	8.4	0.3	8.5
5	2008	38	20	1997	2.5	4.1	7.8	0.0	5.5
6	2003	37	19	1428	2	3.3	3.5	16.1	2.8
6	2008	50	32	1428	2.53	3.5	7.1	6.8	18.9

1) Percentages of undercut and eroding banks are based on accumulated occurrences from both sides of the creek and percentage calculated using the mid-channel length and halving it. Percentages are lower than presented in KBRT 2003 which were based incorrectly on one mid-channel length.

Reach 5 habitat remained generally similar to conditions in 2003 with the exception of a loss of LWD, which declined from 8.5 to 5.5 pieces per 1000', a small increase in the amount of gravel substrate (0 % in 2003, 2.5% in 2008), and a small decline in percent undercut bank.

Reach 2 habitat conditions improved with a large pool quality increase from 2.1 to 3.3 due to increased percentage of undercut bank (from 1.9% to 6.3%) even while the amount of LWD decreased from 16 to 4 pieces per 1000'. In terms of substrate, a substantial increase in aquatic vegetation occurred thereby reducing the percentage of exposed silt.

2.3.4 PhotoPoint Monitoring

The photos are assembled in two PowerPoint files (Appendix 1), for 2003 and 2008. Photos from the nine photopoints along the three reaches suggest a general trend of channel narrowing, increased vegetative cover, and reduced bank erosion, particularly in Reach 6. Figure 18 shows an example of the photo point comparisons.

2.4 Sevenmile Discussion

2.4.1 Changes in Streamflow

Figure 19 compares streamflow (mean daily discharge or MDQ) at the Sevenmile Creek at Sevenmile Road gage for 2003 and 2008. The most noticeable change is the summer baseflow. Between July 1 and September 10, 2008 streamflow was essentially double that of 2003. However, because the 2003 surveys were made in October, well after the end of the irrigation diversion season, while the 2008 surveys were completed in July-August, streamflows were actually higher in 2003 than in 2008 at the time of field work. Significantly more habitat was available in the summer of 2008 than in 2003 due to the large increase in flow.

2.4.2 Riparian Management Changes

Decreased grazing pressure has had the most impact on Reaches 5 and 6 by allowing riparian vegetation to grow and stabilize banks thereby reducing erosion, narrowing and deepening the channel, and reducing the width to depth ratio.

2.4.3 Summary of Channel and Habitat Changes

Reach 6 has experienced the most dramatic changes resulting from the KBRT Project land management changes, which directly affected water diversions and grazing practices. Fish habitat greatly improved as shown by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased, and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Reach 6 clearly demonstrates the possible improvements in channel and riparian conditions over a 5 year period with new management prescriptions. We believe Reach 6 saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches, (2) it has a much steeper gradient than the other reaches (4-5 times steeper) thus providing considerably more energy with the increased streamflows to scour the bed, and (3) it likely saw the highest percentage increase in baseflow, as prior to the management changes, it was essentially dewatered much of the summer.

Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This is likely due to the very low gradient of this reach. With less energy available to promote change, change will take a much longer period of time. Although the mean depth and LWD decreased in Reach 2, there was an increase in pool quality, partly due to an increase in percentage of undercut banks. Being the most downstream (and lowest gradient) reach, one would expect Reach 2 to improve the slowest, both due to low energy available and that much of the sediment released from upstream as those reaches recover will move through the downstream reaches.

A significant increase in amount of habitat available, although not directly measured, is suggested by the increase of base stream flow during the critical summer months as shown in Figure 19. To evaluate such changes this directly, habitat would need to be measured at the same time of year, then, not only would the physical changes be apparent, but the available habitat (not just physically based but also dependent on the base flow amount) during critical periods could also be determined.

3.0 CROOKED CREEK STUDY AREA

3.1 Crooked Creek Monitoring Locations

Crooked Creek was delineated into four contiguous segments for the 2003 study differentiated by hydrologic and morphological characteristics (Figure 20). Data were collected through all 4 reaches (1-4). Reach 4 contains two sites where channel restoration work (channel narrowing) was performed in 2001. Reach 4 also contains 4 other sites where habitat improvement work (large wood placed, willows planted, and eroding banks sloped and stabilized) was undertaken in 1998.

3.2 Crooked Creek Monitoring Methods

3.2.1 Geomorphic Survey Methods

In 2003, it was determined that the channel morphology was different than Sevenmile Creek and that somewhat different methods be used to characterize the system. Four contiguous reaches were delineated for study encompassing 3.2 miles measured as the centerline of the channel. Mapping surveys varied for the previous study period which was spread out over several years but will be referred to as 2003 in this report. The current study mapped the four reaches in August 2008 exclusively using the RTK GPS system referred to earlier. In Reaches 1 to 3 (numbered from upstream), tops, toes and thalweg points were mapped, while in the lowest Reach 4 only toes and thalweg were mapped to repeat the 2003 procedures. During the survey, the extents of any exposed stream banks exhibiting soil erosion were also mapped. Six cross sections in Reaches 1 and 2 were monumented and surveyed in 2003 and were recovered and resurveyed for this study.

As on Sevenmile Creek, the 2003 study established depth, width, and width to depth ratio as parameters to assess and monitor geomorphic conditions on Crooked Creek. The methods established during 2003 were more appropriate for Crooked Creek and thus were more closely duplicated than on Sevenmile. Depths were developed every foot along the 2008 thalweg by comparing the 2008 water surface DTM with a DTM developed from the top, toe and thalweg points. Bankfull channel widths were calculated at the same 2003 locations every 100' along the 2003 thalweg line between channel tops. The depths used for the width to depth ratios were the thalweg depths described above at the location of the channel width.

3.2.2 Habitat Typing Methods

The most important fish habitat variables for Crooked Creek were determined to be undercut banks and pool depths in 2003. Fish habitat surveys then, and in 2008, focused on undercut banks in pools that were >3' deep. One person with a mask waded with a stadia rod in an upstream direction looking for undercut banks and, when one was located, would have a second walking person survey the upstream and downstream margin of the undercut with a RTK rover unit. The diver then used the stadia rod to probe the horizontal depth of the undercut bank at several locations and call them out to the bank person who recorded the measurements in a fieldbook. From these data, average water depth, average width (depth of undercut) and length were calculated and then the area (length * average width) and volume (area * average water depth) were calculated. Results for undercuts and exposed soil areas were standardized on a per mile basis in order to compare different length reaches.

3.2.3 Snorkel Surveys

A fish abundance survey of the four reaches was conducted in late September 2008 using snorkeling methods established between 2000 and 2002 on Crooked Creek. The objectives were to quantify differences in abundance and habitat use among the four reaches and to compare fish numbers to those of past counts in order to detect changes resulting from KBRT project activities. Two snorkelers moved downstream together counting all fish observed by species and age class. The lower section of Reach 4 was an index section in which repeat counts were made to determine a coefficient of variation.

3.2.4 Macroinvertebrate Surveys

Repeating the effort of the August 2002 macroinvertebrate assessment, sampling was performed in Reaches 1 and 4. Five sites were sampled in Reach 4, including four sites within the restoration treatment area (XS #22, XS #23, XS #26, and XS #40) and one reference site immediately upstream of the treatment area (XS #19). One site was sampled in Reach 1, just below the old bridge on the Thomas property (XS #1). At each sample site, a series of three replicate transects, extending laterally across the active channel, was established. An effort was made to avoid large macrophyte beds when placing transects. Wetted channel width was determined for each transect, and benthic macroinvertebrates were collected at distances of 0.25, 0.50, and 0.75 times the total wetted width using a 15.2 cm x 15.2 cm ($0.0023 m^2$) Petite Ponar dredge. For a given transect, all three dredge samples were composited to produce a single sample per transect (effective sampling area = $0.0069\ m^2$), with three replicate samples per sample site. Dredge contents were passed through a 500 µm sieve and the retained material was preserved in 95% ethanol for later processing in the laboratory.

Samples were later sorted to remove a 500-organism subsample from each preserved sample following the procedures described in Oregon DEQ’s Level 3 protocols (WQIW 1999) and using a Caton gridded tray (Caton 1991). Contents of each sample were first emptied onto the gridded tray and then floated with water to evenly distribute the sample material across the tray. Squares of material from the 30-square gridded tray were removed to a Petri dish which then was placed under a dissecting microscope at 7-10X to sort aquatic macroinvertebrates from the sample matrix. Macroinvertebrates were removed from each sample until at least 500 organisms were counted, or until the entire sample had been sorted. Macroinvertebrates were then identified to the lowest practical taxonomic level under 10-110X magnification.

Raw macroinvertebrate data were entered into an Excel Spreadsheet, and then all taxonomic determinations were standardized to those used in the 2002 assessment in order to compare 2008 results with those obtained in 2002. Raw taxonomic count data were converted to density estimates for each replicate sample from each site, and then the average density of each taxon was calculated. Ten metrics were computed for each site from these site-wide average density data. Taxonomic attribute coding (Table 6) and metric calculations were identical to those performed on the 2002 data to facilitate comparisons between the two sampling periods.

3.3 Crooked Creek Monitoring Results

Planform 2008 survey maps of the four reaches along Crooked Creek are shown in Figures 21 and 22, for Reaches 1-2, and 3-4, respectively, presented in a downstream direction. The maps are overlain on a 2005 orthophoto and show top, toe, and thalweg point groups connected by line work, as well as cross section and control point locations.

3.3.1 Longitudinal Profile and Cross Section Results

The only change that stands out from the longitudinal profile (Figure 23) is that the channel bed high points in Reach 4 have deepened thereby causing a slightly steeper bed slope. The change seems to be limited to that reach. Cross sections 1-3 in Reach 1 and 4-6 in Reach 2 do not reflect the rather large channel narrowing in both reaches (Figure 24).

3.3.2 Geomorphic Survey Results

Table 3 summarizes the 2003 and 2008 thalweg lengths, channel widths, depths from water surface, width to (channel) depth ratio, and percent thalweg greater than 4' deep. Figures 25 through 32 chart the distribution and changes of depths, widths, and width to depth ratios for the four reaches over the monitoring period from 2003 to 2008 and also include comparisons within Reach 4 of restored (4B) versus un-restored areas (4A). It should be noted that the 2003 channel dimensions for reach 4 were actually surveyed in 2001, soon after the channel restoration was completed. In some cases, the channel width was reduced by more than 30' during the project construction. Figures 25, 26, 28, 30, and 31 are again box and whisker plots. Figures 27, 29, and 32 are frequency plots, showing the relative frequency of computed values that have been divided into various bins.

Channel widths decreased in all four reaches (Table 3 and Figure 25) indicating the reduction in grazing under the KBRT program has helped to stabilize banks. Mean widths decreased about 10% in Reaches 1 and 2, almost 15% in Reach 3, but only 2% in Reach 4. Reach 4 remains the narrowest section but only slightly now that the other reaches have narrowed over the past 5 years. In addition, it should be noted that the Reach 4 channel widths are taken from the channel toes because the tops of the banks are in many places under water and difficult to distinguish. Figure 26 compares Reaches 4A and 4B and shows very slight changes from 2003, with un-restored areas slightly decreasing in width and restored areas slightly increasing in width. These values are well within the range of measurement error. The frequency distribution of channel widths for the 4 reaches (Figure 27) show that the range of the population of widths has been reduced as the channel narrowed, many of the wider channel areas (the upper tail of the histogram) have disappeared, leaving the channel narrower and more consistent in width.

Table 3. *Width, Depth, Length and W/D Ratio Summary for Crooked Creek Reaches 1, 2, 3, and 4 for 2003 and 2008.*

REACH	YEAR	THALWEG LENGTH (ft)	MEAN DEPTH (ft)[1]	DEPTH Std Dev	MEAN WIDTH (ft)[2]	WIDTH Std Dev	MEAN WIDTH TO DEPTH RATIO[3]	W/D Std Dev	PERCENT THALWEG >4' DEEP
1	2003	2071	3.95	0.69	42.37	9.10	11.51	4.12	41.02
1	2008	2010	4.04	0.62	38.26	6.64	9.90	2.67	48.76
2	2003	6052	3.93	0.74	41.02	7.19	11.11	3.27	40.86
2	2008	5806	3.99	0.61	37.58	5.57	9.73	2.26	43.30
3	2003	5240	3.53	0.74	47.55	8.76	14.09	4.13	19.94
3	2008	5156	3.32	0.68	41.39	8.28	12.89	3.84	15.22
4	2003	4994	3.59	0.85	37.87	8.65	10.77	3.06	29.17
4	2008	4768	3.88	0.71	36.97	5.29	10.00	2.32	39.84

1) Depths below current water surface (2003 or 2008) calculated every foot along the thalweg.
2) Channel widths from top of left bank to top of right bank every 100’ along 2003 thalweg line.
3) Width to depth ratio uses channel widths every 100’ and depth from 1’ depths at channel width location.

Overall, mean thalweg depths changed only slightly, with Reaches 1, 2 and 4 increasing in depth while Reach 3 decreased (Table 3 and Figure 28). Interestingly, the maximum depths measured decreased by over a foot in Reach 2 and 3, while Reach 1 and 4 had smaller declines, however, overall the percentage of the thalweg deeper than 4' substantially increased in Reach 1 and 4 and less so in Reach 2, while Reach 3 declined considerably. All of the frequency distributions, with the exception of Reach 3, have shifted towards an increased percentage of deeper depths (Figure 29).

Channel width to depth ratios decreased accordingly with the width decrease and the depth increase (Figure 30). The size of the boxes as well as the range shown by the min-max values indicate that the channels are becoming more homogeneous as they narrow and deepen. This is particularly true for Reach 4A and 4B (Figure 31), as the range between the max and the min values has decreased by about two-thirds. The frequency distribution clearly depicts this shift as the percentages for bin 12 increased substantially, into a very sharp peak.

3.3.3 Habitat Typing Results

Although it doesn’t show up in the habitat summary (Table 4), large woody debris remains sparse throughout most of the Crooked Creek study area with the notable exception of lower Reach 4 where channel narrowing projects established numerous new rootwad features along the restored banks. This lack makes undercut banks especially important as adult fish habitat throughout the study reaches.

Table 4. *Habitat Summary for Crooked Creek Reaches 1, 2, 3, and 4 for 2003 and 2008.*

Reach Number	Year	Habitat Feature	Number of Segments	Total Length (ft)	Total Area (ft2)	Total Volume (ft3)	Number of Segments per Reach Mile	Total Length per Reach Mile (ft)	Total Area per Reach Mile (ft2)	Total Volume per Reach Mile (ft3)
1	2003	UCR	2	55	51	199	5.6	154	142	555
1	2003	UCL	4	135	225	1043	11.2	377	630	2914
1	2003	ESR	1	63			2.8	176		
1	2008	UCR	8	119	217	901	22.3	332.4	606.2	2517.1
1	2008	UCL	4	267	549	2577	11.2	745.9	1533.7	7199.2
1	2008	ESR	2	63			5.6	176.0		
1	2008	ESL	1	17			2.8	47.5		
2	2003	UCR	9	295	379	1034	8.6	283.3	364.4	992.9
2	2003	UCL	14	754	1134	4685	13.4	724.1	1088.6	4498.9
2	2003	ESR	8	1263			7.7	1212.9		
2	2003	ESL	1	225			1.0	216.1		
2	2008	UCR	10	251	522	2391	9.6	241	501	2296
2	2008	UCL	18	334	655	2847	17.3	321	629	2734
2	2008	ESR	14	1060			13.4	1018		
2	2008	ESL	3	300			2.9	288		
3	2003	UCR	1	14	16	56	1.1	15.3	17.6	60.7
3	2003	UCL	7	288	313	1263	7.7	314.8	342.2	1380.4
3	2003	ESR	4	635			4.4	694.0		
3	2003	ESL	1	111			1.1	121.3		
3	2008	UCR	6	171	306	1045	6.6	186.9	334.4	1142.1
3	2008	UCL	6	197	338	1309	6.6	215.3	369.4	1430.7
3	2008	ESR	6	455			6.6	497.3		
4	2003	UCR	6	148	182	670	6.9	169.7	209.1	768.6
4	2003	UCL	4	148	259	1182	4.6	169.7	297.6	1355.9
4	2003	ESR	2	149			2.3	170.9		
4	2003	ESL	1	92			1.1	105.5		
4	2008	UCR	4	192	463	1744	4.6	220.2	531.0	2000.1
4	2008	UCL	6	127	208	923	6.9	145.6	238.5	1058.5

UCR = Undercuts on Right Bank, UCL = Undercuts on Left Bank, ESR = Exposed Soil on Right Bank, ESL = Exposed Soil on Left Bank

Figures 33-35 standardize undercut banks and eroded banks per reach mile to better compare the different length study reaches. Total length of undercut banks has decreased overall but the loss is entirely in Reach 2, particularly along the right bank. The other three reaches have experienced an increase in total length of undercuts. The largest increase in undercuts since 2003 was in Reach 1, in particular along the right bank where cattle grazing was more dominant prior to the KBRT program. In the 2003 study, Reach 2 had the most undercut length and area and is now second to Reach 1.

Bank erosion has overall decreased in length through the four reaches since 2003. The number of exposed soil segments increased in Reaches 1 and 2 (and slightly in 3) but the length of erosion per reach mile decreased in all four reaches. The right bank of Reach 2 continues to have the most bank erosion.

3.3.4 Snorkel Survey Results

Annual snorkeling surveys of fish present in Crooked Creek began in 2000, focusing on the Root Ranch section (Reach 4) first and then in 2002 expanding to include all four reaches. The main objectives have been to: 1) quantify differences in abundance and habitat use among the four reaches, and 2) provide baseline and continued monitoring data for the detection of changes resulting from the KBRT project activities.

The 2008 snorkel survey was conducted in late August with water temperature ranging from 46-53° F. Visibility was generally around 9' and when it dropped much below that, diving ceased for the day. The diving necessarily had to proceed downstream because velocities were too high to swim upstream but several problems arose. Any time the bed was disturbed, turbidity increased thereby lowering visibility and probably causing fish movement away from the disturbance. It is likely that snorkeling downstream alarms fish anyway and consequently some fish were probably not seen and counted. On the other hand, the index section 4B was repeat snorkeled 3 times with more than an hour between dives and the coefficient of variation for adult counts was 0.05 indicating that the snorkel counts were not missing many adult fish.

Very few juvenile fish (<100mm and 100-200mm) were observed so either they are rare at this time of year or more likely they are better able to avoid divers with limited visibility. The remaining discussion includes only adult trout (> 200mm). Of the 43 adult trout observed (Table 5), 49% were identified as redband rainbow, 1 as a definite brown trout and the rest counted as unknown trout (assumed to be rainbow or brown). Approximately 19% were positively associated with woody debris and about 21% with undercut banks but it is likely that many of the remaining adult trout were associated with wood since they were observed moving from areas with wood present.

Table 5. *Adult Trout Snorkel Counts for Crooked Creek Reaches 1, 2, 3, and 4 from 2000 to 2008.*

Reach	Top	Bottom	Jul-00	Jul-01	Aug-02	Oct-02	Jul-03	Oct-03	Aug-08
1	Old Bridge	Departure from Terrace				4	4		2
2a	Departure from Terrace	Agency Creek			24	21	25	20	7
2b	Agency Creek	Thomas Bridge				30	44	45	1
3	Thomas Bridge	Root prop. Line					25		5
4a	Root prop. Line	Index top	12	8			28	11	12
4b	Index top	Index bottom	15	16	10	19	39	36	18

It is notable that total numbers of adult trout are considerably lower than in summer or fall, 2003 and that the Reach 4 numbers are similar to the counts in 2000-2002. This is probably not surprising since anecdotal evidence suggests that fish numbers are down throughout the Wood River system. Despite the lower numbers, the index Reach 4B which has undergone restoration by channel narrowing and installation of LWD, encompasses 13% of the total length studied but contained almost 42% of the adult trout present in 2008. This reach contains a much higher density of LWD than the rest of the study reaches. When the 2008 fish counts are standardized per reach mile, Reach 1 through 3 had 5.6, 6.7, and 5.5 fish/mile respectively, yet Reach 4A has 27.7 fish/mile and Reach 4B (Index) has 41 fish/mile. The obvious indication is that the addition of LWD in Reach 4B has improved the fish habitat and has attracted more adult trout.

3.3.5 Macroinvertebrate Results

Across all six Crooked Creek sample sites, 16 insect taxa representing 8 orders were collected from Crooked Creek in August 2008. This is similar to the insect richness (18 families) reported in 2002, and suggests that the significant increase in insect diversity has been maintained over the 1999 levels of 8 families representing 3 orders. Including other phyla and orders, 25 families were collected, which is very similar to that reported in 2002 (24 families). Family richness was highest at two sites within the restoration treatment reach (XS #23 and XS #40) and lowest for XS #1, the upstream Thomas property site (Table 7). Total family richness was similarly low in the reference site, XS #19, immediately upstream of the restoration treatment area. Total family richness in each of the restoration sites exceeded that from either of the reference sites in 2008 (Table 7). This pattern is generally similar to that observed in 2002, with treatment sites generally supporting a higher richness than did reference sites (Figure 36).

Total macroinvertebrate densities in 2008 ranged from 2,569 organisms per m^2 (XS #26) to 19,967 organisms per m^2 (XS #19), and averaged 11,986 organisms per m^2 across all six sites. Densities were generally higher than those reported in 2002, which ranged from 1,909 to 3,766 organisms per m^2. Higher densities in 2008 are attributable to a significant increase in the Amphipoda species, *Hyalella azteca*, which exceeded densities of 8,000 organisms per m^2 in four of the six sites. Increases in densities to this extent suggest a potential increase in nutrient loading into the system or an increased capacity for nutrient retention within Crooked Creek.

Ten macroinvertebrate families were sampled from the reference site (XS #19) and 8 were sampled from the upstream Thomas property site (XS #1). Each of these reference reaches supported 2 mayfly families (*Baetis tricaudatus* from the Baetidae family and *Ephemerella excrucians* from the Ephemerellidae family), while no stonefly or caddisfly families were sampled from either reach. In contrast, four or five Ephemeroptera, Plecoptera, and Trichoptera (collectively referred to as “EPT”) families were collected from each of the 4 sites within the treatment reach (Table 7). A number of EPT taxa were collected from one or more treatment reach sites that were not sampled from the reference site (XS #19) or the Thomas property site (XS #1), including the mayflies *Pseudocloeon dardanum* and *Centroptilum* sp., the stonefly genera *Sweltsa* (Chloroperlidae) and *Malenka* (Nemouridae), and the caddisflies *Glossosoma* (Glossosomatidae), *Hydroptila* (Hydroptilidae), and *Psychoglypha subborialis* (Limnephilidae).

All sites were numerically dominated by Amphipoda, Oligochaeta, Chironomidae, and Pelecypoda. Treatment reach sites XS #22, XS #23, and XS #40 also supported moderately high densities of Baetidae mayflies and Simuliidae. Community dominance by the two most abundant families was high across all sites, ranging from 75% at XS #26 to 92% at XS #1 (Table 7). These values are generally higher than those reported in 2002 (Figure 36) and are likely the result of the significant increase in abundance of Amphipoda. The contribution of EPT orders to the observed assemblage (% EPT) was generally lower in 2008 than in 2002, also a result of the increased Amphipoda abundance (Figure 36). Among all sites, % EPT was lowest in XS #1 and highest in XS #26.

HBI values ranged from 4.8 in XS #40 to 5.5 is XS #22, and were similar between reference and treatment sites (Table 6), suggesting that benthic communities at the six sites are similarly tolerant to organic enrichment pollution. HBI values were slightly lower at all sites in 2008 than in 2002, again a result of the increase in Amphipoda densities. It is noteworthy that, while the HBI tolerance value (TV) for the order Amphipoda is 4 (that used to calculate HBI in 2002 and 2008 for this study) the tolerance value for the Amphipoda species, *Hyalella azteca*, occurring in the study area is 8 (Clark and Maret 1993). Therefore, while HBI values have slightly decreased using the order-level HBI tolerance value, using a tolerance value of 8 for both years (this is the TV for both the species, *Hyalella azteca* and the family, Talitridae) results in an increase in the HBI score from 2002 to 2008.

Collectively, results of the 2008 macroinvertebrate sampling suggest that benthic conditions have not significantly changed since the 2002 sampling; the significant increase in Amphipoda densities was the only noteworthy deviation from 2002 assemblage conditions. Furthermore, 2008 results once again suggested that the restoration area potentially supports a higher taxonomic richness and higher EPT richness than do the upstream reference sites.

Table 6. *Functional Feeding Group (FFG) designations and pollution tolerance values (TV) of organisms collected from Crooked Creek in August 2008.*

Class	Order	Family	FFG	TV
OLIGOCHAETA			Collector-Gatherer	10
HIRUDINEA		Erpobdellidae	Predator	10
ARACHNOIDEA	Acarina		Predator	8
CRUSTACEA	Amphipoda		Collector-Gatherer	4
	Ostracoda		Collector-Gatherer	8
INSECTA	Coleoptera	Dytiscidae	Predator	5
		Elmidae	Collector-Gatherer	4
		Haliplidae	Macrophyte Herbivore	7
INSECTA	Diptera	Chironomidae	Omnivore	6
		Empididae	Predator	6
		Simuliidae	Collector-Filterer	6
		Tipulidae	Omnivore	3
INSECTA	Ephemeroptera	Baetidae	Collector-Gatherer	4
		Ephemerellidae	Collector-Gatherer	1
INSECTA	Plecoptera	Chloroplerlidae	Predator	1
		Nemouridae	Shredder	2
		Perlodidae	Predator	2
INSECTA	Trichoptera	Glossosomatidae	Scraper	0
		Hydroptilidae	Collector-Gatherer	4
		Limnephilidae	Omnivore	3
INSECTA	Megaloptera	Sialidae	Predator	4
MOLLUSKA	Gastropoda	Ancylidae	Scraper	6
		Planorbidae	Scraper	7
	Pelecypoda	Pisidiidae	Collector-Filterer	8
NEMATA			Parasite	5

Table 7. *Macroinvertebrate community metrics calculated from samples collected from six Crooked Creek sites in August 2008.*

	Sample Site					
Metric	XS 1	XS 19	XS 22	XS 23	XS 26	XS 40
Family Richness	8	10	14	17	12	17
EPT Richness	2	2	4	5	4	4
EPT/Chironomidae + Oligochaeta Ratio	0.01	0.02	0.11	0.18	0.05	0.26
% Dominance	92.05	80.24	77.33	82.56	74.89	85.32
% Filterers	2.07	11.06	9.69	10.16	6.74	7.49
% EPT	0.15	0.46	2.94	2.19	1.50	2.93
% Ephemeroptera	0.15	0.46	2.77	1.70	1.12	2.74
% Plecoptera	0	0	0.06	0.11	0.19	0.15
% Trichoptera	0	0	0.11	0.38	0.19	0.04
Hilsenhoff's Biotic Index	5.4	5.1	5.5	4.9	5.2	4.8

3.4 Crooked Creek Discussion

3.4.1 Changes in Streamflow

Comparison of mean daily discharge between 2003 and 2008 (Fig. 37) indicates that streamflow was higher in the spring and fall of 2008 but about the same both years during the critical summer period July through September.

3.4.2 Riparian Management Changes

Decreased grazing pressure has caused channel narrowing and a decrease in width to depth ratio throughout the monitoring reaches. There is a current effort to increase the cattle exclusion area along the right bank through most of reaches 3 and 4 which should further reduce bank erosion and increase bank undercuts.

3.4.3 Summary of Channel and Habitat Changes

Overall, channel widths and width to depth ratios decreased as bank erosion has decreased. Undercut banks have not increased as much as one would expect except in Reach 1 where the difference is significant.

The most dramatic change between 2003 and 2008 has been with the distribution of adult trout in the four reaches. Although the number of fish was lower than in 2003, a much higher percentage of the fish counted were in the index section of Reach 4. It is likely that the increase in depth and decrease in width and even more so the increase in LWD incorporated with the channel narrowing projects have improved the fish habitat and encouraged fish use.

4.0 CONCLUSIONS

The changes in irrigation and grazing management through the KBRT program have had several positive effects on the channel morphology and fish habitat for Sevenmile Creek and Crooked Creek. On Sevenmile Creek, Reach 6, the uppermost section studied, showed the most improvement in fish habitat with increases in pool numbers, depth, large woody debris, and a decrease in deleterious fine sediment. Reaches 5 and 6 both have more stable banks and narrower, deeper channels.

The effects of the new management were somewhat less but still substantial for the Crooked Creek study reaches. Channel width and width to depth ratios decreased and bank erosion decreased. The areas of Crooked Creek Reach 4 that have undergone restoration in the form of channel narrowing and LWD enhancement showed an increase in adult trout usage.

The rate of recovery for channels affected by grazing appears to be strongly influenced by the flow and sediment regime available to initiate change. Sevenmile Creek has a more extensive watershed and higher winter storm and spring snowmelt runoff compared to the spring-dominated Crooked Creek. In addition, upstream areas have higher gradients, providing more energy to scour the bed, creating deeper pools and improving substrate by selectively winnowing fines. As a result, lower gradient reaches will take longer to recover.

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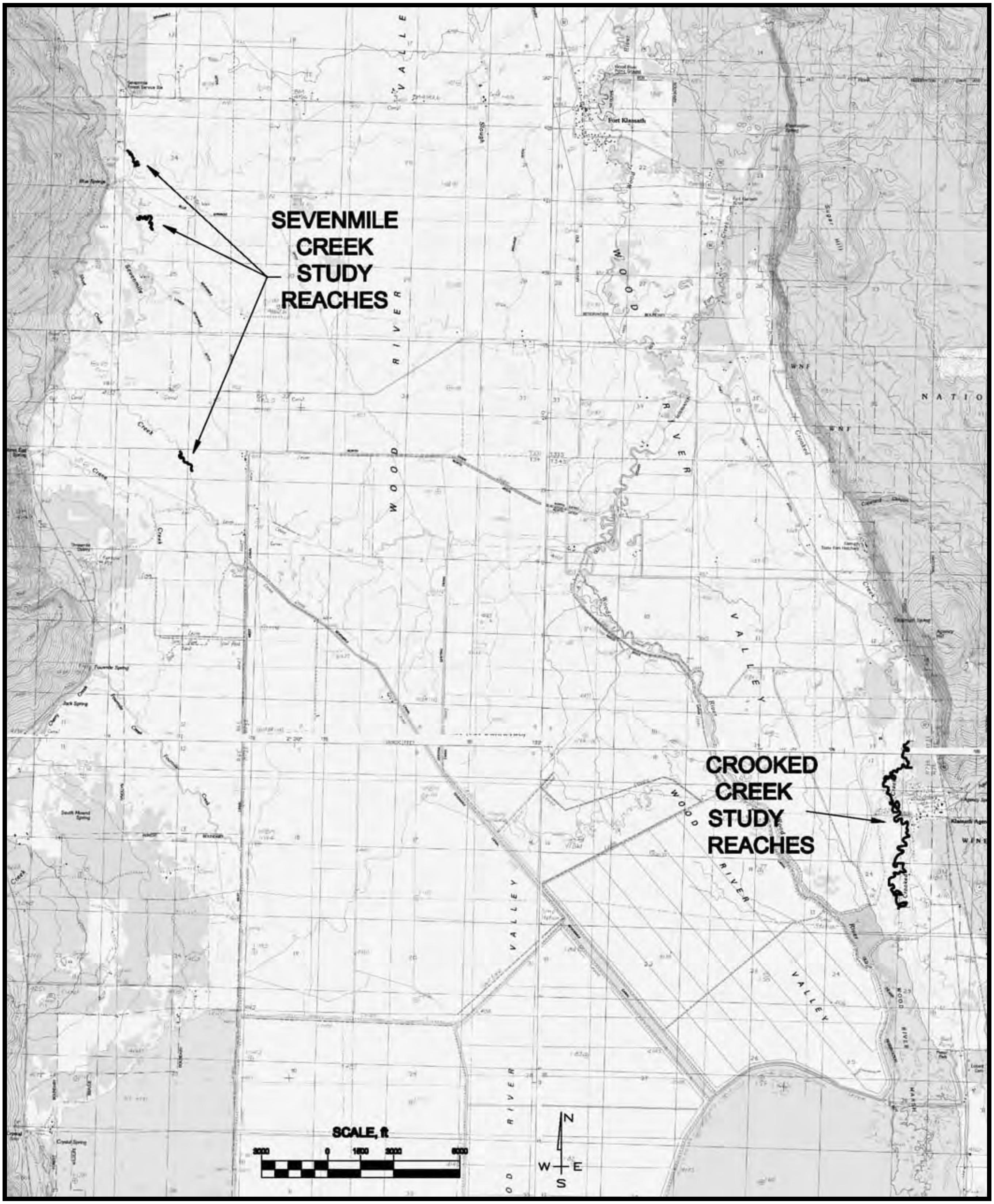
WOOD RIVER VALLEY STUDY SITES LOCATION MAP



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SEVENMILE CREEK STUDY SITES LOCATION MAP

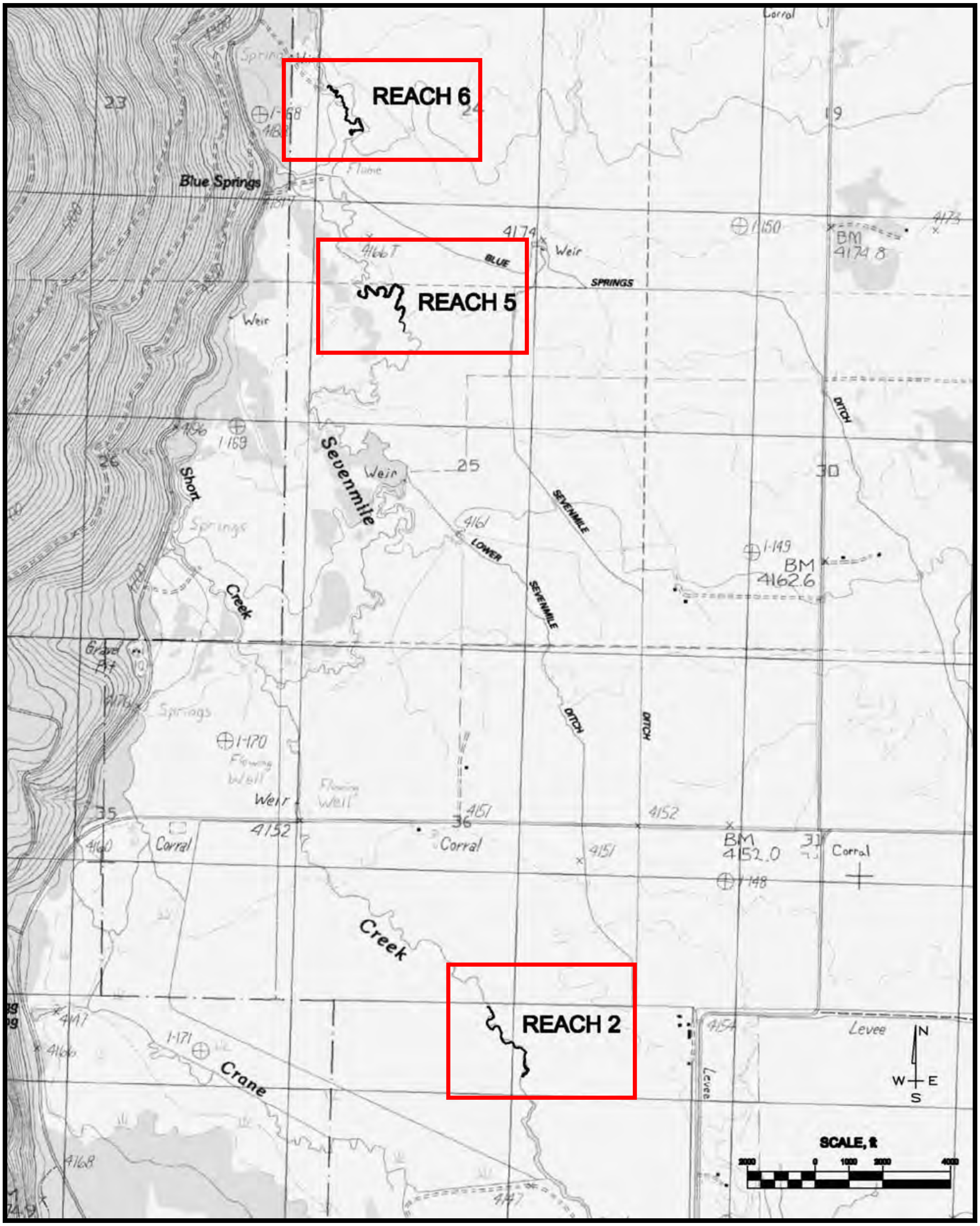

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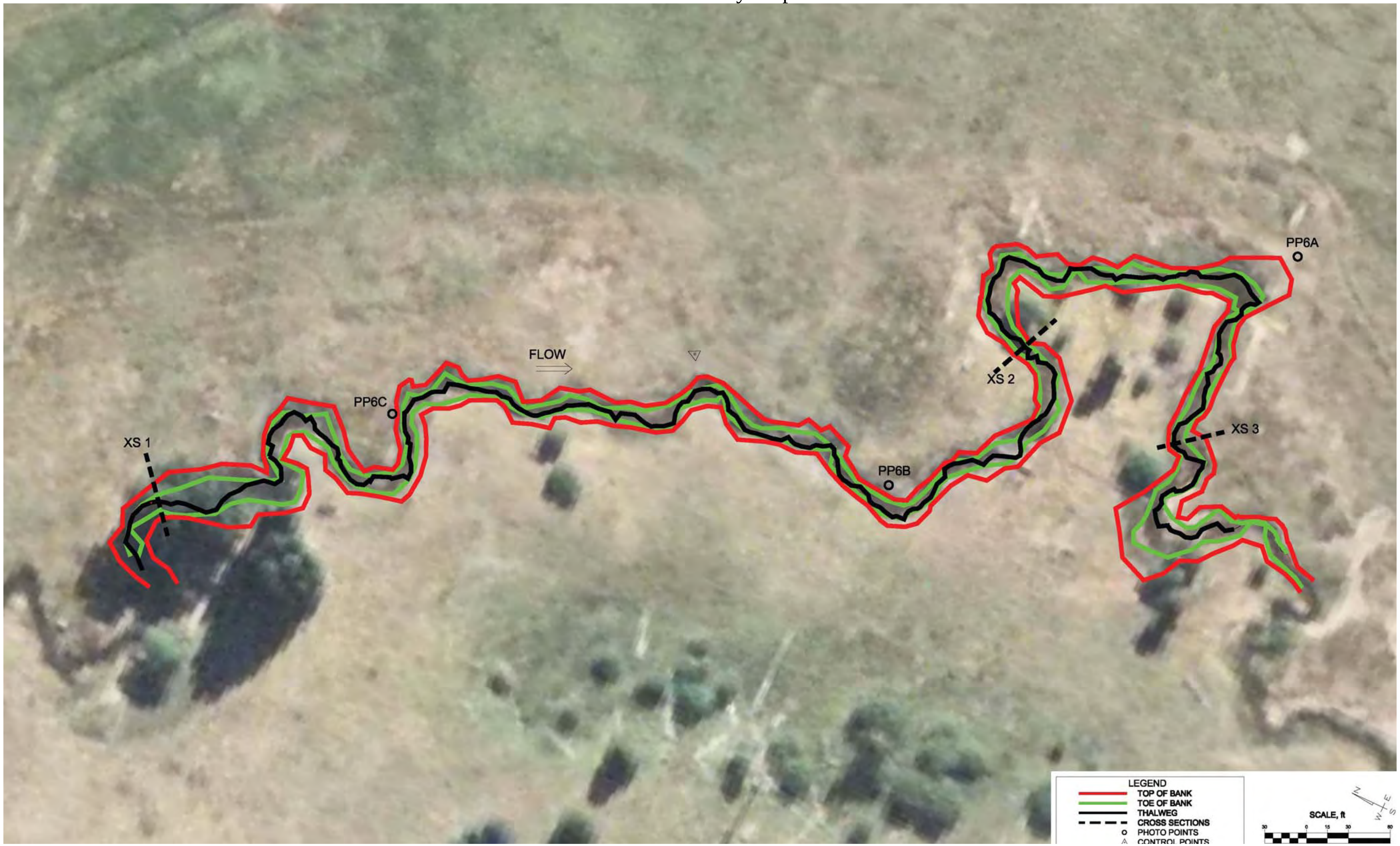
FIGURE

2

SEVENMILE CREEK

Reach 6 Survey Map



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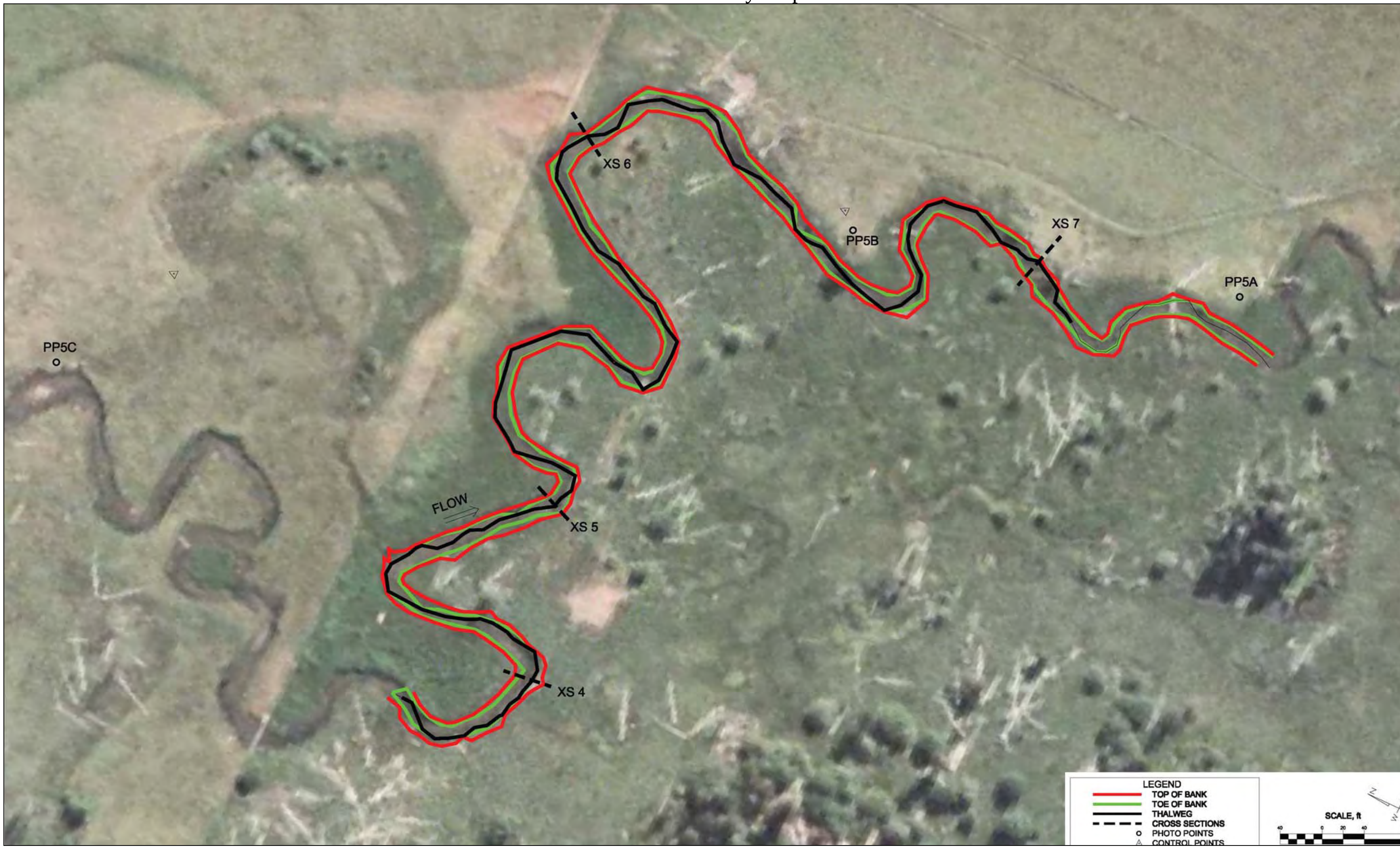
SEVENMILE CREEK
Reach 5 Survey Map



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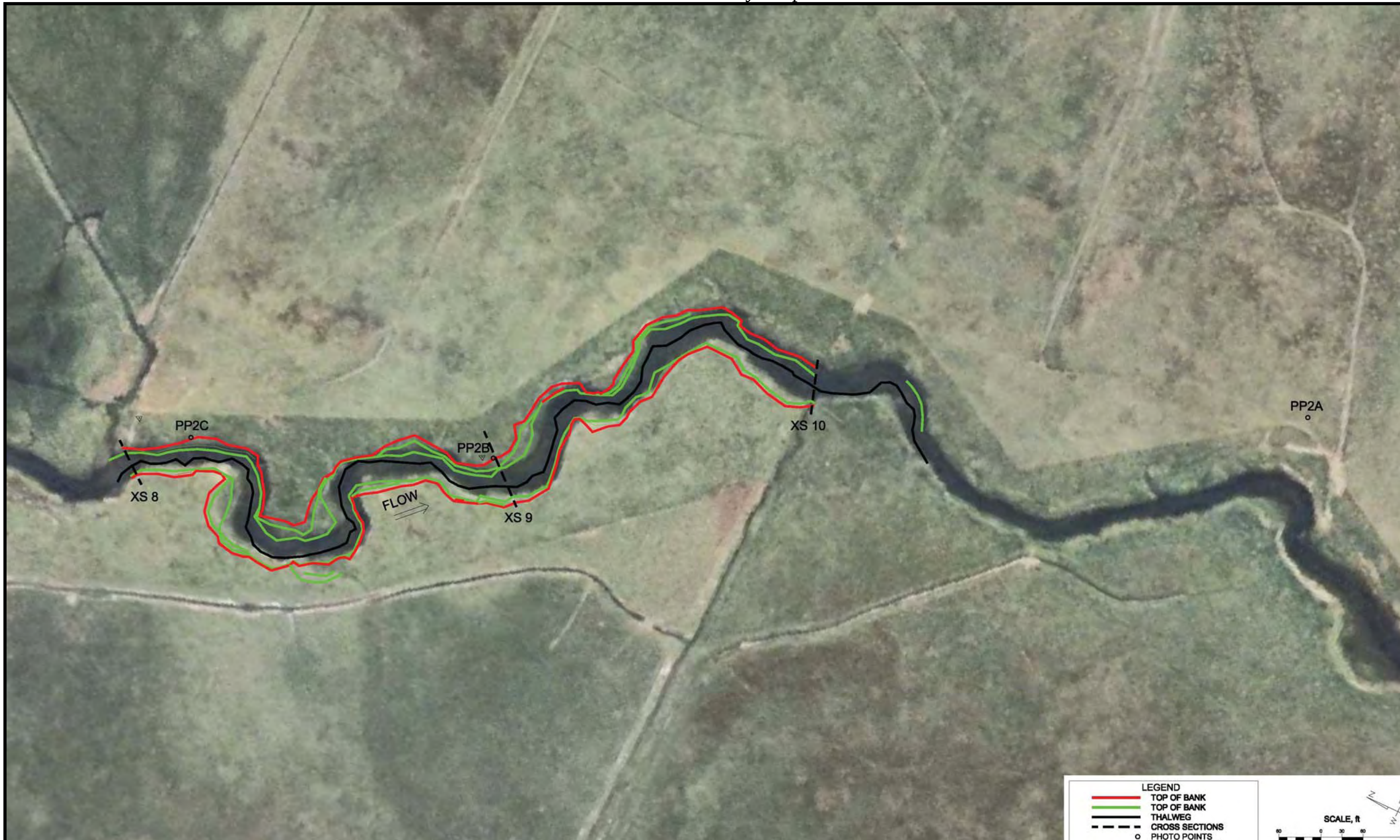
SEVENMILE CREEK

Reach 2 Survey Map



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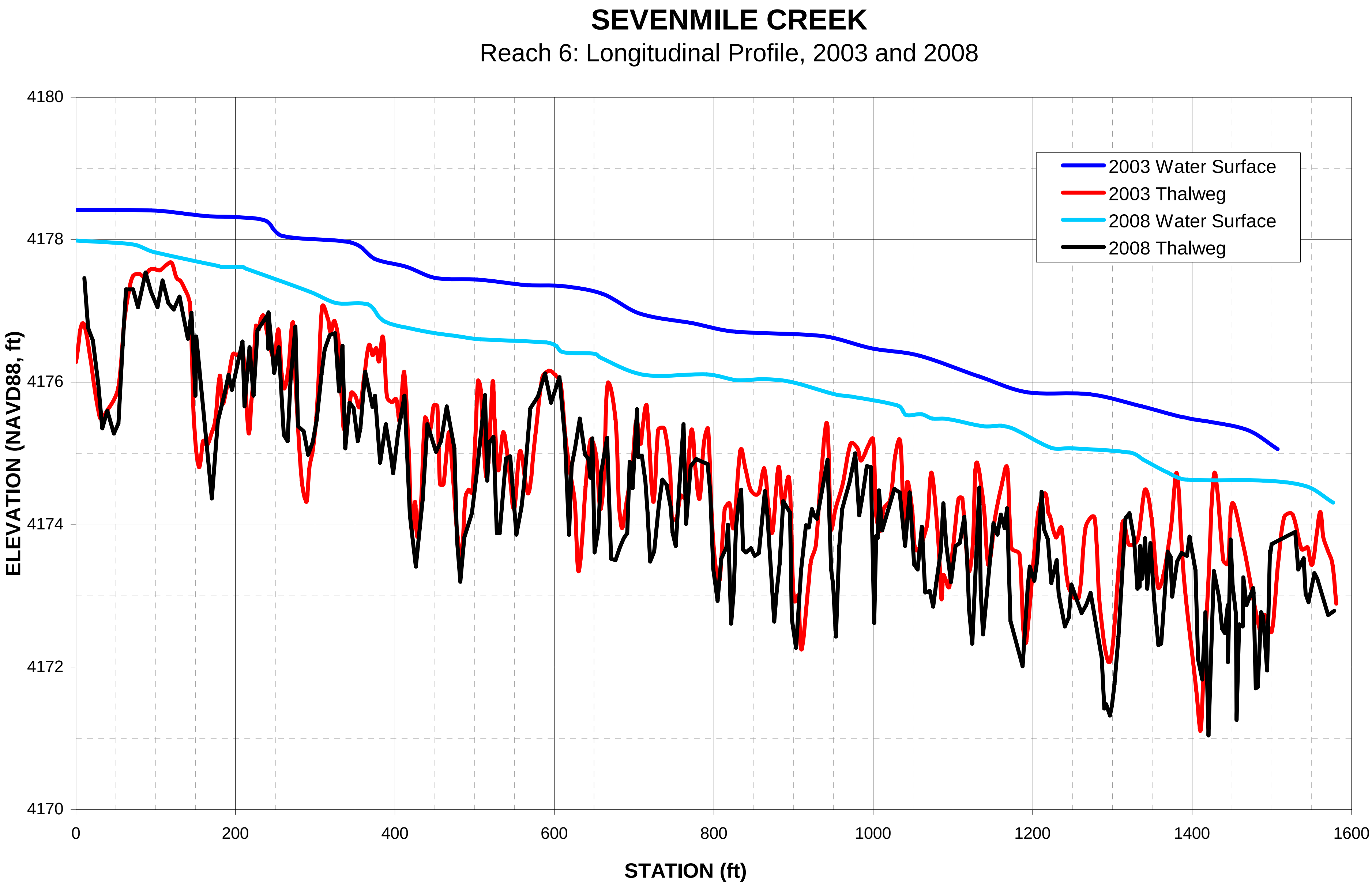

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6

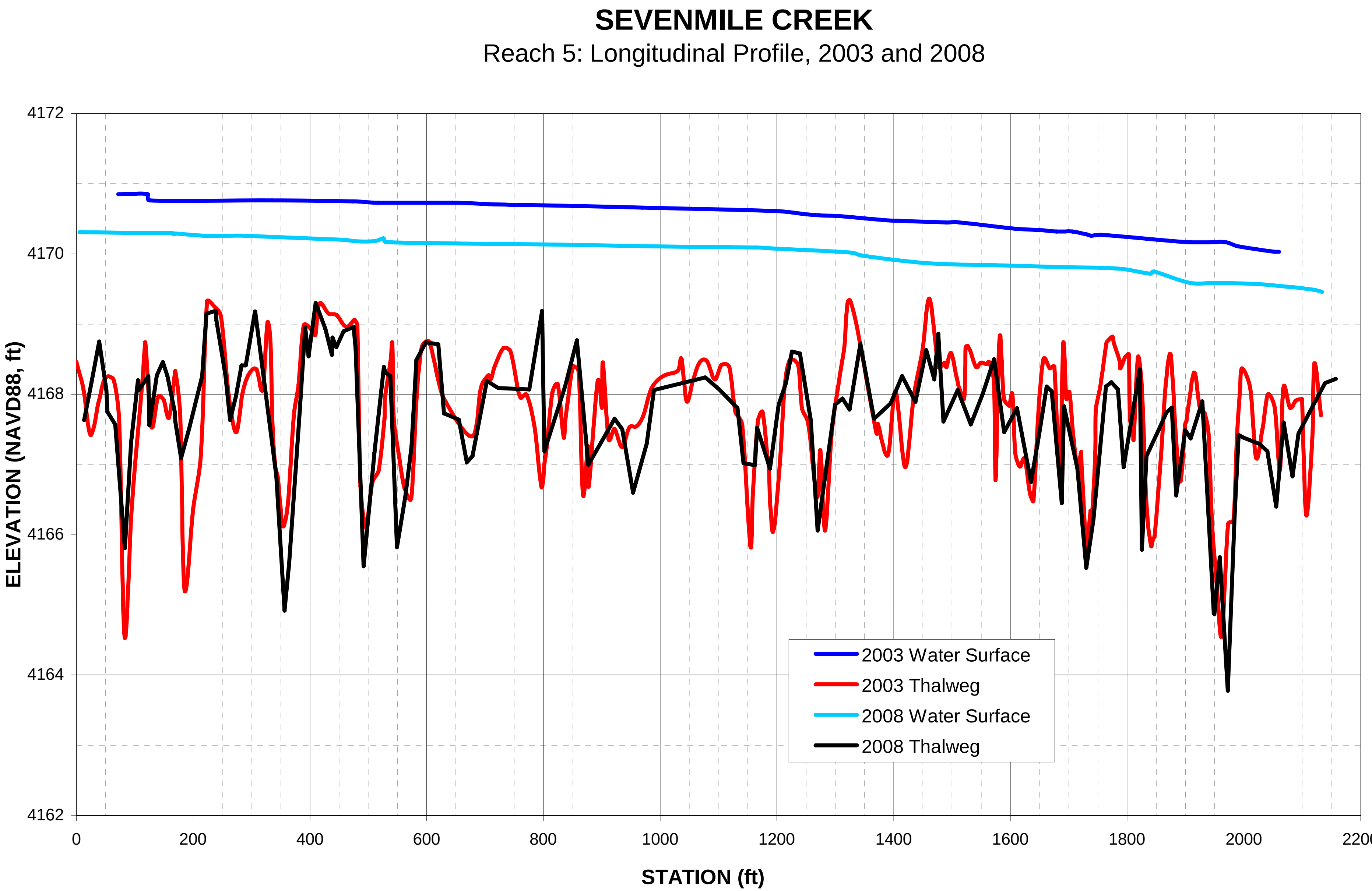

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FIGURE

7

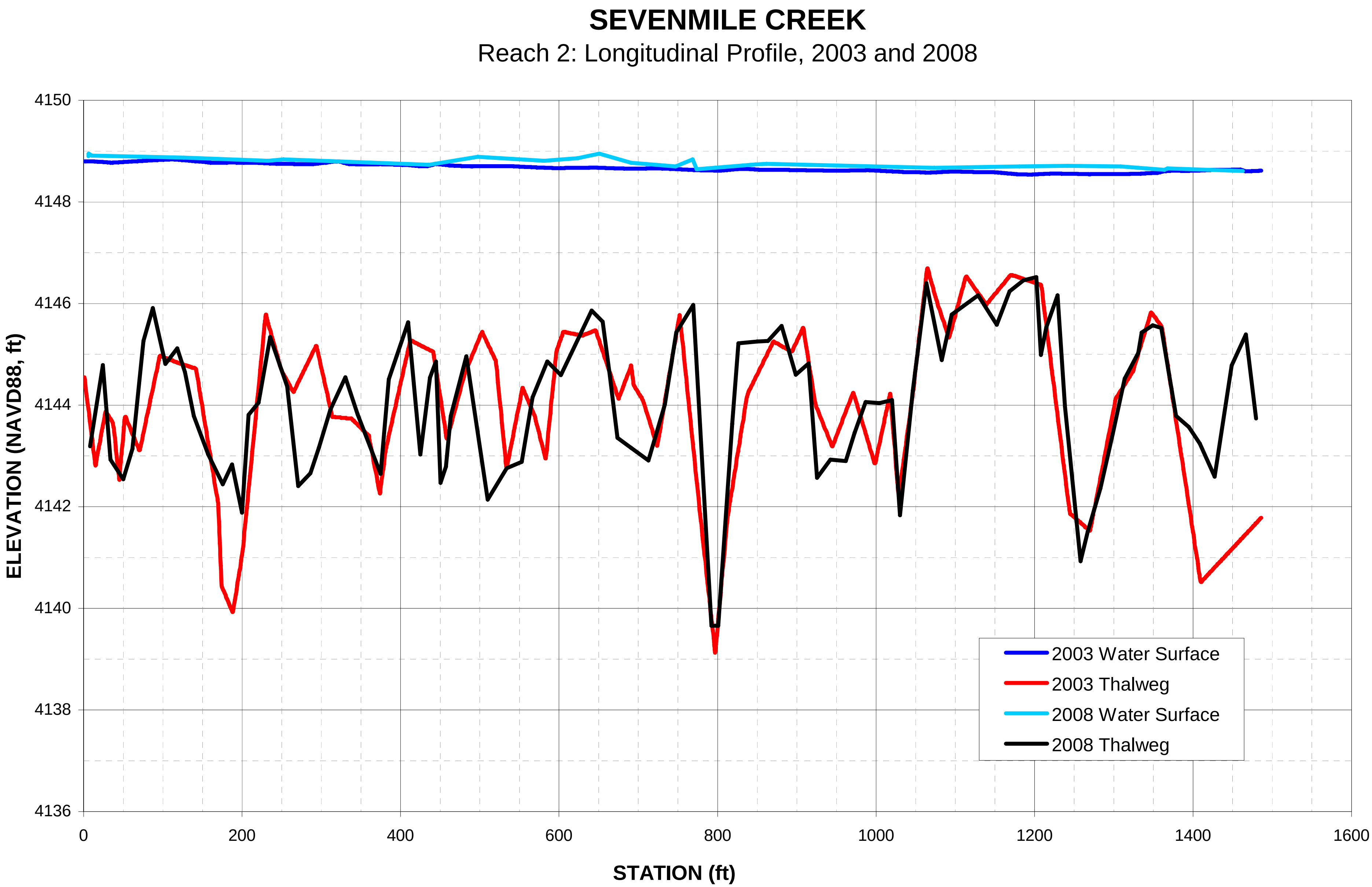

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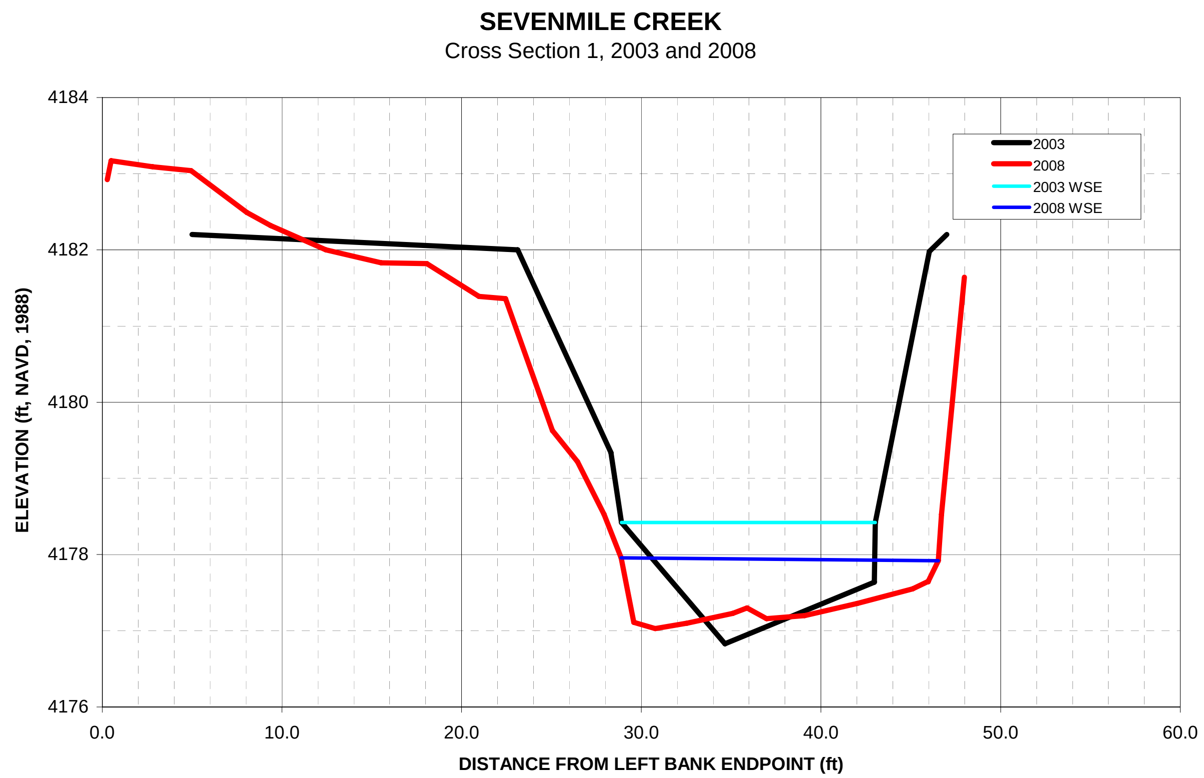
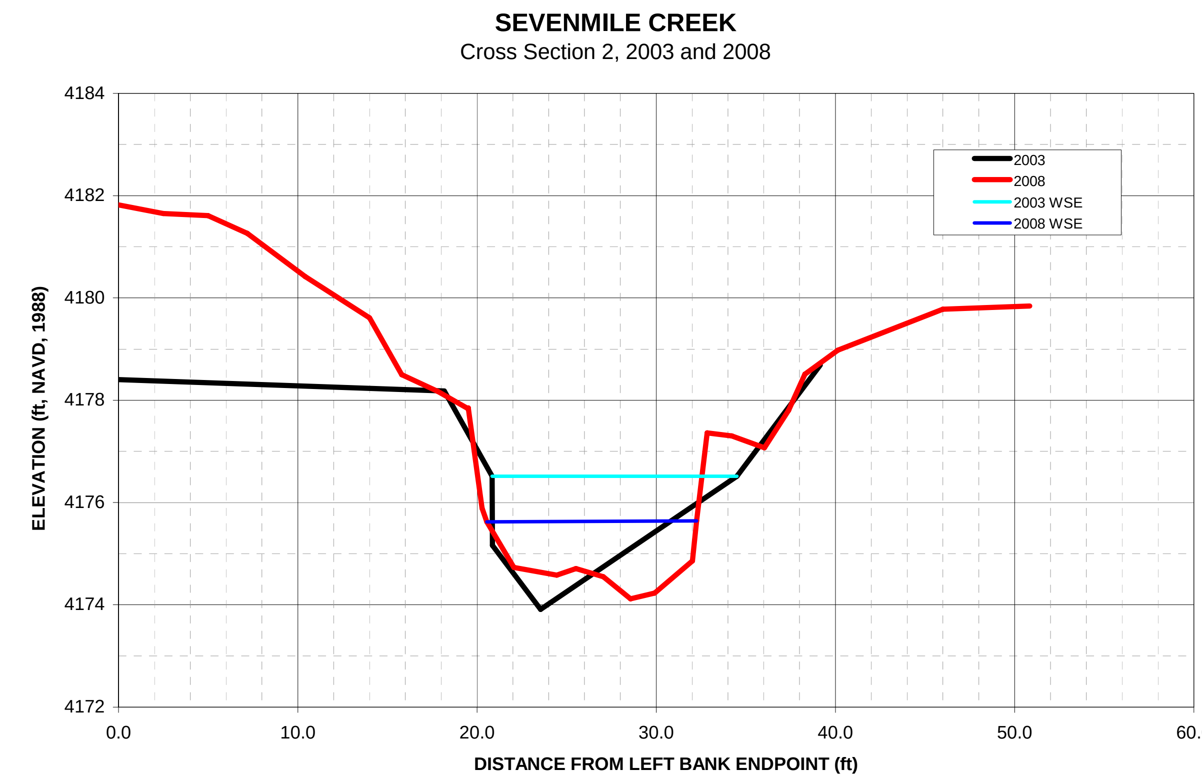
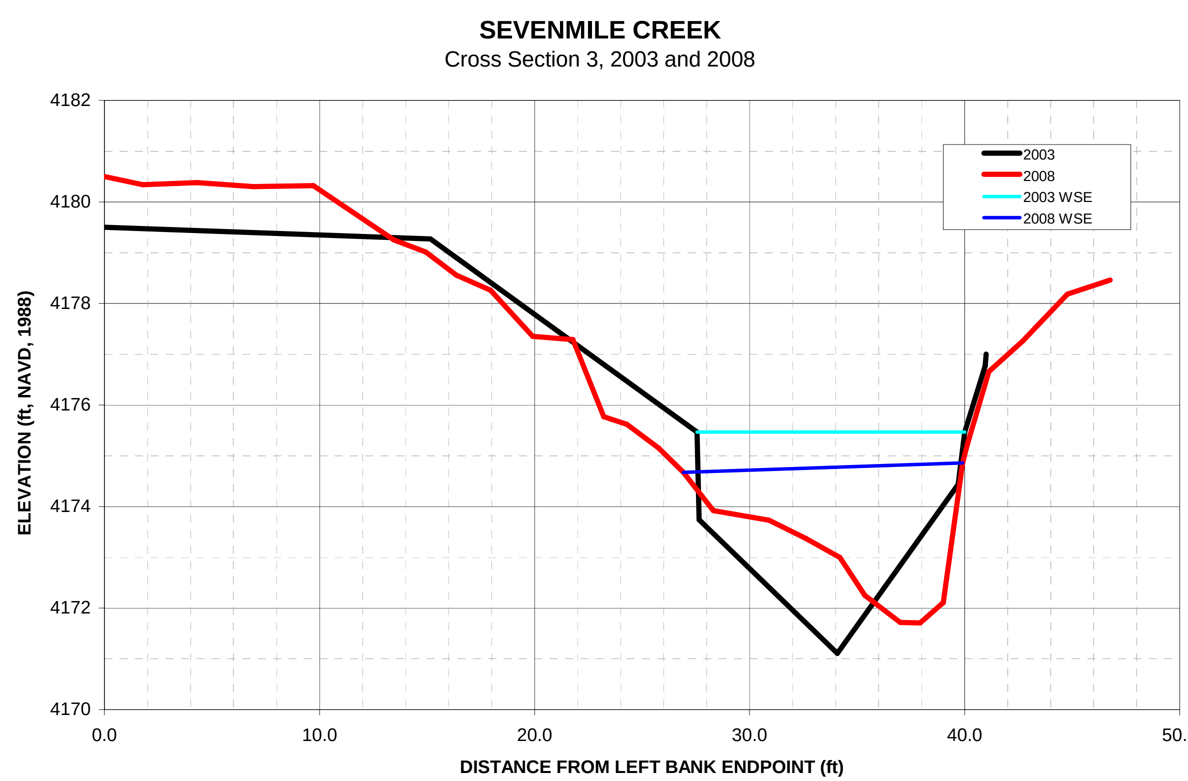
FIGURE

8

SEVENMILE CREEK, REACH 6 CROSS SECTIONS, 2003 AND 2008







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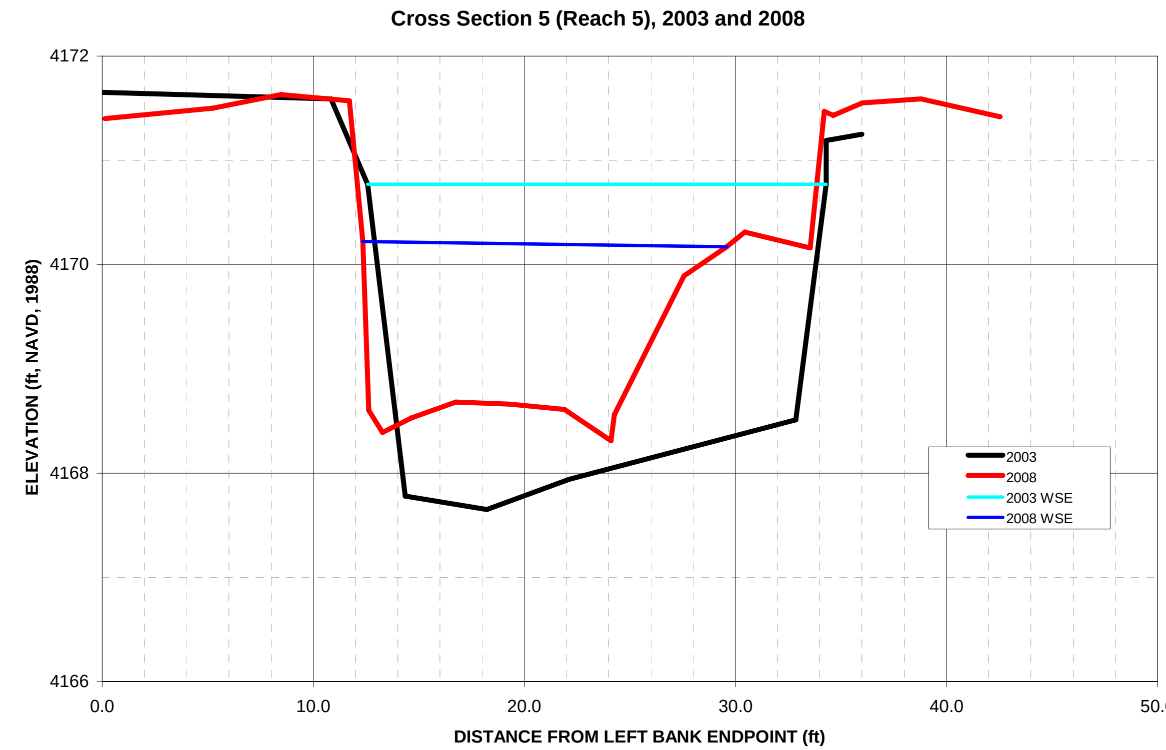
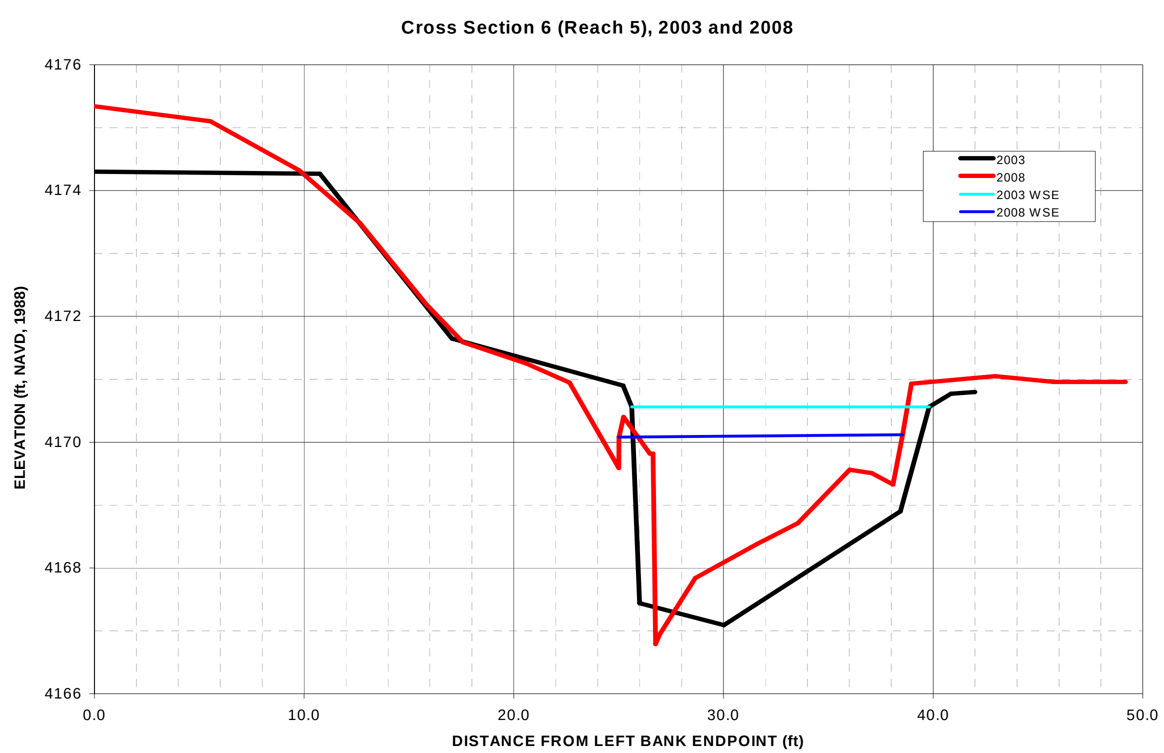
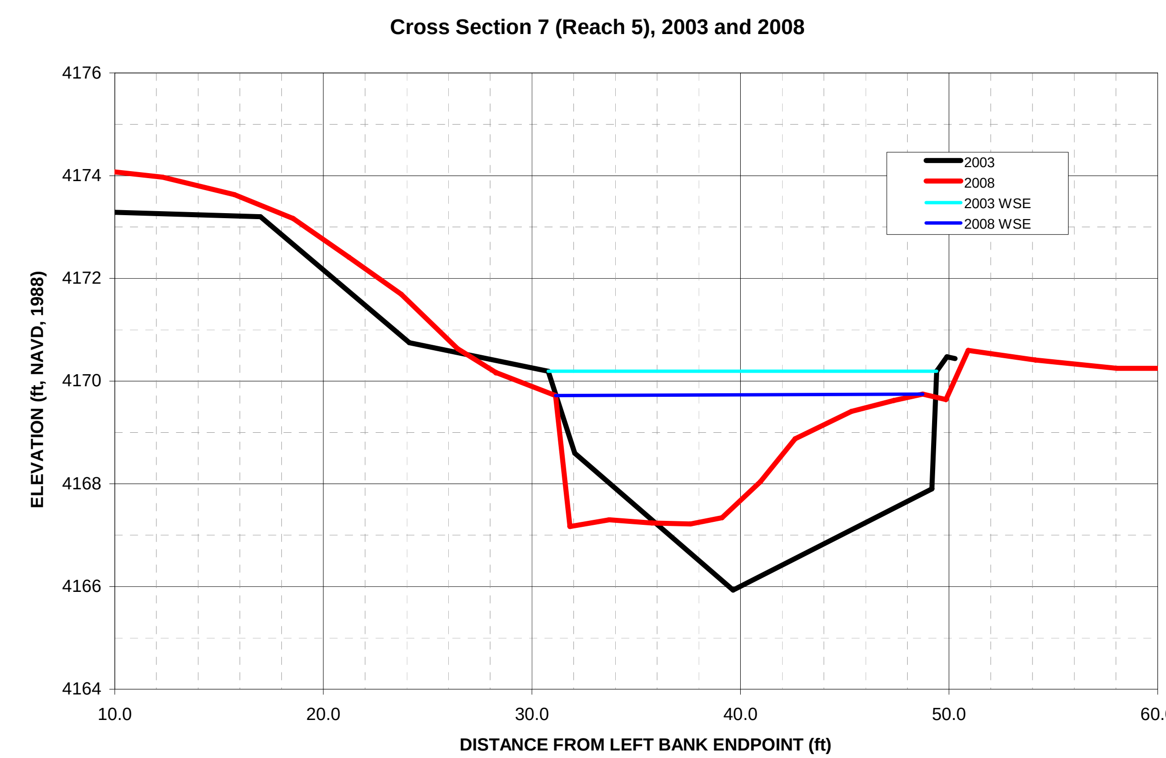
SEVENMILE CREEK, REACH 5 CROSS SECTIONS, 2003 AND 2008







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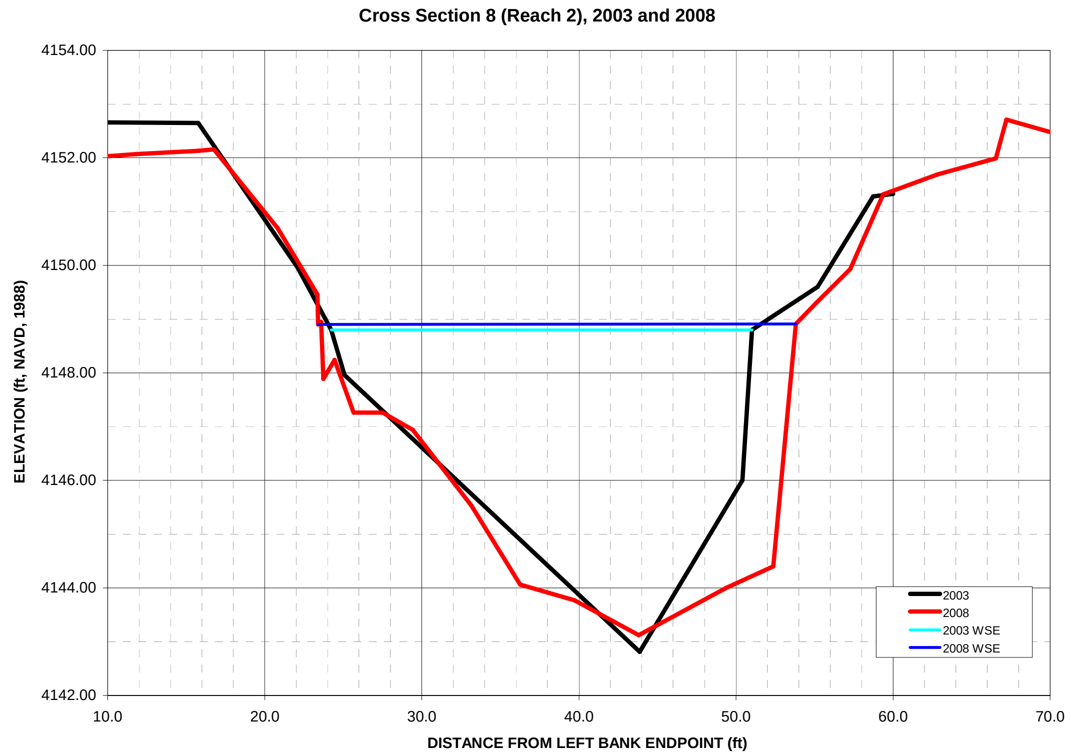
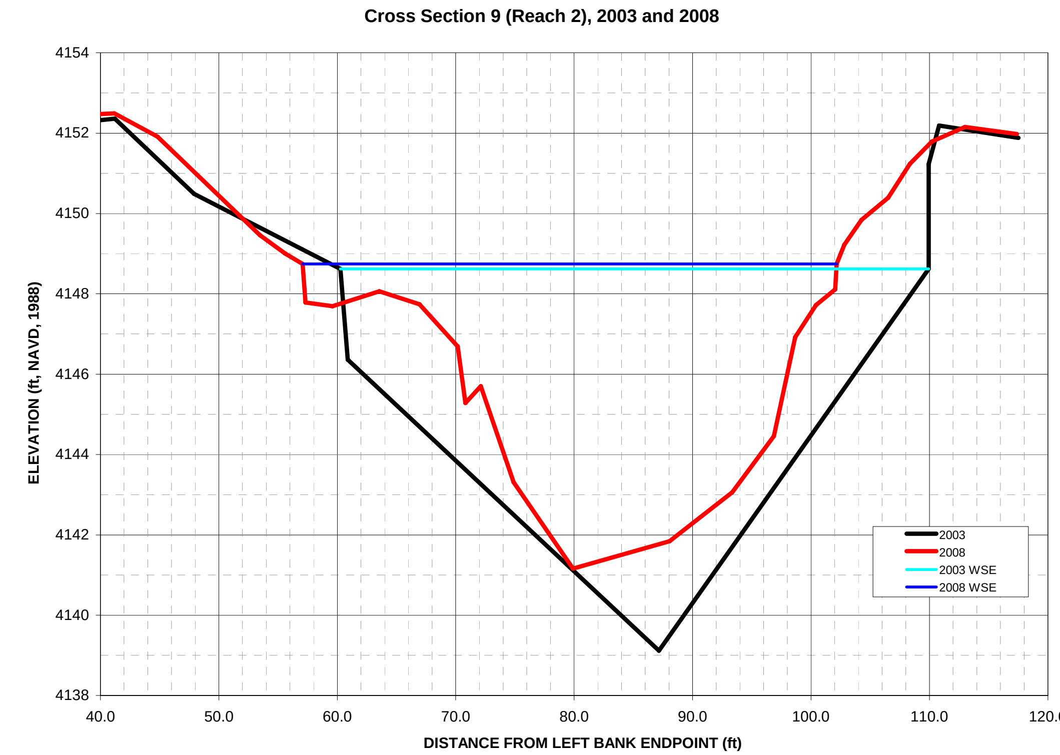
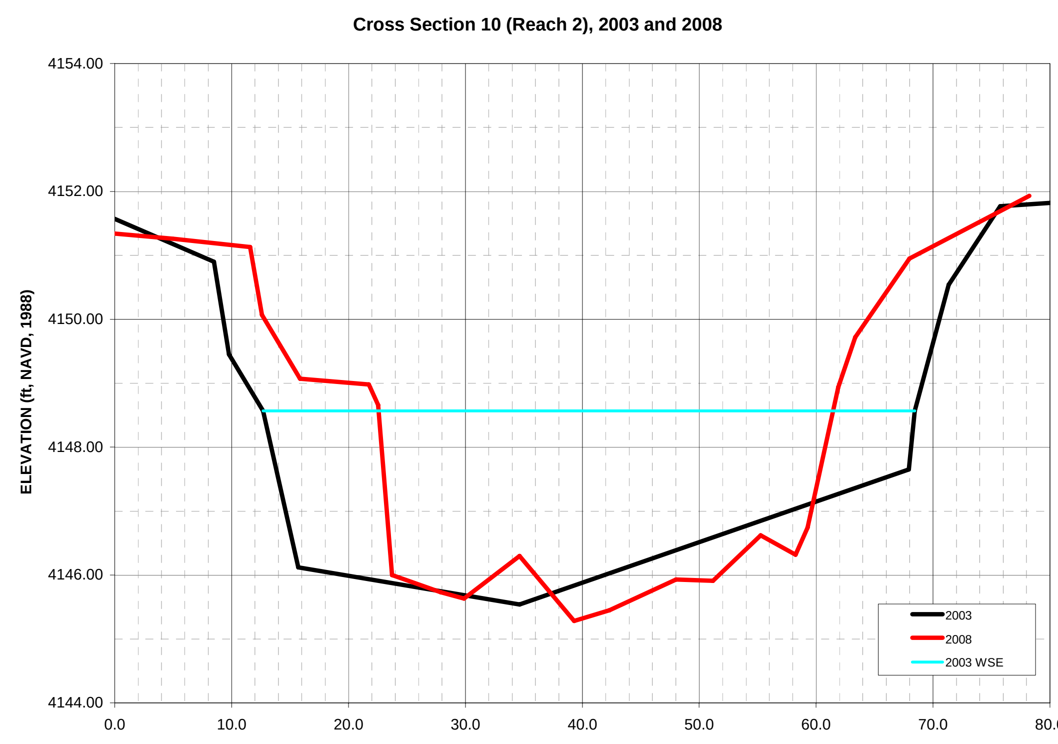
SEVENMILE CREEK, REACH 2 CROSS SECTIONS, 2003 AND 2008







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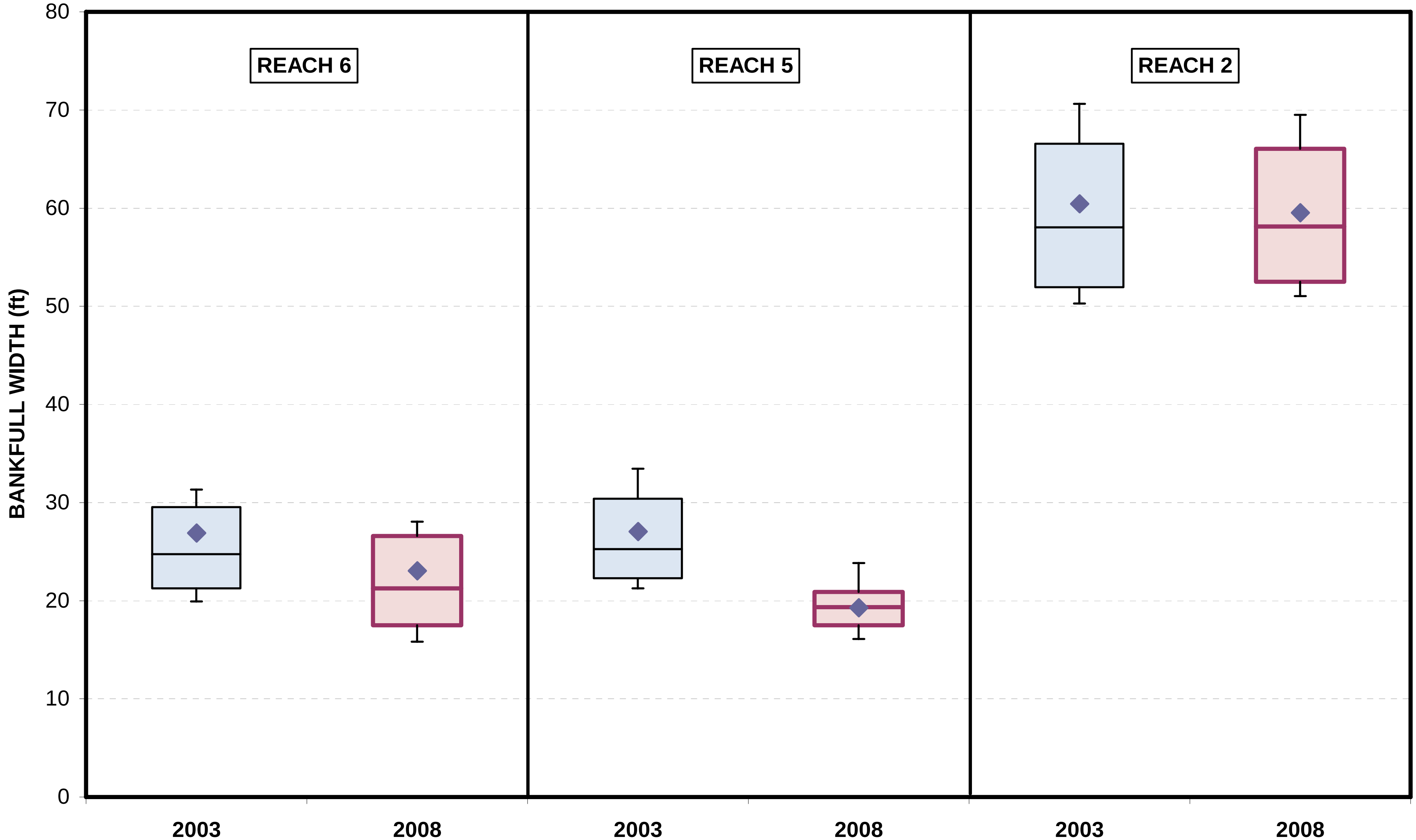
SEVENMILE CREEK

Comparison of Bankfull Channel Widths by Reach, 2003 and 2008



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10

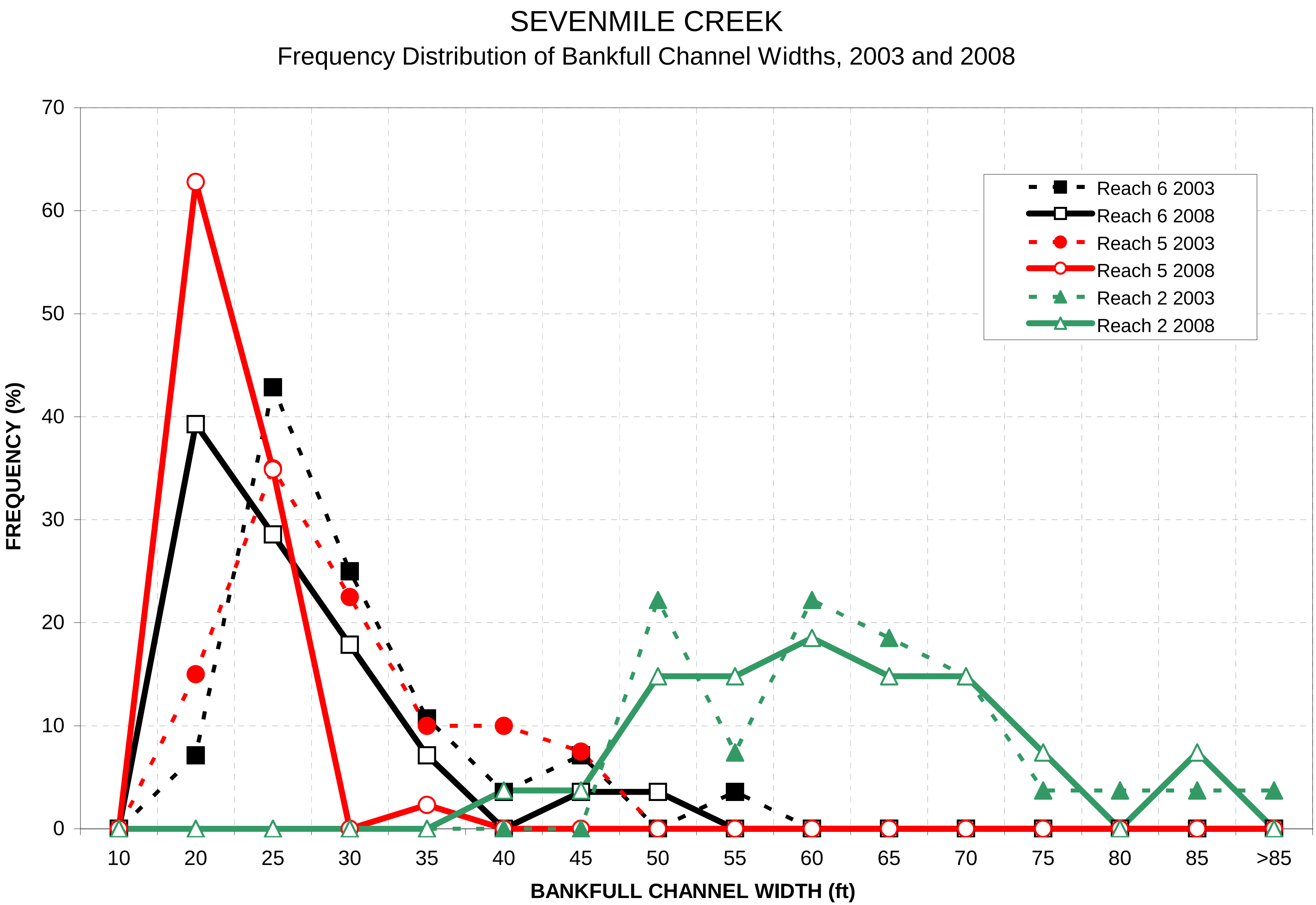

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FIGURE

11

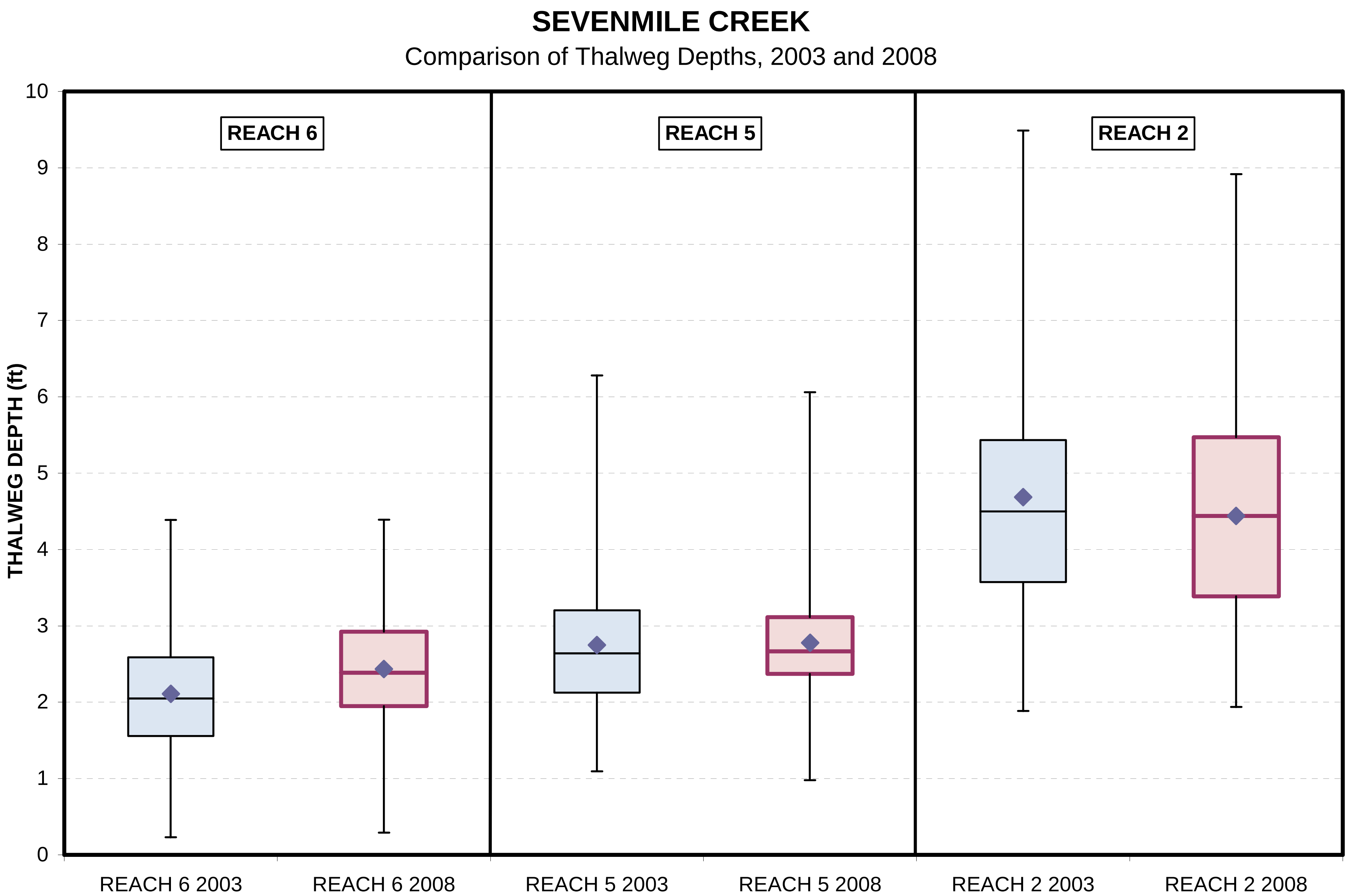

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FIGURE

12

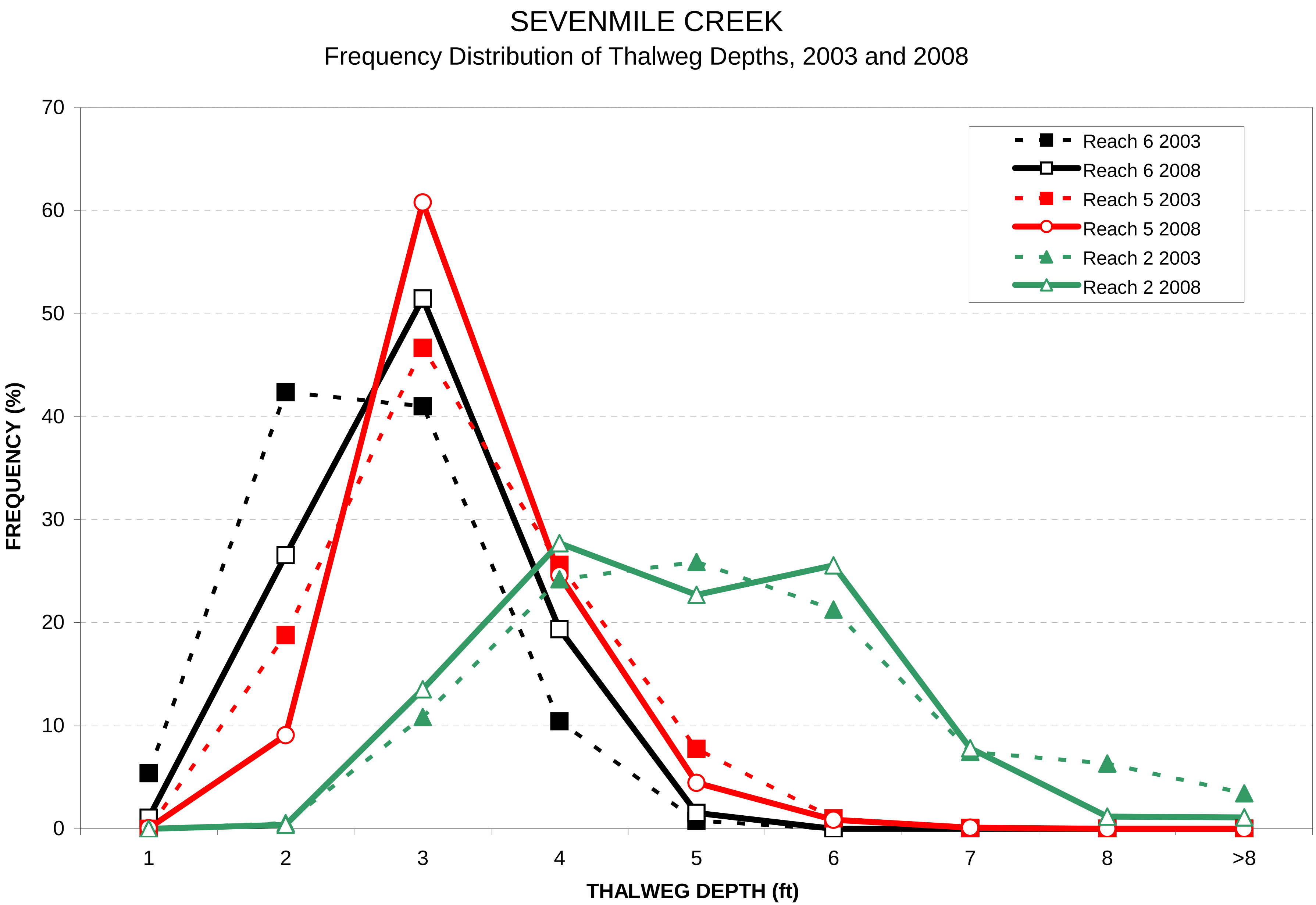

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FIGURE

13

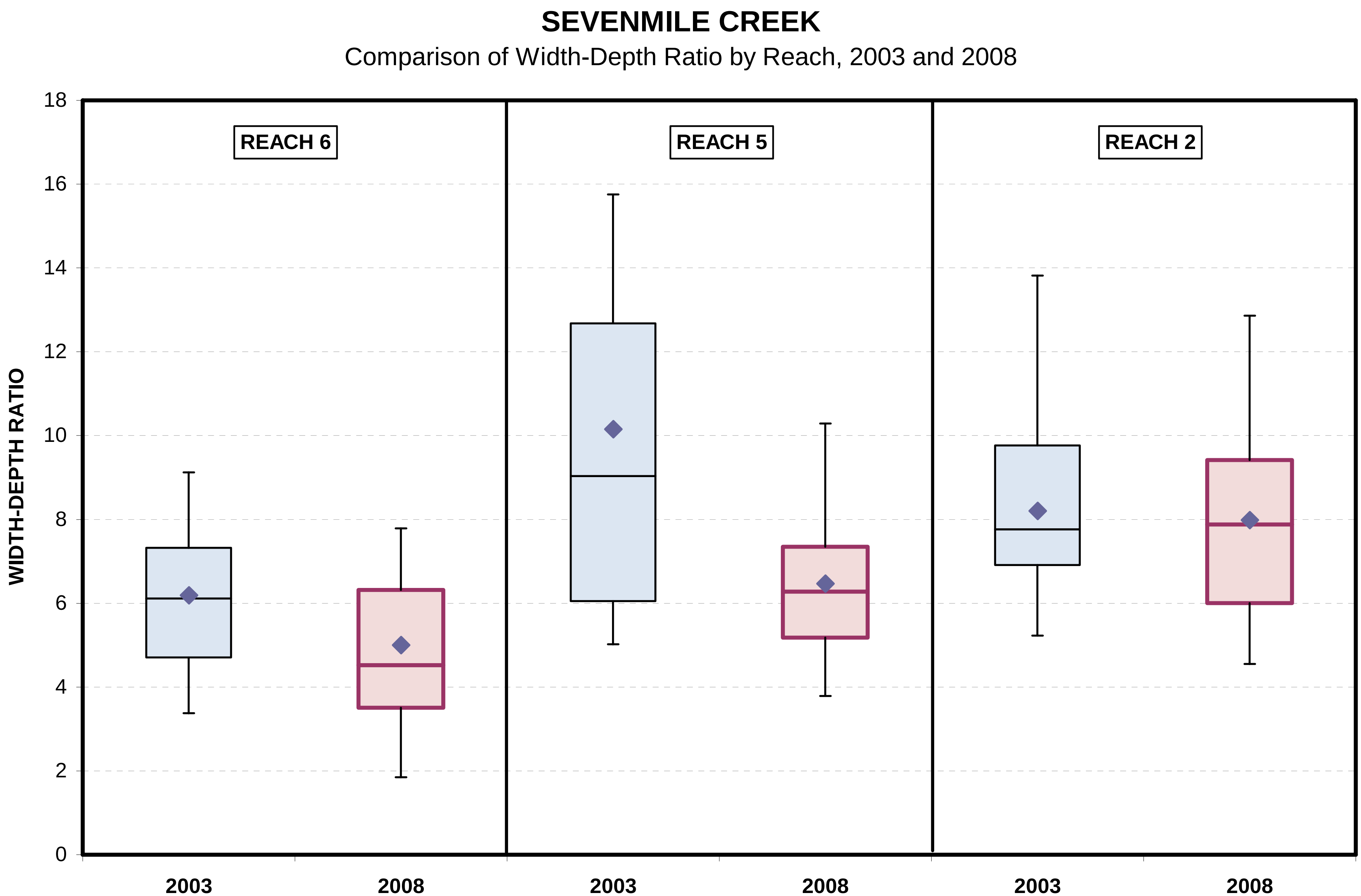

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FIGURE

14

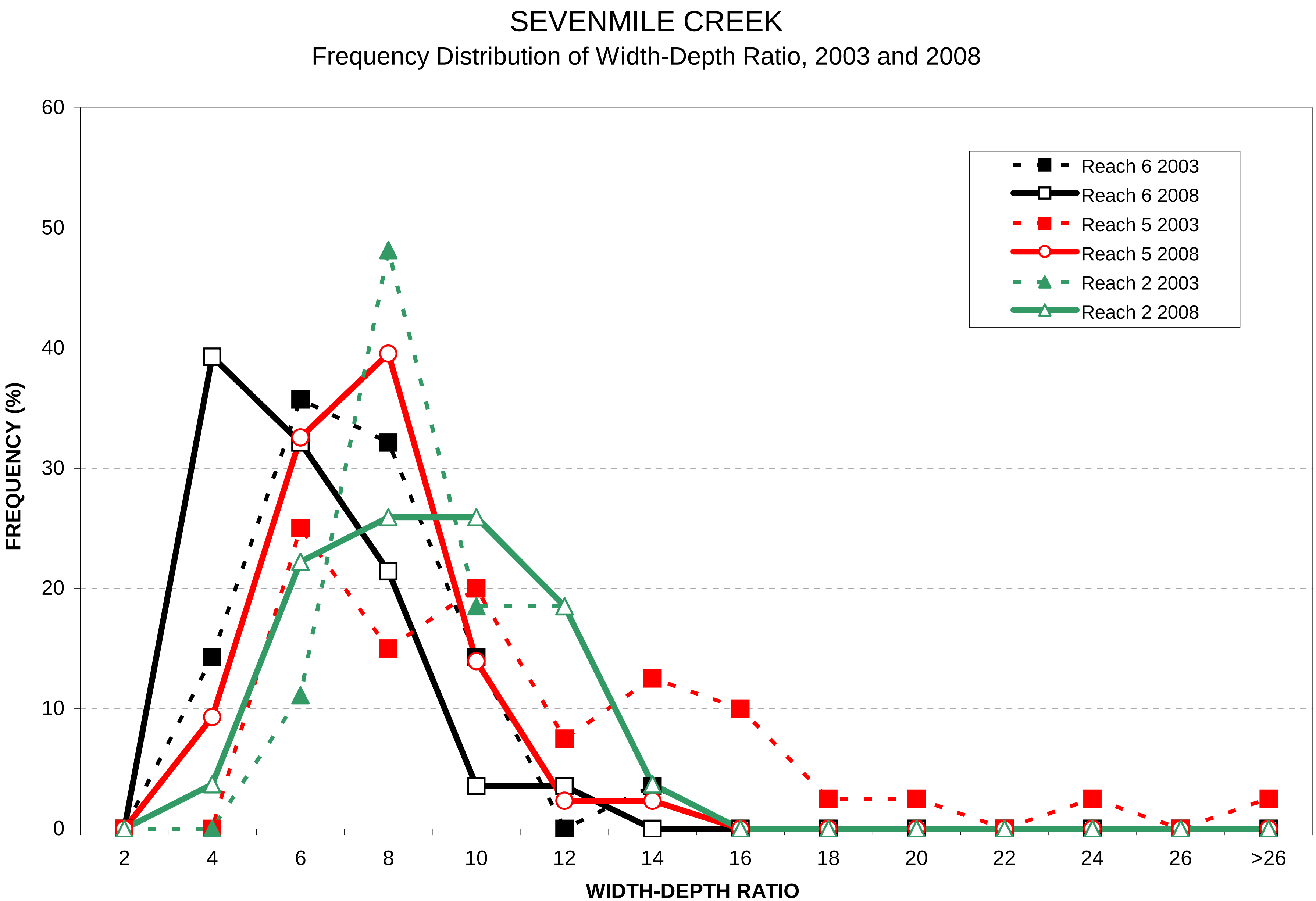

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FIGURE 15

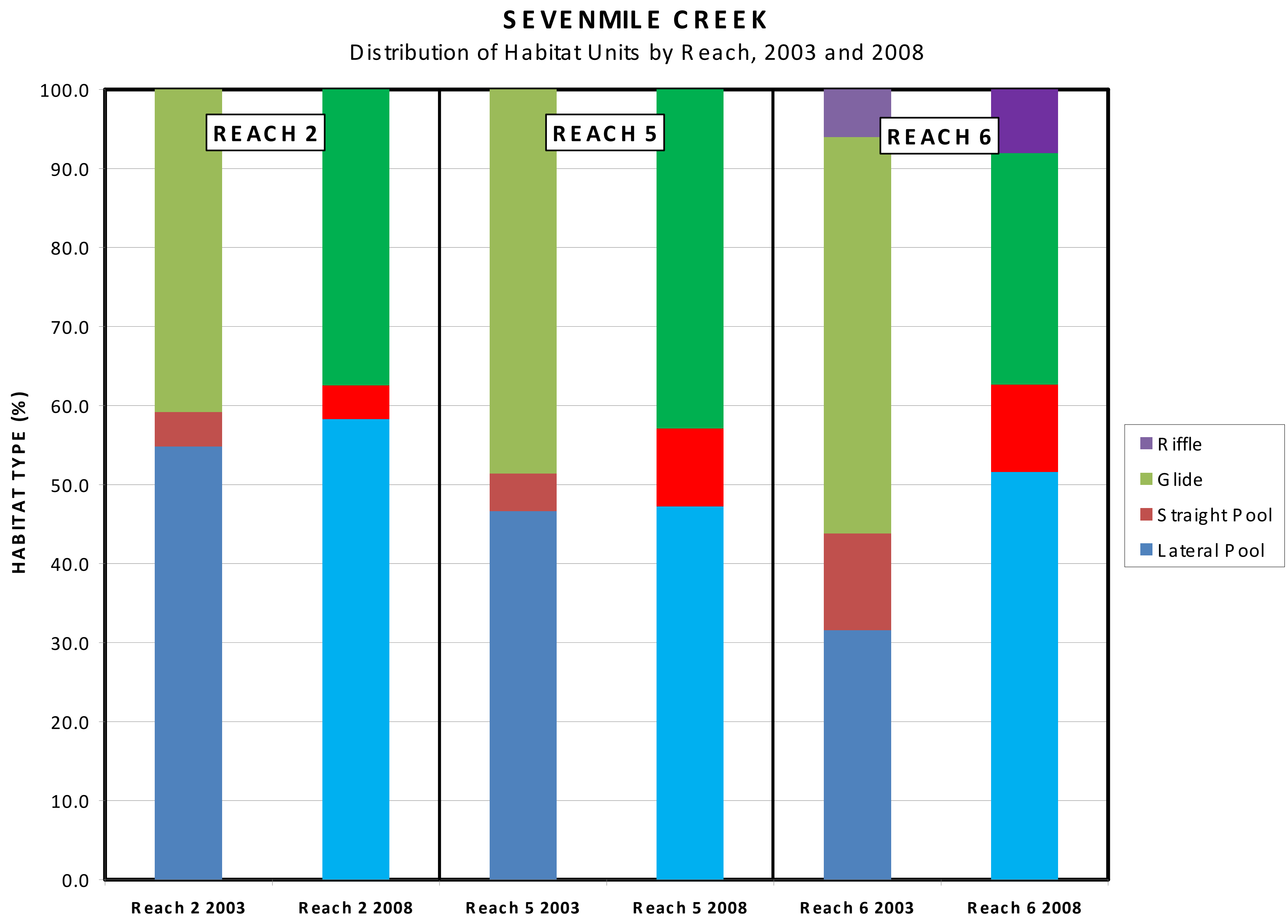

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FIGURE

16

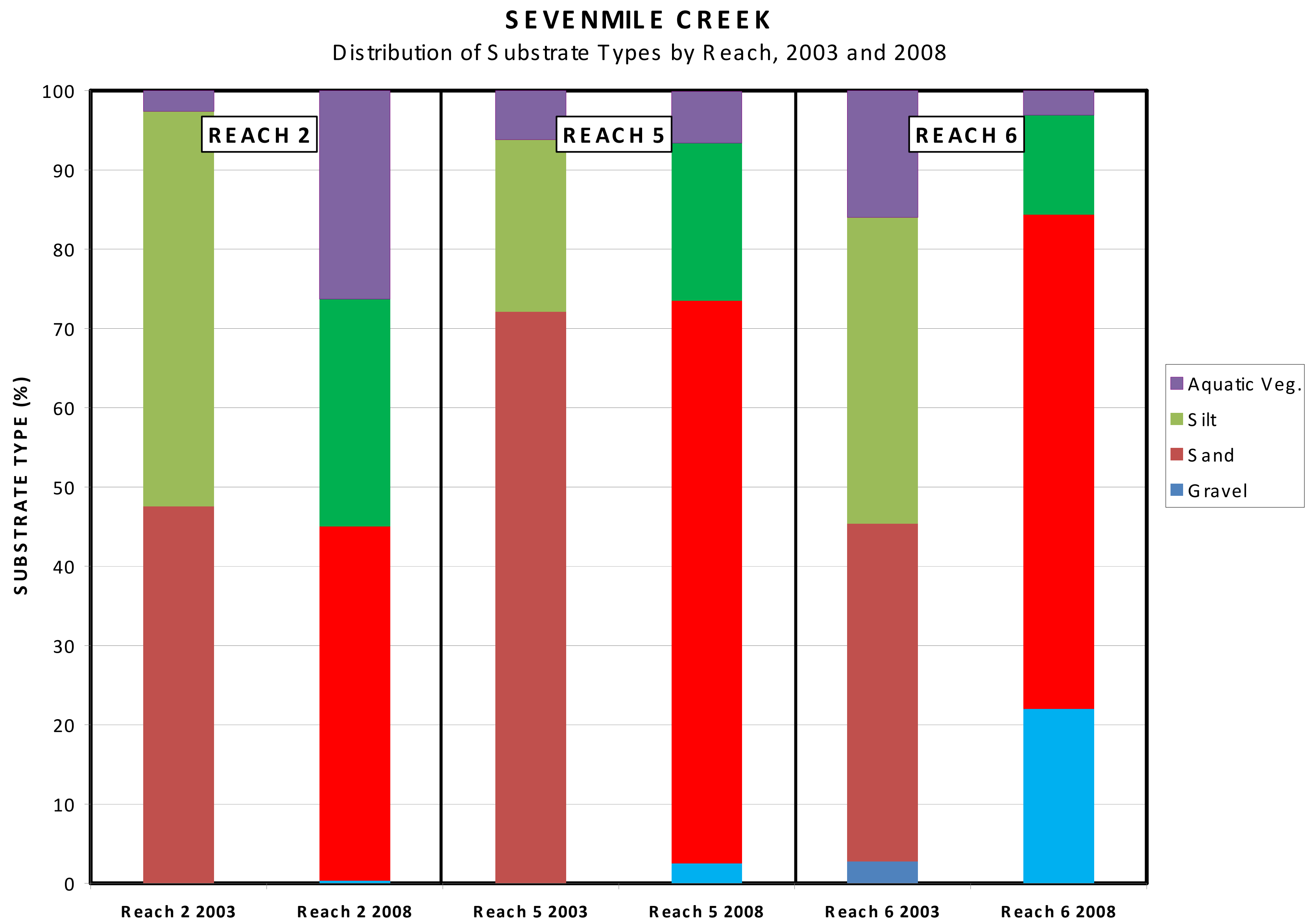

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FIGURE

17

TYPICAL SEVENMILE CREEK PHOTOPOINT COMPARISON

2003

2008

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FIGURE

18

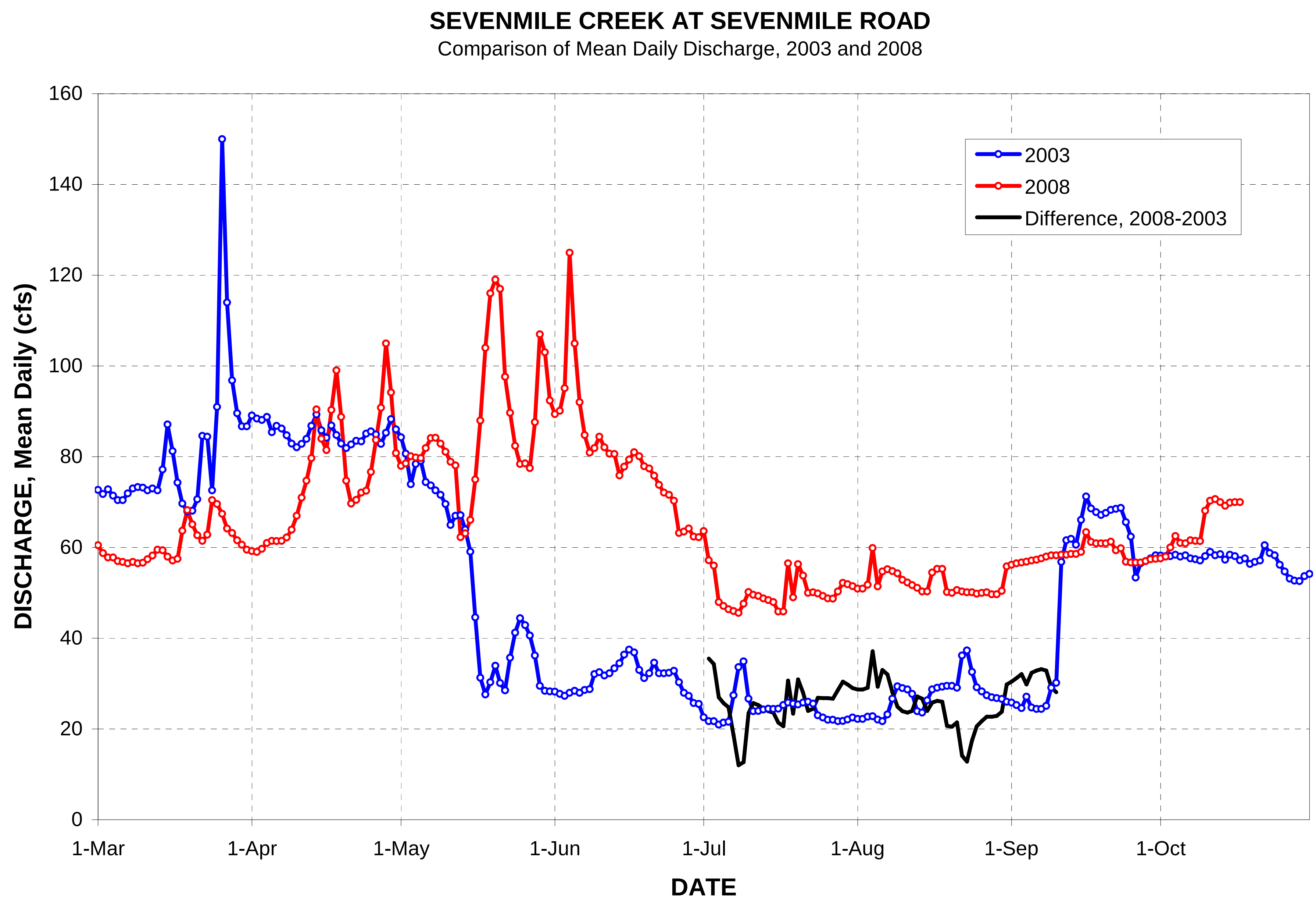

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FIGURE

19

CROOKED CREEK STUDY SITES LOCATION MAP

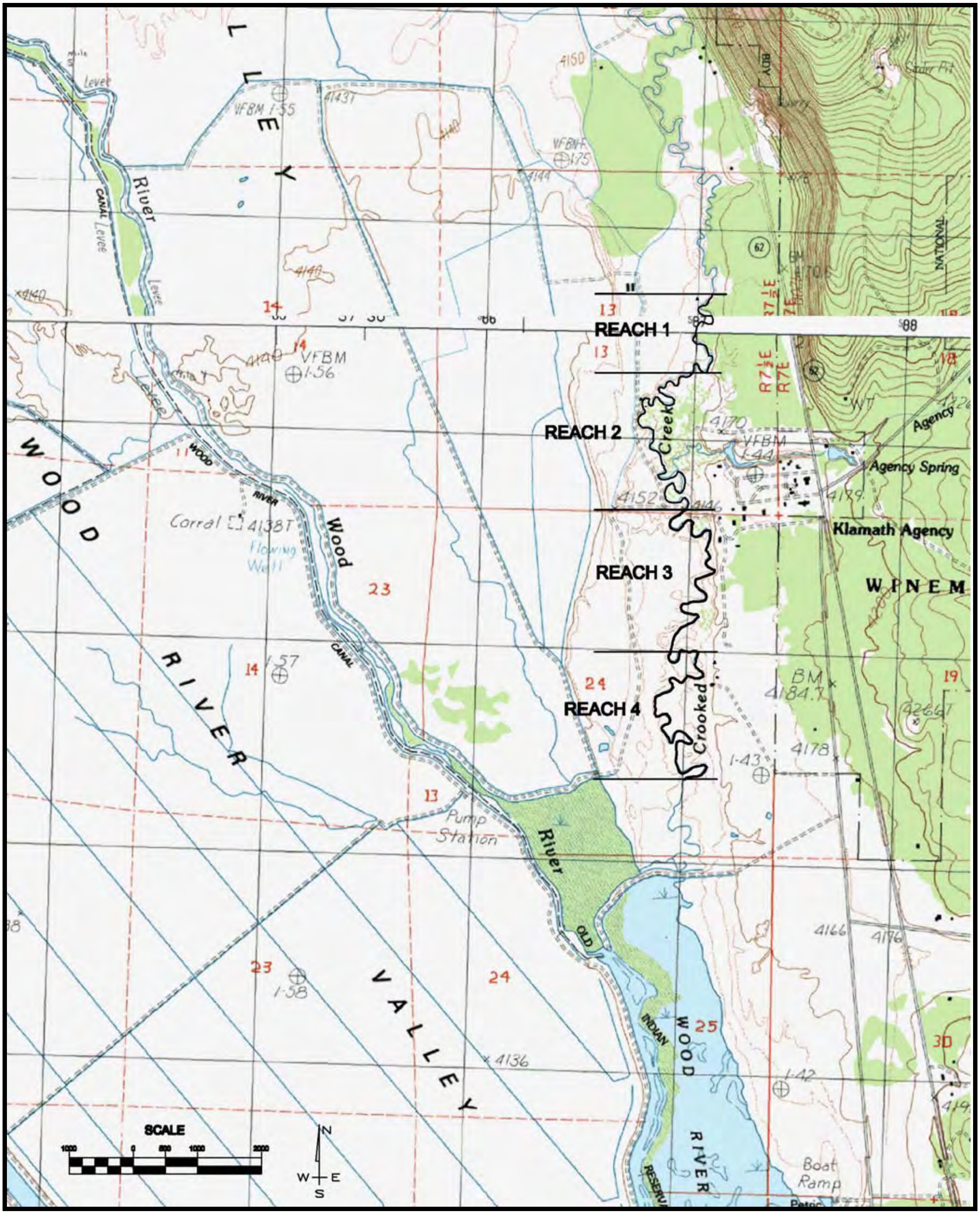

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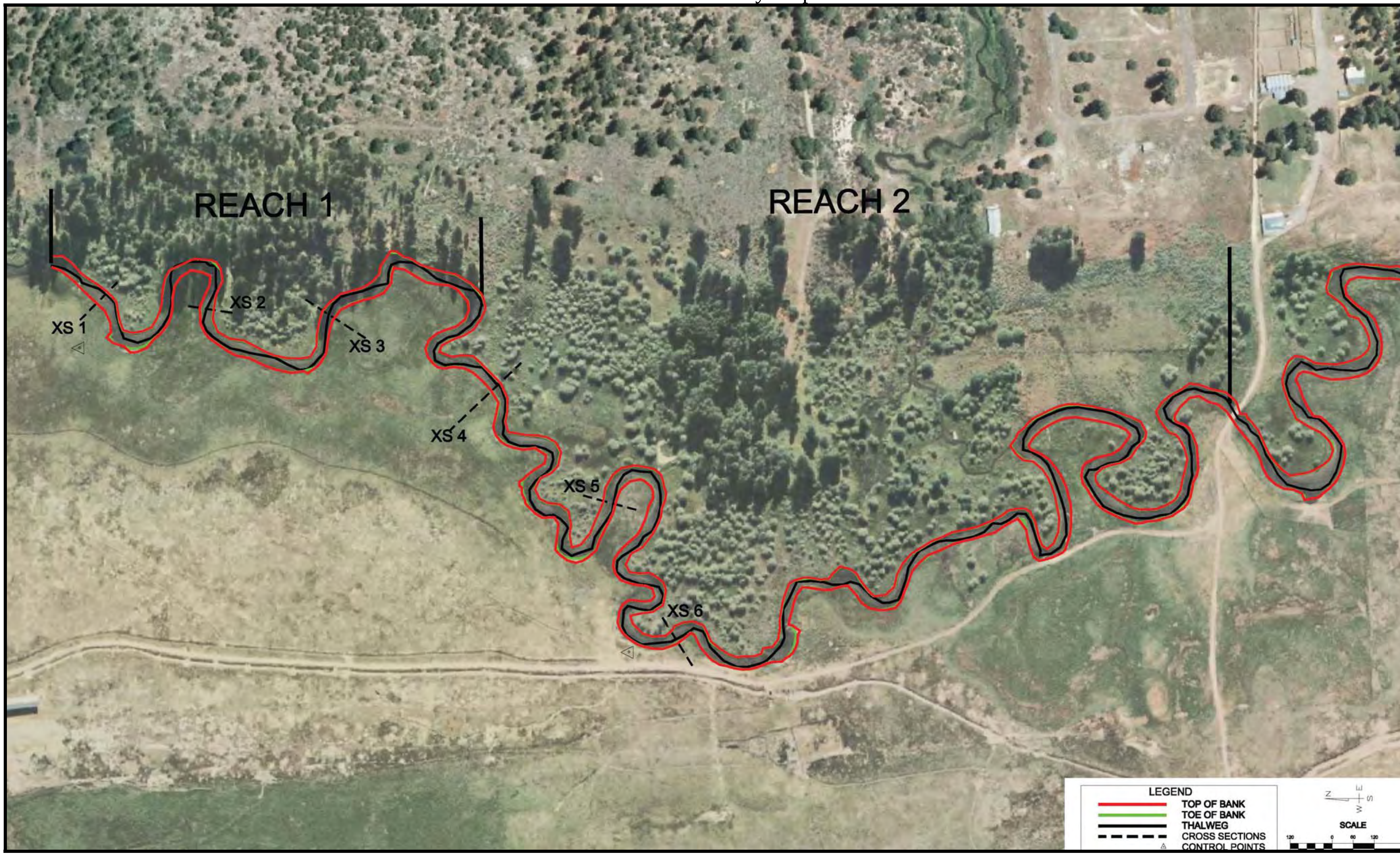
FIGURE

20

CROOKED CREEK

Reach 1-2 Survey Map



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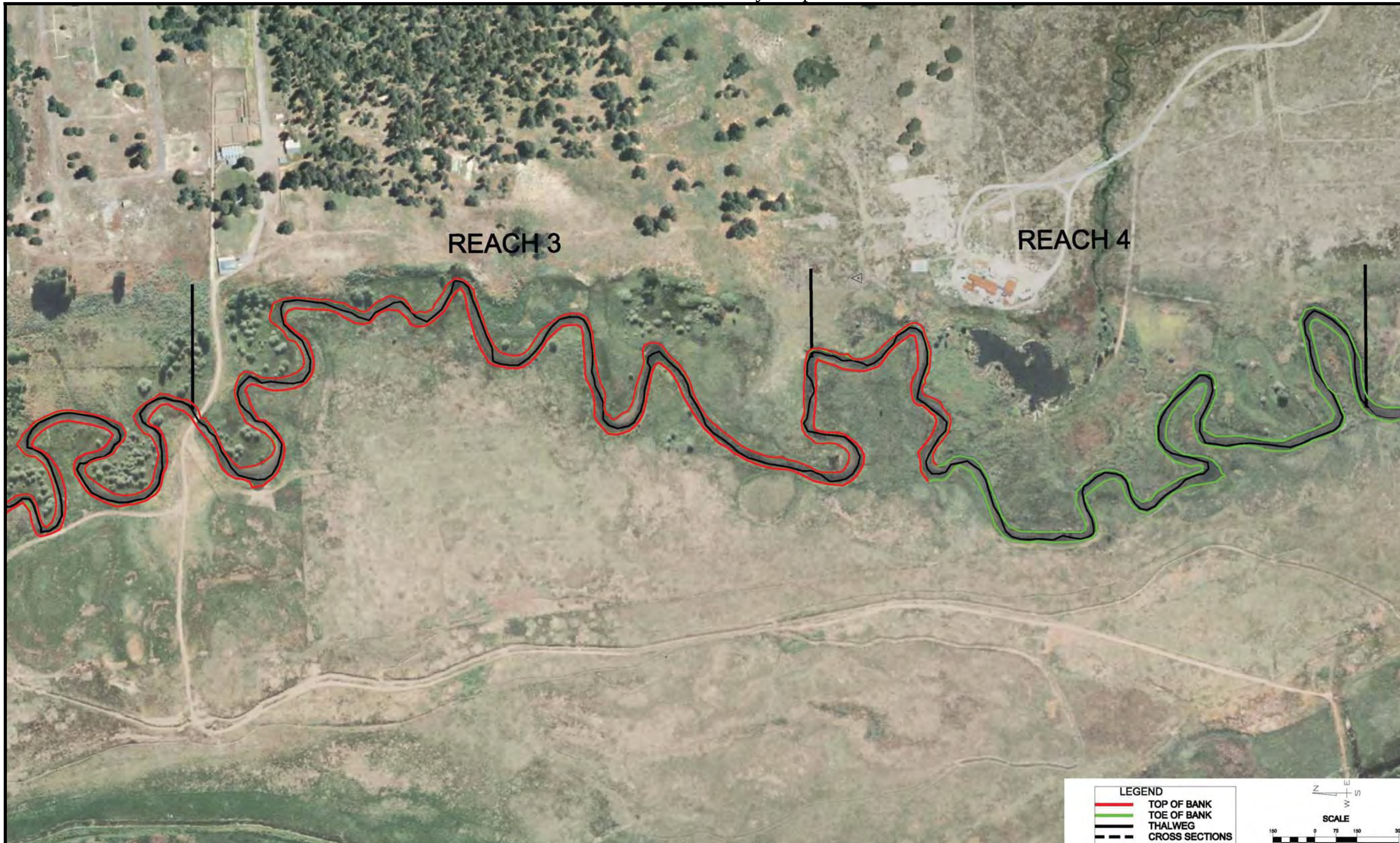
CROOKED CREEK

Reach 3-4 Survey Map



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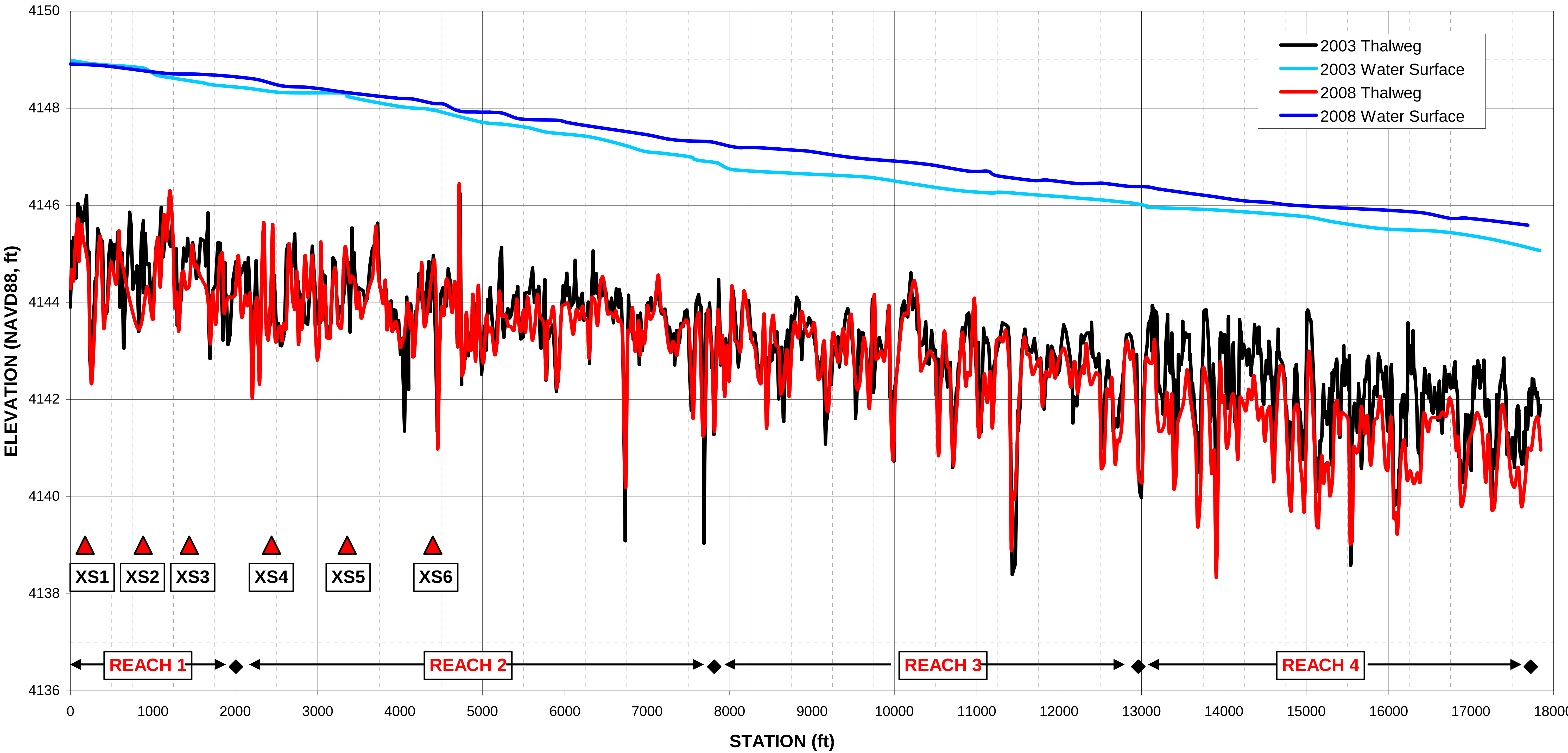
CROOKED CREEK

Longitudinal Profile, 2003 and 2008



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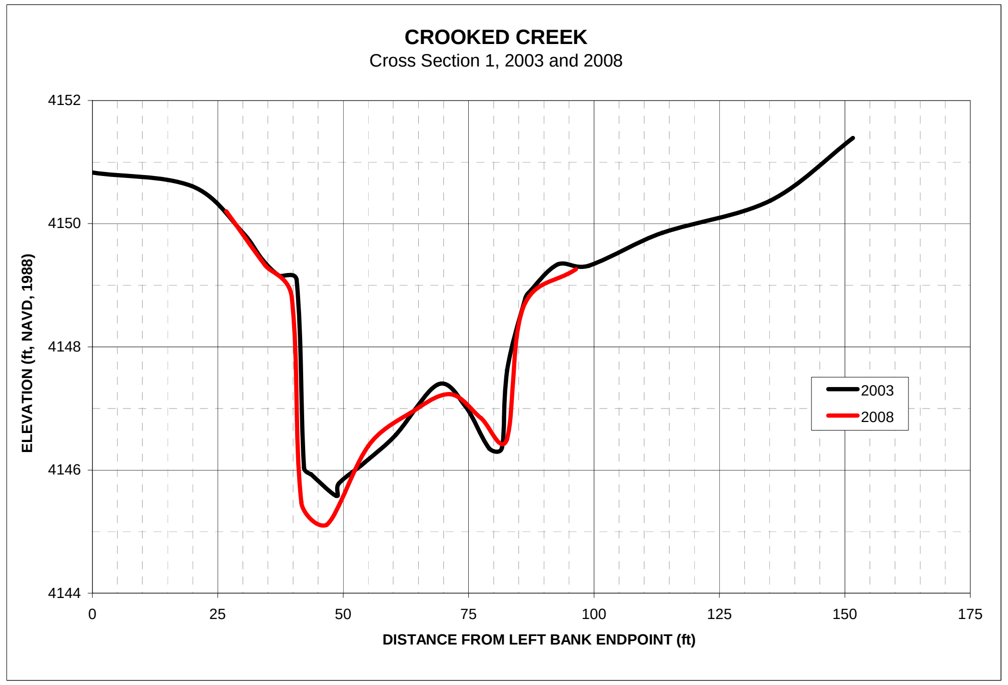
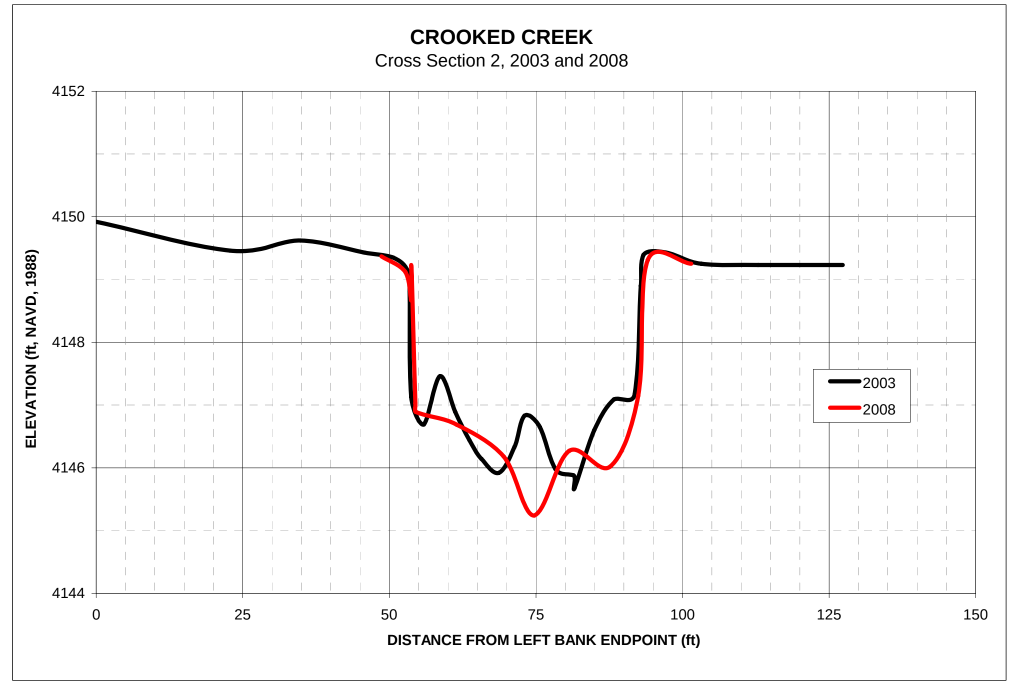
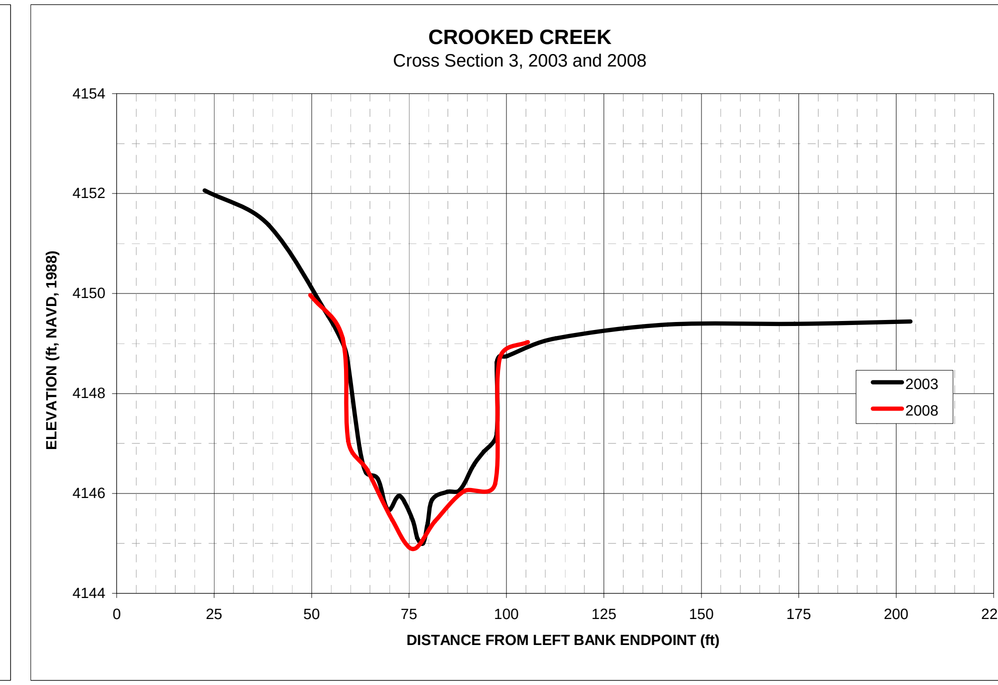
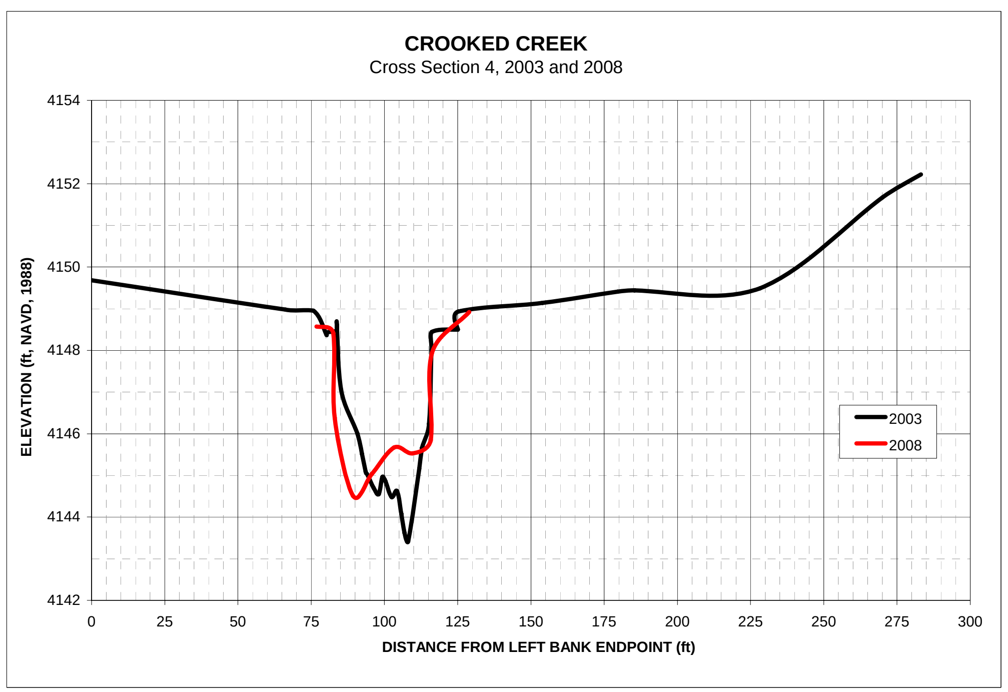
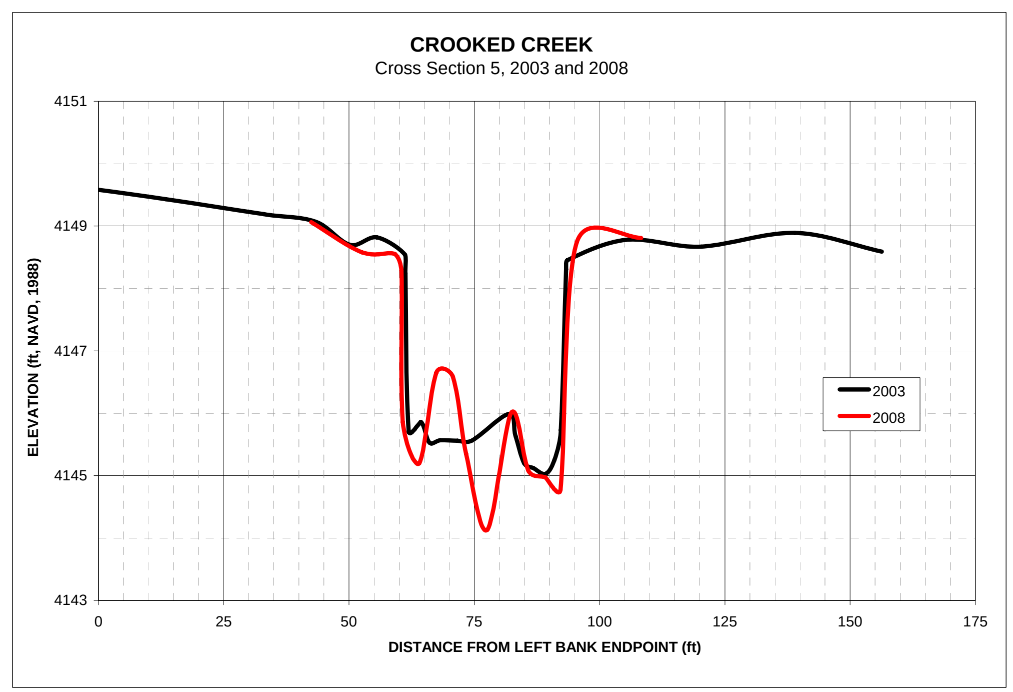
CROOKED CREEK CROSS SECTIONS, 2003 AND 2008

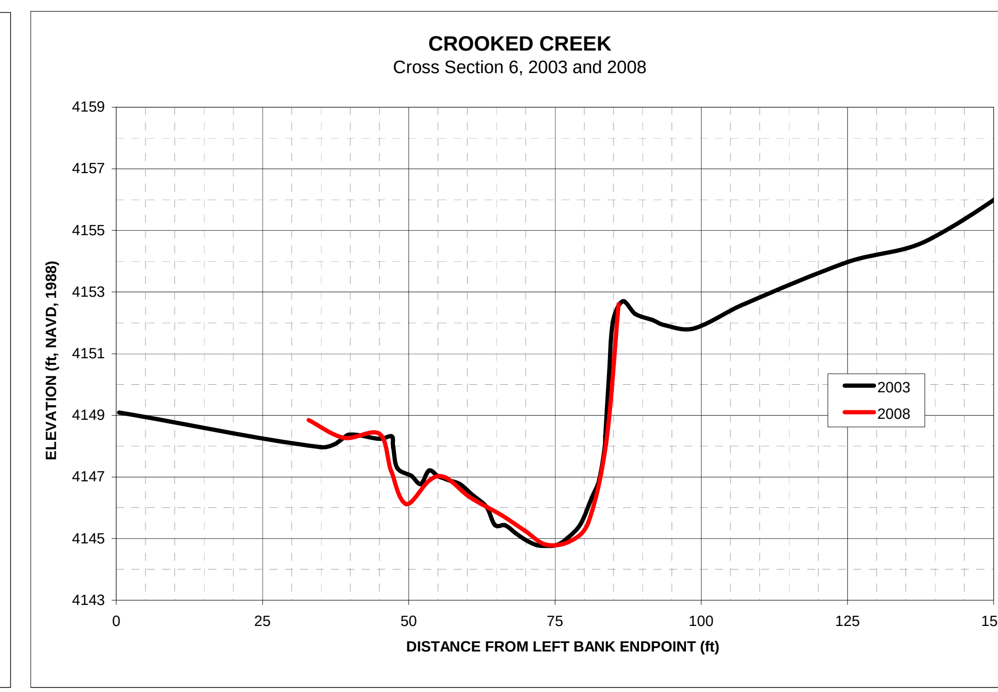












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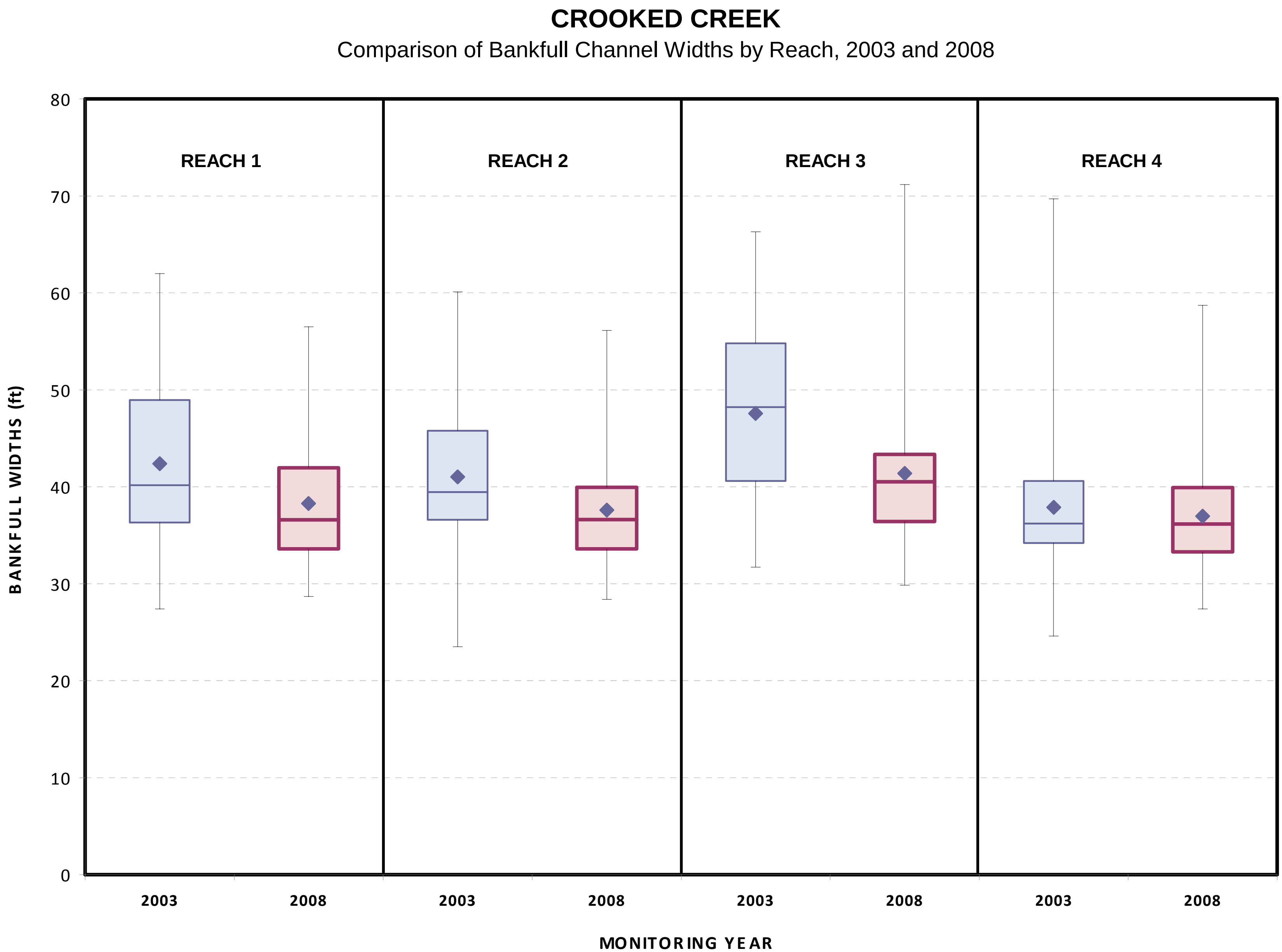

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FIGURE

25

CROOKED CREEK

Comparison of Bankfull Channel Width outside of (4A) and within (4B) Channel Restoration Area in Reach 4, 2003 and 2008

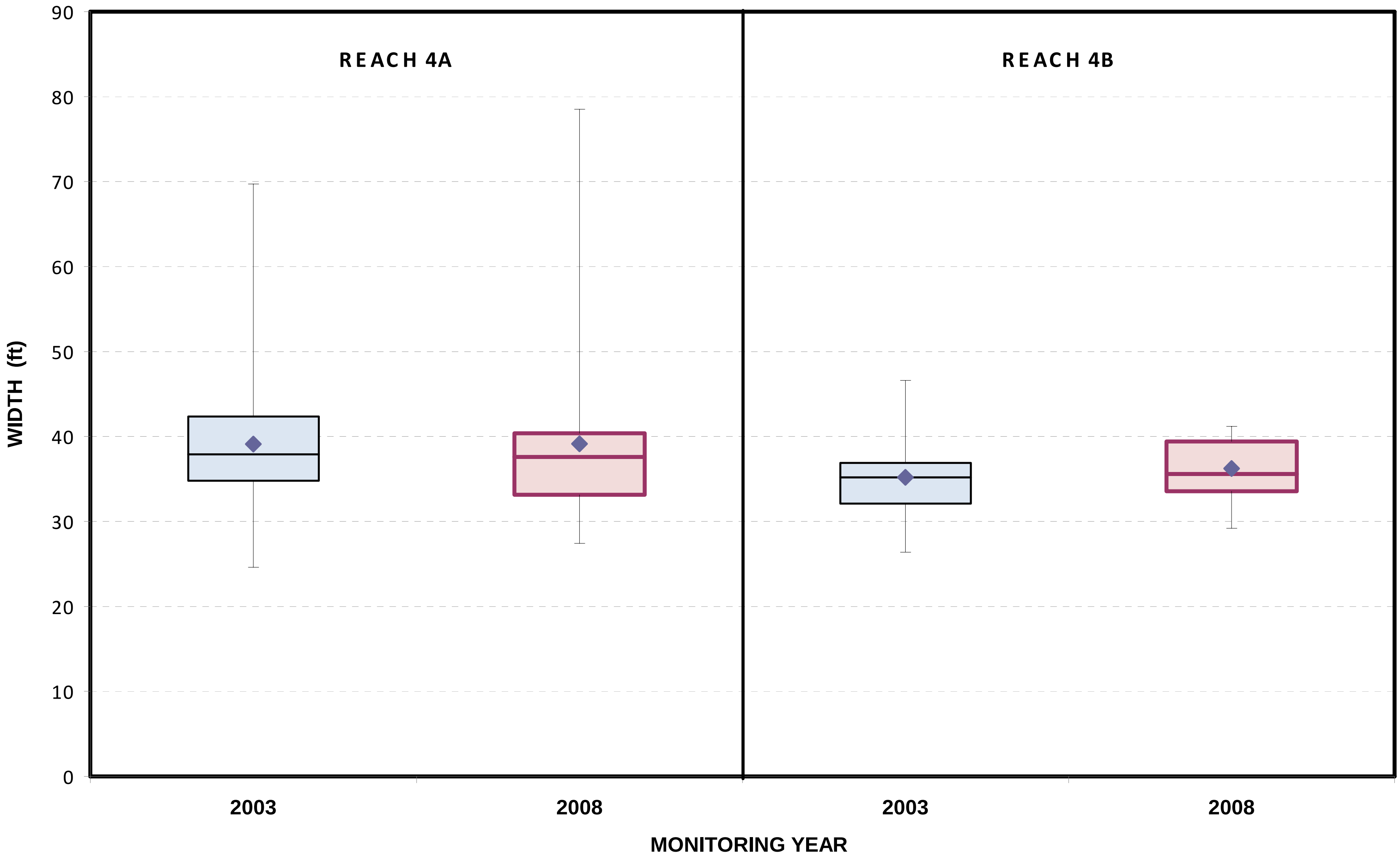

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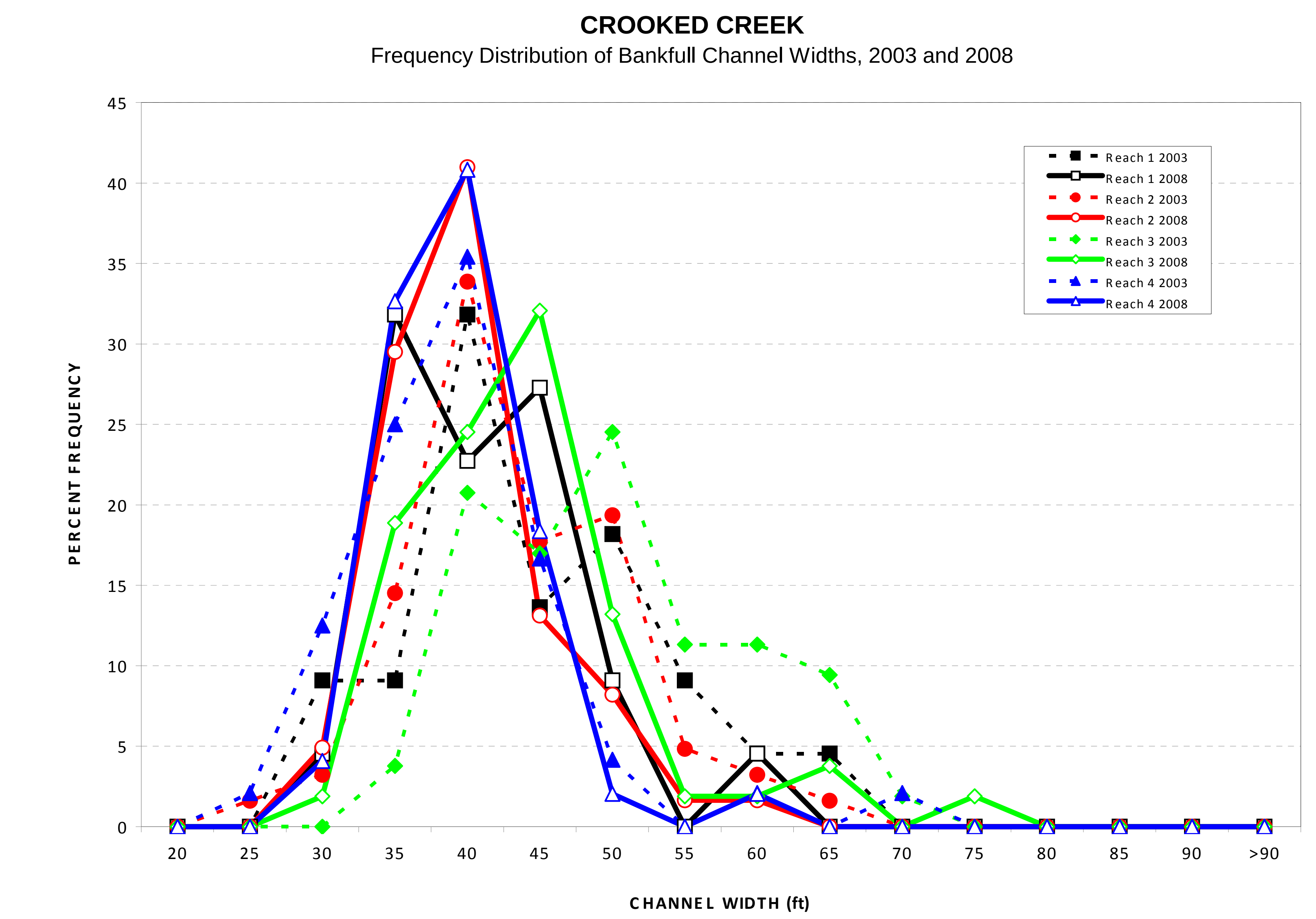
FIGURE

26



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CROOKED CREEK

Comparison of Thalweg Depths by Reach, 2003 and 2008

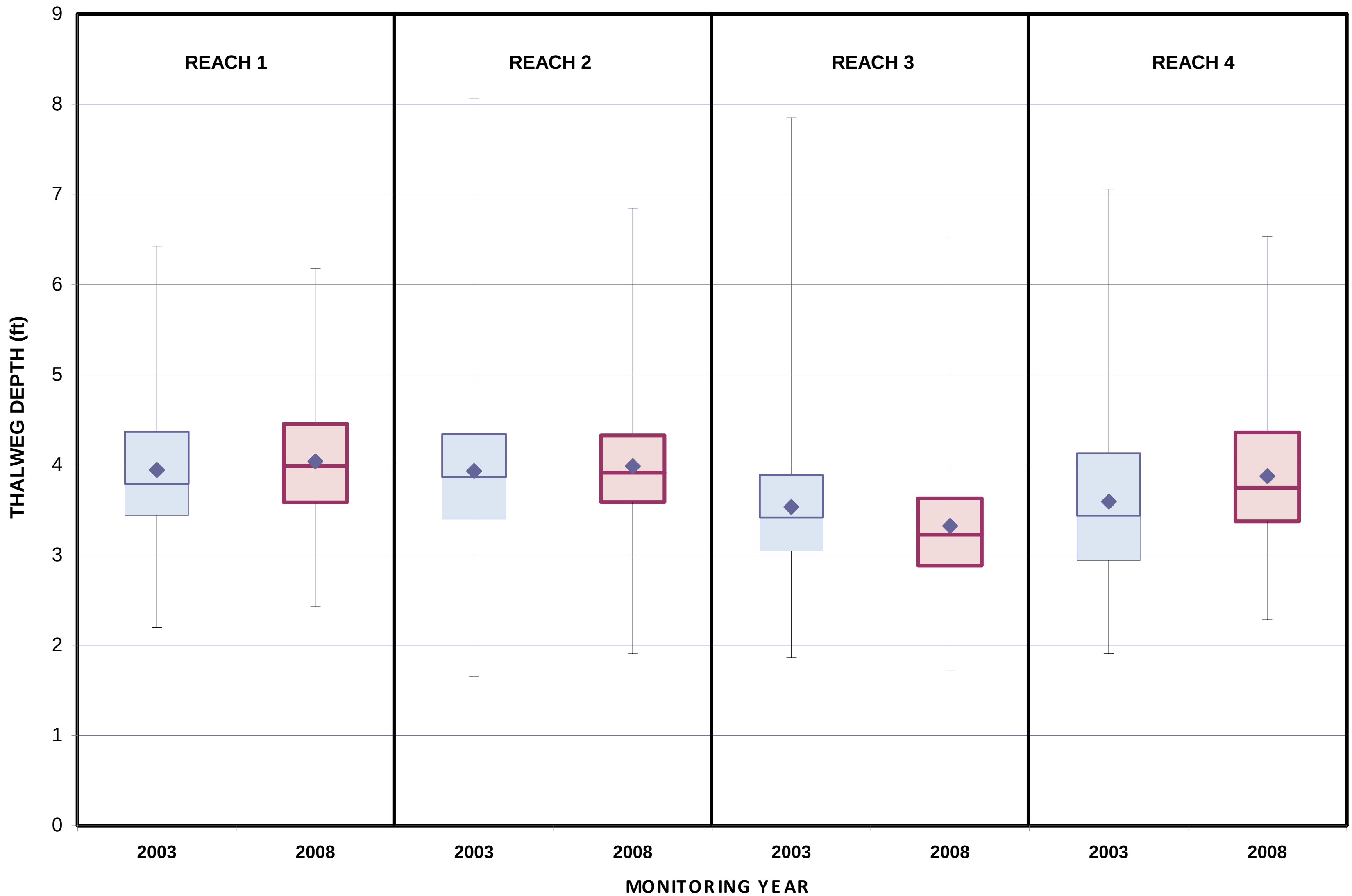

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FIGURE

28

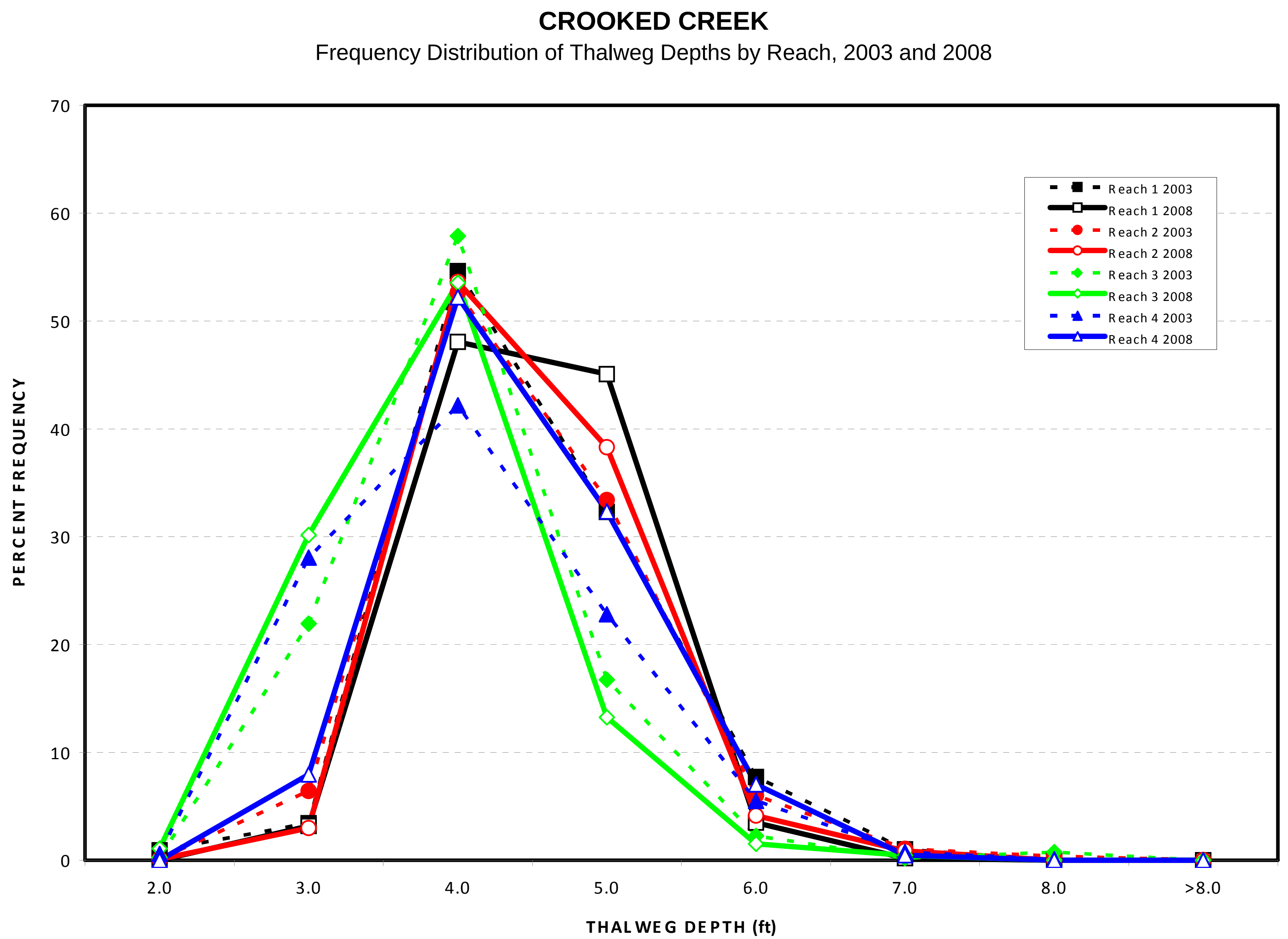

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FIGURE

29

CROOKED CREEK

Comparison of Width/Depth Ratio by Reach, 2003 and 2008

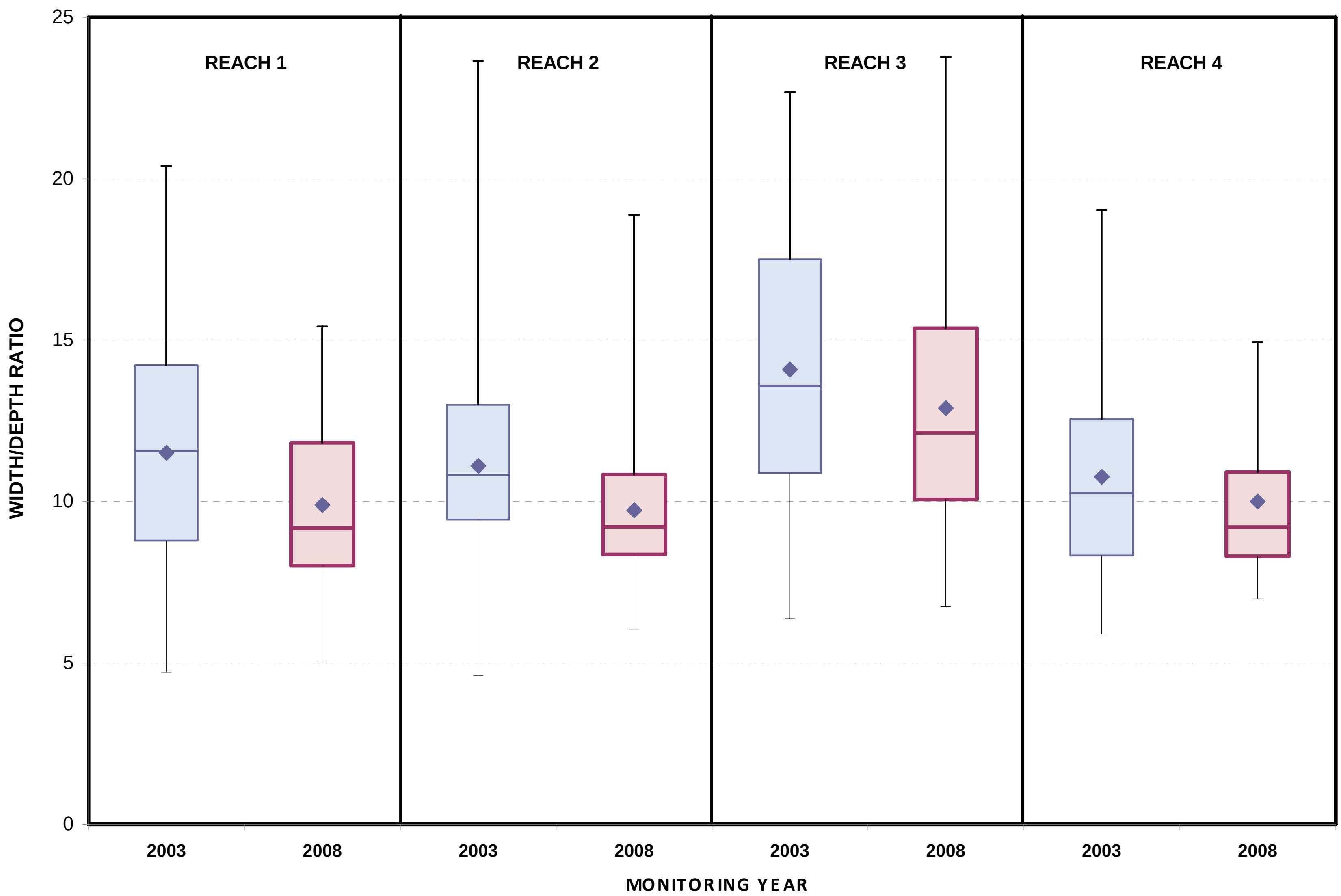

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FIGURE

30

CROOKED CREEK

Comparison of Width/Depth Ratio outside of (4A) and within (4B) Channel Restoration Area in Reach 4, 2003 and 2008

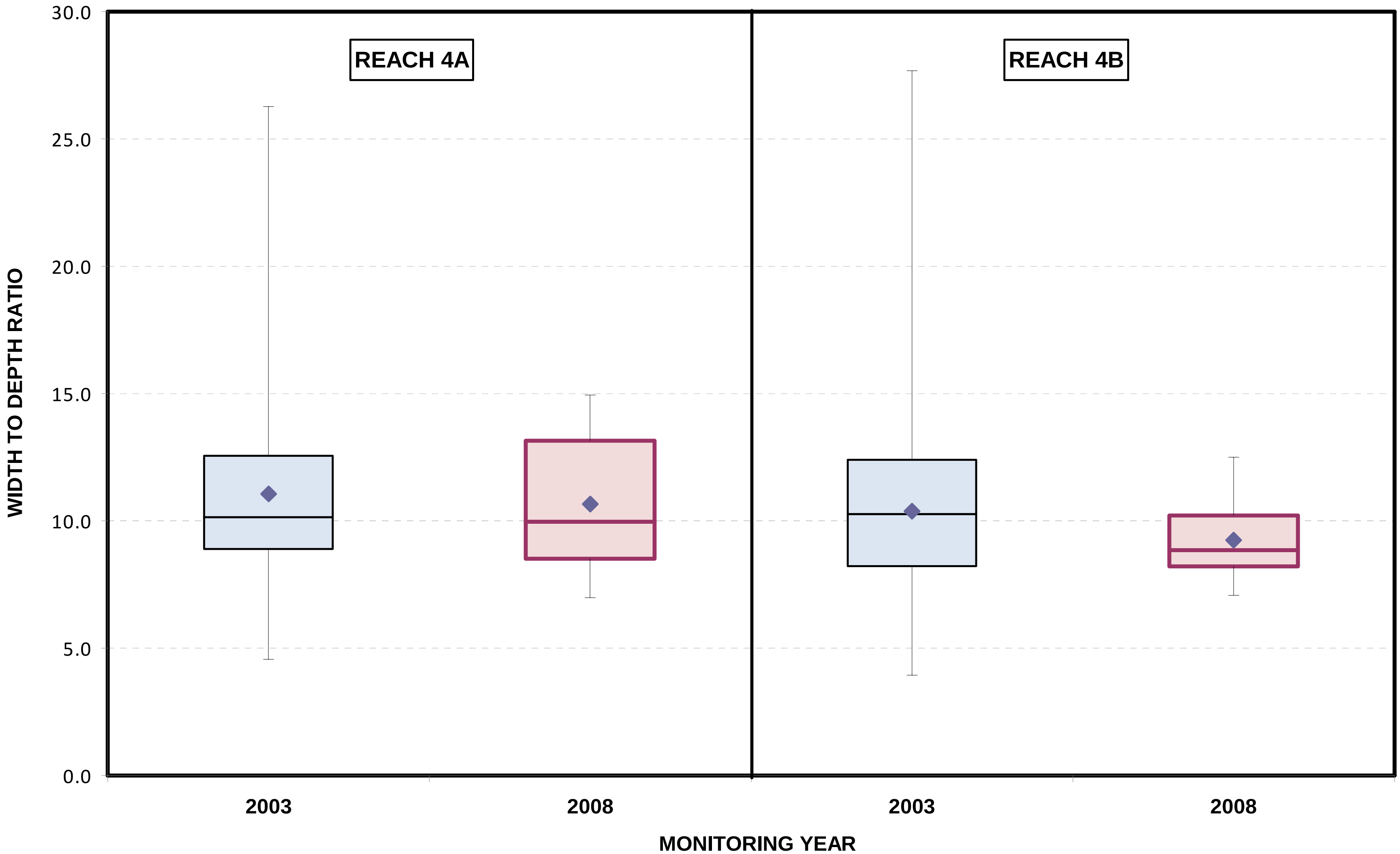

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FIGURE

31

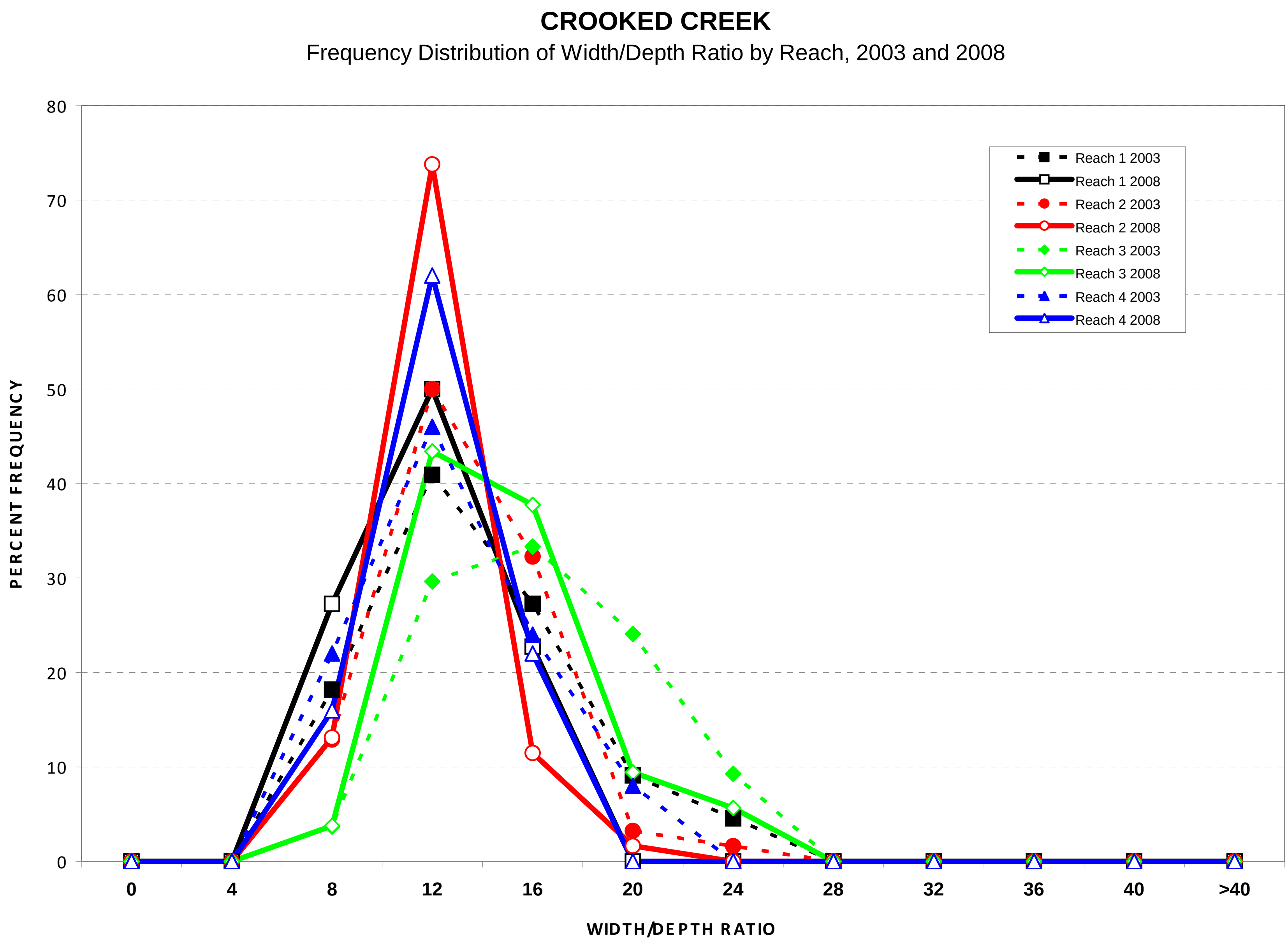

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FIGURE

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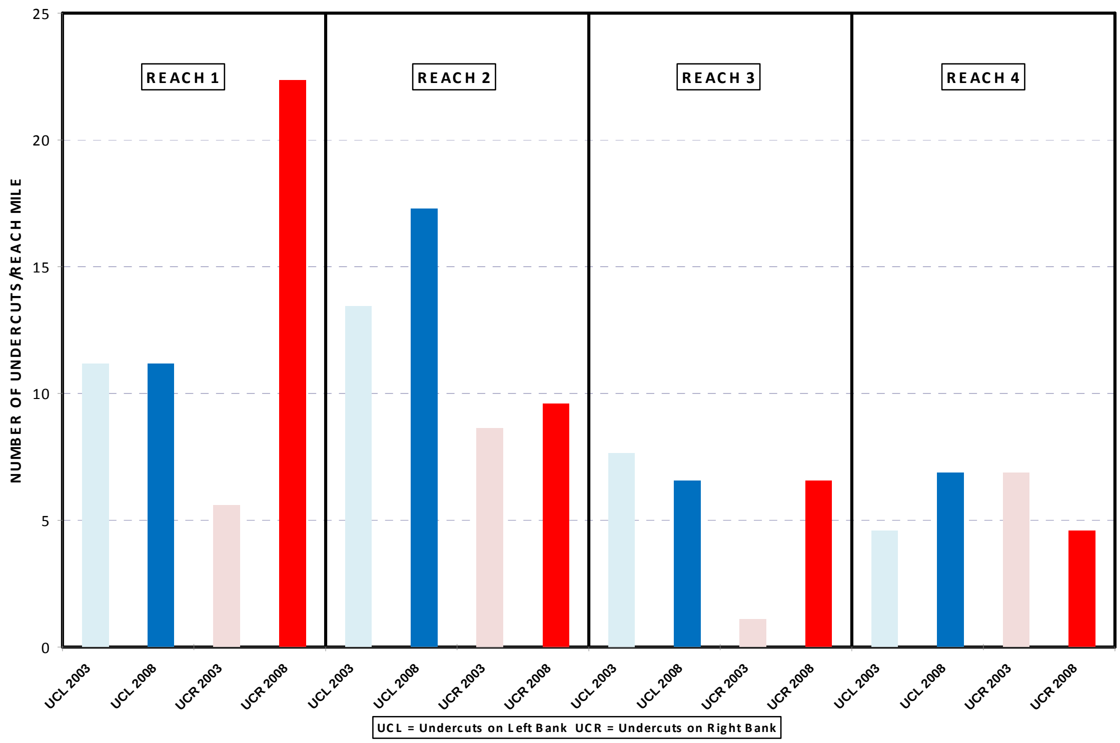
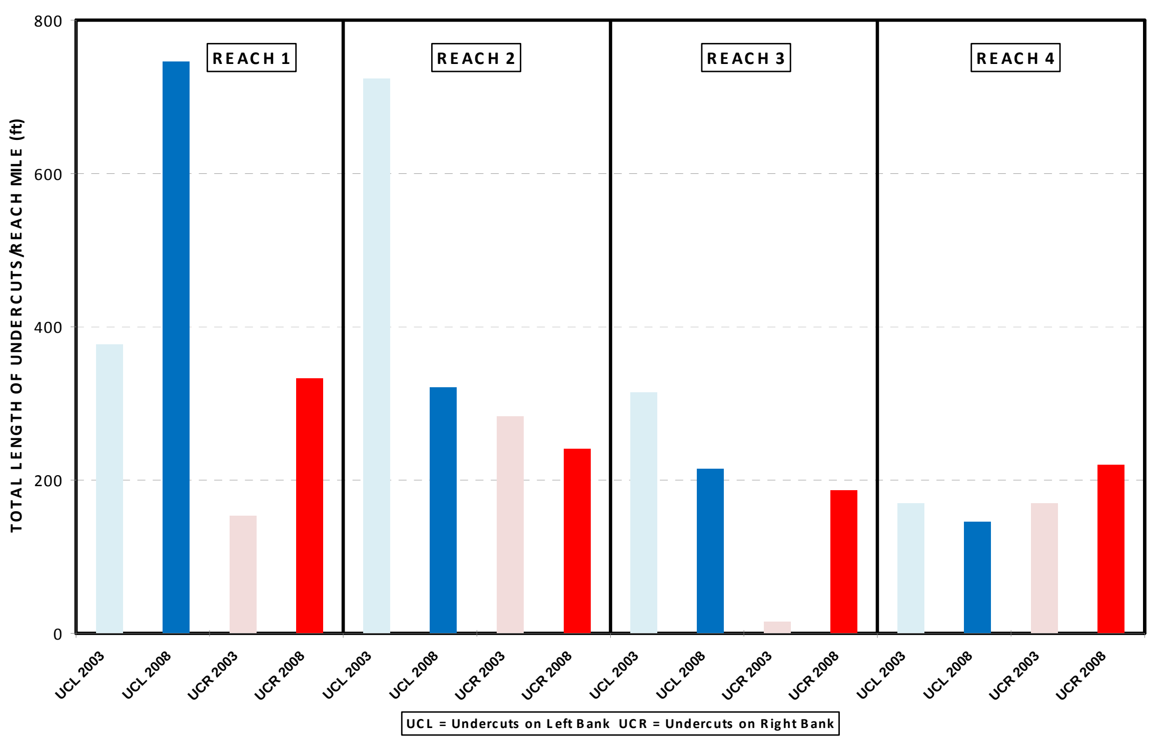
CROOKED CREEK HABITAT SURVEYS

Number of Undercuts per Reach Mile by Left/Right Bank, 2003 and 2008

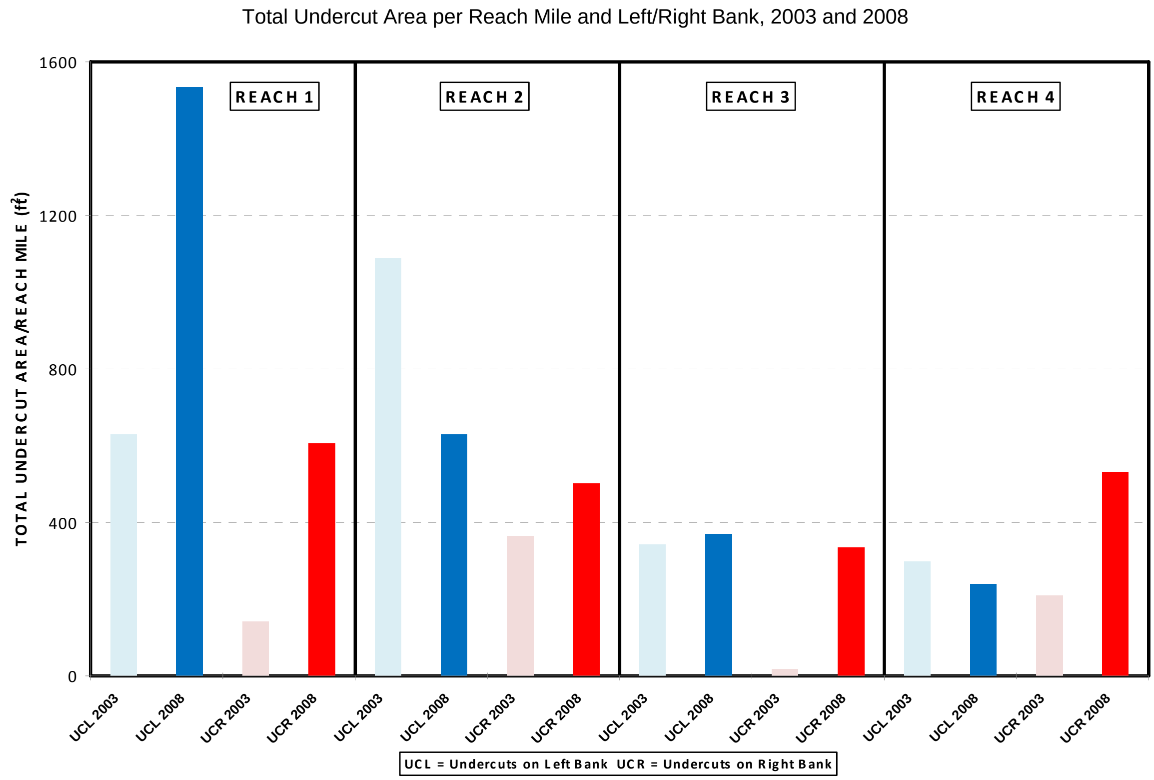


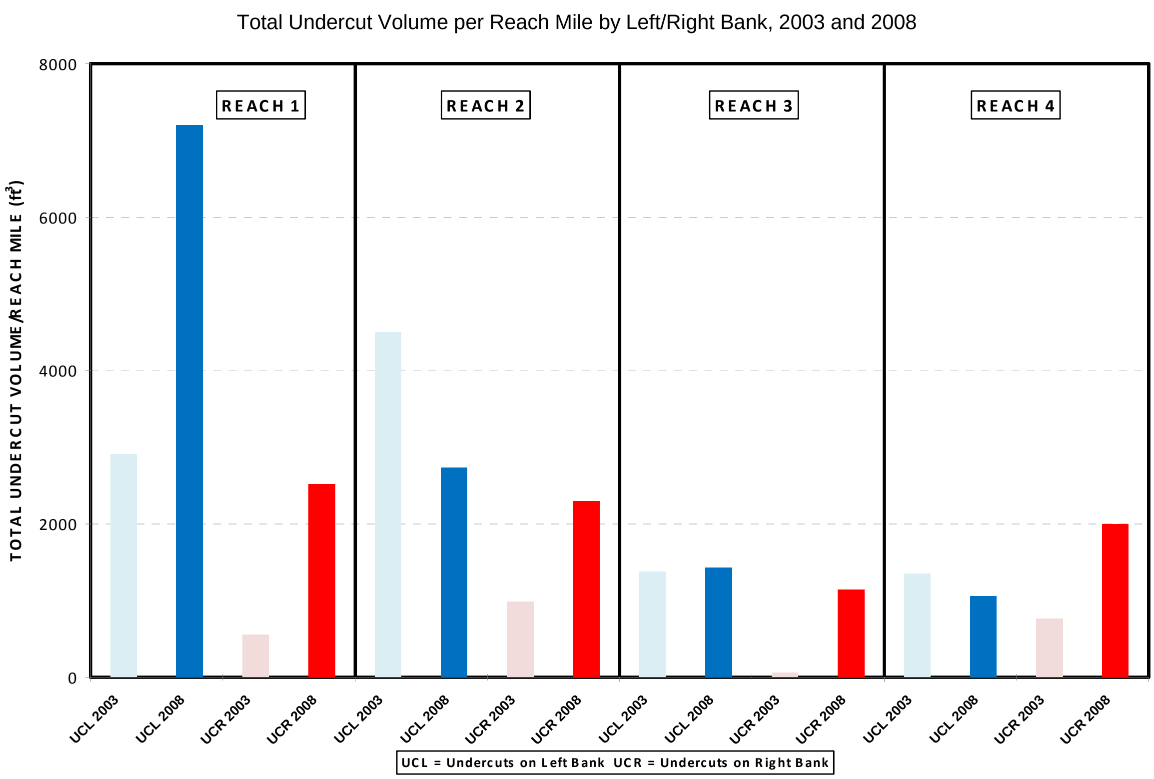
Total Length of Undercuts per Reach Mile by Left/Right Bank, 2003 and 2008



WOOD RIVER VALLEY AQUATIC HABITAT STUDY 2008 MONITORING REPORT	GMA GRAHAM MATTHEWS & ASSOCIATES Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-0520	FIGURE 33

CROOKED CREEK HABITAT SURVEYS





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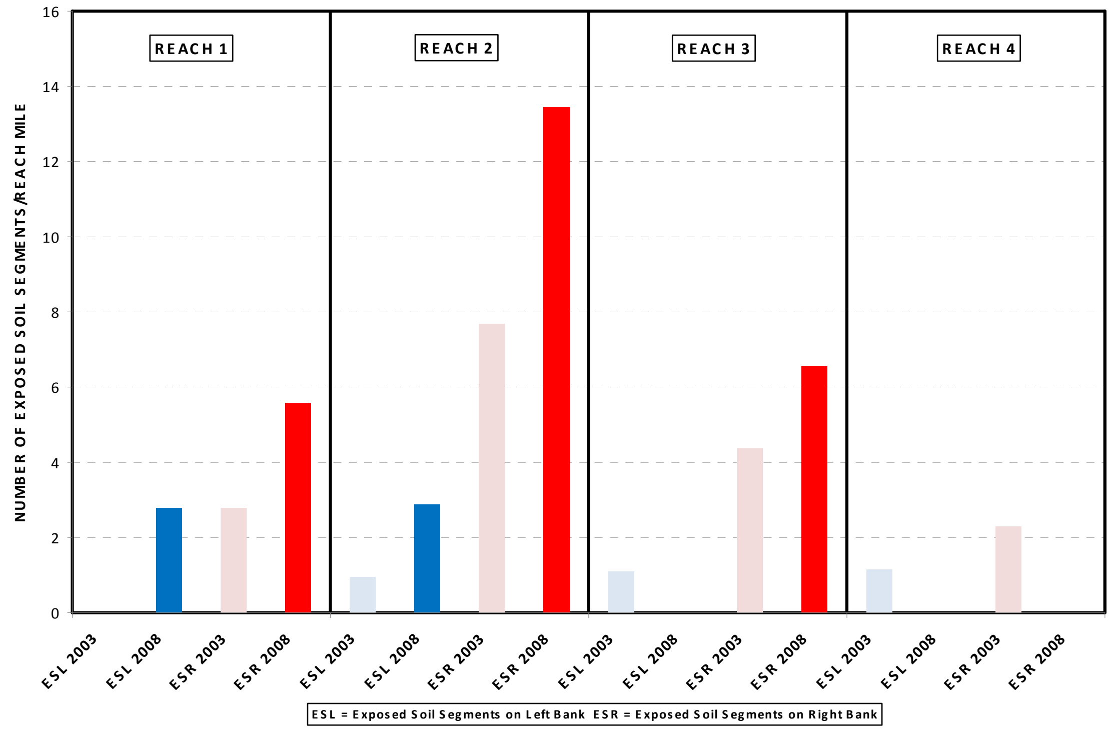
GRAHAM MATTHEWS & ASSOCIATES
Hydrology • Geomorphology • Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-0520

FIGURE

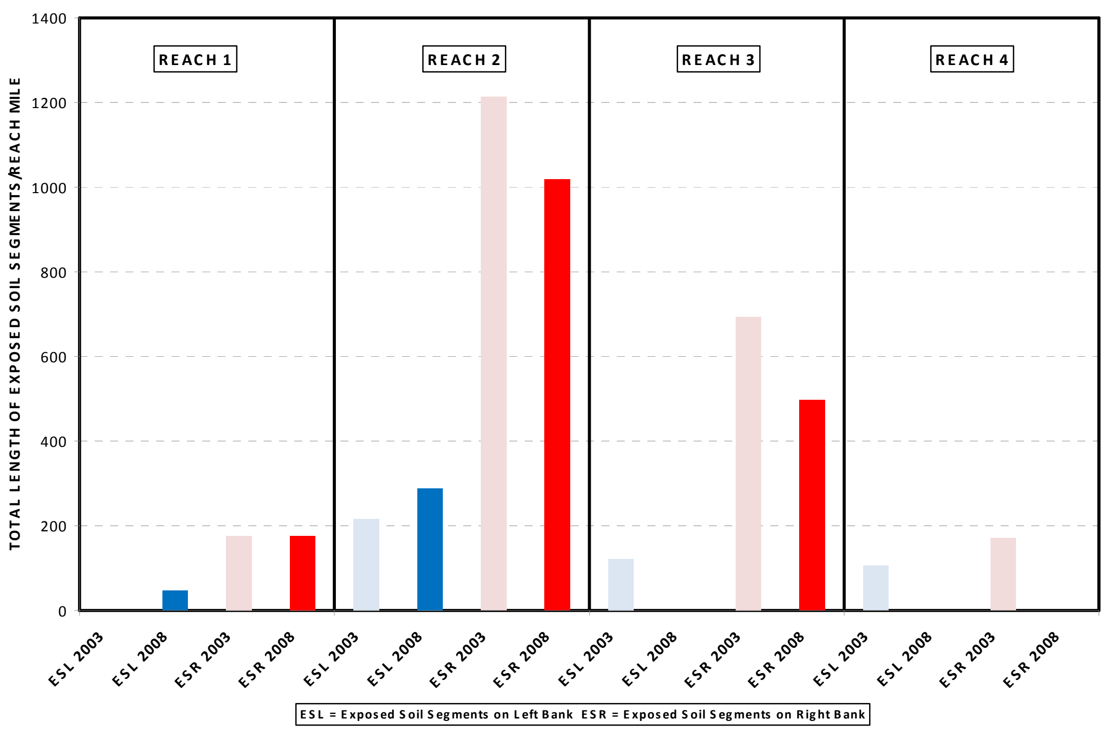
34

CROOKED CREEK HABITAT SURVEYS

Total Number of Exposed Soil Segments per Reach Mile by Left/Right Bank, 2003 and 2008

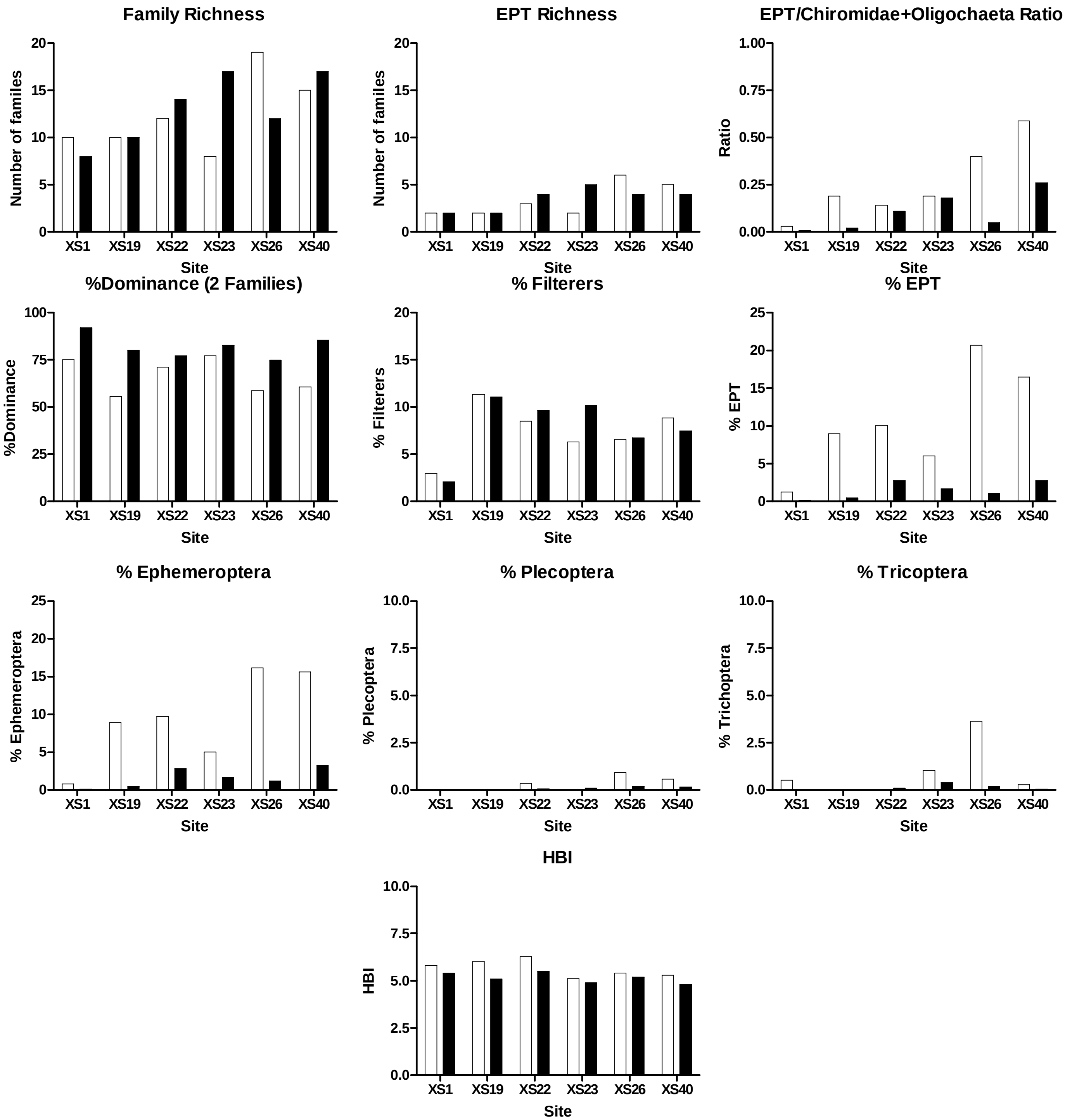


Total Length of Exposed Soil Segments per Reach Mile by Left/Right Bank, 2003 and 2008



WOOD RIVER VALLEY AQUATIC HABITAT STUDY 2008 MONITORING REPORT	GMA GRAHAM MATTHEWS & ASSOCIATES Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-0520	FIGURE 35

CROOKED CREEK
Macroinvertebrate Community Metrics



Metrics calculated from samples collected from six Crooked Creek sites in August 2002 (white bars) and August 2008 (black bars).

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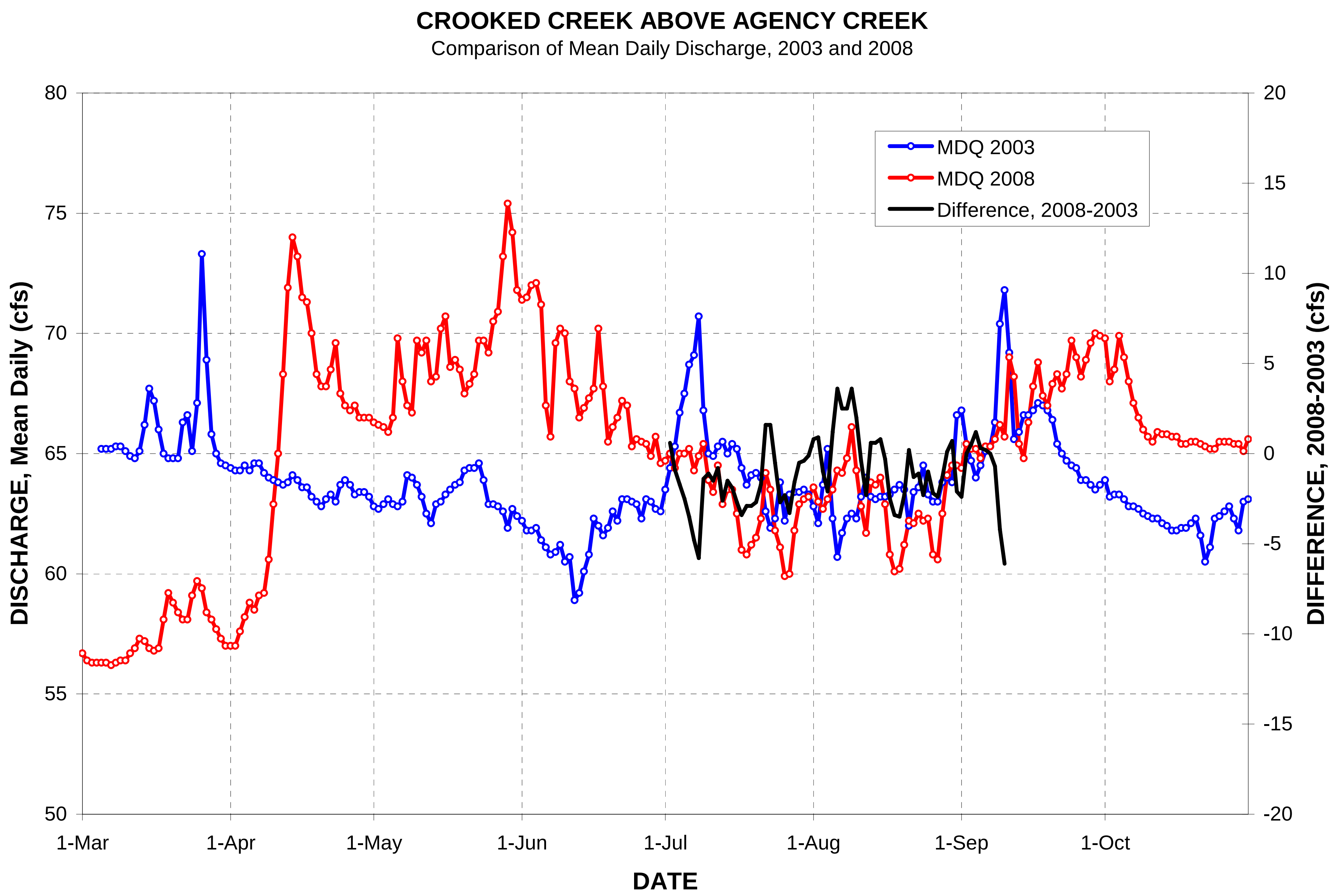
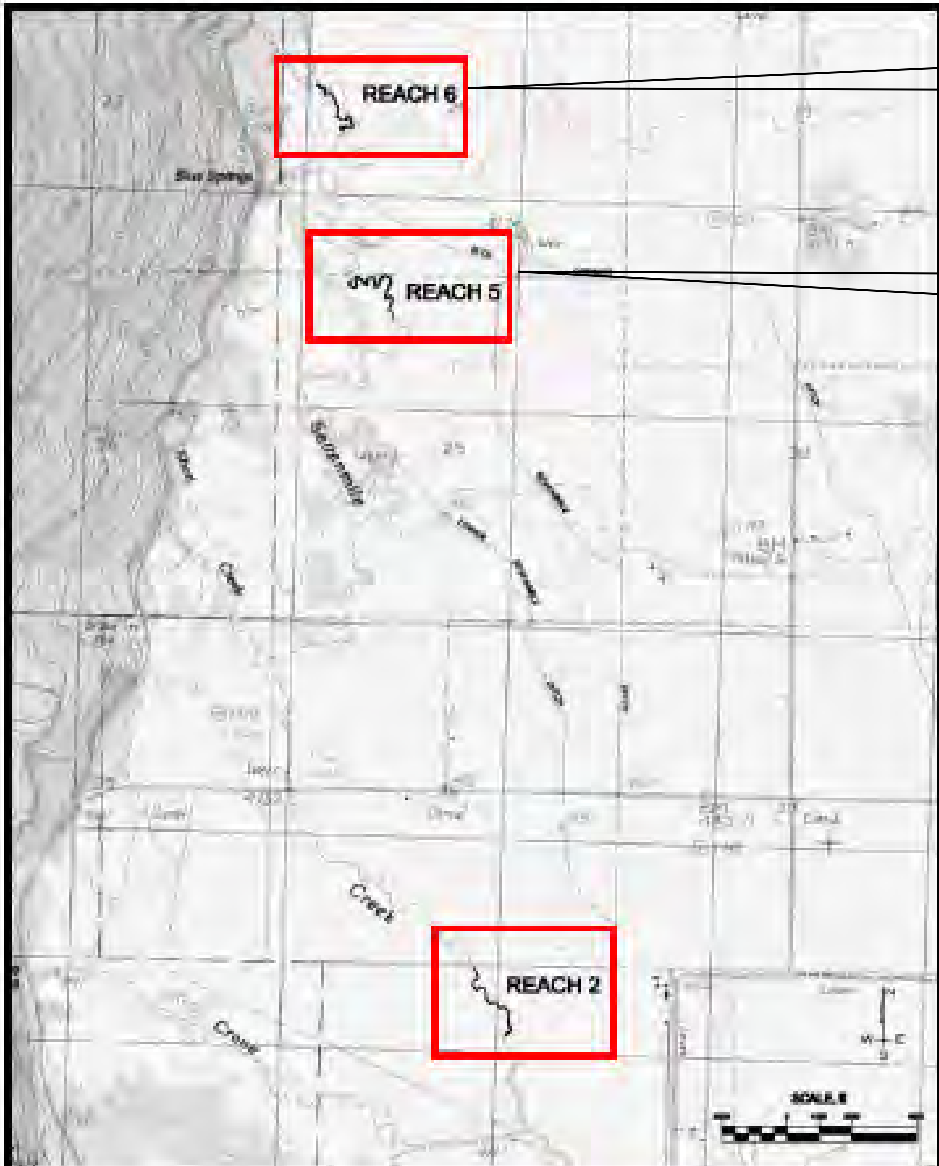


WOOD RIVER VALLEY AQUATIC HABITAT STUDY **2008 MONITORING REPORT**	GMA **GRAHAM MATTHEWS & ASSOCIATES** Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-0520	**FIGURE** **37**

Appendix A

SEVENMILE CREEK STUDY SITES LOCATION MAP

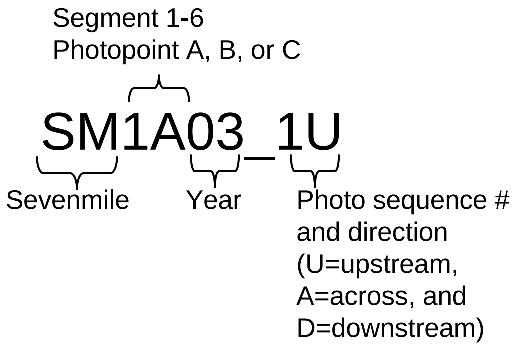


Same as T.Strigham Reach 3

Same as T.Strigham Reach 6

WOOD RIVER VALLEY AQUATIC HABITAT STUDY 2008 MONITORING REPORT	GMA GRAHAM MATTHEWS & ASSOCIATES Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-0520	FIGURE 2

Key to Photo Point Labels



GMA Reach 5 (TS Reach 6)

2003 Photos

SM5A03_1D

SM5A03_2A

SM5A03_3U

SM5B03_1D

SM5B03_2A

SM5B03_3U

SM5B03_3A

SM5B03_4A

SM5B03_5D

SM5B03_6D

SM5C03_1D

SM5C03_2A

SM5C03_3U

GMA Reach 5 (TS Reach 6)

2008 Photos

SM5A08_1D

SM5A08_2D

SM5A08_3A

SM5A08_4U

SM5B08_1D

SM5B08_2A

SM5B08_3A

SM5B08_4U

SM5C08_1D

SM5C08_2A

SM5C08_3U

GMA Reach 6 (TS Reach 3)

2003 Photos

SM6A03_1D

SM6A03_2A

SM6A03_3U

SM6B03_1D

SM6B03_2A

SM6B03_3U

SM6C03_1D

SM6C03_2A

SM6C03_3U

SM6C03_4U

GMA Reach 6 (TS Reach 3)

2008 Photos

SM6A08_1D

SM6A08_2A

SM6A08_3U

SM6B08_1D

SM6B08_2A

SM6B08_3U

SM6C08_1D

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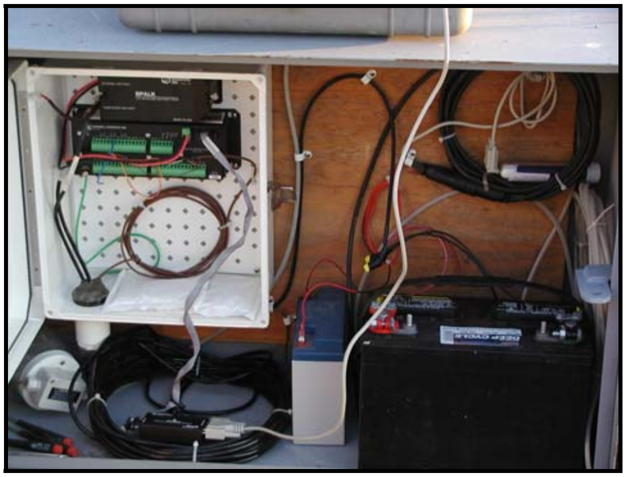
SM6C08_3U

2007-2010 PROJECT MONITORING REPORT

VOLUME 1: SURFACE WATER

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April 2011

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WY2007-2010 MONITORING PROGRAM
Volume 1: Surface Water

1.0 INTRODUCTION

1.1 Project Setting and Overview
Implementation of a comprehensive surface water monitoring program by the Klamath Basin Rangeland Trust (KBRT) has had several purposes: (1) to collect baseline streamflow data on all major streams in the overall project area (both inflow to the valley and outflow into Agency Lake), (2) to provide continuous (or instantaneous) streamflow data as the basis for load computations for water quality parameters, (3) to assess if reduced irrigation demand through forbearance results in higher instream flows, and (4) to quantify the amount of return (tailwater) flows reaching the main channel network.

Water years 2007 through 2010 are the sixth through ninth years of monitoring by KBRT. Continued reductions in scope have occurred in the period as funding constraints developed. For most of this period only key system gages, those with the longest term records, were able to be maintained. A new restoration project (Agency Ranch WRP) came on line in 2008 which allowed one additional surface water station to be added. Still, most of the effort was focused in the Sevenmile System. Four or five continuous streamflow stations were operated in the period. Beginning in WY2008, however, the continuous gages were operated only during the irrigation season of May 1 through October 31.

In WY2007-2010, continued gaging in the Sevenmile Creek system allowed evaluation of the increase in channel flows due to the reductions in diversions for flood irrigation, as well as continuing the quantification of tailwater delivered from West Canal.

Streamflow within the Wood River Valley has been greatly modified over the past 100 years. Irrigation began in the Wood River Valley in 1883. The existing system of diversions, returns, and ditches is very complex, providing irrigation water through an area of over 60,000 acres. Currently, the three stream systems are interconnected in various ways, either by irrigation canals, or by tailwater. For example, substantial diversions occur from Annie Creek and the Wood River, and virtually all of the tailwater from these diversions ends up in the Sevenmile system. The current Sevenmile/Fourmile system is even more complex. The network of streamflow monitoring sites operated in 2007-2010 is shown for the Wood River system and the Sevenmile Creek system (Figure 1).

1.2 Scope and Objectives
The scope of this project in WY2007-2010 was to continue to provide relatively detailed streamflow data for the major streams and tributaries in the Sevenmile Creek watershed, while only operating two sites in the Wood River watershed. The geographical extent of the monitoring was reduced from 2006 due to funding limitations. The work consisted of collecting field data and completing the following tasks for each sampling site:

1. Operate 4 continuous streamflow monitoring stations,

2. Maintain the stage/discharge relationship or index velocity relationship,
3. Compute streamflow records at each site,
4. Compare continuous records or synoptic streamflow measurements in accounting units, when possible, to verify accuracy of the flow measurement data, and
5. Comparing WY2007-10 data to data from previous years to identify trends.

1.3 Previous Studies and Other Data Collection Programs

Several previous studies have collected substantial streamflow data in the Wood River Valley, and a number of gages in the Wood River Valley are currently operated by various agencies and organizations for different programs and purposes.

From April 1991 until January 1994, the U.S. Bureau of Reclamation (USBR) maintained a set of 4 streamflow gages on the mainstem Wood River. Much of these data has not been published, or has only been published as stage readings (Campbell, et al. 1992). Two of the gages (Wood River at Weed Road and Wood River at Dixon Road were continued until 1997 and 1996, respectively, although missing periods of record exist.

Beginning in 1992, the US Forest Service operated 3 gages at locations of important inflow to the valley: Annie Creek at the National Park Boundary, Sevenmile Creek above Guard Station, and Cherry Creek above Diversions. These gages all reflect unimpaired tributary inflows to the system. In Water Year 2005 the US Forest Service ceased operation of these gages. The US Forest Service agreed to leave the equipment in place and KBRT assumed operation of the gages in the spring on Water Year 2005. Unfortunately, the funding for these gages only ran through WY2006.

Since 1995, the Klamath Tribes have been collecting periodic instantaneous streamflow measurements and water quality measurements at a number of sites including Wood River at Weed Road, Wood River at Dike Road, Sevenmile Canal at Dike Road, and more recently, Annie Creek near the Park Boundary.

In 1998, Graham Matthews & Associates (GMA) reoccupied the same sites as the USBR, and additionally collected data on the three major tributaries (Annie Creek, Fort Creek, and Crooked Creek) to evaluate the effects of diversions on streamflow in the Wood River. Several of the gages established in that study were kept in operation (Wood River at Dixon Road, Wood River at Weed Road, Fort Creek at Hwy 62, Crooked Creek at Root Ranch), while others were discontinued. No discharges were able to be computed at Crooked Creek at Root Ranch during this period due to variable backwater conditions from Agency Lake and the Wood River.

The Bureau of Indian Affairs (BIA) has operated four gages in the Wood River Valley (Wood River at Dixon Road, Wood River at Highway 62, Fort Creek on Rivers of Light Ranch, and Crooked Creek at Hwy 62) since 1999, although the Crooked Creek gage was discontinued during the ODOT bridge reconstruction project in the summer of 2003.

In 2002, ODWR installed a streamflow gage on the Wood River at Dixon Road. It is not known if this gage is still in operation.

2.0 OVERVIEW OF 2007-2010 SURFACE WATER MONITORING SITES

2.1 2007-2010 Program

The KBRT surface water monitoring program was further scaled back after Water Year 2006, including the elimination of most continuous and periodic recording gages in the Wood River system and many of the continuous gages were increased in the upper Sevenmile Creek system. Four or five continuous stations were operated in WY2007-2010 depending on year, compared to seven in WY2006, 8 in WY2005, and 14 continuous stations in WY2004. No periodic sites (typically monthly or quarterly discharge measurements) were maintained in WY2007-2010, compared to 3 in WY2006, 10 in WY2005, and 8 in WY2004.

2.2 Wood River System

The Wood River originates from a series of springs in the Jackson F. Kimball State Park north of Fort Klamath. Three major tributaries contribute to the Wood River: Annie Creek, which originates in Crater Lake National Park, Fort Creek, and Crooked Creek. Most of the streamflow of these creeks is derived from springs, although a significant portion of the flow of Annie Creek is seasonally derived from precipitation and snowmelt.

WY2007-2010 continued the significant changes to the scope of the gaging program originally made in WY2006 to the formerly extensive gaging network in the Wood River System. One continuous gage (Wood River at Weed Road, GMA0591100) was operated on the Wood River mainstem. This gage has a nearly continuous record from 1991 and is the longest running gage in the Wood River Valley. In addition, one continuous gage (Crooked Creek above Agency) was operated in the Crooked Creek system in WY2007-2010. One tributary (Agency Creek) and one diversion ditch (Agency Ditch) were monitored as periodic gages but were done so outside of the KBRT program.

2.3 Sevenmile Creek System

In Water Year 2007-2010, the gaging network in the Sevenmile Creek system was scaled back. Only Sevenmile Creek at Sevenmile Road (GMA0592100) and West Canal above Sevenmile (GMA0592050) were operated in WY2007-2009. Sevenmile Creek at the USFS Guard Station (last operated in 2003) was added in WY2010. No periodic measurement sites were operated in 2007-2010.

3.0 METHODS

This section provides a brief overview of methods used in the surface water monitoring program. For a complete review, refer to the GMA Surface Water Quality Assurance Plan and its references contained in an appendix to the 2003 KBRT Monitoring Plan.

3.1 Stage Measurement

3.1.1 Manual Sites

Two types of stage measurement may occur at manual sites. At key sites, staff plates were attached to either fence posts or channel iron that was driven into the streambed as stage measuring devices. In some locations, staff plates were attached directly to bridge abutments or bridge piers. River stage was measured directly off the staff plate at each of these locations. At other locations, river stage was measured from the water surface to the top of a fence post using a pocket surveyor's tape. Most stage locations were surveyed to a locally established benchmark using an auto level in the event that the sites were disturbed (by vandalism or high flows) and the original gage datum needed to be re-established.

3.1.2 Continuous Sites

Stage at continuous gaging sites is measured by one of several types of dataloggers (Campbell or Nortek) combined with either pressure transducers (Design Analysis H-310) or Doppler velocity meters (Nortek EasyQ). Stage is recorded at 30-minute intervals. Most gaging stations are operated to produce records with a stage accuracy of 0.03 feet, although several sites (Wood River at Weed Road and Sevenmile Creek at Sevenmile Road) should produce records with a stage accuracy of 0.01 feet and thus meet USGS primary station accuracy standards. Gaging stations are typically visited and downloaded monthly, however, beginning in WY2008 continuous gages were only officially operated during the irrigation season May 1 through October 31. No winter gaging occurred during this period.

3.2 Discharge Measurements

Discharge measurements were made periodically during the season, with the number depending on the variation in stage and stability of the discharge rating at the site. The measurements were made following standard hydrologic practice using standard stream gaging equipment. Conventional discharge measurements were taken at all sites using standard hydrologic practice. Most measurements were performed by wading at the gage location, however at several sites measurements were taken from bridges. Streamflow equipment for wading measurements included a 4ft top-set wading rod, JBS Instruments AquaCalc 5000 - Advanced Stream Flow Computer, and either a Price AA or Pygmy current meter. All measurements were made with the magnetic head version of the Price AA or Pygmy meter. High flow or bridge measurements were made using an A-55 reel, bridgeboard or bridge crane, and either a 30# or 50# sounding weight. Typically 25-30 verticals at a given streamflow section were used, and the 5% rule was met in virtually all feasible scenarios.

3.3 Doppler Velocity Measurements

At only one site (West Canal above Sevenmile Creek) with backwater effects were index-velocity methods (USGS 2002) used to compute streamflow from Doppler datalogger stage/velocity datasets. Velocity data were collected with a Nortek EasyQ Acoustic Doppler Profiler. The index-velocity method is a complicated procedure requiring considerable datasets relating observed discharges to measured velocities. Considerable challenges were encountered applying this technology to this site, as described later on in this report; however, records were able to be developed.

3.4 Rating Curves and Streamflow Computations

All discharge measurements were entered and cataloged using a form similar to the standard USGS 9-207 discharge measurement summary form. Forms summarizing all discharge measurements made over the course of WY2007-2010 for each site are contained in the Appendices to this report. After collection of the discharge measurements, a discharge-rating curve is developed for each station by plotting the stage/discharge pairs and electronically hand fitting a curve. Stage/discharge pairs were evaluated and ratings developed within the WISKI Suite of software. The WISKI Suite is a comprehensive hydrologic time series database management system developed by Kisters AG. The suite is broken down into three parts, WISKI, BIBER, and SKED. WISKI manages all time series data, BIBER is used to evaluate discharge measurements, and SKED is used to develop rating curves. The WISKI Suite includes complete USGS standards for surface water programs. These standards include USGS computational methods according to WSP 2175, Measurement and Computation of Streamflow vols.1 and 2 (Rantz 1982), multiple ratings with log offsets, shifts and stage adjustments, gage height and datum correction, and standard printouts such as primary computation sheets, mean daily value summaries, rating tables, and shift tables. In Water Year 2007-2010, as in WY2004-2006, the WISKI suite was used to develop all rating tables and performed all computations for continuous surface water gaging stations. Index velocity relationships were developed using the regression tools in Excel. Once the relationships were developed in Excel, the equation was entered into WISKI where the records were computed

4.0 2007-2010 RESULTS: WOOD RIVER SYSTEM

A simplified flow chart of the Wood River streamflow and diversion network is shown in Figure 2. The flow chart provides the schematic location of tributaries and diversions (red), as well as 2007-2010 streamflow gaging sites (blue), and discontinued (black) surface water monitoring sites. The actual gage locations are plotted on the project base map in Figure 1. In WY2007-2010, continuous streamflow records were only computed for Wood River at Weed Road and Crooked Creek above Agency. Crooked Creek above Thomas Pumps was operated as a periodic station from 2008 to 2010. A summary of the sites, the operational condition, whether there is continuous or periodic data available, and the number of discharge measurements made in 2007-2010 can be found in Table .

Table 1. Wood River System Gage and Data Collection Summary, WY2007-2010

Mainstem Site	Site	Stage	# GMA Discharge Measurements				
Tributary Site	Acronym	Continuous	2007	2008	2009	2010	Total
Wood River at Weed Road	WRWR	Y	8	5	4	3	20
Crooked Creek abv Agency	CCAA	Y	--	4	4	3	11
Crooked Creek abv Pump Ditch	CCATP	N	--	3	1	2	6
		Total by Year:	8	12	9	8	37

All hydrologic data developed for the Wood River system sites are contained in Appendices 1 through 4. Each appendix contains a station description, rating curve, rating table, stage hydrograph, mean daily discharge hydrograph, and summary table of mean daily discharges, as appropriate.

4.1 Mean Daily Discharge, 2007-2010

Wood River at Weed Road

Mean daily discharge at Weed Road reflects (1) additional inflow from tributaries during the non-irrigation season coupled with additional storm response from a much larger drainage area and the tributary influence, and (2) the effects of significant diversions between April and September. Figure 3 compares the mean daily discharge from the Wood River at Weed Road from WY2007 through WY2010.

Winter base flow, mid-October through March, was consistently between 375 cfs and 400 cfs, reflecting roughly a combined tributary accretion of 200 cfs (based on typical Wood River Springs discharge of 175 to 200 cfs), except during storm or snowmelt runoff periods when discharge spikes occurred. The maximum mean daily discharge in the four year period was 718 cfs on 12/14/2006, and the minimum was 140 cfs, which occurred on 5/25/2010. Other annual maximum and minimum MDQ and their respective dates are listed in Table 2.

Table 2. Wood River at Weed Road, Annual Max/Min MDQ, WY2007-2010

WOOD RIVER AT WEED ROAD				
WATER YEAR	Annual Maximum MDQ		Annual Minimum MDQ	
	Discharge (cfs)	Date	Discharge (cfs)	Date
2007	718	12/14/2006	154	6/15/2007
2008	603	10/20/2007	181	7/19/2008
2009	495	1/8/2009	153	9/4/2009
2010	575	1/13/2010	140	5/25/2010

In most years, winter storms produce the highest flows, although snowmelt in certain years, such as 2008 and 2010, can also produce significant peaks. Fall rain events, such as occurred in late October 2007, can also produce the annual peak.

Figure 4 compares the mean daily discharge from the Wood River at Weed Road gage from WY2007 through WY2010 for the May through September portion of each Water Year. Mean monthly flow from mid-June through mid-September (the irrigation season) was between 170 and 210 cfs. The annual minimum MDQ can occur anywhere in the May to September period, depending on irrigation diversions. All 4 years were fairly similar between mid-July and mid-September, although 2008 was clearly the wettest, almost always over 200 cfs in that period.

Crooked Creek above Agency Creek

Crooked Creek is predominately spring fed and therefore has greatly subdued hydrographs compared to streams with a substantial winter storm or snowmelt regime. Figure 5 compares the mean daily discharge from the Crooked Creek above Agency gage from WY2008 through WY2010, with the first few months of WY2011 included. Streamflow records for WY2007 were not computed.

The maximum mean daily discharge in the three year period was 86 cfs on 9/18/2010, and the minimum was 55.5 cfs, which occurred on 2/01/2008. Other annual maximum and minimum MDQ and their respective dates are listed in Table 3.

Table 3. Crooked Creek above Agency, Annual Max/Min MDQ, WY2008-2010

CROOKED CREEK ABOVE AGENCY				
WATER YEAR	Annual Maximum MDQ		Annual Minimum MDQ	
	Discharge (cfs)	Date	Discharge (cfs)	Date
2008	75.4	5/29/2008	55.5	2/1/2008
2009	78.2	1/2/2009	61.9	6/25/2009
2010	86.0	9/18/2010	59.9	4/19/2010

Of particular interest is the variability in both winter and fall between the 3 water years. Flows dropped substantially in WY2008 during the Dec-Mar period, before rebounding in the spring. In contrast, flows were almost constant in WY2009 with the addition of small (10-15 cfs) storm peaks. From mid-summer through fall of each water year, flows begin to rise, often reaching their maximum in early October. The pattern in 2009 and 2010 is even more pronounced, with fall flows in WY2010 more than 20 cfs higher than spring and early summer flows. No explanation for this seasonal variability is currently known.

Figure 6 compares the mean daily discharge from the Crooked Creek above Agency gage from WY2008 through WY2010 for the May through September portion of each Water Year, which highlights the mid-summer to fall increases in flow.

4.2 Comparison to Previous Data, 2003-2010

Wood River at Weed Road

Figure 7 compares the WY2007-2010 streamflow records with streamflow records from WY2003-2006 period. In WY2003-2005 flows were all consistently lower than 2006-2010 flows. While 2006 was an extremely wet year, that was not the case for the other water years, yet both winter and summer flows have remained higher. Without flow records at the Wood River at Dixon Road site, it is not possible to determine if increased spring flows are responsible for this change, though it would appear that this is the only explanation. Reduced diversions, for example, would not increase the winter baseflow. The 2006 flows are the highest observed flows in the period during the entire irrigation season, but were similar to the 2004 and 2005 flows in the winter.

Crooked Creek above Agency Creek

Figure 8 compares the WY2008-2010 streamflow records with streamflow records from WY2003-2005 period. The seasonal and yearly patterns observed in the Wood River at Weed Road streamflow records are not seen in the Crooked Creek above Agency Creek data. Summer flows in 2003-2005 and 2008 are all lower than 2009 and 2010, but 2008 and 2009 had lower flows than most of the other years during portions of the winter and early spring periods.

4.3 Comparison to Historic Data, 1991-2010

Wood River at Weed Road

Figure 9 presents streamflow records for Weed Road from WY1991 through 2010, allowing evaluation of the current water year within the larger context of about 20 years of records. Summer flows in WY2007-10 were similar but slightly lower than 2006, yet were higher than any other year since 1999. Winter base flows in 2007-2010 were the highest since 1996,1997, and 2000.

Figure 10 only looks at the discharge records from June 1998 to present and includes generalized trend lines. In contrast to the dry and wet periods previously observed (1999-2002, and 2003-2006), the 2007-2010 period had relatively consistent flows that are among the highest in the record. The winter baseflow of 375-400 cfs is higher than anything in the past decade, while the summer flows of around 200 cfs are the highest 1998 and 1999.

5.0 2007-2010 RESULTS: SEVENMILE CREEK SYSTEM

A simplified flow chart of the Sevenmile Creek streamflow and diversion network is shown in Figure 11. The flow chart provides the schematic location of tributaries (blue) and diversions (red), as well as 2010 streamflow gaging sites (cyan), and discontinued (black) surface water monitoring sites. The actual gage locations are plotted on the project base map in Figure 1. A summary of the sites, the operational condition, whether there is continuous or periodic data available, and the number of discharge measurements made in 2007-2010 can be found in Table 4.

Table 4. Sevenmile Creek System Gage and Data Collection Summary, WY2007-2010

Mainstem Site	Site	Stage	Doppler	# GMA Discharge Measurements				
Tributary Site	Acronym	Continuous	Flow	2007	2008	2009	2010	Total
Sevenmile Creek at Guard Station	**SMGS**	**Y**		**--**	**--**	**--**	**3**	**3**
Sevenmile Creek at Sevenmile Road	**SSMR**	**Y**		**6**	**5**	**4**	**4**	**19**
West Canal above Sevenmile	**WCAS**	**Y**	**Y**	**16**	**11**	**13**	**8**	**48**
			Total by Year	**22**	**16**	**17**	**15**	**70**

Notes: SMGS was operated in WY2010 only
Beginning in 2008, all gages operated only during the irrigtaion season, May 1-Oct 31

All hydrologic data developed for the Sevenmile Creek system sites are contained in Appendices 5 through 7. The appendices contain station descriptions, rating curves, rating tables, stage hydrographs, mean daily discharge hydrographs, and summary tables of mean daily discharges, when applicable for the continuous stations.

5.1 Mean Daily Discharge, 2007-2010

Figure 12 compares the mean daily discharge for the two mainstem gaging stations on Sevenmile Creek along with the gage on West Canal for their periods of record in WY2010.

<u>Sevenmile Creek at Guard Station</u>

Figure 13 shows the Sevenmile Creek at Guard Station (located just upstream of the Nicholson Road bridge) in the 2010 season (mid-April through October 31), the only year in the period that this gage was operated. An early snowmelt peak occurred in late April and then May was quite cool and wet. With a warm spell in late May and early June, a large and rapid increase in flow occurred, reaching the snowmelt peak of about 55 cfs on June 5. Streamflow decreased quickly thereafter, reaching 4-5 cfs by mid-July. A single drop for about a week to as low as 1.7 cfs occurred from July 9-15, otherwise flows were between 3.5 cfs and 6 cfs until the end of the irrigation season. Flows increased rapidly from 3.2 to 18 cfs when the Upper Sevenmile Ditch diversion was ended for the season on September 18. The October 24 storm reached 28 cfs.

Sevenmile Creek at Sevenmile Road
Mean daily discharge for Sevenmile Creek at Sevenmile Road is much higher than at the upstream gages, reflecting significant spring inflow during the non-irrigation season (Blue Springs and Short Creek contribute roughly 50 cfs). In addition, this site shows considerably more storm response during fall, winter, and early spring months.

The maximum mean daily discharge in the four year period was 165 cfs on 12/14/2006, and the minimum was 32 cfs, which occurred on 8/16/2010 (Figure 14). Other annual maximum and minimum MDQ and their respective dates are listed in Table 5. The next largest events occurred in October and November 2007, followed by January and March storms in 2009 and an early January storm in 2007. Snowmelt typically occurs between March and June depending on the extent of the snowpack. 2007 was a dry year and a modest snowmelt peak occurred in April with flows declining through May and June. 2008-2010 were average years and snowmelt peaked between early May and early June. Winter baseflows varied between 60 and 80 cfs in WY2007-2009. Winter data were not collected at this site in WY2010.

Table 5. Sevenmile Creek at Sevenmile Road, Annual Max/Min MDQ, WY2007-2010

SEVENMILE CREEK AT SEVENMILE ROAD				
WATER YEAR	Annual Maximum MDQ		Annual Minimum MDQ	
	Discharge (cfs)	Date	Discharge (cfs)	Date
2007	165	12/14/2006	47.7	6/16/2007
2008	147	11/18/2007	45.6	7/9/2008
2009	126	5/5/2009	35.5	8/28/2009
2010	115	6/5/2010	32.0	8/16/2010

Figure 15 compares the streamflow records at this site for the June-September period (most of the irrigation season) of WY2007 through 2010. The highest mid-summer flows were in 2007, when they exceeded 60 cfs from mid-July on. Both 2008 and 2010 had snowmelt peaks in early June, while 2008 and 2009 had much higher flows on the declining snowmelt hydrograph in June. For most of the summer, 2008 and 2009 were generally similar in the 50 cfs range. 2010 had by far the lowest summer flows in the period, which were consistently around 40 cfs.

West Canal above Sevenmile Creek
West Canal provides the primary conduit for return flows from various upstream diversions, including flows from the Wood River and Annie Creek. Substantial pasture runoff (tailwater) also occurs during the irrigation season and in response to precipitation events in fall and winter months.

The maximum mean daily discharge in the four year period was 443 cfs on 12/14/2006, and the minimum was 12.4 cfs, which occurred on 9/25/2010 (Figure 16). Other annual maximum and minimum MDQ and their respective dates are listed in Table 6. There were numerous runoff peaks during the winter-spring periods with mean daily discharge values exceeding 200 cfs between December and June numerous times. No winter data were collected in WY2010.

Summer flows at this site are typically between 30 and 50 cfs and flows can fluctuate rapidly and are dependent on irrigation configurations upstream. Figure 17 compares the streamflow records at this site for the June-September period (most of the irrigation season) of WY2007 through

2010. Flows in all 4 water years were generally similar although 2010 had lower flows in parts of July and again in late September.

Table 6. West Canal above Sevenmile, Annual Max/Min MDQ, WY2007-2010

WEST CANAL ABOVE SEVENMILE				
WATER YEAR	Annual Maximum MDQ		Annual Minimum MDQ	
	Discharge (cfs)	Date	Discharge (cfs)	Date
2007	443	12/14/2006	25.7	8/3/2007
2008	401	4/15/2008	19.5	12/15/2007
2009	400	3/16/2009	12.9	12/26/2008
2010	249	6/4/2010	12.4	9/25/2010

5.2 Comparison to Previous Data

Sevenmile Creek at Guard Station

Figure 18 compares WY2010 streamflow records with the same records from WY2003 at SMGS gage. WY2010 was clearly wetter than 2003, with a higher and later snowmelt hydrograph. Most importantly, summer base flows were substantially higher in 2010 than in 2003, as a result of the instream lease program between KBRT and Popson, which reduced the amount of diversion at the Upper Sevenmile Ditch and kept an additional 4-6 cfs instream. In 2003, ditch diversions essentially dewatered several miles of the creek until spring inflows primarily from Blue Springs and Short Creek restored instream flows.

Sevenmile Creek at Sevenmile Road

Figure 19 compares WY2007-2010 data with streamflow records for WY2003-2006. The largest storm in the period was in December 2004 (WY 2005), followed by December 2006 (WY2007) and two events in WY2003.

Figure 20 compares only the June-September period for WY2003-2010. The most apparent trend is that flows were quite low in 2003 and 2004, increased somewhat in 2005, increased a bit more in 2006, and then a lot more in 2007, which had the highest summer flows in the period. Flows in 2008 and 2009 were somewhat lower than 2007, but still higher than any other year. Flows in 2010 were the lowest since 2005. Also of interest is the change in flows at the end of the irrigation season, since diversions for irrigation typically end in the middle of September, although the date has varied by as much as two weeks from September 10 to as late as Sept 24. Only in 2003 and 2004 was there a rapid increase of more than 30 cfs when diversions ended. Since then, the increases when diversions are ceased have typically only been 10-15 cfs, reflecting the much higher instream flows and reduced diversions that have characterized the Sevenmile system since 2005.

Figure 21 compares streamflow in the summer months of July, August, and September for the 8 water years in the period of record. The average monthly discharge in July or August in 2003 and 2004 was 1653 acre-feet, while the average monthly discharge in July or August 2005 through 2010 was 2986 acre-feet, with a maximum of 3963 acre-feet in August 2007. Thus, the average since the KBRT instream leasing began in 2005 is almost double the pre-project amount at this site.

West Canal above Sevenmile Creek
Figure 22 compares flows in West Canal for WY2005-2010. The maximum mean daily discharge of almost 600 cfs in the period occurred in 2005. The next largest event occurred in December 2006 (WY2007), followed by events in 2009 and 2008. Both winter and summer baseflow has been generally similar in all 6 of these water years. A decline in West Canal tailwater similar in magnitude to the reduced diversions seen at Sevenmile Creek at Sevenmile Road is **not** observed, although such a decline might be expected.

6.0 DISCUSSION OF SURFACE WATER PROGRAM, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Discussion
Virtually all elements contained in the discussion sections of the WY2004, WY2005, and WY2006 reports, describing many of the challenges encountered in implementation of the surface water monitoring program at the various types of monitoring gages, apply to the WY2007-2010 period as well, even at the reduced scale of the monitoring program.

In 2007-2010, 5 stage-discharge streamflow gaging stations were operated for the Klamath Basin Rangeland Trust. Due to the physical characteristics of the basin, as well as budget constraints, it was not possible to produce Primary Stations Records according to USGS standards. Even though stream gaging stations were not operated according to all USGS standards, generally accepted streamflow gaging and streamflow measurement techniques were employed at all stations and the records for the period of 2003 through 2010 have been produced by similar techniques, making the dataset internally consistent.

Challenges encountered in 2007-2010 for producing accurate streamflow records for stage-discharge stations in the Wood River Valley included:

- Several of the streamflow gaging sites were located in sand bed streams with shifting controls.
- Aquatic vegetation at several of the streamflow gaging sites made discharge measurements difficult and stage-discharge relationships unstable.
- Weather conditions, ice, and snow in winter made it difficult to access and operate some streamflow gaging stations, although this became much less of an issue in 2008 when gages were only operated for the irrigation season.

Due to budget constraints, fewer measures were taken to address these challenges than had occurred in 2005 and 2006. However, most of the streamflow records computed still produced "fair" ratings.

6.2 Conclusions
In 2007-2010, the Klamath Basin Rangeland Trust operated a network of surface water monitoring stations in portions of the Wood River Valley. The primary focus was on streamflow

in the Sevenmile System, although the implementation of the Agency WRP project in 2008-2010 provided a second focus area. Continuous gage records provide a limited view of inflow, tributary contributions, diversions, and outflow to Agency Lake.

Overall, since 2005, the effect of reduced diversions producing increased streamflow is dramatic in the six years of the KBRT program, especially at the Sevenmile Creek at Sevenmile Road gage.

6.3 Recommendations

The Klamath Basin Rangeland Trust established an extensive network of surface water monitoring stations in the Upper Klamath Basin from 2002 through 2006. In that period, the data gathered under this monitoring program have greatly improved the understanding of surface water inflows/outflows in the Upper Klamath Basin and also formed the basis for evaluating nutrient loads. Unfortunately, in 2007-2010, the program had to be substantially scaled back and was unable to compute an overall water balance of inflows and outflows in the Wood River Valley. Should funding be available, the most important gages to be considered for continued operation are:

1. Wood River at Weed Road

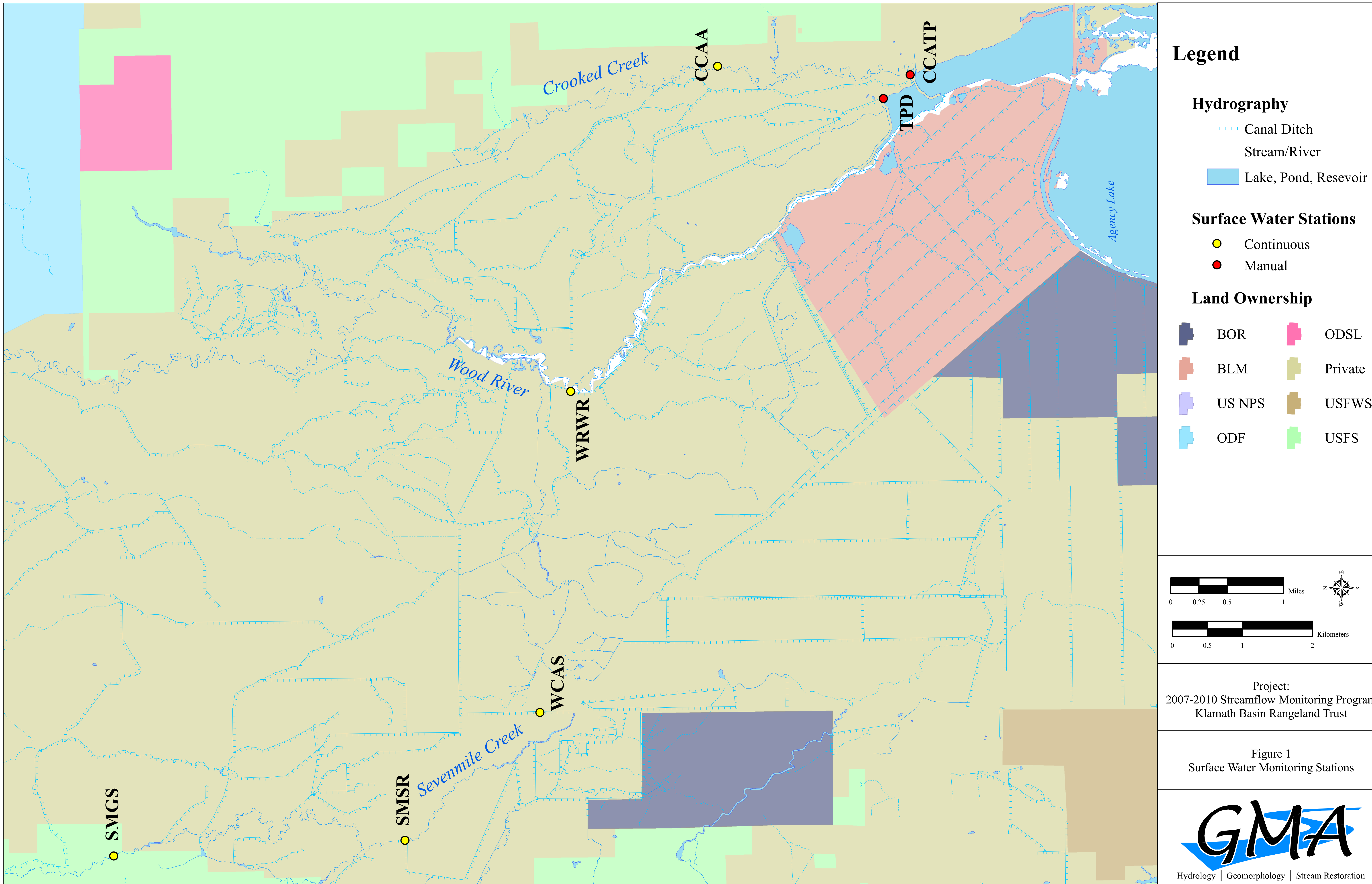
This gage has the longest record in the basin and should be the highest priority for operation.

2. Sevenmile Creek at Sevenmile Road

This gage integrates most of the large spring inflows, as well as the large diversions, of the upper Sevenmile Creek drainage.

3. West Canal above Sevenmile Creek

This canal contains the bulk of the return flow (and nutrient loads) for the Wood River Valley.


Crooked Creek
CCAA
CCATP
TPD
Agency Lake
Wood River
WRWR
WCAS
Sevenmile Creek
SMSR
SMGS
Legend
Hydrography
Canal Ditch
Stream/River
Lake, Pond, Resevoir
Surface Water Stations
Continuous
Manual
Land Ownership
BOR
ODSL
BLM
Private
US NPS
USFWS
ODF
USFS
Miles
0 0.25 0.5 1
Kilometers
0 0.5 1 2
Project:
2007-2010 Streamflow Monitoring Program
Klamath Basin Rangeland Trust
Figure 1
Surface Water Monitoring Stations
Hydrology | Geomorphology | Stream Restoration

FLOW CHART OF WOOD RIVER STREAMFLOW TRIBUTARY/DIVERSION POINTS AND STREAMFLOW MEASUREMENT LOCATIONS

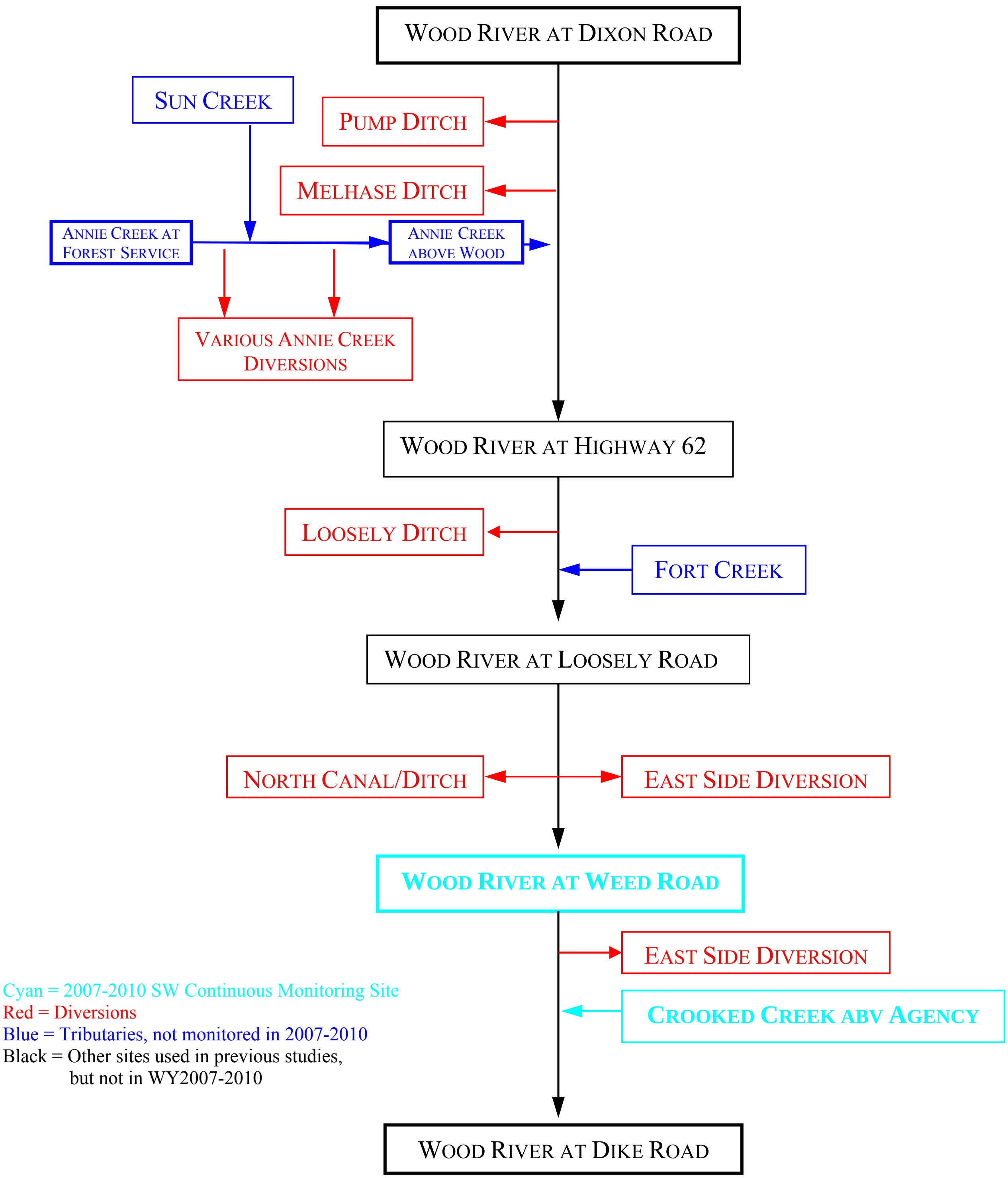


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FIGURE

2

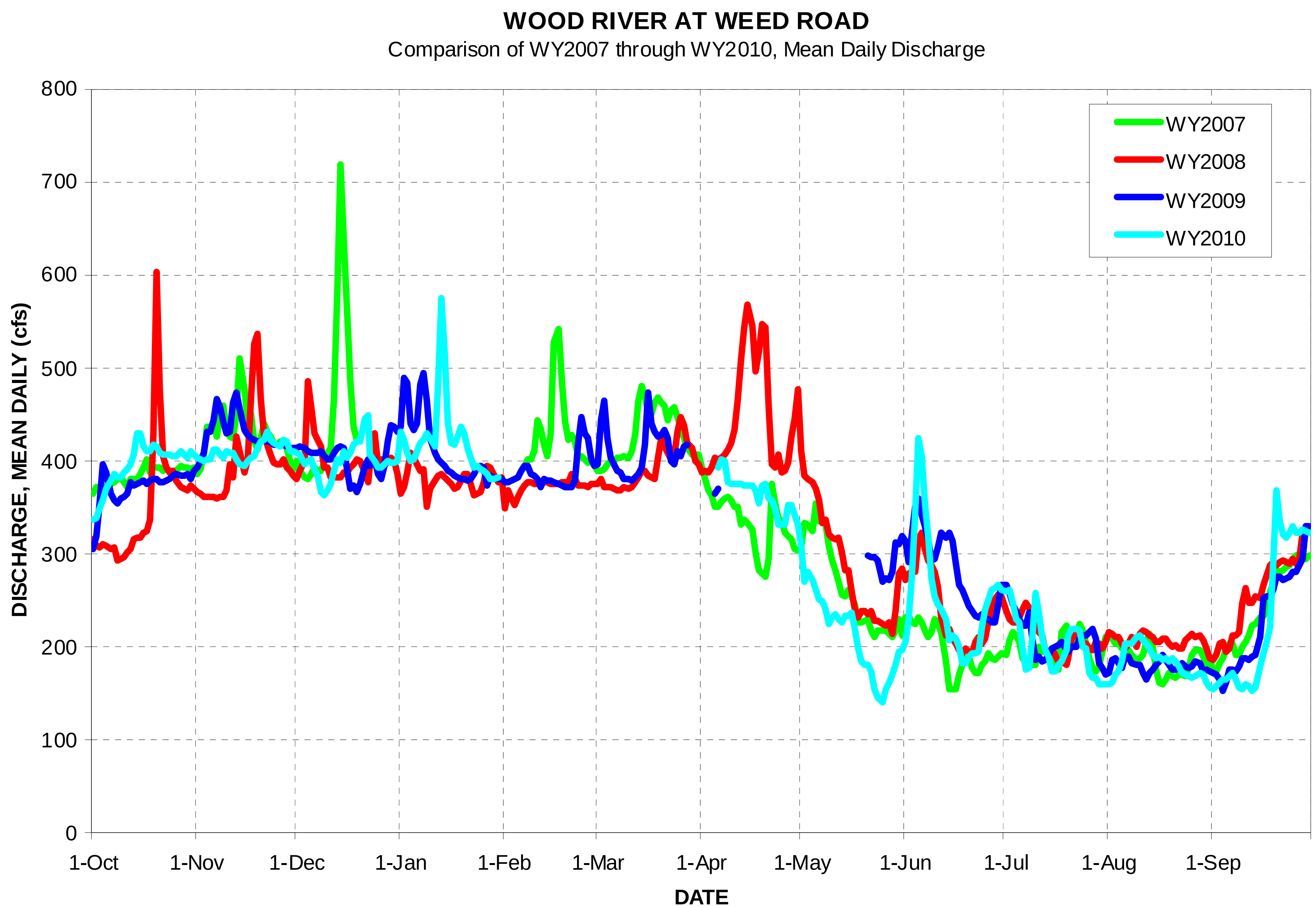

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FIGURE
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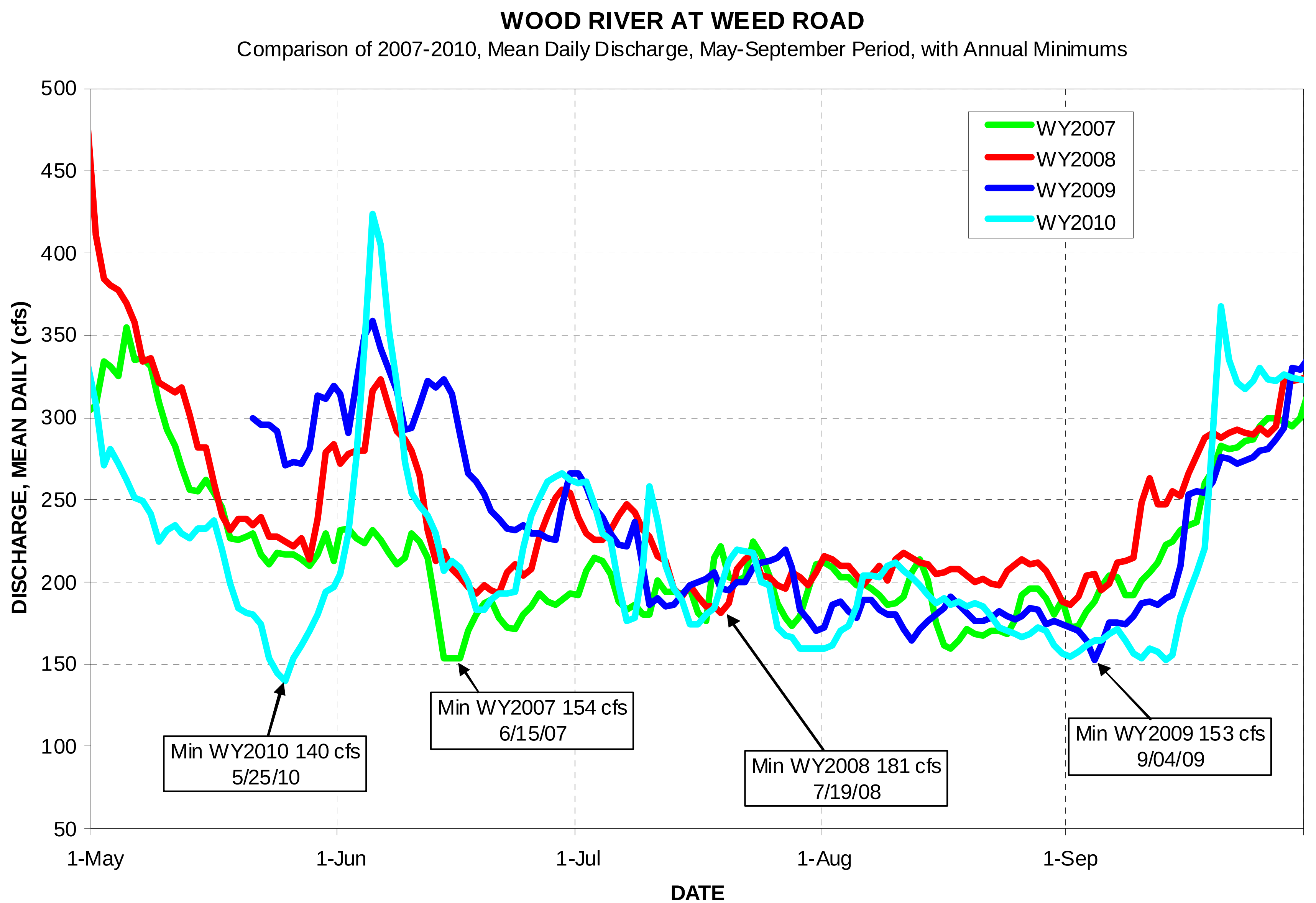

2007-2010 SURFACE WATER MONITORING PROGRAM Klamath Basin Rangeland Trust	GMA Hydrology | Geomorphology | Stream Restoration	FIGURE 4

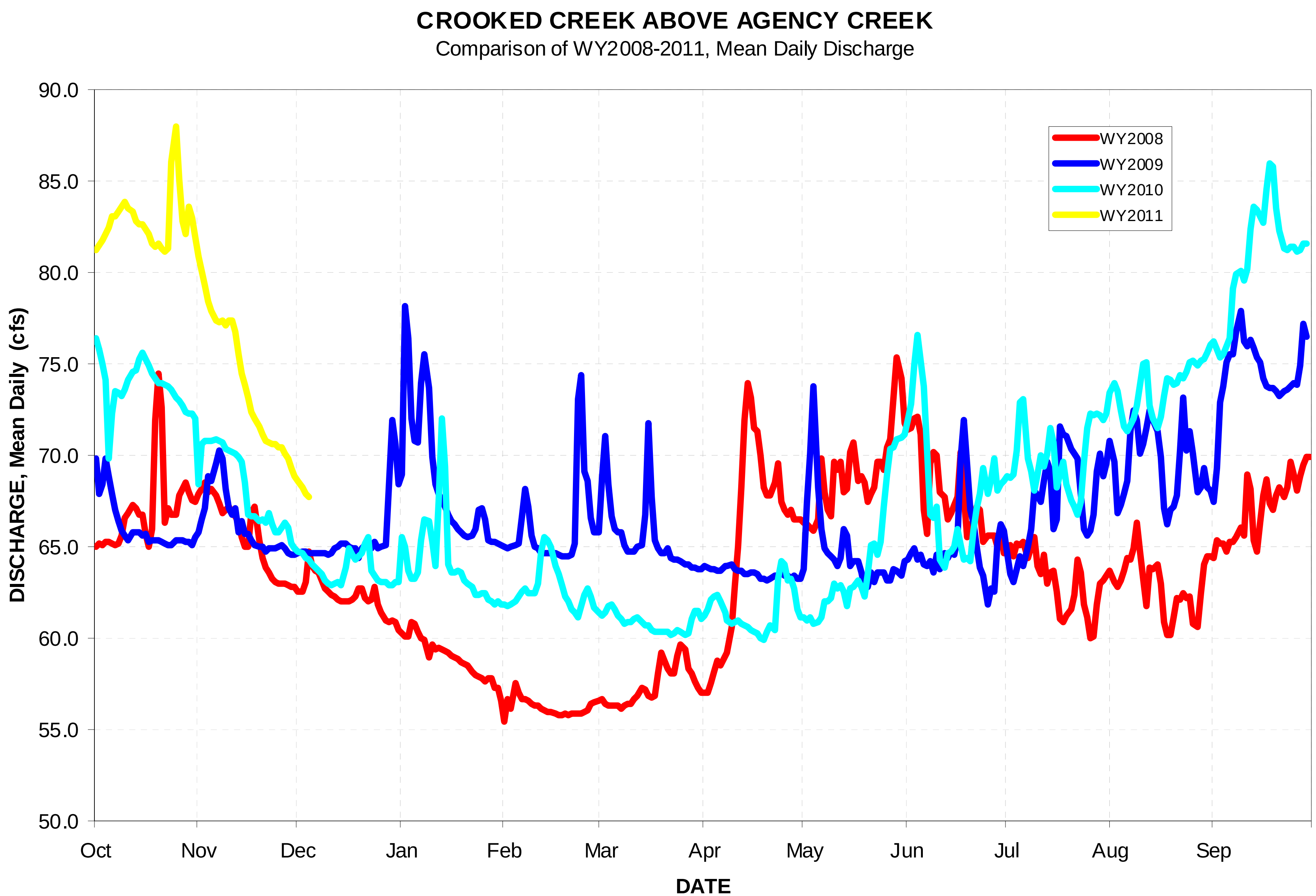

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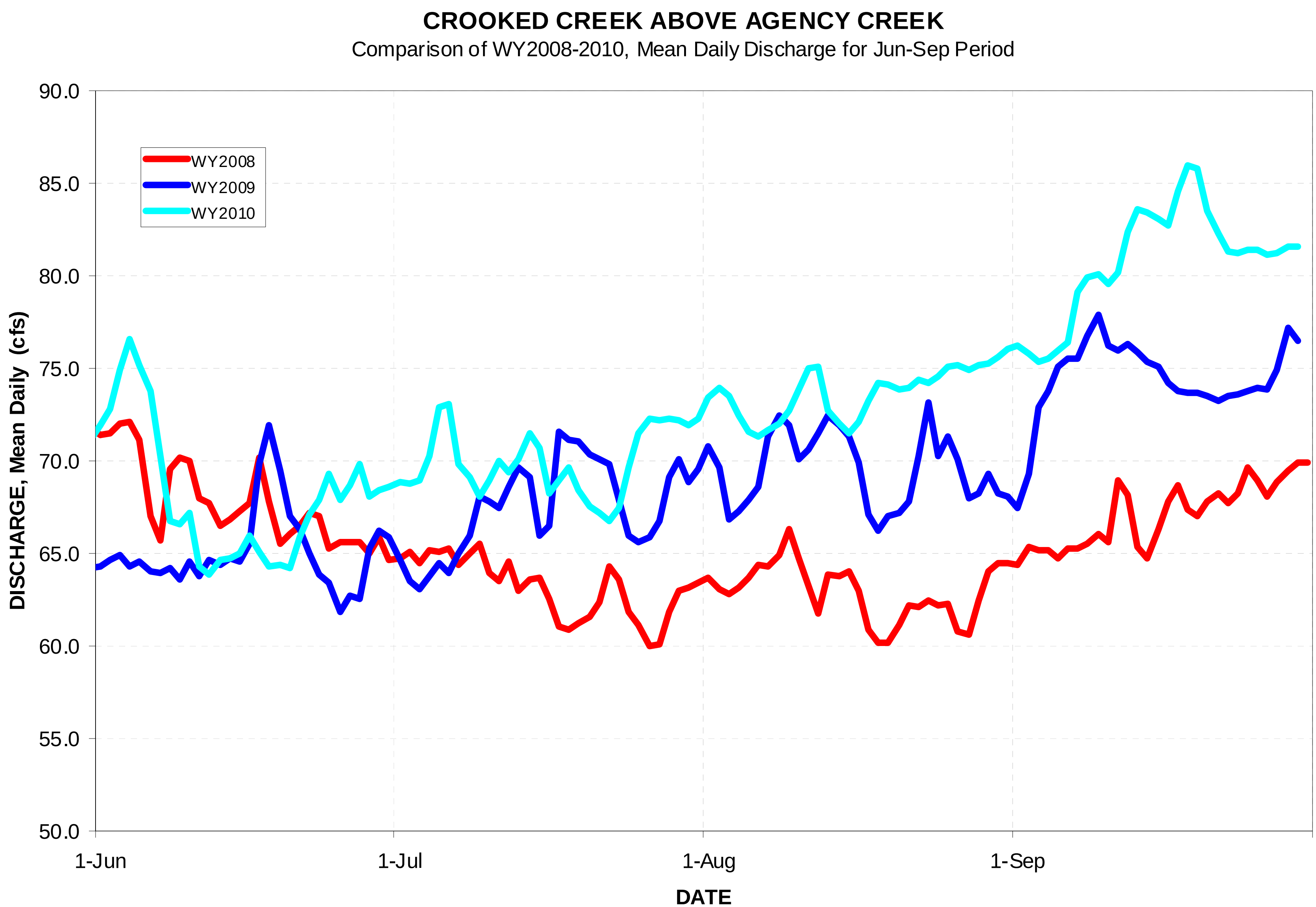
FIGURE

5



2007-2010 SURFACE WATER MONITORING PROGRAM
Klamath Basin Rangeland Trust

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Hydrology | Geomorphology | Stream Restoration

FIGURE
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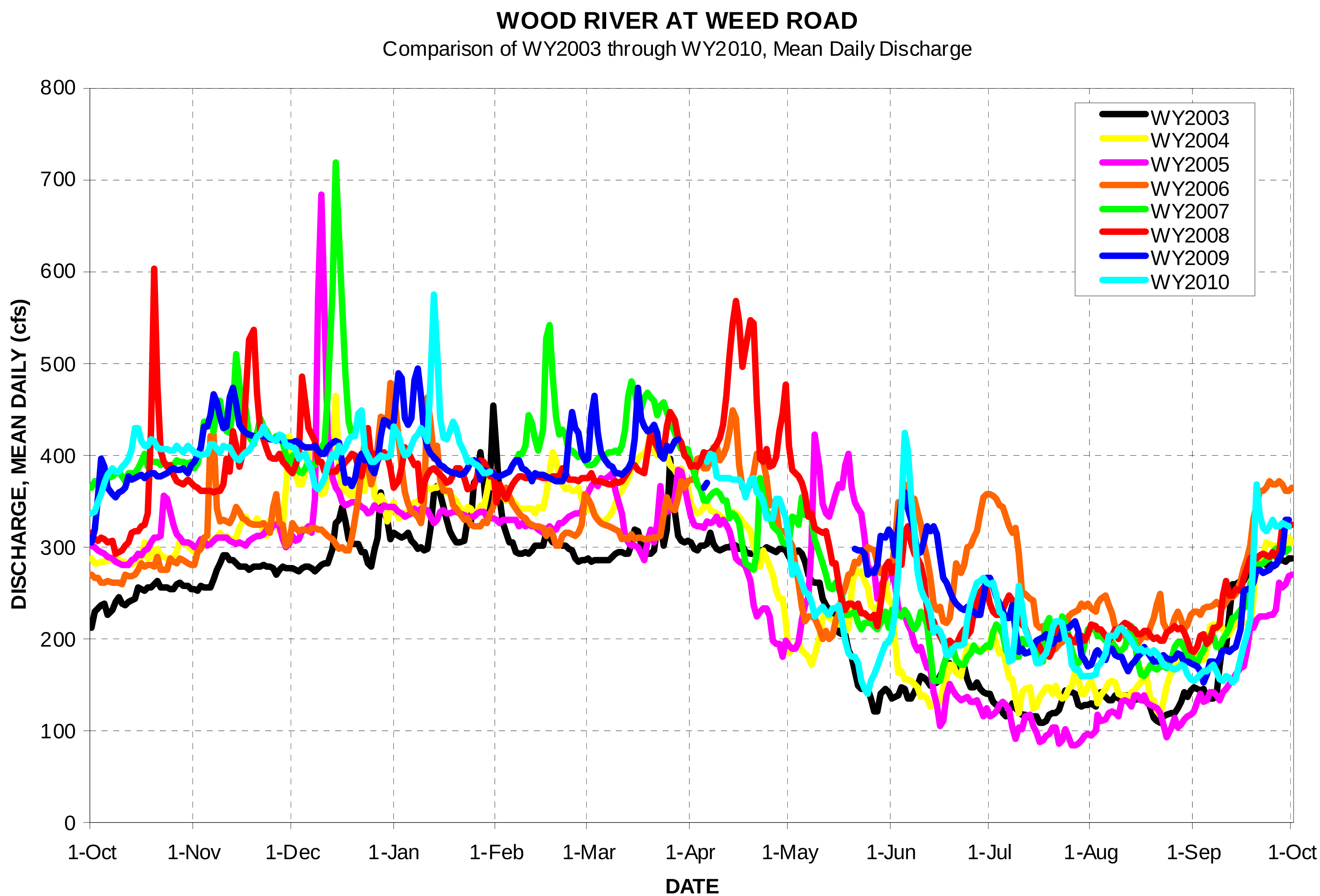

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FIGURE

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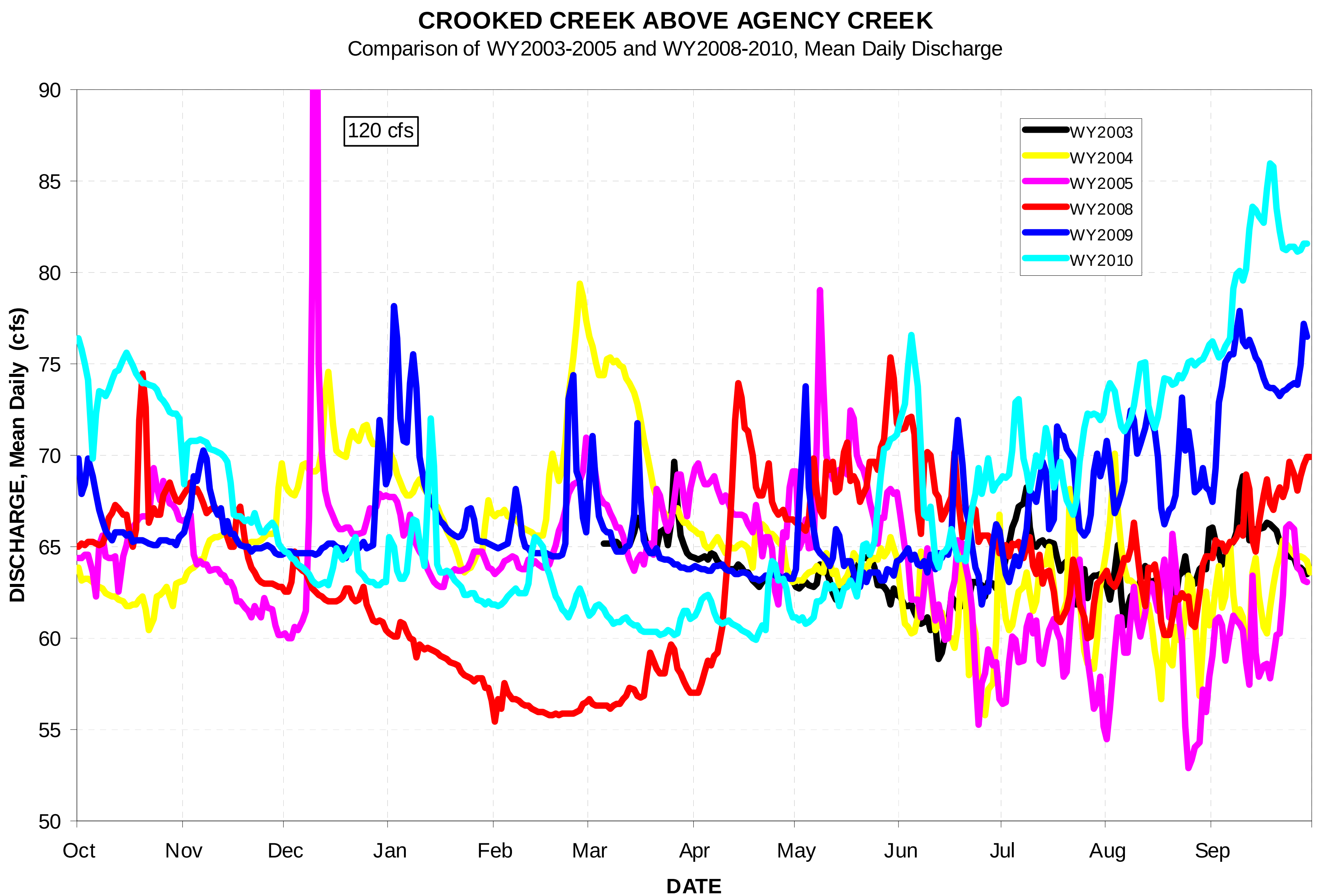

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FIGURE
8

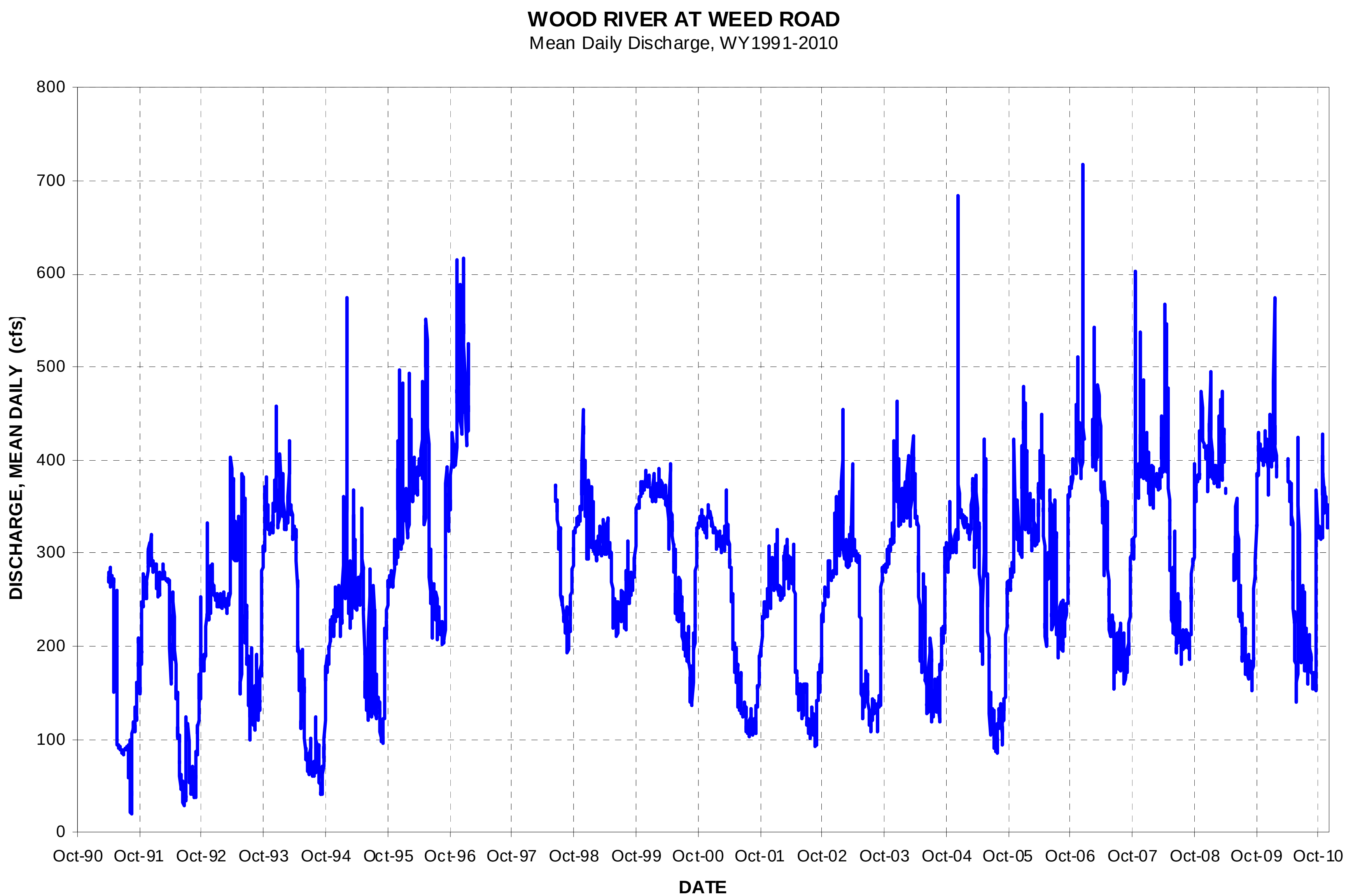

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FIGURE
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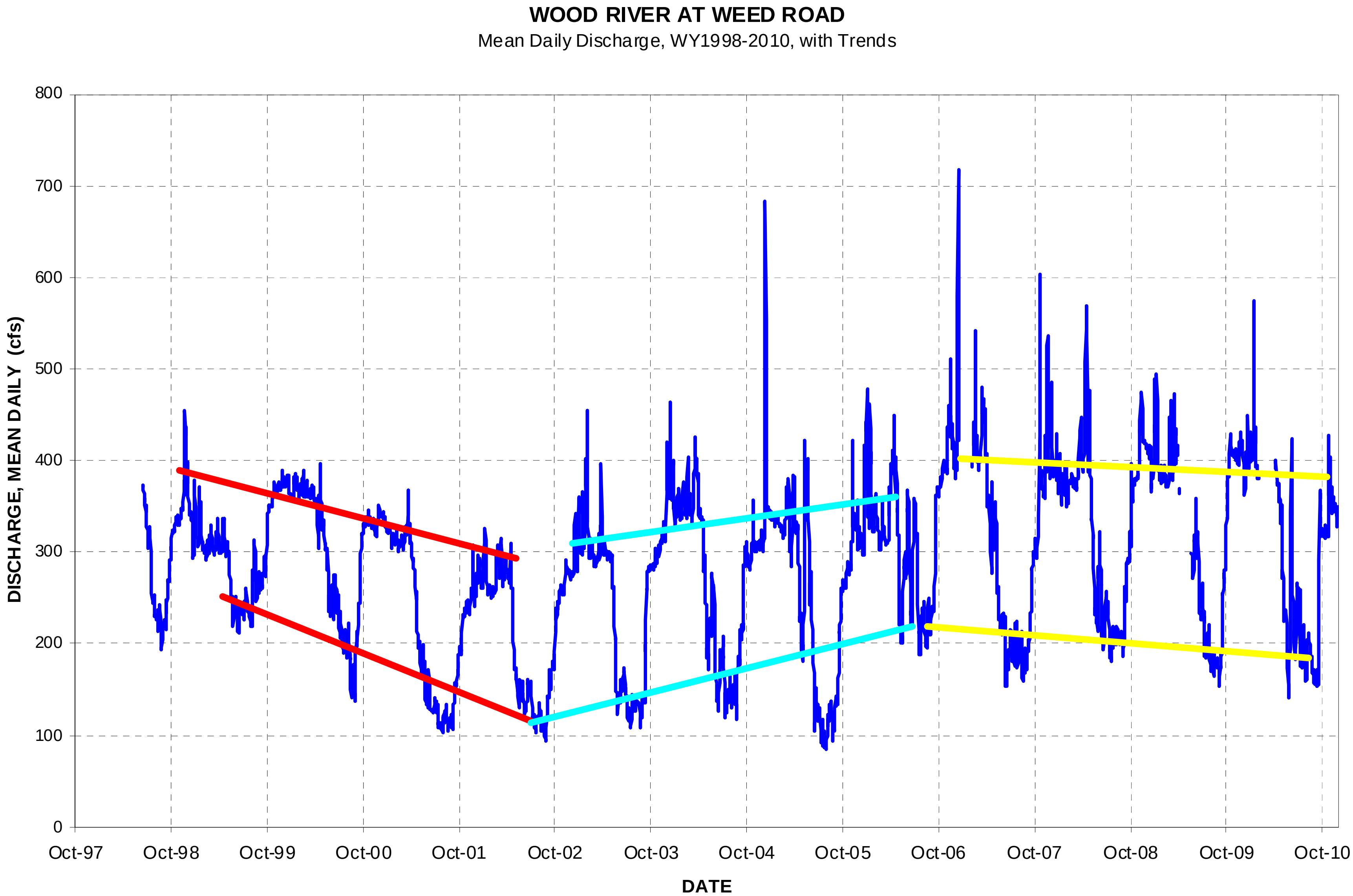

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FIGURE
10

Flow Chart of Sevenmile Creek Streamflow Tributary/Diversion Points and Streamflow Measurement Locations

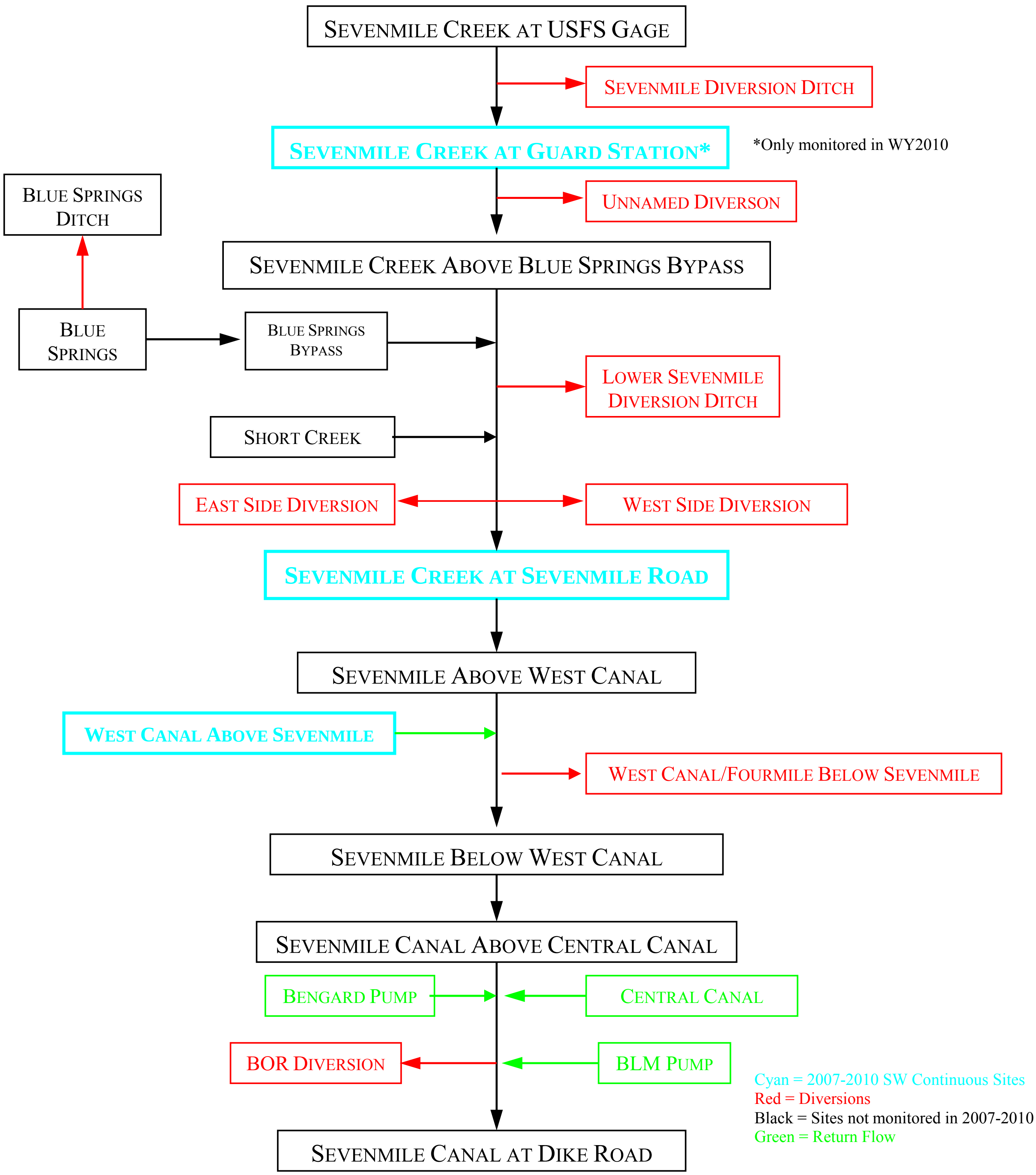

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FIGURE 11

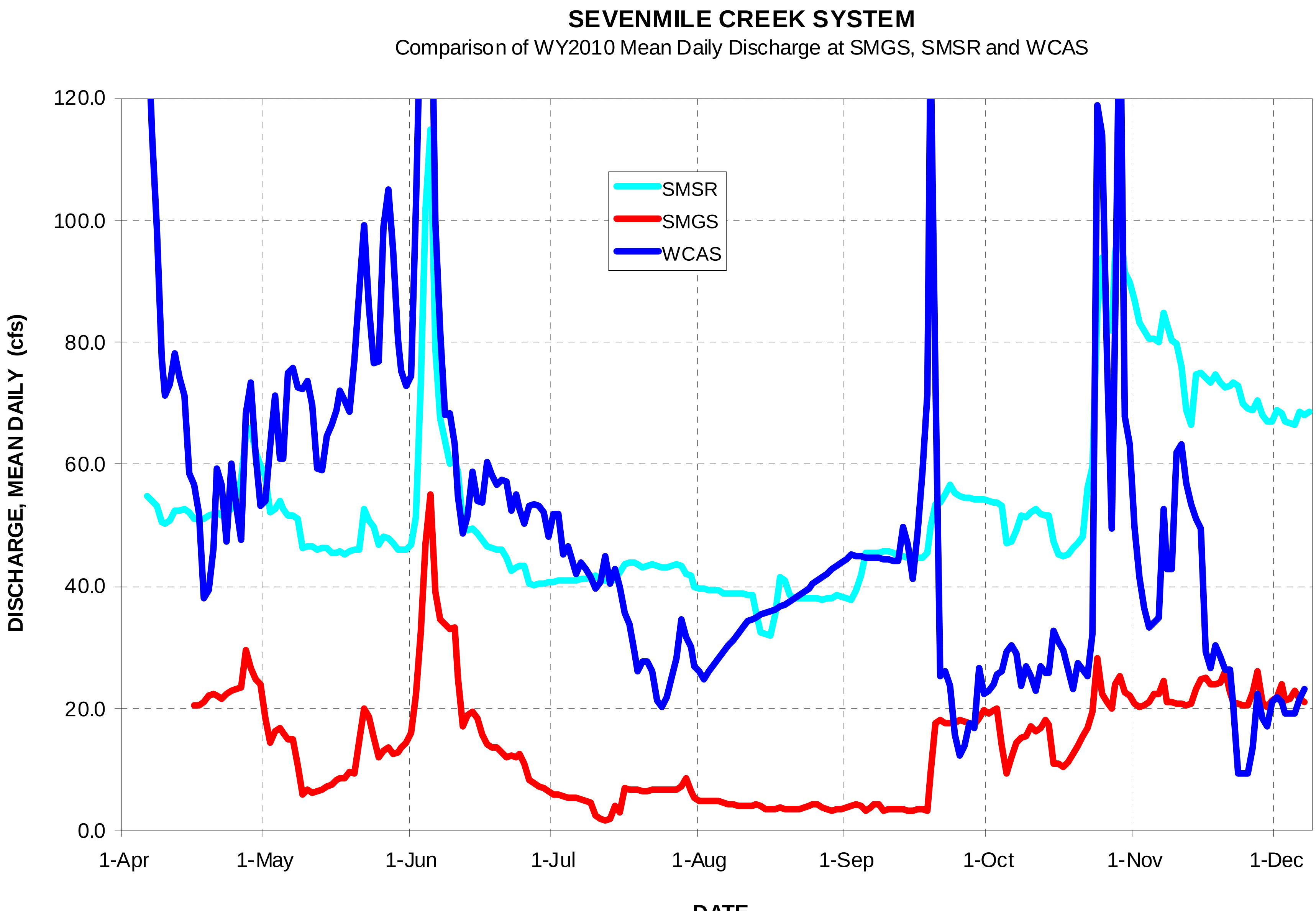

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FIGURE
12

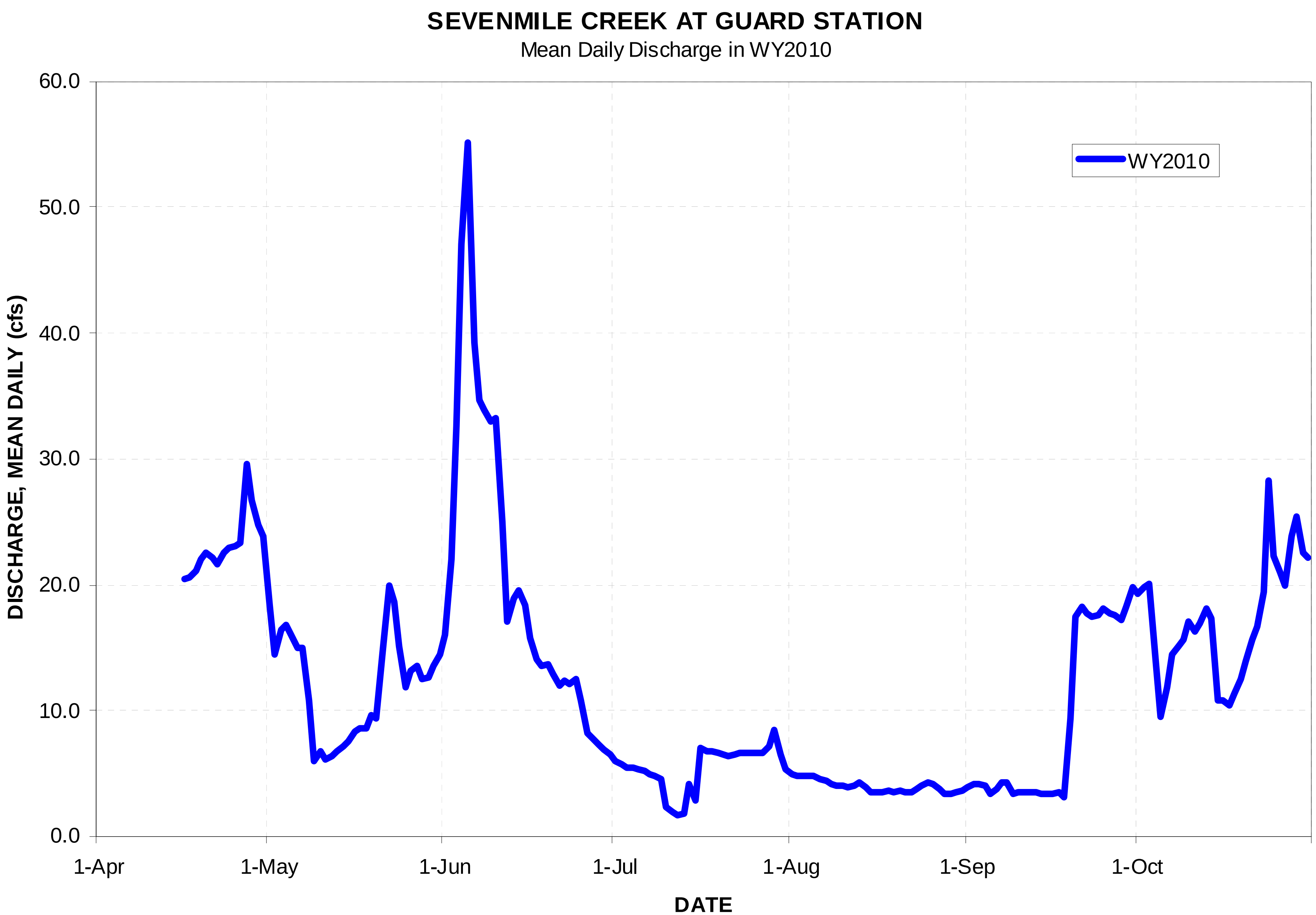

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FIGURE
13

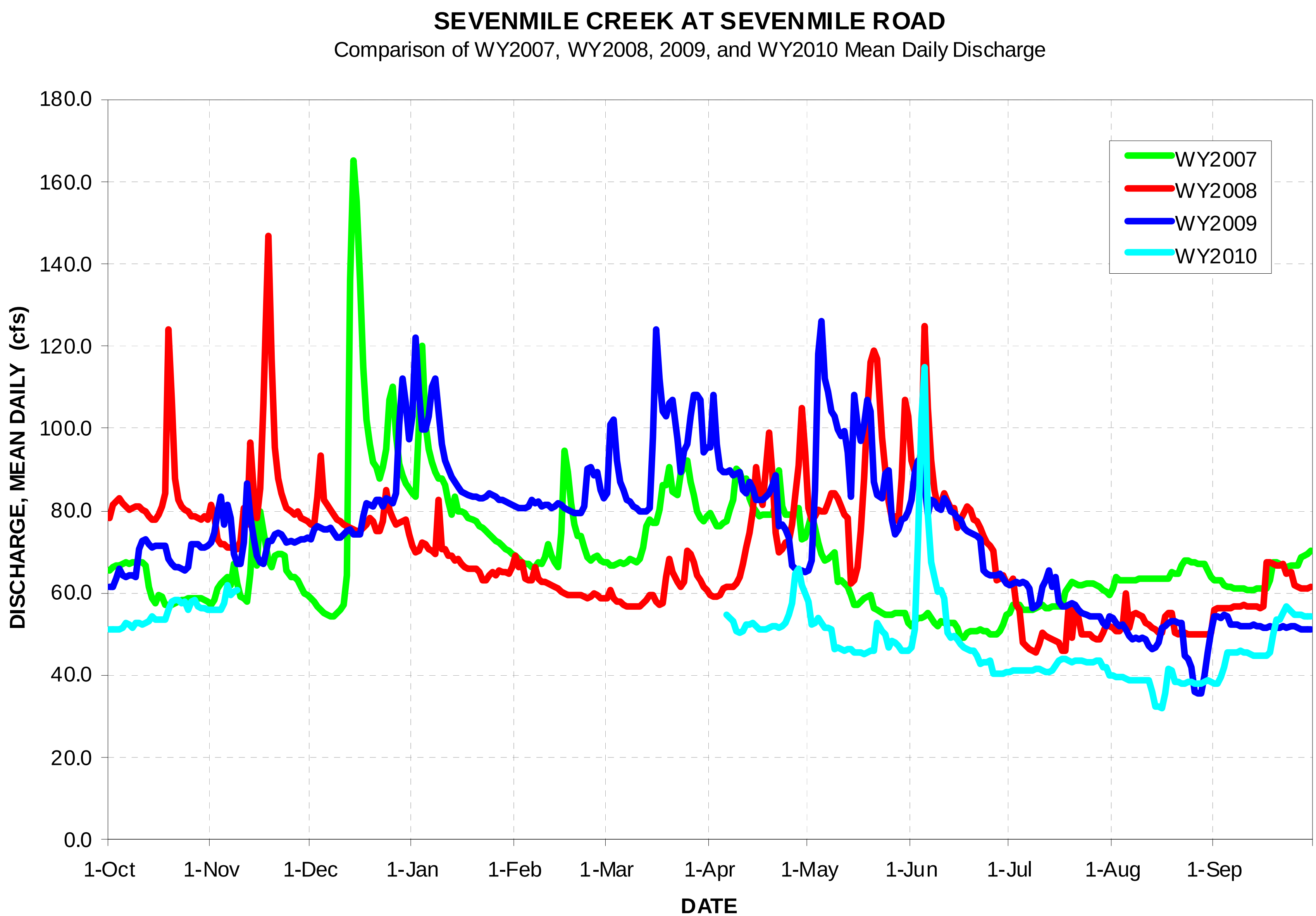

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FIGURE

14

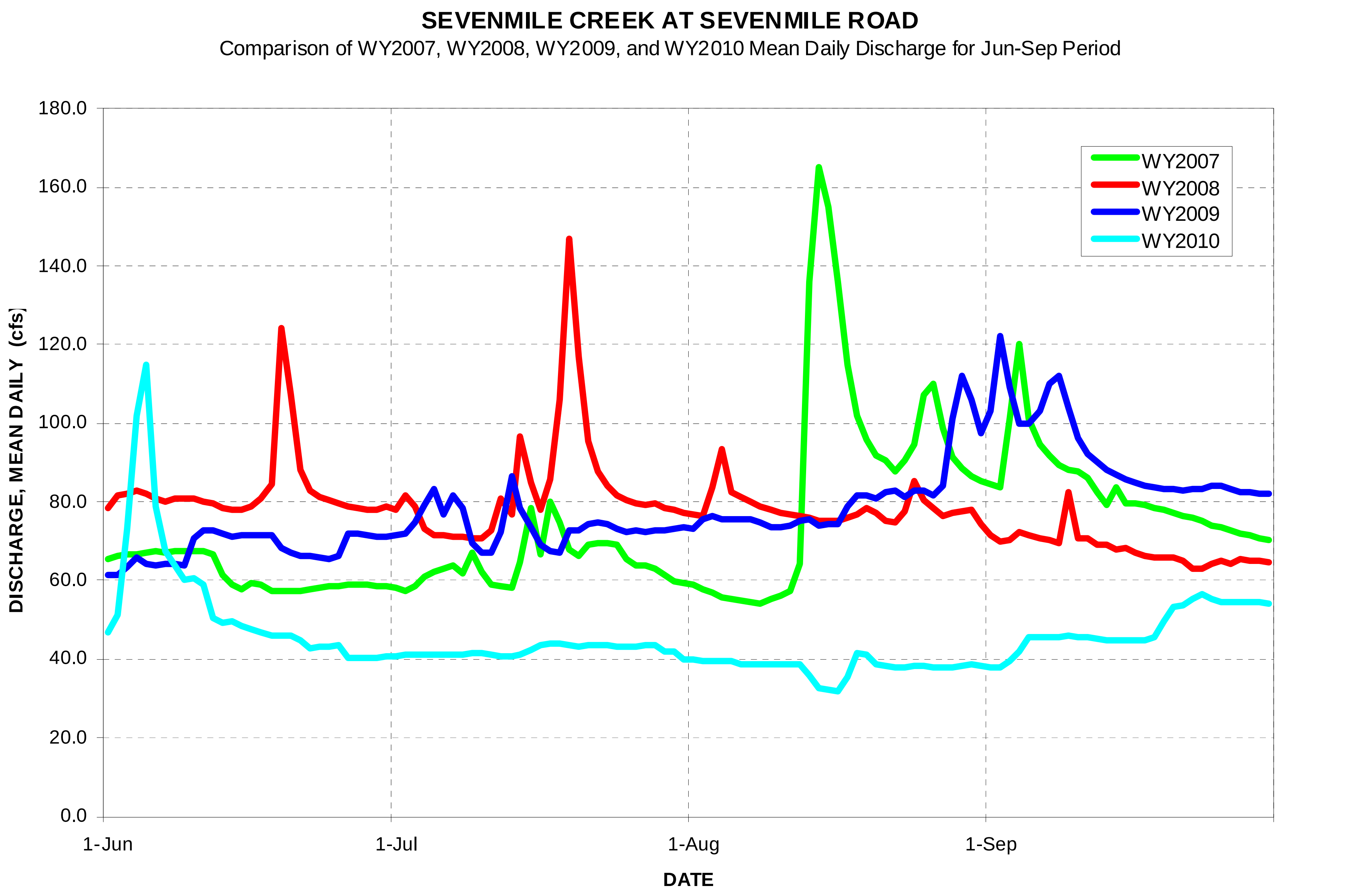

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FIGURE
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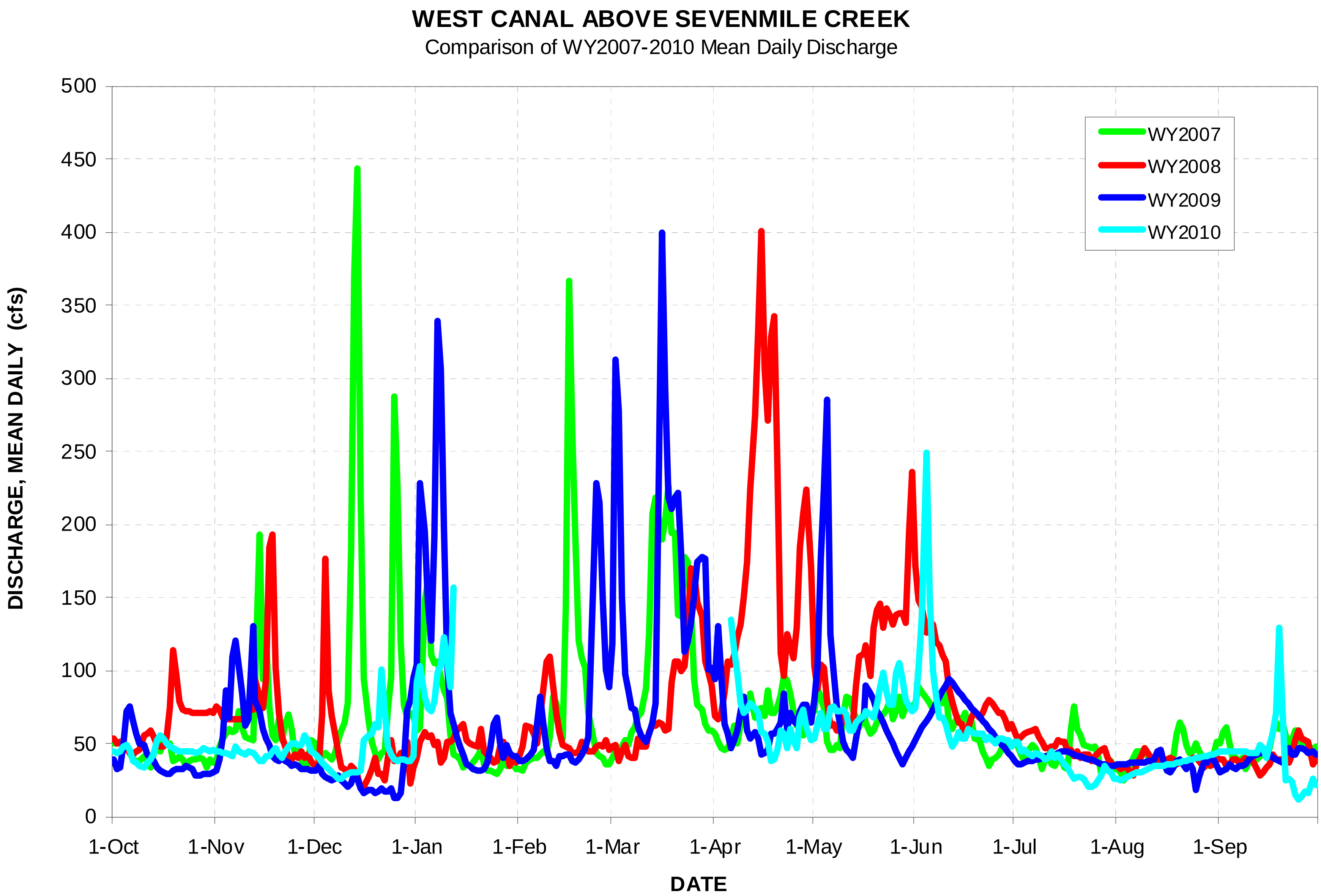

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FIGURE
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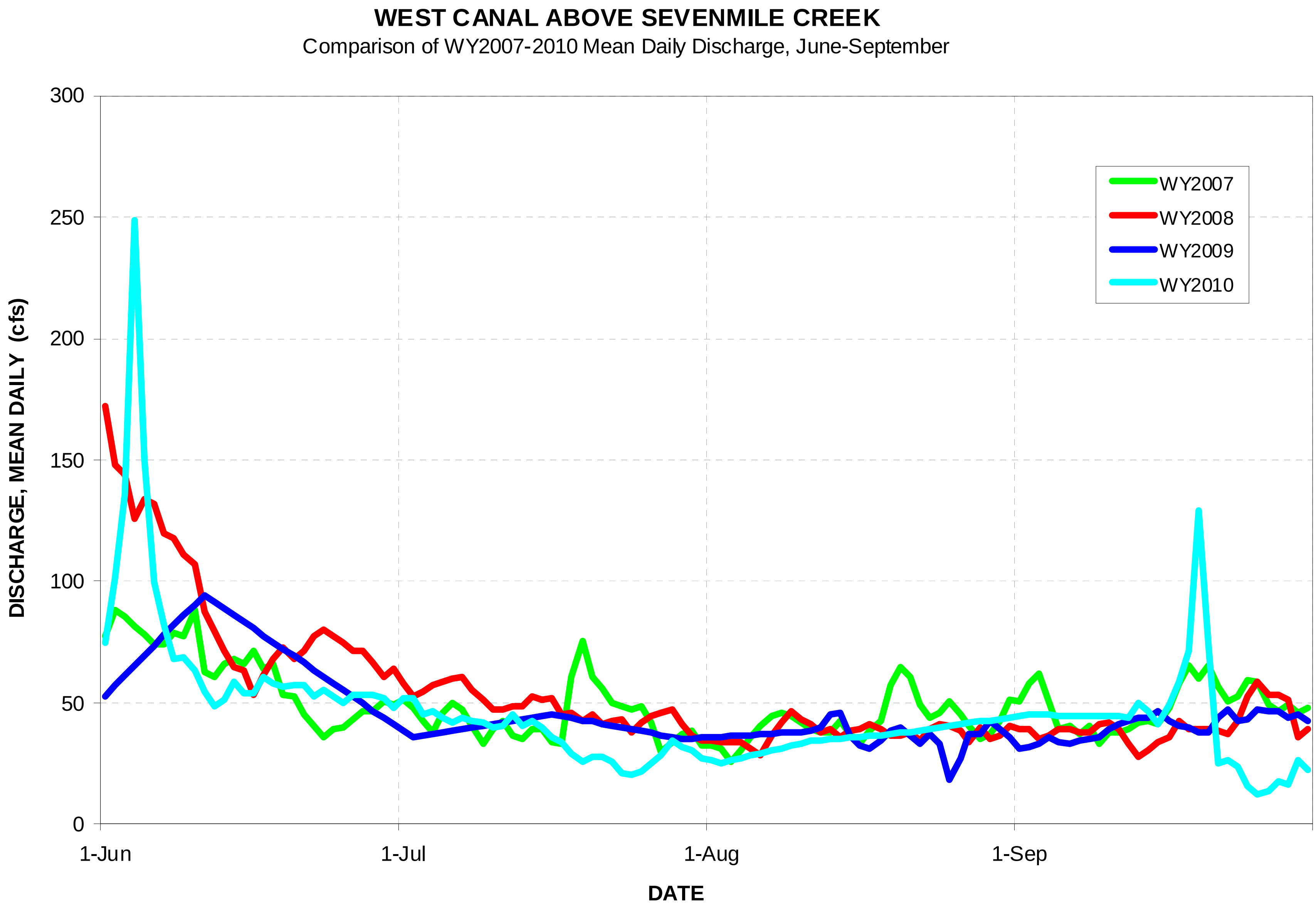

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FIGURE
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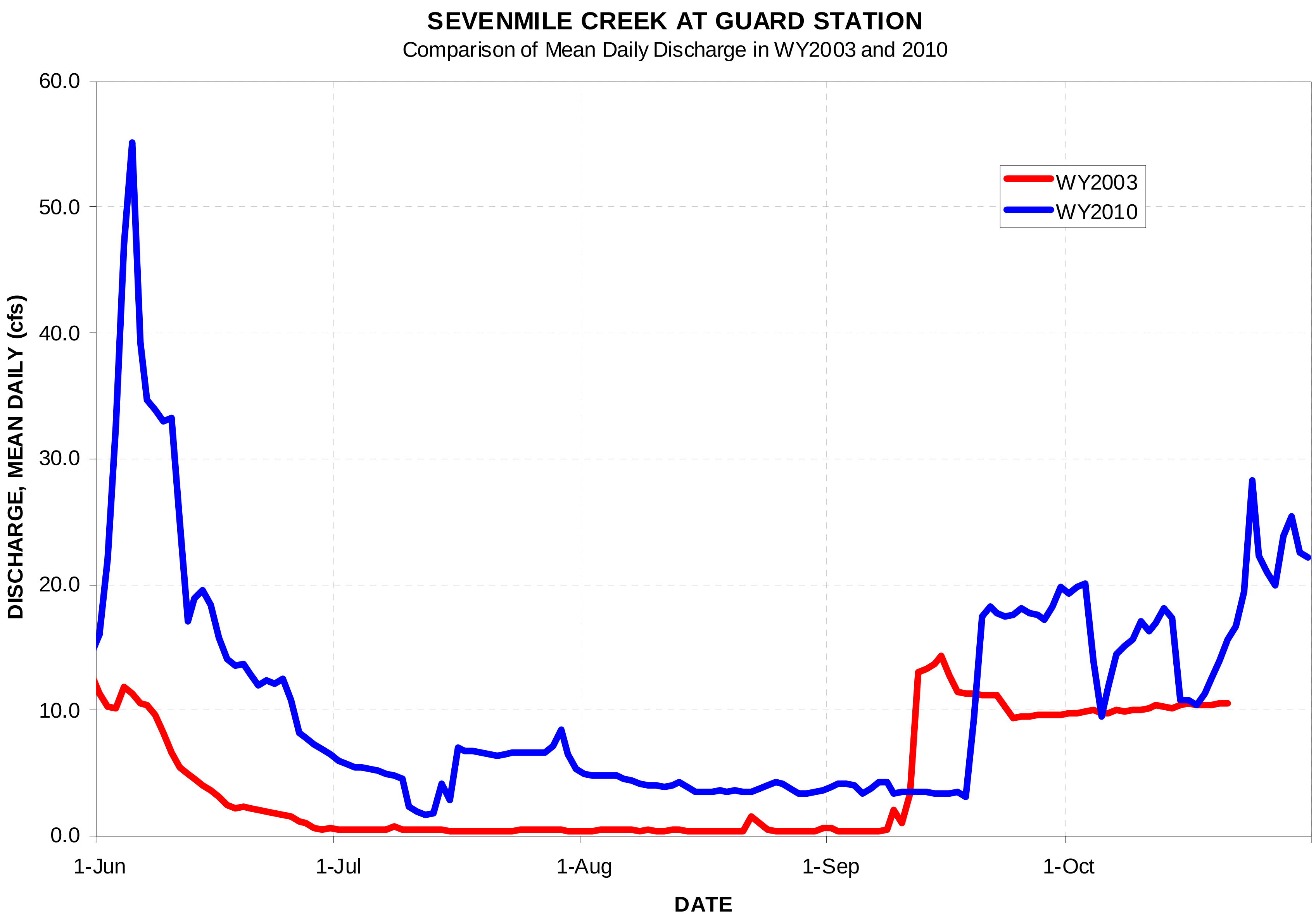

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FIGURE
18

SEVENMILE CREEK AT SEVENMILE ROAD

Comparison of WY2003-2010 Mean Daily Discharge

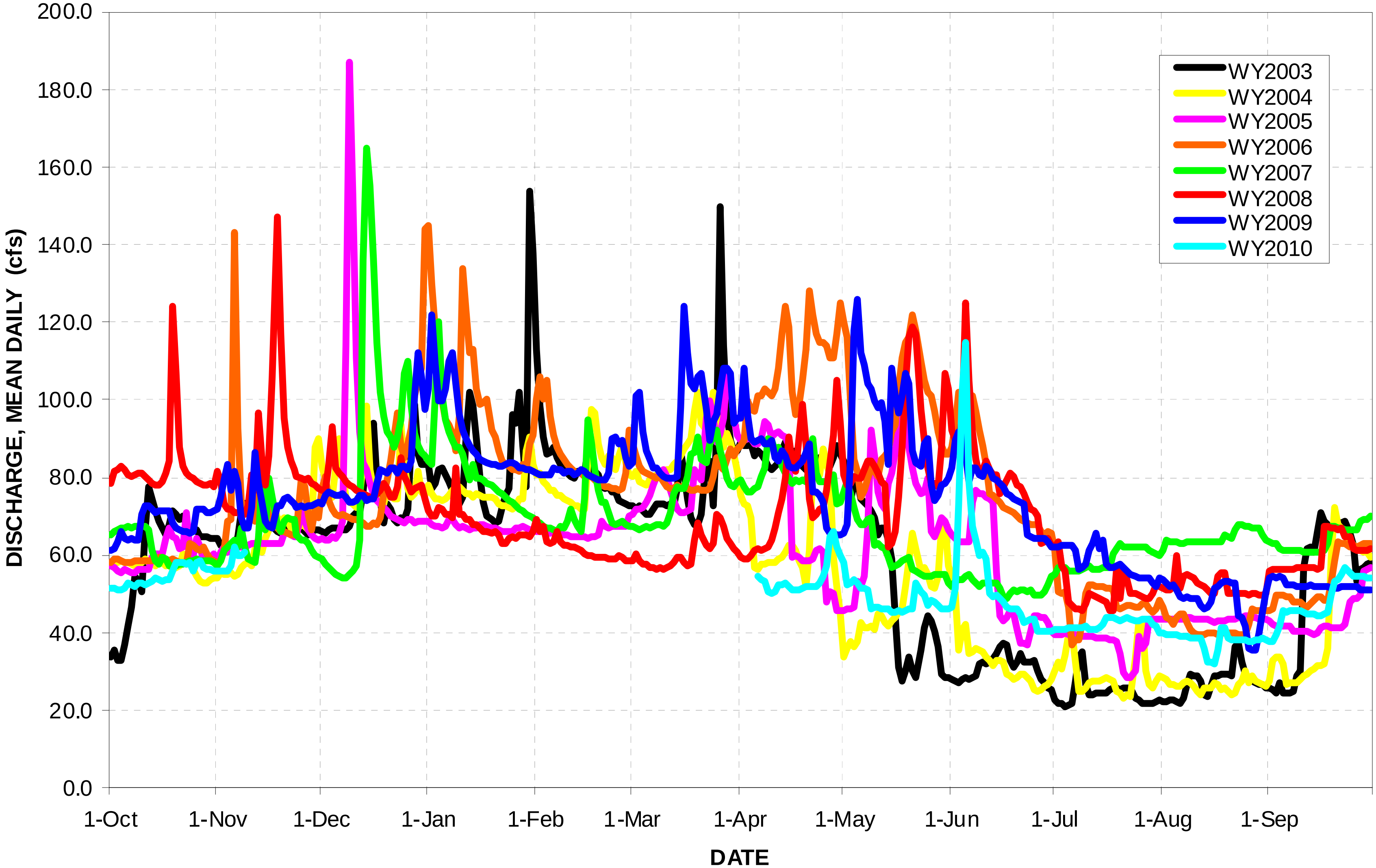

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FIGURE
19

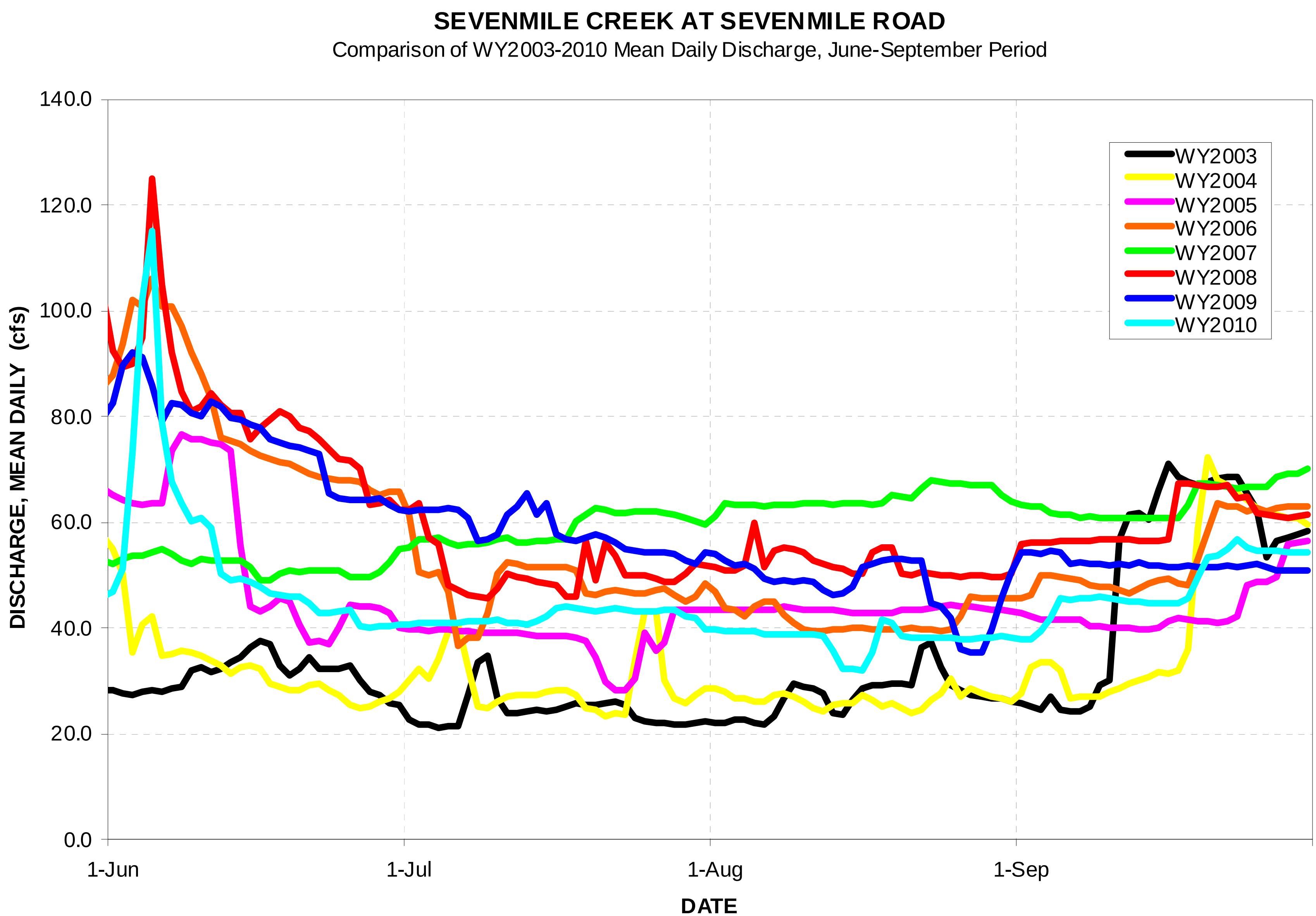

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FIGURE

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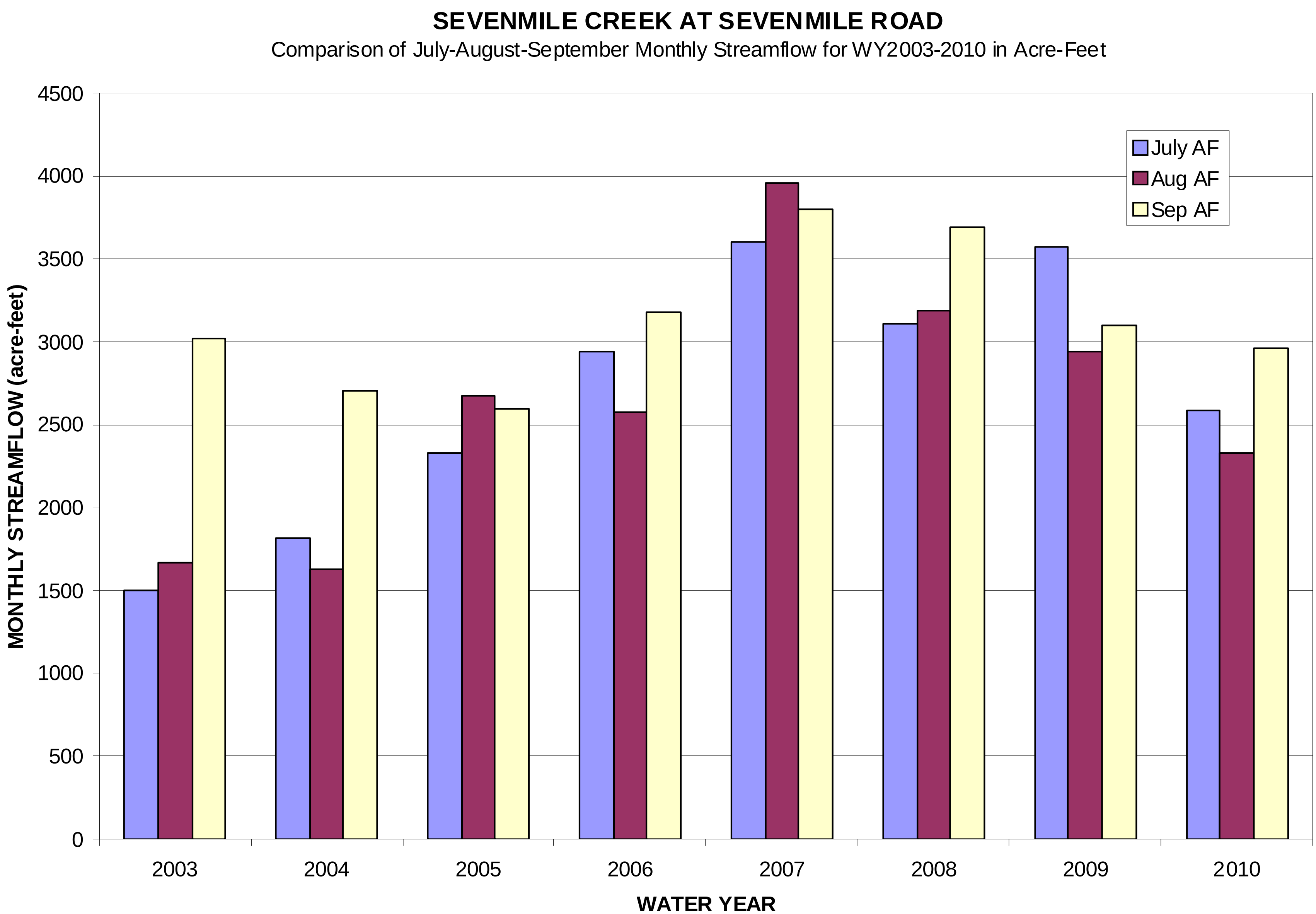

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FIGURE

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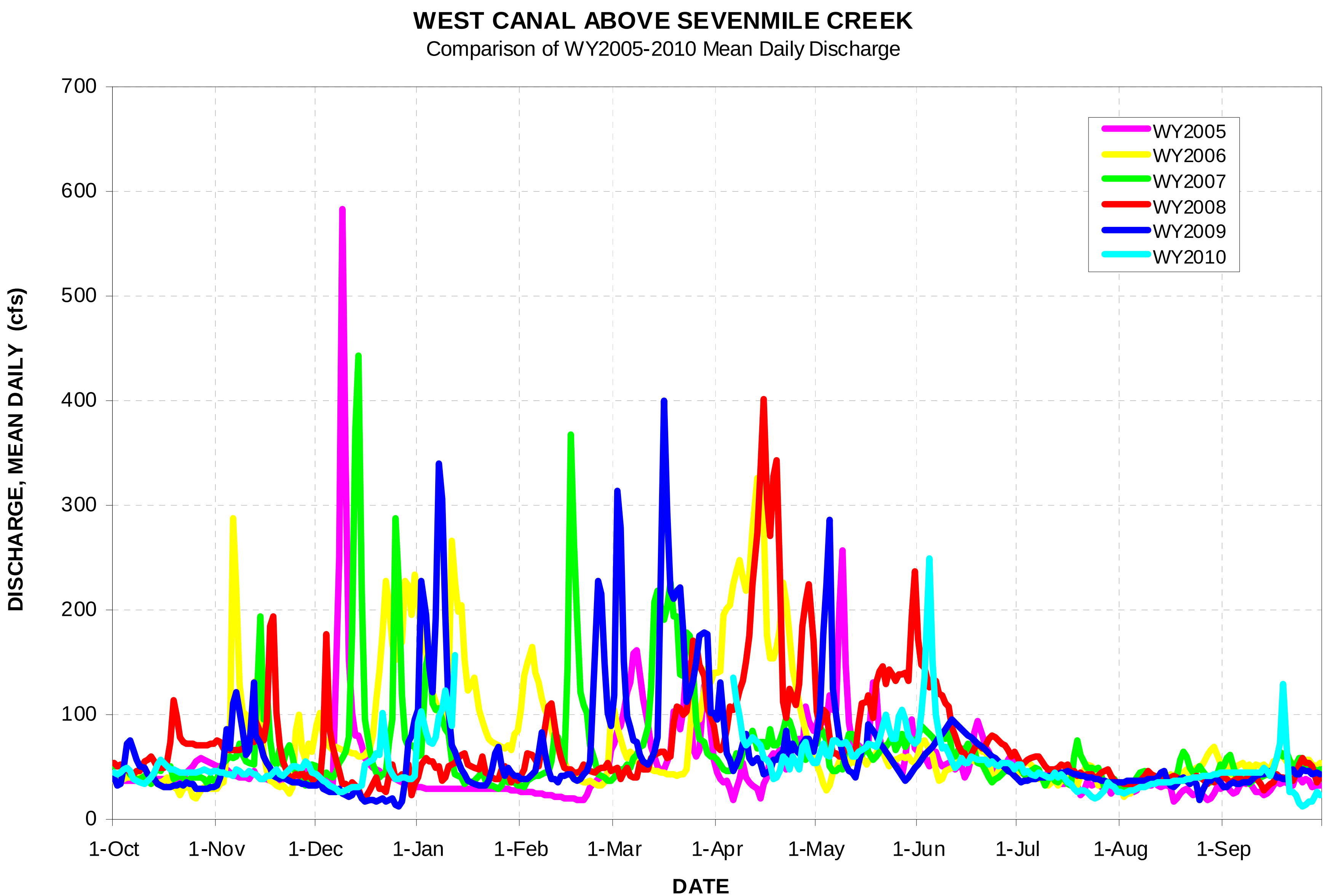

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FIGURE
22

WY2007-2010 SURFACE WATER MONITORING PROGRAM

SUMMARY OF DATA PRESENTED IN THE APPENDICES

APPENDIX NUMBER	Abbreviation	Station Name	Station Description	9-207	Rating Curve	Rating Table	Stage 30	Velocity 30	MDQ Hydrograph	MDQ Table
1	WRWR	Wood River at Weed Road	1-1	1-2	1-3	1-4	1-5	---	1-7	1-8
2	CCAA	Crooked Creek above Agency	2-1	2-2	2-3	2-4	2-5	---	2-7	2-8
3	CCATP	Crooked Creek above Thomas Pumps	---	3-2	---	---	---	---	3-7	3-8
4	ATP	Thomas Pumps (Squaw Creek)	---	---	---	---	---	---	4-7	4-8
5	SMSR	Sevenmile Creek at Sevenmile Road	5-1	5-2	5-3	5-4	5-5	---	5-7	5-8
6	SMGS	Sevenmile Creek at the Guard Station	6-1	6-2	6-3	6-4	6-5	---	6-7	6-8
7	WCAS	West Canal above Sevenmile Creek	7-1	7-2	7-3	7-4	7-5	7-6	7-7	7-8

Description of Gaging Station on: *Wood River at Weed Road*

Drainage Basin: *Wood River*

1. Location

Lat. 42° 38' 47.63", Long. 121° 59' 40.10" (NAD 27), in the Sec 4., T34S, R71/2E, Klamath County, 0.71 miles downstream from the North Canal confluence. The elevation of the gage is 4146.22 ft (NAVD 88). The gage can be reached by traveling 8.9 miles north on Hwy 62 from the intersection of Highway 62 and Highway 97. Turn left onto Weed Road and travel 2.2 miles to the bridge crossing the Wood River. The gage is located along the left bank under the bridge.

2. Hydrologic Conditions

The upper Klamath Basin primarily consists of agricultural lands interspersed with wetlands on the basin floor rising to evergreen forests on the basin slopes. Geology in the basin results from past volcanic events in the surrounding area. Average temperatures in the basin range from 17.2°F to 80.7°F based on 13 years of record from the National Weather Service station in Chiloquin. Precipitation averages 20.69 inches per year and is produced in a combination of snow and rain. Peak flows are generated from rain-on-snow events and spring snowmelt.

3. Establishment and History

This gage was established by USBR on April 2, 1991, and operated continuously until January 24, 1997 when USBR datalogger was vandalized and was not replaced. In June 1998, Graham Matthews & Associates re-established the gage as a continuous streamflow monitoring station.

4. Gage

On October 6, 2004 a Design Analysis H-310 pressure transducer was installed on the right back immediately downstream of the bridge.

A Global Water WL-14 pressure transducer/datalogger is mounted under the bridge in a steel enclosure near the left bank and is used as a backup.

Inside recording gage: Design Analysis H-310 (Accuracy to ± 0.007 ft)
Global Water WL-14 (Accuracy to 0.03 ft)

Outside staff gage: One USGS style C staff gage (0.00 – 0.33 ft) is mounted on the right bank. Staff height references used in the computation of records are from the upstream staff plate. An offset of five feet is applied to staff height readings due to the fact that during periods of low flow the staff plate may be out of the water. A staff plate reading of 0.00 ft is recorded as 5.00 ft. A pocket rod is used to measure down to the water surface when the water level is below the staff plate.

View of USBR staff gage and stilling well, RB

View of older staff plate, downstream side bridge

5. Reference Marks (RM)

The reference mark is PK nail at the edge of the pavement on the upstream left side of the bridge and has an elevation of 4156.859 ft (NAVD 88).

6. Control

The control at the gage is downstream channel form, bedforms, and occasionally aquatic vegetation.

7. Discharge Measurements

Discharge measurements are taken off of the downstream side of the bridge using a bridge board, A-reel, and a price AA meter. A 15 lb weight can be used most of the year, but in high flow conditions the 30 lb weight is needed (6 ft gage height and higher). Periodically, a 3.0 MHz Sontek acoustic Doppler current profiler is used to perform discharge measurements at an established cross-section 20 ft downstream of the bridge.

Channel Conditions At Measurement Section

The channel has a grassy left bank with a gradual slope; the right bank is covered with marsh grass and has an undercut beneath the roots. The bottom is sandy and very shallow toward the center with a deeper right side than left.

Horizontal Angle Corrections

Minor horizontal angle corrections are needed due to the channel alignment with the bridge

Flow Conditions

Flow lines are semi smooth and mostly parallel with the majority of the flow on the right side.

8. Floods

Flows have reached at least 600 cfs in the period since 1998, however, Weed Road is overtopped to the east by flood waters and the gage is not accurate for these extreme events.

9. Point of Zero Flow

Unknown, and has never occurred since gage operation began in 1991, although flows did drop as low as about 25 cfs in the 1994 drought.

10. Winter Flow

Typical winter flows are derived from rain and/or snowmelt. Rain-on-snow events are responsible for most of the extreme flood events on the stream. Flows at the gage are not likely to be affected by ice except during extremely cold winters.

11. Regulation

None.

12. Diversion

A large portion of the streamflow of the Wood River and its tributaries is diverted at numerous locations upstream during a portion of the year for agricultural purposes. Often, irrigation diversions total 100 to 300 cfs.

13. Accuracy

The accuracy of the record for this site is fair.

14. Cooperation

None.

15. Land Ownership

The gage is located on public property, within the easement for Weed Road.

16. Purpose of Record

The purpose of the record is to study streamflow along with nutrient and sediment transport through this section of the Wood River above the confluence with Crooked Creek.

17. Cross Section Survey History

None.

GRAHAM MATTHEWS & ASSOCIATES
Hydrology -- Geomorphology -- Stream Restoration
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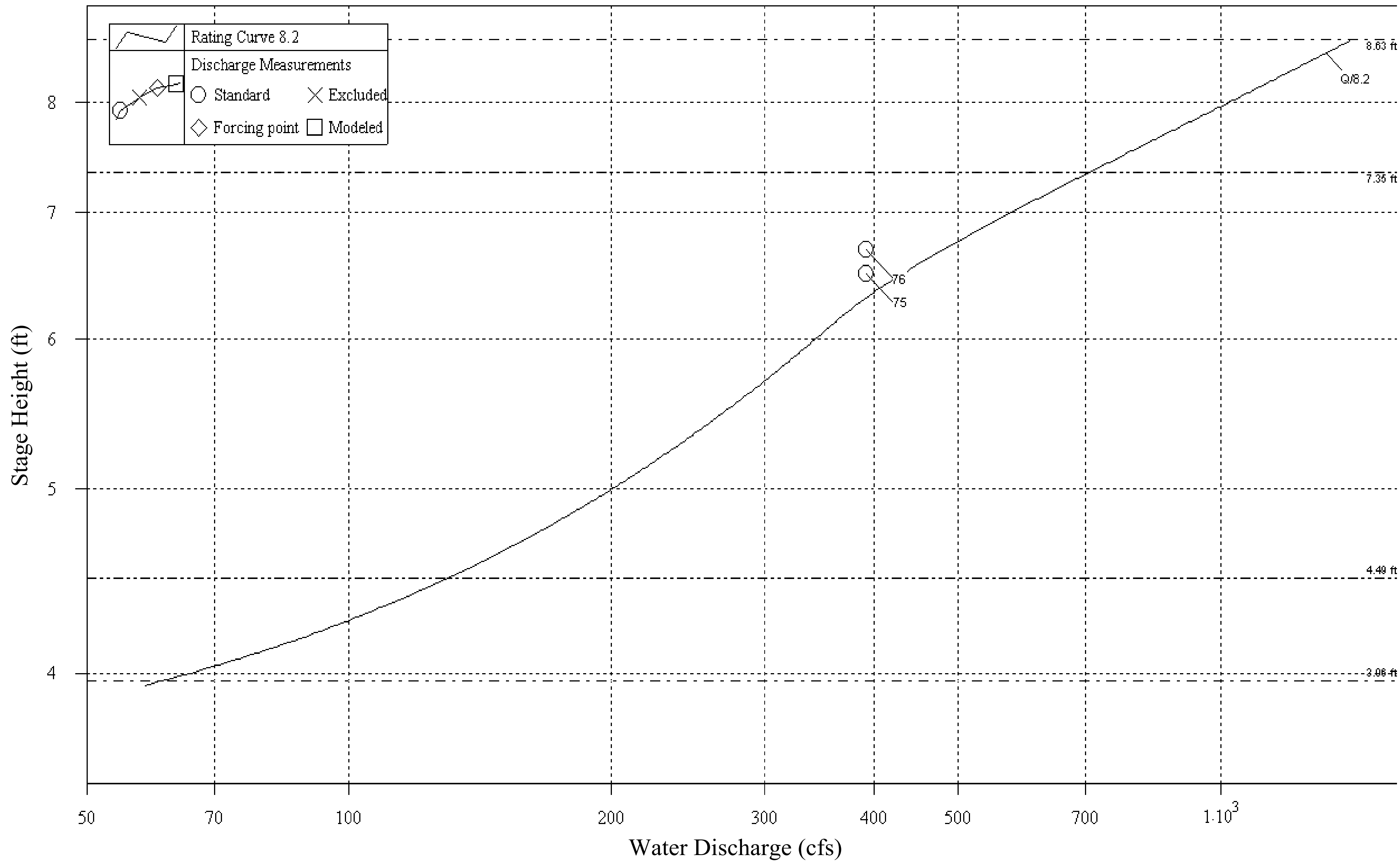
DISCHARGE SUMMARY SHEET

LOCATION: WOOD RIVER at WEED ROAD **WATER YEAR:** 2007-2010

STATION NUMBER: GMA0591100

Measurement Number	WY Msmt #	Date	Made By:	Width (feet)	Mean Depth (feet)	Area (ft2)	Mean Velocity (ft/sec)	Stage Height (feet)	Gage Height (feet)	Discharge (cfs)	Rating 8.2 Comp. Shift (feet)	Used Shift (feet)	% Diff.	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	GZF	Notes
75	2007-01	10/30/2006	M. Anderson	81.7	3.26	266	1.47	6.50	6.50	392	-0.19	-0.19	0	Bridge	25	14:42	15:55	Good		
76	2007-02	12/08/2006	M. Anderson	63.0	4.20	265	1.48	6.69	6.69	392	-0.38	-0.38	0	Bridge	27	15:39	16:51	Good		
											Rating 9.0									
77	2007-03	12/13/2006	M. Anderson	85.0	4.17	355	1.70	7.30	7.28	603	0.00	0.00	0	Bridge	25	15:04	16:18	Fair		
78	2007-04	01/31/2007	M. Anderson	80.5	3.61	291	1.31	6.50	6.50	382	0.01	0.00	1	Bridge	29	15:06	16:15	Fair		
79	2007-05	02/19/2007	M. Anderson	84.3	3.79	319	1.35	6.80	6.78	432	0.00	0.00	0	Bridge	26	15:48	16:56	Good		
80	2007-06	03/16/2007	M. Anderson	85.5	3.77	322	1.37	6.84	6.84	441	-0.02	0.00	-1	Bridge	24	13:14	14:32	Fair		
81	2007-07	04/16/2007	M. Anderson	79.0	3.41	269	1.21	6.19	6.18	325	0.00	0.00	0	Bridge	29	13:44	14:54	Fair		
82	2007-08	05/30/2007	M. Anderson	61.0	3.37	206	1.12	5.52	5.53	229	0.00	0.00	0	Bridge	24	15:23	16:42	Fair		
83	2008-01	12/21/2007	M. Anderson	80.0	3.65	292	1.28	6.37	6.34	374	-0.13	0.16	-2	Bridge	27	14:31	15:51	Good		
84	2008-02	02/05/2008	M. Anderson	79.5	3.44	274	1.34	6.25	6.24	368	0.20	0.16	2	Bridge	28	13:54	15:19	Good		
85	2008-03	05/30/2008	M. Anderson	62.0	3.73	232	1.268	5.91	5.91	294	0.07	0.00	4	Bridge	27	15:25	16:53	Good		
86	2008-04	06/17/2008	M. Anderson	61.0	3.07	188	1.08	5.24	5.26	202	0.04	0.00	3	Bridge	24	14:25	15:31	Fair		
87	2008-05	08/19/2008	M. Anderson	62.2	2.77	172	1.14	5.28	5.29	197	0.03	0.00	-2	Bridge	23	12:18	13:30	Good		
88	2009-01	11/4/2008	M. Anderson	86.0	3.81	328	1.32	6.96	6.94	432	-0.16	-0.14	-1	Bridge	28	11:26	12:42	Good		
89	2009-02	02/20/2009	M. Anderson	82.4	3.65	301	1.25	6.60	6.60	377	-0.12	-0.14	1	Bridge	31	16:15	17:42	Good		
90	2009-03	05/27/2009	M. Anderson	79.5	3.30	262	1.01	6.10	6.09	265	-0.30	-0.26	-2	Bridge	26	14:55	16:20	Good		
91	2009-04	09/01/2009	M. Anderson	61.5	3.13	193	0.92	5.30	5.31	178	-0.22	-0.26	3	Bridge	29	14:18	16:45	Good		
92	2010-01	11/10/2009	M. Anderson	83.0	3.74	310	1.32	6.56	6.54	411	0.13	0.13	0	Bridge	31	14:21	15:54	Good		
93	2010-02	06/21/2010	M. Anderson	62.0	2.92	181	1.06	5.23	5.24	192	-0.02	0.00	-1	Bridge	25	17:09	18:24	Good		Do not have Data file
94	2010-03	09/30/2010	M. Anderson	79.0	3.06	242	1.33	6.31	6.31	322	-0.14	-0.14	0	Bridge	28	17:57	19:23	Good		



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

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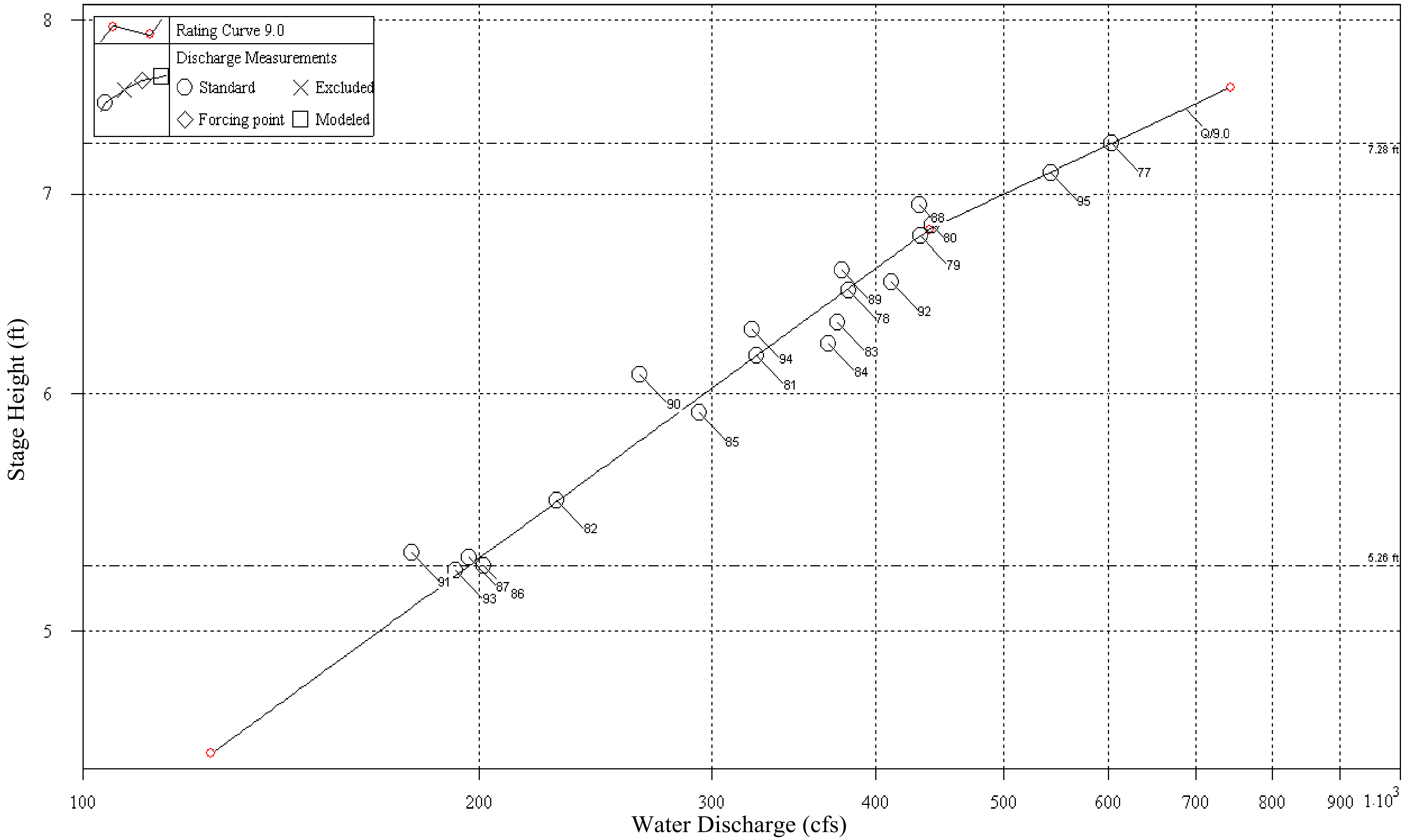

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Graham Matthews & Associates

WOOD RIVER AT WEED ROAD

RATING TABLE 8.2 --- Begin Date FEBRUARY 26, 2004

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
2.4	---	---	---	---	---	---	---	---	---	---	---	---
2.5	---	---	---	---	---	---	---	---	---	---	---	---
2.6	---	---	---	---	---	---	---	---	---	---	---	---
2.7	---	---	---	---	---	---	---	---	---	---	---	---
2.8	---	---	---	---	---	---	---	---	---	---	---	---
2.9	---	---	---	---	---	---	---	---	---	---	---	---
											---	---
3.0	---	---	---	---	---	---	---	---	---	---	---	---
3.1	---	---	---	---	---	---	---	---	---	---	---	---
3.2	---	---	---	---	---	---	---	---	---	---	---	---
3.3	---	---	---	---	---	---	---	---	---	---	---	---
3.4	---	---	---	---	---	---	---	---	---	---	---	---
3.5	---	---	---	---	---	---	---	---	---	---	---	---
3.6	---	---	---	---	---	---	---	---	---	---	---	---
3.7	---	---	---	---	---	---	---	---	---	---	---	---
3.8	---	---	---	---	---	---	---	---	---	---	---	---
3.9	---	---	---	---	---	---	*60.7*	*60.7*	*63.3*	*63.3*	---	---
											---	---
4.0	*65.8*	*67.1*	*68.3*	*69.6*	*70.9*	*72.2*	*73.4*	*74.7*	*76*	*77.3*	---	---
4.1	*78.6*	*78.6*	*79.9*	*82.5*	*83.8*	*83.8*	*85.1*	*87.7*	*89*	*89*	---	---
4.2	*91.6*	*92.9*	*94.2*	*95.5*	*96.8*	*98.1*	*99.4*	*101*	*102*	*103*	---	---
4.3	*105*	*106*	*106*	*109*	*110*	*111*	*111*	*114*	*115*	*117*	---	---
4.4	*118*	*119*	*121*	*122*	*123*	*125*	*126*	*127*	*129*	*130*	---	---
4.5	131	133	134	136	137	138	140	141	142	144	---	---
4.6	145	145	146	149	150	150	152	154	156	156	12.0	---
4.7	159	160	161	163	164	165	167	168	169	171	15.0	3.00

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Graham Matthews & Associates

WOOD RIVER AT WEED ROAD

RATING TABLE 8.2 --- Begin Date FEBRUARY 26, 2004

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
4.8	172	174	174	176	178	179	179	182	183	185	14.0	-1.00
4.9	186	187	189	190	192	193	194	196	197	199	14.0	0.00
5.0	200	201	203	204	206	207	208	210	211	213	14.0	0.00
5.1	214	214	215	218	220	220	221	224	225	225	12.0	-2.00
5.2	228	229	231	232	234	235	236	238	239	241	16.0	4.00
5.3	242	243	243	246	248	249	249	252	253	255	14.0	-2.00
5.4	256	258	259	261	262	263	265	266	268	269	14.0	0.00
5.5	270	272	273	275	276	278	279	281	282	283	14.0	0.00
5.6	285	285	286	289	291	291	292	295	296	296	13.0	-1.00
5.7	299	301	302	304	305	306	308	309	311	312	16.0	3.00
5.8	314	315	315	318	319	321	321	324	325	327	15.0	-1.00
5.9	328	330	331	332	334	335	337	338	340	341	14.0	-1.00
6.0	343	344	346	347	348	350	351	353	354	356	15.0	1.00
6.1	357	357	359	362	363	363	365	368	369	369	13.0	-2.00
6.2	373	374	376	378	379	381	383	385	387	388	19.0	6.00
6.3	390	392	392	396	398	400	400	404	406	408	20.0	1.00
6.4	410	412	415	417	419	421	424	426	428	430	22.0	2.00
6.5	433	435	437	440	442	445	447	450	452	455	25.0	3.00
6.6	457	457	460	465	467	467	470	475	478	478	23.0	-2.00
6.7	484	486	489	492	495	498	500	503	506	509	31.0	8.00
6.8	512	515	515	521	524	527	527	533	537	540	31.0	0.00
6.9	543	546	550	553	556	559	563	566	569	573	33.0	2.00
7.0	576	579	583	586	590	593	597	600	604	607	34.0	1.00

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RATING TABLE 8.2 --- Begin Date FEBRUARY 26, 2004

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
7.1	611	611	615	622	626	626	629	637	640	640	33.0	-1.00
7.2	648	652	656	660	663	667	671	675	679	683	43.0	10.00
7.3	687	691	691	699	704	708	708	716	720	724	41.0	-2.00
7.4	729	733	737	742	746	*750*	*755*	*759*	*763*	*768*	44.0	3.00
7.5	772	777	781	786	790	*795*	*799*	*804*	*809*	*813*	45.0	1.00
7.6	818	818	823	832	837	*837*	*841*	*851*	*856*	*856*	---	---
7.7	866	871	875	880	885	*890*	*895*	*900*	*905*	*910*	---	---
7.8	916	921	921	931	936	*941*	*941*	*952*	*957*	*962*	---	---
7.9	968	973	978	984	989	*995*	*1000*	*1010*	*1010*	*1020*	---	---
											---	---
8.0	1020	1030	1030	1040	1040	*1050*	*1060*	*1060*	*1070*	*1070*	---	---
8.1	1080	1080	1090	1090	1100	*1110*	*1110*	*1120*	*1120*	*1130*	---	---
8.2	1140	1140	1140	1150	1150	*1170*	*1170*	*1180*	*1180*	*1190*	---	---
8.3	1200	1200	1210	1220	1220	*1230*	*1230*	*1240*	*1250*	*1250*	---	---
8.4	1260	1270	1270	1280	1290	*1290*	*1300*	*1300*	*1310*	*1320*	---	---
8.5	1320	1330	1340	1340	1350	*1360*	*1360*	*1370*	*1380*	*1380*	---	---
8.6	1390	1400	1410	1410	1410	---	---	---	---	---	---	---
8.7	---	---	---	---	---	---	---	---	---	---	---	---
8.8	---	---	---	---	---	---	---	---	---	---	---	---
8.9	---	---	---	---	---	---	---	---	---	---	---	---
9.0	---	---	---	---	---	---	---	---	---	---	---	---
9.1	---	---	---	---	---	---	---	---	---	---	---	---
9.2	---	---	---	---	---	---	---	---	---	---	---	---
9.3	---	---	---	---	---	---	---	---	---	---	---	---
9.4	---	---	---	---	---	---	---	---	---	---	---	---

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WOOD RIVER AT WEED ROAD

RATING TABLE 9.0 --- Begin Date DECEMBER 13, 2006

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
2.4	---	---	---	---	---	---	---	---	---	---	---	---
2.5	---	---	---	---	---	---	---	---	---	---	---	---
2.6	---	---	---	---	---	---	---	---	---	---	---	---
2.7	---	---	---	---	---	---	---	---	---	---	---	---
2.8	---	---	---	---	---	---	---	---	---	---	---	---
2.9	---	---	---	---	---	---	---	---	---	---	---	---
											---	---
3.0	---	---	---	---	---	---	---	---	---	---	---	---
3.1	---	---	---	---	---	---	---	---	---	---	---	---
3.2	---	---	---	---	---	---	---	---	---	---	---	---
3.3	---	---	---	---	---	---	---	---	---	---	---	---
3.4	---	---	---	---	---	---	---	---	---	---	---	---
3.5	---	---	---	---	---	---	---	---	---	---	---	---
3.6	---	---	---	---	---	---	---	---	---	---	---	---
3.7	---	---	---	---	---	---	---	---	---	---	---	---
3.8	---	---	---	---	---	---	---	---	---	---	---	---
3.9	---	---	---	---	---	---	---	---	---	---	---	---
											---	---
4.0	---	---	---	---	---	---	---	---	---	---	---	---
4.1	---	---	---	---	---	---	---	---	---	---	---	---
4.2	---	---	---	---	---	---	---	---	---	---	---	---
4.3	---	---	---	---	---	---	---	---	---	---	---	---
4.4	---	---	---	---	---	---	---	---	---	---	---	---
4.5	---	---	---	---	---	---	*126*	*127*	*128*	*129*	---	---
4.6	*130*	*130*	*130*	*132*	*133*	*133*	*134*	*136*	*137*	*137*	8.0	---
4.7	*139*	*139*	*140*	*141*	*142*	*143*	*144*	*145*	*146*	*147*	10.0	2.00

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WOOD RIVER AT WEED ROAD

RATING TABLE 9.0 --- Begin Date DECEMBER 13, 2006

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
4.8	*148*	*149*	*149*	*151*	*152*	*153*	*153*	*155*	*156*	*157*	10.0	0.00
4.9	*158*	*159*	*160*	*161*	*162*	*163*	*164*	*165*	*166*	*167*	10.0	0.00
5.0	*168*	*169*	*170*	*171*	*172*	*173*	*174*	*175*	*176*	*177*	10.0	0.00
5.1	*179*	*179*	*180*	*182*	*183*	*183*	*184*	*186*	*187*	*187*	10.0	0.00
5.2	*190*	*191*	*192*	*193*	*194*	*195*	*197*	198	199	200	13.0	3.00
5.3	201	202	202	205	206	207	207	210	211	212	12.0	-1.00
5.4	213	215	216	217	218	219	221	222	223	225	13.0	1.00
5.5	226	227	228	230	231	232	234	235	236	237	12.0	-1.00
5.6	239	239	240	243	244	244	246	248	250	250	13.0	1.00
5.7	252	254	255	256	258	259	261	262	263	265	15.0	2.00
5.8	266	268	268	271	272	274	274	276	278	279	14.0	-1.00
5.9	281	282	284	285	287	288	290	291	293	294	15.0	1.00
6.0	296	297	299	301	302	304	305	307	308	310	16.0	1.00
6.1	312	312	313	316	318	318	320	323	324	324	14.0	-2.00
6.2	328	329	331	333	334	336	338	339	341	343	19.0	5.00
6.3	344	346	346	350	351	353	353	356	358	360	17.0	-2.00
6.4	362	363	365	367	369	371	372	374	376	378	18.0	1.00
6.5	380	381	383	385	387	389	391	392	394	396	18.0	0.00
6.6	398	398	400	404	406	406	407	411	413	413	17.0	-1.00
6.7	417	419	421	423	425	427	429	431	433	435	22.0	5.00
6.8	437	439	439	445	448	451	451	457	461	464	29.0	7.00
6.9	467	470	474	477	480	484	487	490	494	497	33.0	4.00
7.0	501	504	507	511	514	518	522	525	529	532	35.0	2.00

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WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

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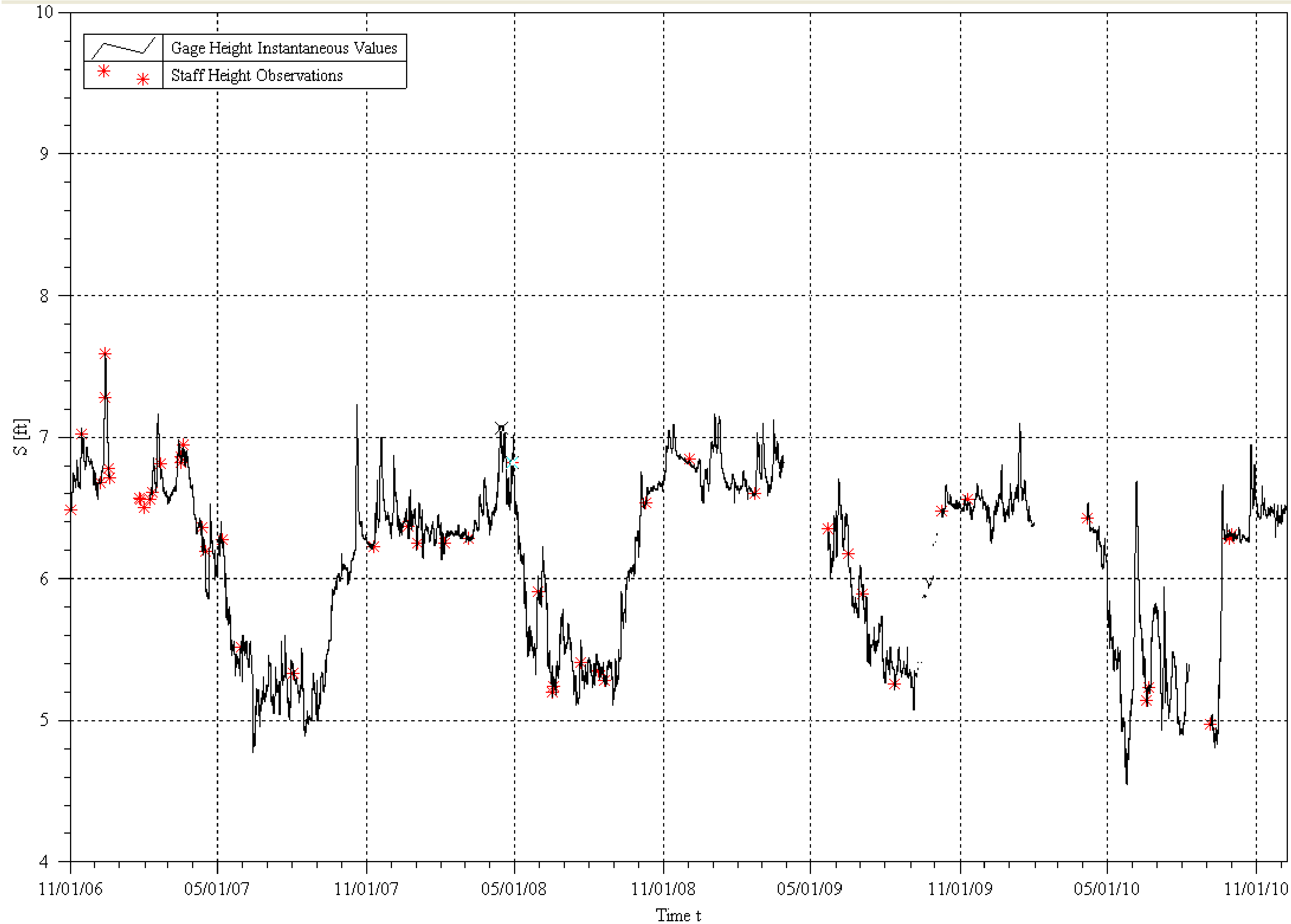
RATING TABLE 9.0 --- Begin Date DECEMBER 13, 2006

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
7.1	536	536	540	547	551	551	554	562	566	566	34.0	-1.00
7.2	573	577	581	585	589	593	597	601	604	*609*	43.0	9.00
7.3	*613*	*617*	*617*	*625*	*629*	*633*	*633*	*641*	*646*	*650*	41.0	-2.00
7.4	*654*	*658*	*663*	*667*	*671*	*676*	*680*	*684*	*689*	*693*	43.0	2.00
7.5	*698*	*702*	*707*	*711*	*716*	*720*	*725*	*729*	*734*	*739*	46.0	3.00
7.6	---	---	---	---	---	---	---	---	---	---	---	---
7.7	---	---	---	---	---	---	---	---	---	---	---	---
7.8	---	---	---	---	---	---	---	---	---	---	---	---
7.9	---	---	---	---	---	---	---	---	---	---	---	---
											---	---
8.0	---	---	---	---	---	---	---	---	---	---	---	---
8.1	---	---	---	---	---	---	---	---	---	---	---	---
8.2	---	---	---	---	---	---	---	---	---	---	---	---
8.3	---	---	---	---	---	---	---	---	---	---	---	---
8.4	---	---	---	---	---	---	---	---	---	---	---	---
8.5	---	---	---	---	---	---	---	---	---	---	---	---
8.6	---	---	---	---	---	---	---	---	---	---	---	---
8.7	---	---	---	---	---	---	---	---	---	---	---	---
8.8	---	---	---	---	---	---	---	---	---	---	---	---
8.9	---	---	---	---	---	---	---	---	---	---	---	---
9.0	---	---	---	---	---	---	---	---	---	---	---	---
9.1	---	---	---	---	---	---	---	---	---	---	---	---
9.2	---	---	---	---	---	---	---	---	---	---	---	---
9.3	---	---	---	---	---	---	---	---	---	---	---	---
9.4	---	---	---	---	---	---	---	---	---	---	---	---

Wood River at Weed Road – Water Year 2007-2010



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

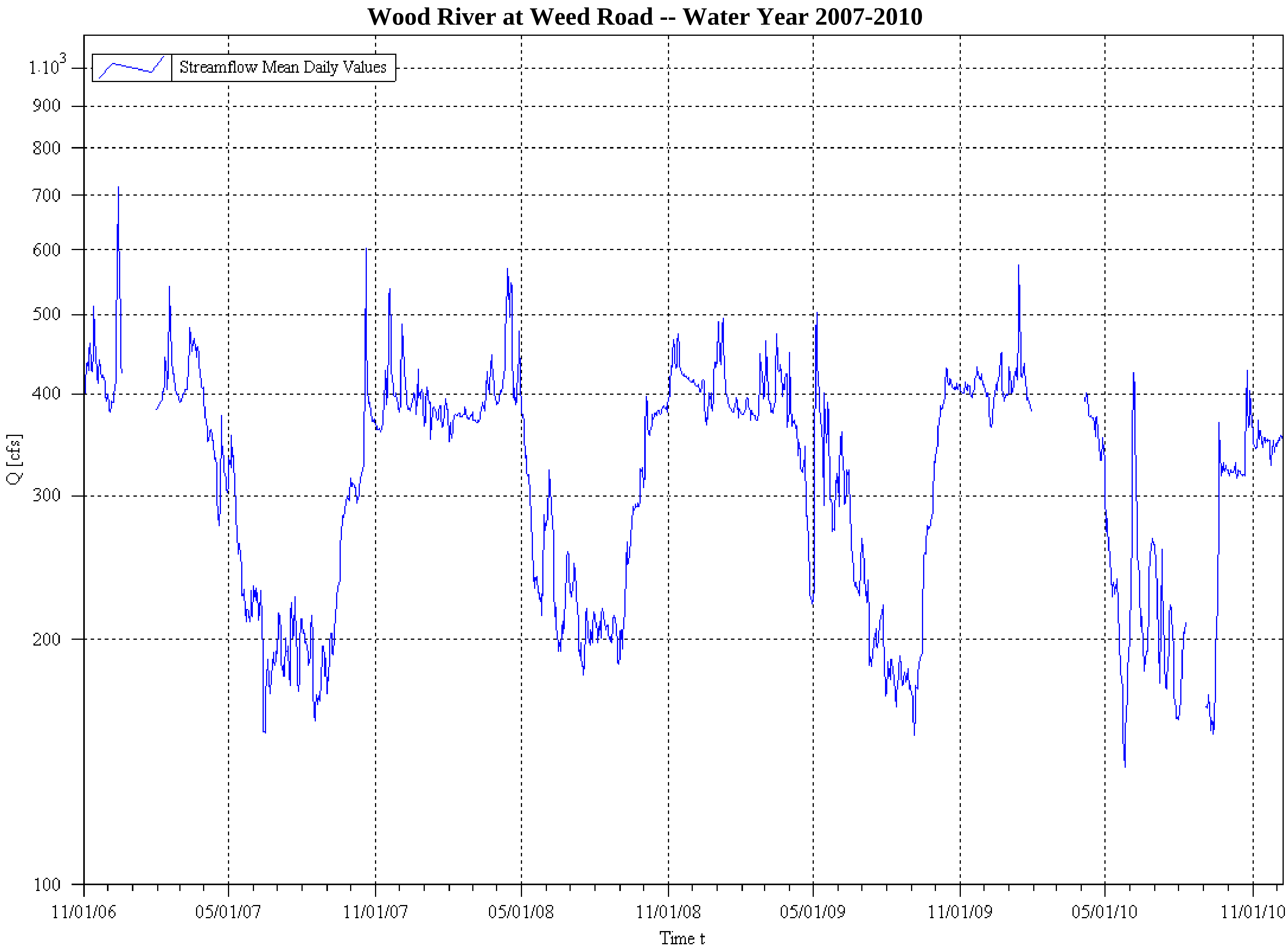
Klamath Basin Rangeland Trust

GMA

Hydrology | Geomorphology | Stream Restoration

APPENDIX

1-5



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APPENDIX
1-7

WOOD RIVER AT WEED ROAD GMA0591100
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2006 TO 9/30/2007
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	364	385	399	---	384e	389	393	307	232	192	212	172
2	371	391	389	---	385e	390	380	334	233	207	209	173
3	371	407	382	---	387e	391	368	331	227	215	203	182
4	369	436	380	---	388e	396	363	325	224	213	203	188
5	372	436	386	---	390e	399	350	355	231	205	198	197
6	375	438	392	---	391e	399	350	335	226	188	199	204
7	377	427	390	---	393	403	356	336	218	183	196	203
8	380	449	390	---	401	404	359	331	211	186	192	192
9	382	460	398	---	402	405	362	309	215	180	186	192
10	378	434	408	---	411	404	357	293	229	180	187	201
11	371	427	414	---	443	410	350	283	225	201	191	206
12	380	425	466	---	435	428	350	270	215	194	206	212
13	381	450	580	---	417	464	332	256	185	194	214	223
14	381	511	718	---	405	481	336	255	154	193	201	225
15	385	477	637	---	428	470	334	262	154	196	175	231
16	392	440	562	---	527	451	326	254	154	181	162	234
17	401	450	488	---	542	451	301	245	170	176	159	236
18	387	420	436	---	485	463	282	227	180	215	165	260
19	393	412	423	---	442	468	279	226	187	222	171	268
20	393	424	---	---	423	463	276	228	189	203	168	283
21	393	440	---	---	428	459	294	230	178	201	167	281
22	390	431	---	---	420	443	376	217	172	203	170	282
23	391	427	---	---	405	454	354	211	171	225	170	286
24	389	419	---	---	405	457	338	218	180	217	168	287
25	389	418	---	---	401	448	335	217	185	204	177	295
26	389	421	---	---	398	436	322	217	193	187	192	299
27	394	419	---	---	400	424	319	214	188	178	196	300
28	392	413	---	---	395	413	315	210	186	173	196	298
29	393	399	---	---	---	407	305	217	189	179	190	295
30	391	391	---	---	---	406	303	229	193	195	180	299
31	391	---	---	382	---	407	---	213	---	211	189	---
TOTAL	11905	12877	8638	382	11731	13283	10065	8155	5894	6097	5792	7204
MEAN	384	429	455	382	419	429	336	263	196	197	187	240
MAX	401	511	718	382	542	481	393	355	233	225	214	300
MIN	364	385	380	382	384	389	276	210	154	173	159	172
AC-FT	23610	25540	17130	758	23270	26350	19960	16180	11690	12090	11490	14290

Values For Period

TOTAL 102023 **MEAN** 315.9 **MAX** 718 **MIN** 154 **AC-FT** 202400

WOOD RIVER AT WEED ROAD GMA0591100
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2007 TO 9/30/2008
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	315	367	380	365	349	380	389	384	278	230	214	191
2	308	364	389	371	368	372	388	380	280	226	210	204
3	307	362	399	387	359	371	392	377	280	226	210	205
4	310	361	486	408	353	371	403	370	316	231	204	195
5	309	361	457	403	362	370	402	358	323	240	198	199
6	306	362	429	396	368	369	403	334	306	247	204	212
7	307	359	423	389	374	368	407	336	292	242	210	213
8	293	361	415	391	377	371	412	321	287	231	201	215
9	295	362	393	351	377	370	419	318	280	228	214	248
10	296	368	393	370	376	372	434	315	265	216	218	263
11	301	396	382	379	376	378	465	318	232	213	215	247
12	305	382	383	384	377	382	508	301	213	196	212	247
13	316	427	383	385	378	390	544	282	219	191	211	255
14	317	411	382	382	378	390	568	282	208	198	205	252
15	318	388	388	379	375	384	546	260	203	191	206	266
16	323	401	387	375	375	382	496	240	197	185	208	277
17	325	467	392	370	375	381	517	231	193	185	208	288
18	337	525	397	372	377	403	547	238	198	181	204	291
19	428	537	401	379	377	425	543	238	195	187	200	288
20	603	466	400	386	377	415	459	235	193	208	202	291
21	477	428	387	386	385	408	397	239	206	214	199	293
22	405	418	378	376	381	401	393	228	211	218	198	291
23	392	407	394	363	374	405	406	228	204	204	207	290
24	388	398	429	365	374	432	387	225	208	203	211	294
25	390	396	396	366	373	447	390	222	228	198	214	290
26	379	397	401	378	372	439	398	227	240	196	211	295
27	372	401	395	394	376	419	426	214	251	206	212	323
28	370	393	399	393	375	413	445	238	256	203	207	322
29	369	390	404	386	376	400	477	279	254	198	198	323
30	373	384	399	377	---	396	411	284	239	206	188	325
31	370	---	386	382	---	387	---	272	---	216	186	---
TOTAL	10904	12039	12427	11788	10814	12191	13372	8774	7255	6514	6385	7893
MEAN	351.7	401.4	400.9	380.3	372.9	393.3	445.8	283	241.8	210.1	206	263.1
MAX	603	537	486	408	385	447	568	384	323	247	218	325
MIN	293	359	378	351	349	368	387	214	193	181	186	191
AC-FT	21630	23880	24650	23380	21450	24180	26520	17400	14390	12920	12660	15660

Values For Period

TOTAL 120356 **MEAN** 328.8 **MAX** 603 **MIN** 181 **AC-FT** 238700

WOOD RIVER AT WEED ROAD GMA0591100
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2008 TO 9/30/2009
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	306	392	413	437	377	397	380e	222e	314	266	172	172
2	319	400	416	489	378	444	449e	232e	291	258	186	170
3	355	408	414	484	379	465	392e	313e	321	245	188	164
4	396	432	411	441	380	424	365e	467e	350	239	182	153
5	388	431	409	434	383	404	366e	503e	359	230	178	162
6	364	444	408	440	390	396	370e	433e	342	223	189	175
7	357	466	408	483	395	389	371e	421e	329	222	189	175
8	355	457	410	495	394	388	363e	396e	316	236	183	174
9	359	442	405	465	385	380	363e	387e	293	209	180	179
10	362	430	402	425	384	381	365e	371e	294	186	180	187
11	365	431	402	409	380	379	341e	362e	307	190	171	188e
12	377	462	408	402	371	382	336e	367e	322	185	165	189e
13	373	474	413	398	381	386	348e	342e	318	186	171	191e
14	376	456	416	394	379	392	339e	292e	323	192	176	192
15	378	433	414	390	379	418	324e	400e	314	198	180	210
16	379	428	391	387	377	473	322e	368e	290	200	184	253
17	376	424	370	384	376	440	320e	348e	266	202	191	255
18	379	423	374	383	373	431	324e	362e	261	206	186	254
19	381	421	366	380	372	426	327e	391e	253	196	181	261
20	381	420	376	380	372	428	336e	376e	243	195	176	276
21	378	422	395	379	372	434	345e	299e	238	200	176	275
22	378	420	401	381	379	424	283e	296e	233	200	178	272
23	379	420	394	386	419	400	283e	296	232	209	182	274
24	380	418	401	393	447	397	277e	292	235	212	179	276
25	384	418	386	395	430	410	267e	271	230	213	177	280
26	386	418	381	392	424	405	232e	273	229	215	179	281
27	384	417	394	374	401	415e	227e	272	227	220	184	287
28	384	415	421	384	394	423e	225e	281	226	209	183	294
29	385	413	438	382	---	423e	223e	313	246	183	174	330
30	380	413	437	380	---	364e	221e	311	266	177	176	329
31	389	---	431	380	---	374e	---	319	---	170	174	---
TOTAL	11533	12848	12505	12726	10871	12692	9684	10576	8468	6472	5570	6878
MEAN	372.1	428.2	403.4	410.5	388.2	409.5	322.8	341.1	282.2	208.8	179.6	229.3
MAX	396	474	438	495	447	473	449	503	359	266	191	330
MIN	306	392	366	374	371	364	221	222	226	170	165	153
AC-FT	22880	25480	24800	25240	21560	25170	19210	20980	16800	12840	11050	13640

Values For Period

TOTAL 120823 **MEAN** 331 **MAX** 503 **MIN** 153 **AC-FT** 239600

WOOD RIVER AT WEED ROAD GMA0591100
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2009 TO 9/30/2010
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	336	404	409	431	---	---	---	308	205	260	160	---
2	339	402	406	423	---	---	---	271	229	261	162	---
3	349	400	397	409	---	---	---	281	276	247	170	---
4	360e	401	400	400	---	---	---	272	344	229	173	165
5	370	401	401	402	---	---	---	262	424	226	185	165
6	379	412	391	411	---	---	392	251	405	198	204	168
7	386	412	384	419	---	---	401	249	354	176	204	171
8	382	406	367	422	---	---	399	241	320	178	203	165
9	383	404	363	430	---	---	378	225	273	210	210	157
10	387	410	369	424	---	---	376	232	254	258	---	154
11	391	409	376	415	---	---	375	235	246	237	---	159
12	396	409	389	484	---	---	376	230	240	210	---	158
13	407	401	401	575	---	---	375	227	230	196	---	153
14	429	397	398	515	---	---	373	233	207	189	---	156
15	429	395	410	441	---	---	373	233	213	174	---	179
16	415	400	403	419	---	---	373	237	209	174	---	193
17	410	403	409	418	---	---	369	220	200	180	---	206
18	410	405	417	427	---	---	355	199	183	184	---	221
19	417	414	421	436	---	---	373	184	183	197	---	291
20	416	420	420	430	---	---	375	181	189	213	---	368
21	408	422	446	413	---	---	360	180	193	220	---	335
22	407	431	449	404	---	---	357	174	193	219	---	321
23	406	423	406	393	---	---	348	154	194	218	---	317
24	407	419	399	395	---	---	332	145	221	200	---	322
25	405	417	393	391	---	---	331	140	240	198	---	330
26	405	415	392	390	---	---	331	154	251	172	---	323
27	411	423	396	386	---	---	353	162	261	167	---	322
28	406	420	399	381	---	---	352	170	264	166	---	326
29	404	410	398	381	---	---	341	180	266	160	---	324
30	410	410	398	382	---	---	332	194	262	160	---	323
31	406	---	400	---	---	---	---	197	---	159	---	---
TOTAL	12266	12295	12407	12647	0	0	9100	6621	7529	6236	1671	6472
MEAN	395.8	409.8	400.3	421.6	---	---	363.9	213.6	250.9	201.1	185.5	239.8
MAX	429	431	449	575	---	---	401	308	424	261	210	368
MIN	336	395	363	381	---	---	331	140	183	159	160	153
AC-FT	24330	24390	24610	25080	0	0	18050	13130	14930	12370	3314	12840

Values For Period

TOTAL 87244 **MEAN** 317.3 **MAX** 575 **MIN** 140 **AC-FT** 173000

Description of Gaging Station on: *Crooked Creek Above Agency Creek*

Drainage Basin: *Wood River*

1. Location

Lat. 42° 37' 38.03"N, Long. 121° 56' 17.76"W (NAD 27), SE ¼, NE ¼, Sec. 13, T34S, R7 ½E, Klamath County. The elevation of the gage is 4145.95 ft (NAVD 88). The gage can be reached by traveling 6.5 miles north on Highway 62 from the intersection of Highway 62 and Highway 97. Turn left at the intersection of Highway 62 and Modoc Point Road and then continue straight into the Agency Ranch. Travel 0.53 miles down the gravel road through a gate and over a bridge. Turn right a Y in the road and drive 0.67 miles, passing through a cattle gate. Park just before reaching the pole barn and walk 1000 ft east to the gage mounted on the right bank of Crooked Creek.

2. Hydrologic Conditions

The upper Klamath Basin primarily consists of agricultural lands interspersed with wetlands on the basin floor rising to evergreen forests on the basin slopes. Geology in the basin results from past volcanic events in the surrounding area. Average temperatures in the basin range from 17.2°F to 80.7°F based on 13 years of record from the National Weather Service station in Chiloquin. Precipitation averages 20.69 inches per year and is produced in a combination of snow and rain. Peak flows are generated from rain-on-snow events and spring snowmelt.

3. Establishment and History

The gage was installed by Graham Matthews & Associates for the Klamath Basin Rangeland Trust in July 2002. The site was upgraded to a continuous stage recording station in March 2003.

4. Gage

An Optical Stowaway Temperature sensor is mounted to the channel iron holding the staff plate. The orginal water level recording gage was a Unidata 8007WDP datalogger/pressure transducer powered by an internal lithium battery, housed in a 6-in diameter metal cylinder mounted to a post on the right bank. On July 16, 2004 the gage was upgraded to a Campbell Scientific, Inc CR10X data collector and a Design Analysis H310 pressure transducer. The CR10X is housed in large steel enclosure on the right bank. The H310 pressure transducer is 13 ft streamward of the gage housing; the orifice line is enclosed in a 2 inch galvanized pipe.

Inside recording gage: Accuracy to 0.01 ft.

Outside staff gage: One enameled section mounted on channel iron driving into streambed, 10 ft from gage; limits 0.00 ft to 3.33 ft.

5. Reference Marks (RM)

The reference mark at the site is a survey cap near a fence corner west of creek, 40 ft upstream of the gage. The elevation of the reference mark is 4150.615 ft (NAVD 88).

6. Control

Hydraulic control at the site is most likely a combination of channel control and a downstream rise in the channel bottom. Migration of dunes through the site cause regular shifting of the stage discharge relationship.

7. Discharge Measurements

Wading discharge measurements are taken at the cross section 3 ft upstream the staff plate. The measurements are made with a Price AA current meter, top-set rod, and Aquacalc streamflow computer.

CHANNEL CONDITIONS AT MEASUREMENT SECTION

The banks are near vertical, covered with grass, and have small undercuts. The measurement cross-section is deeper near the left edge water. The bed material is sand in the middle and very soft silt on the left bank. Formation and migration of dunes occurs regularly at the site.

HORIZONTAL ANGLE CORRECTIONS

No horizontal angle corrections are required at the site

FLOW CONDITIONS

Flow lines are perpendicular to the cross section. Boils are often visible in the discharge measurement cross section.

8. Floods

No floods have occurred since the establishment of the site.

9. Point of Zero Flow

Unknown.

10. Winter Flow

Typical winter flows are derived from rain and/or snowmelt. Rain-on-snow events are responsible for most of the extreme flood events on the stream. Flows at the gage are not likely to be affected by ice except during extremely cold winters.

11. Regulation

None.

12. Diversion

Crooked Creek is diverted in several places for agricultural purposes during a portion of the year.

13. Accuracy

The accuracy of the site is fair due to the soft bed material and undercut banks.

14. Cooperation

None.

15. Land Ownership

The gage is located on private property.

16. Purpose of Record

The purpose of the gaging record is to study streamflow, sediment transport, and nutrient load in this section of Crooked Creek above the confluence with Agency Creek.

17. Cross Section Survey History

Cross Section #1 surveyed: October 2003

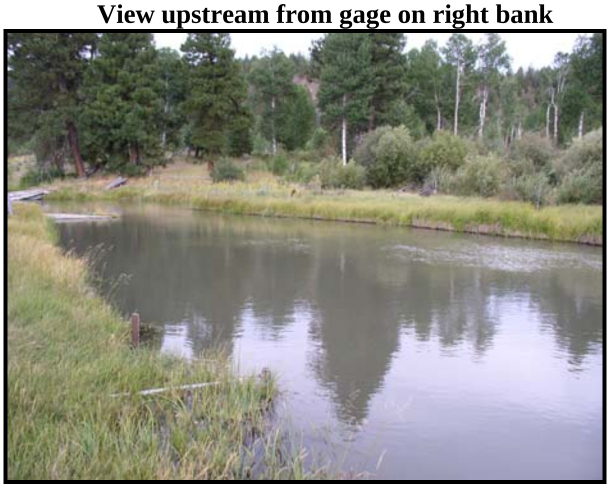
18. Rating Table History

Rating Table #1.1: Valid from July 18, 2002 to June 4, 2004
Rating Table #2.1: Valid from June 4, 2004 to Present

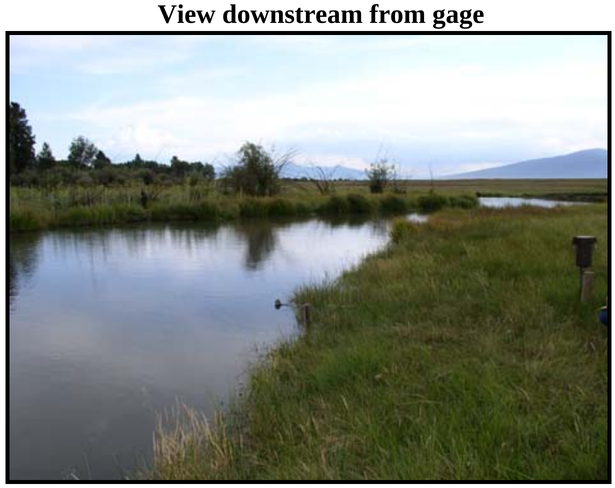
19. Photo History

Photographs of gage taken in September 2003.

View upstream from gage on right bank



View downstream from gage



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DISCHARGE SUMMARY SHEET

LOCATION: CROOKED CREEK above AGENCY CREEK **WATER YEAR:** 2008-2010

STATION NUMBER: GMA0591040

Measurement Number	WY Msmt #	Date	Made By:	Width (feet)	Mean Depth (feet)	Area (ft2)	Mean Velocity (ft/sec)	Stage Height (feet)	Gage Height (feet)	Discharge (cfs)	Rating __1.2__ Comp. Shift (feet)	Used Shift (feet)	% Diff.	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	GZF	Notes
56	2008-01	11/27/2007	M. Anderson	41.6	1.99	82.90	0.76	1.98	1.98	63.0	0.00	0.00	0	Wading	25	15:41	16:21	Good		
57	2008-02	05/15/2008	M. Anderson	41.6	1.73	71.90	1.02	1.71	1.71	71.9	-0.65	-0.55	4	Wading	30	12:45	14:00	Good		
58	2008-03	06/26/2008	M. Anderson	41.6	1.47	61.30	0.98	1.57	1.57	64.3	-0.42	-0.54	-4	Wading	27	13:54	14:25	Good		
59	2008-04	08/19/2008	M. Anderson	41.5	1.83	75.90	0.78	1.83	1.83	75.9	0.04	0.00	-1	Wading	28	14:42	15:14	Good		
60	2009-01	11/22/2008	M. Anderson	41.6	2.07	85.94	0.77	2.09	2.09	66.2	0.04	0.00	2	Wading	26	15:25	15:58	Good		
61	2009-02	02/20/2009	M. Anderson	41.7	1.60	66.84	1.00	1.59	1.58	66.9	0.58	0.48	4	Wading	32	13:24	14:03	Good		
62	2009-03	05/01/2009	M. Anderson	41.6	1.55	64.38	0.98	1.53	1.52	63.0	0.46	0.48	-1	Wading	28	12:36	13:12	Good		
63	2009-04	05/29/2009	M. Anderson	41.8	1.58	66.13	0.94	1.54	1.54	62.2	0.39	0.48	-2	Wading	25	17:08	17:37	Good		
64	2010-01	11/06/2009	M. Anderson	41.6	2.28	94.77	0.74	2.28	2.28	69.8	-0.04	0.00	-2	Wading	30	14:23	15:17	Good		
65	2010-02	06/30/2010	M. Anderson	41.6	2.20	91.50	0.73	2.22	2.21	66.8	-0.06	0.00	-3	Wading	24	18:18	18:58	Good		Do not have Data File
66	2010-03	09/24/2010	M. Anderson	41.8	2.91	121.47	0.66	2.88	2.88	79.7	-0.33	-0.29	-2	Wading	25	10:02	10:57	Good		Some veg. along right side, not able to get all 0.8 msmts

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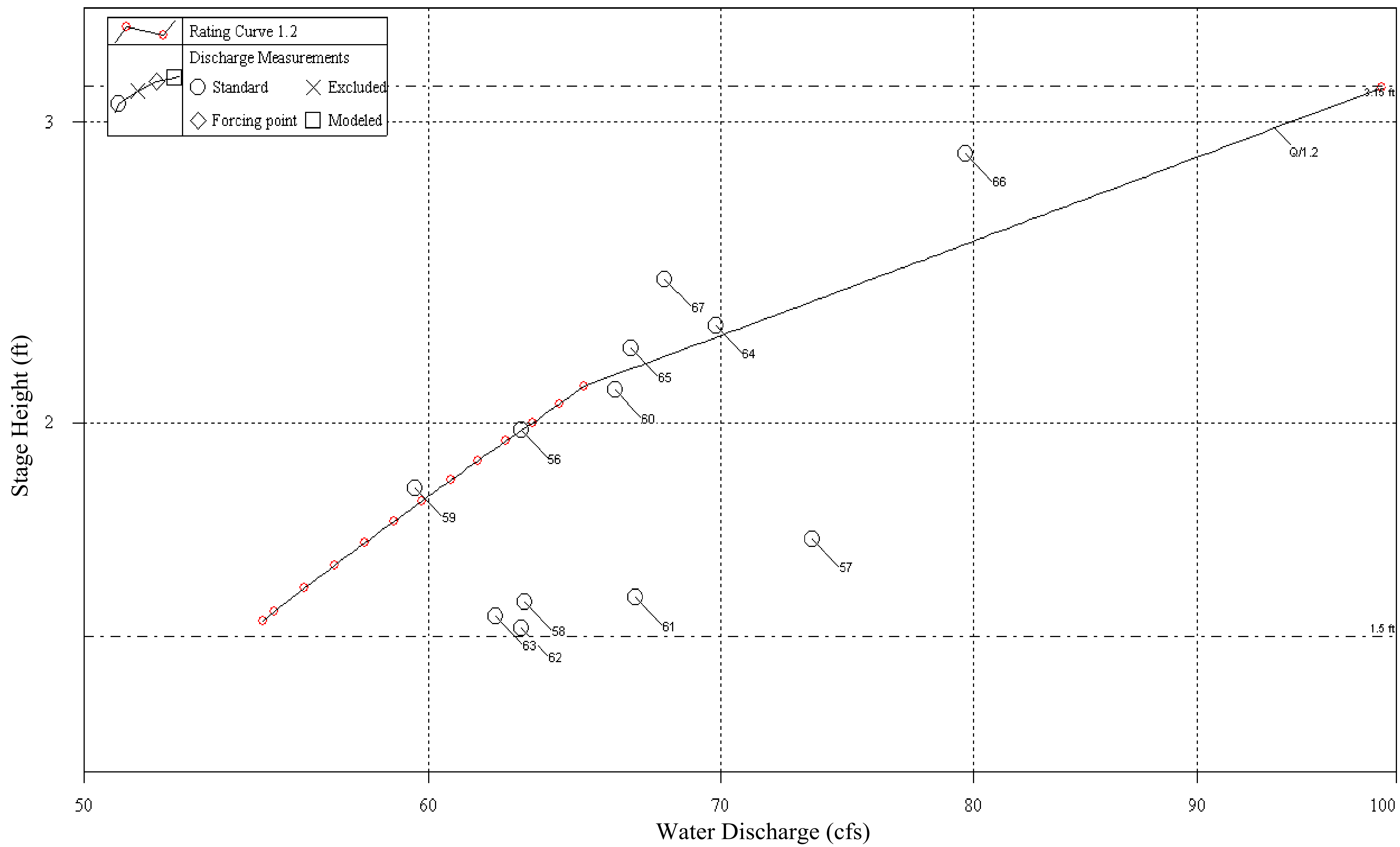

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APPENDIX

2-3

Graham Matthews & Associates

CROOKED CREEK above AGENCY CREEK

RATING TABLE 1.2 – Begin Date OCTOBER 1, 2007

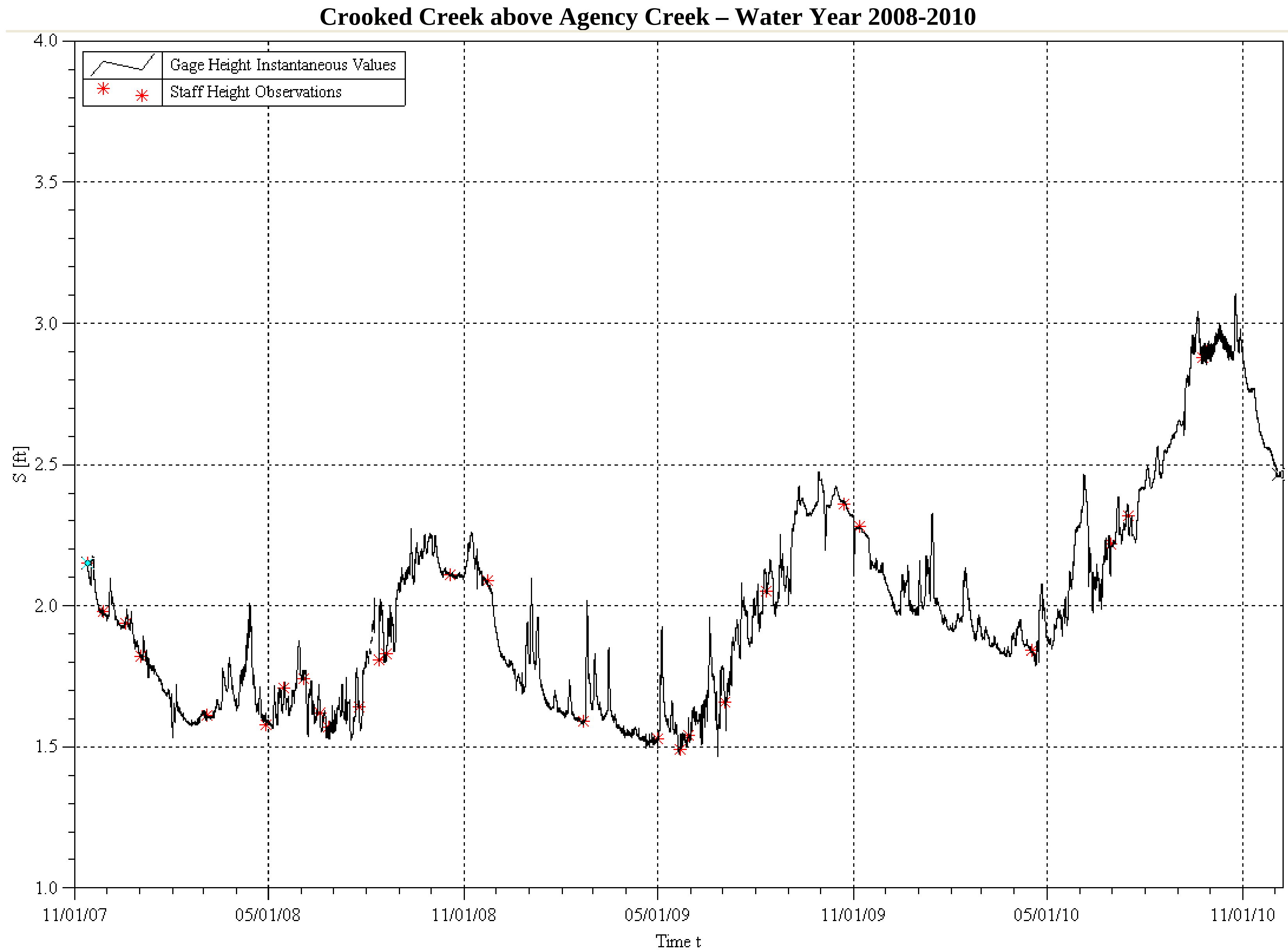
GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
0.0	---	---	---	---	---	---	---	---	---	---		
0.1	---	---	---	---	---	---	---	---	---	---	---	
0.2	---	---	---	---	---	---	---	---	---	---	---	---
0.3	---	---	---	---	---	---	---	---	---	---	---	---
0.4	---	---	---	---	---	---	---	---	---	---	---	---
0.5	---	---	---	---	---	---	---	---	---	---	---	---
0.6	---	---	---	---	---	---	---	---	---	---	---	---
0.7	---	---	---	---	---	---	---	---	---	---	---	---
0.8	---	---	---	---	---	---	---	---	---	---	---	---
0.9	---	---	---	---	---	---	---	---	---	---	---	---
1.0	---	---	---	---	---	---	---	---	---	---	---	---
1.1	---	---	---	---	---	---	---	---	---	---	---	---
1.2	---	---	---	---	---	---	---	---	---	---	---	---
1.3	---	---	---	---	---	---	---	---	---	---	---	---
1.4	---	---	---	---	---	---	---	---	---	---	---	---
1.5	---	---	---	55.0	55.1	55.3	55.5	55.7	55.8	56.0	---	---
1.6	56.2	56.4	56.6	56.7	56.9	57.1	57.3	57.4	57.6	57.8	1.8	---
1.7	58.0	58.2	58.4	58.5	58.7	58.9	59.1	59.3	59.4	59.6	1.8	-0.01
1.8	59.8	60.0	60.1	60.3	60.5	60.7	60.9	61.1	61.2	61.4	1.8	0.01
1.9	61.6	61.8	61.9	62.1	62.3	62.5	62.7	62.8	63.0	63.2	1.8	0.00
2.0	63.4	63.6	63.7	63.9	64.1	64.3	64.5	64.6	64.8	64.9	1.7	-0.06
2.1	65.1	65.4	65.8	66.1	66.4	66.7	67.1	67.4	67.7	68.1	3.1	1.37
2.2	68.4	68.7	69.0	69.4	69.7	70.0	70.3	70.7	71.0	71.3	3.3	0.16
2.3	71.7	71.7	72.3	72.3	73.0	73.0	73.6	73.6	74.3	74.3	3.0	-0.32

Graham Matthews & Associates

CROOKED CREEK above AGENCY CREEK

RATING TABLE 1.2 -- Begin Date OCTOBER 1, 2007

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
2.4	74.9	74.9	75.6	75.6	76.2	76.2	76.9	76.9	77.5	77.5	3.3	0.32
2.5	78.2	78.5	78.9	79.2	79.5	79.8	80.2	80.5	80.8	81.1	3.6	0.33
2.6	81.5	81.8	82.1	82.5	82.8	83.1	83.4	83.8	84.1	84.4	3.3	-0.33
2.7	84.7	85.1	85.4	85.7	86.1	86.4	86.7	87.0	87.4	87.7	3.3	0.00
2.8	88.0	88.0	88.7	88.7	89.3	89.3	90.0	90.0	90.6	90.6	2.9	-0.32
2.9	91.3	91.3	91.9	91.9	92.6	92.6	93.3	93.3	93.9	93.9	3.3	0.32
3.0	94.6	94.9	95.2	95.5	95.9	96.2	96.5	96.8	97.2	97.5	3.6	0.33
3.1	97.8	98.2	98.5	98.8	99.1	---	---	---	---	---		
3.2	---	---	---	---	---	---	---	---	---	---		
3.3	---	---	---	---	---	---	---	---	---	---		
3.4	---	---	---	---	---	---	---	---	---	---		
3.5	---	---	---	---	---	---	---	---	---	---		
3.6	---	---	---	---	---	---	---	---	---	---		
3.7	---	---	---	---	---	---	---	---	---	---		
3.8	---	---	---	---	---	---	---	---	---	---		
3.9	---	---	---	---	---	---	---	---	---	---		
4.0	---	---	---	---	---	---	---	---	---	---		
4.1	---	---	---	---	---	---	---	---	---	---		
4.2	---	---	---	---	---	---	---	---	---	---		
4.3	---	---	---	---	---	---	---	---	---	---		
4.4	---	---	---	---	---	---	---	---	---	---		
4.5	---	---	---	---	---	---	---	---	---	---		
4.6	---	---	---	---	---	---	---	---	---	---		
4.7	---	---	---	---	---	---	---	---	---	---		



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

Klamath Basin Rangeland Trust

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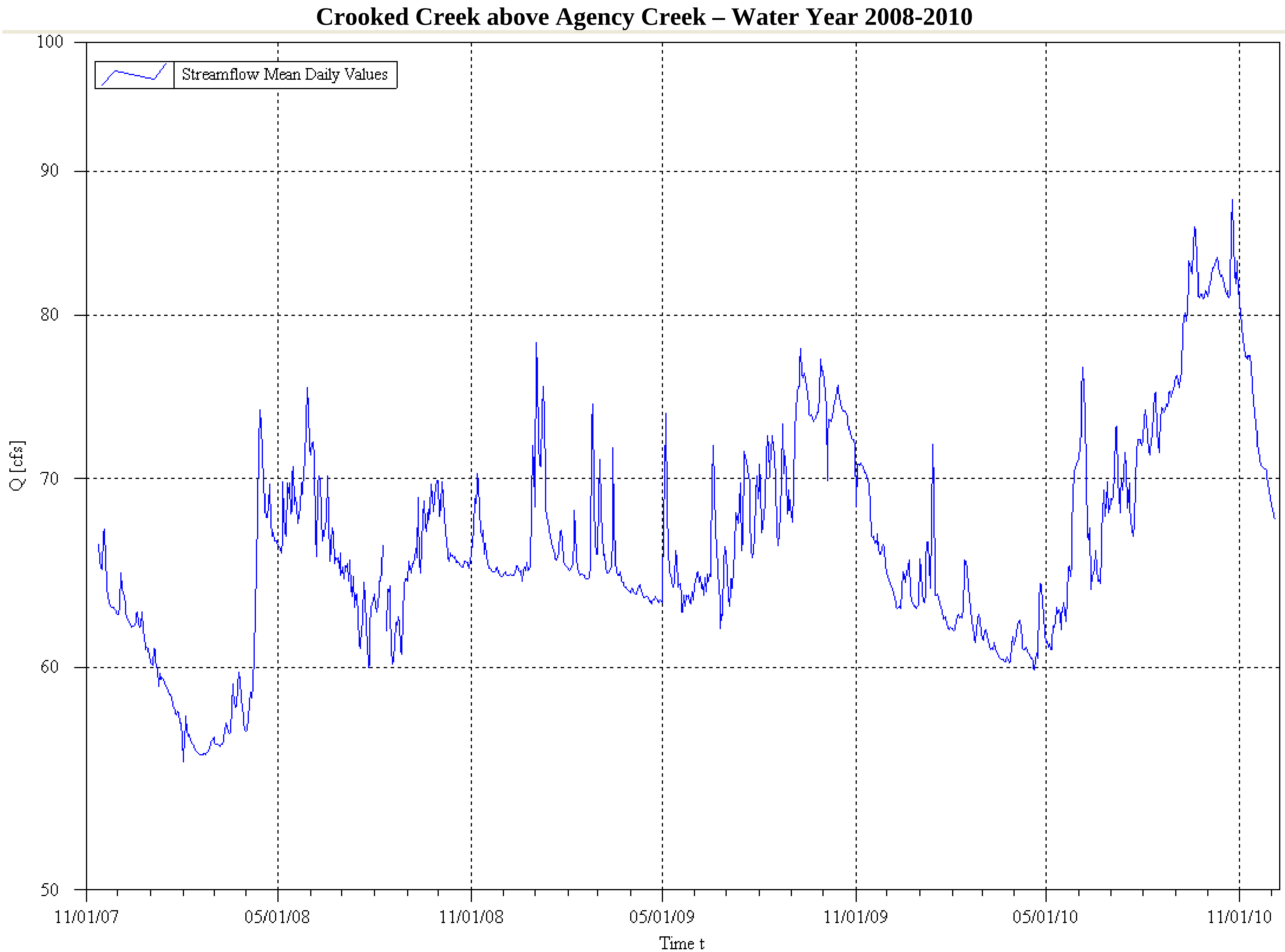
APPENDIX

2-5



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

Klamath Basin Rangeland Trust

Hydrology | Geomorphology | Stream Restoration

APPENDIX

2-7

CROOKED CREEK ABOVE AGENCY CREEK GMA0591400
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2007 TO 9/30/2008
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	57.0	---	63.0	60.0	55.0	57.0	57.0	66.0	71.0	65.0	64.0	64.0
2	65.0	---	63.0	60.0	57.0	56.0	57.0	66.0	72.0	65.0	63.0	65.0
3	65.0	---	63.0	60.0	56.0	56.0	58.0	66.0	72.0	64.0	63.0	65.0
4	65.0	---	65.0	61.0	58.0	56.0	58.0	66.0	72.0	65.0	63.0	65.0
5	65.0	---	64.0	61.0	57.0	56.0	59.0	66.0	71.0	65.0	64.0	65.0
6	65.0	---	64.0	60.0	57.0	56.0	59.0	70.0	67.0	65.0	64.0	65.0
7	65.0	---	64.0	60.0	57.0	56.0	59.0	68.0	66.0	64.0	64.0	65.0
8	65.0	---	63.0	60.0	57.0	56.0	59.0	67.0	70.0	65.0	65.0	66.0
9	66.0	---	63.0	59.0	56.0	56.0	61.0	67.0	70.0	66.0	66.0	66.0
10	67.0	---	63.0	60.0	56.0	56.0	63.0	70.0	70.0	64.0	65e	66.0
11	67.0	---	62.0	59.0	56.0	57.0	65.0	69.0	68.0	64.0	63e	69.0
12	67.0	---	62.0	59.0	56.0	57.0	68.0	70.0	68.0	65.0	62.0	68.0
13	67.0	66.0	62.0	59.0	56.0	57.0	72.0	68.0	67.0	63.0	64.0	65.0
14	67.0	65.0	62.0	59.0	56.0	57.0	74.0	68.0	67.0	64.0	64.0	65.0
15	67.0	65.0	62.0	59.0	56.0	57.0	73.0	70.0	67.0	64.0	64.0	66.0
16	66.0	65.0	62.0	59.0	56.0	57.0	71.0	71.0	68.0	63.0	63.0	68.0
17	65.0	67.0	62.0	59.0	56.0	57.0	71.0	69.0	70.0	61.0	61.0	69.0
18	66.0	67.0	62.0	59.0	56.0	58.0	70.0	69.0	68.0	61.0	60.0	67.0
19	72.0	65.0	63.0	59.0	56.0	59.0	68.0	69.0	65.0	61.0	60.0	67.0
20	75.0	64.0	63.0	59.0	56.0	59.0	68.0	68.0	66.0	62.0	61.0	68.0
21	73.0	64.0	62.0	58.0	56.0	58.0	68.0	68.0	66.0	62.0	62.0	68.0
22	66.0	64.0	62.0	58.0	56.0	58.0	68.0	68.0	67.0	64.0	62.0	68.0
23	---	63.0	62.0	58.0	56.0	58.0	70.0	70.0	67.0	64.0	63.0	68.0
24	---	63.0	63.0	58.0	56.0	59.0	67.0	70.0	65.0	62.0	62.0	70.0
25	---	63.0	62.0	58.0	56.0	60.0	67.0	69.0	66.0	61.0	62.0	69.0
26	---	63.0	61.0	58.0	56.0	59.0	67.0	71.0	66.0	60.0	61.0	68.0
27	---	63.0	61.0	58.0	56.0	58.0	67.0	71.0	66.0	60.0	61.0	69.0
28	---	63.0	61.0	58.0	56.0	58.0	67.0	73.0	65.0	62.0	63.0	70.0
29	---	63.0	61.0	57.0	57.0	58.0	67.0	75.0	66.0	63.0	64.0	70.0
30	---	63.0	61.0	57.0	---	57.0	67.0	74.0	65.0	63.0	64.0	70.0
31	---	---	61.0	57.0	---	57.0	---	72.0	---	63.0	65.0	---
TOTAL	1463	1156	1934	1826	1631	1776	1965	2144	2034	1960	1952	2014
MEAN	66.5	64.3	62.3	58.9	56.2	57.4	65.5	69.1	67.8	63.2	63.0	67.1
MAX	75.0	67.0	65.0	61.0	58.0	60.0	74.0	75.0	72.0	66.0	66.0	70.0
MIN	57.0	63.0	61.0	57.0	55.0	56.0	57.0	66.0	65.0	60.0	60.0	64.0
AC-FT	2902	2293	3836	3622	3235	3523	3898	4253	4034	3888	3872	3995

Values For Period

TOTAL 21855 **MEAN** 63.3 **MAX** 75.0 **MIN** 55.0 **AC-FT** 43350

CROOKED CREEK ABOVE AGENCY CREEK GMA0591400
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2008 TO 9/30/2009
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	70.0	66.0	65.0	69.0	65.0	66.0	64.0	63.0	64.0	66.0	70.0	68.0
2	68.0	66.0	65.0	78.0	65.0	69.0	64.0	64.0	64.0	65.0	71.0	68.0
3	68.0	67.0	65.0	76.0	65.0	71.0	64.0	67.0	65.0	64.0	70.0	69.0
4	70.0	69.0	65.0	72.0	65.0	68.0	64.0	70.0	65.0	63.0	67.0	73.0
5	69.0	69.0	65.0	71.0	65.0	67.0	64.0	74.0	64.0	64.0	67.0	74.0
6	68.0	70.0	65.0	71.0	67.0	66.0	64.0	68.0	65.0	64.0	68.0	75.0
7	67.0	70.0	65.0	74.0	68.0	66.0	64.0	66.0	64.0	64.0	69.0	75.0
8	66.0	70.0	65.0	75.0	67.0	66.0	64.0	65.0	64.0	65.0	71.0	75.0
9	66.0	68.0	65.0	74.0	66.0	65.0	64.0	65.0	64.0	66.0	72.0	77.0
10	66.0	67.0	65.0	70.0	65.0	65.0	64.0	64.0	64.0	68.0	72.0	78.0
11	65.0	67.0	65.0	68.0	65.0	65.0	64.0	64.0	65.0	68.0	70.0	76.0
12	66.0	67.0	65.0	68.0	65.0	65.0	64.0	64.0	64.0	67.0	71.0	76.0
13	66.0	66.0	65.0	68.0	65.0	65.0	64.0	64.0	65.0	69.0	72.0	76.0
14	66.0	66.0	65.0	67.0	65.0	65.0	64.0	66.0	64.0	70.0	72.0	76.0
15	66.0	66.0	65.0	67.0	65.0	67.0	64.0	66.0	65.0	69.0	72.0	75.0
16	66.0	66.0	65.0	66.0	65.0	72.0	64.0	64.0	65.0	66.0	71.0	75.0
17	65.0	65.0	65.0	66.0	65.0	68.0	64.0	64.0	65.0	66.0	70.0	74.0
18	65.0	65.0	65.0	66.0	64.0	65.0	63.0	64.0	70.0	72.0	67.0	74.0
19	65.0	65.0	64.0	66.0	64.0	65.0	63.0	64.0	72.0	71.0	66.0	74.0
20	65.0	65.0	65.0	66.0	65.0	65.0	63.0	63.0	70.0	71.0	67.0	74.0
21	65.0	65.0	65.0	65.0	65.0	65.0	63.0	63.0	67.0	70.0	67.0	74.0
22	65.0	65.0	65.0	66.0	65.0	65.0	63.0	64.0	66.0	70.0	68.0	73.0
23	65.0	65.0	65.0	66.0	73.0	64.0	63.0	63.0	65.0	70.0	70.0	74.0
24	65.0	65.0	65.0	67.0	74.0	64.0	63.0	64.0	64.0	68.0	73.0	74.0
25	65.0	65.0	65.0	67.0	69.0	64.0	64.0	64.0	63.0	66.0	70.0	74.0
26	65.0	65.0	65.0	66.0	69.0	64.0	63.0	64.0	62.0	66.0	71.0	74.0
27	65.0	65.0	65.0	65.0	67.0	64.0	63.0	63.0	63.0	66.0	70.0	74.0
28	65.0	65.0	68.0	65.0	66.0	64.0	63.0	63.0	63.0	67.0	68.0	75.0
29	65.0	65.0	72.0	65.0	---	64.0	63.0	64.0	65.0	69.0	68.0	77.0
30	65.0	65.0	71.0	65.0	---	64.0	63.0	64.0	66.0	70.0	69.0	76.0
31	65.0	---	68.0	65.0	---	64.0	---	63.0	---	69.0	68.0	---
TOTAL	2048	1990	2033	2120	1854	2037	1908	2008	1952	2089	2157	2227
MEAN	66.2	66.3	65.5	68.4	66.1	65.7	63.6	64.8	65	67.4	69.6	74.2
MAX	70.0	70.0	72.0	78.0	74.0	72.0	64.0	74.0	72.0	72.0	73.0	78.0
MIN	65.0	65.0	64.0	65.0	64.0	64.0	63.0	63.0	62.0	63.0	66.0	68.0
AC-FT	4062	3947	4032	4205	3677	4040	3784	3983	3872	4143	4278	4417

Values For Period

TOTAL 24423 **MEAN** 66.9 **MAX** 78.0 **MIN** 62.0 **AC-FT** 48440

CROOKED CREEK ABOVE AGENCY CREEK GMA0591400
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2009 TO 9/30/2010
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	76.0	68.0	65.0	66.0	62.0	61.0	61.0	61.0	71.0	69.0	72.0	76.0
2	76.0	71.0	65.0	65.0	62.0	61.0	61.0	61.0	72.0	69.0	73.0	76.0
3	75.0	71.0	64.0	64.0	62.0	61.0	62.0	61.0	73.0	69.0	74.0	76.0
4	74.0	71.0	64.0	63.0	62.0	62.0	62.0	61.0	75.0	69.0	73.0	75.0
5	70.0	71.0	64.0	63.0	62.0	62.0	62.0	61.0	77.0	70.0	72.0	76.0
6	72.0	71.0	64.0	64.0	63.0	62.0	62.0	61.0	75.0	73.0	72.0	76.0
7	73.0	71.0	64.0	65.0	63.0	61.0	62.0	61.0	74.0	73.0	71.0	76.0
8	73.0	71.0	63.0	66.0	62.0	61.0	61.0	62.0	70.0	70.0	72.0	79.0
9	73.0	70.0	63.0	66.0	63.0	61.0	61.0	62.0	67.0	69.0	72.0	80.0
10	74.0	70.0	63.0	65.0	62.0	61.0	61.0	62.0	67.0	68.0	73.0	80.0
11	74.0	70.0	63.0	64.0	63.0	61.0	61.0	63.0	67.0	69.0	74.0	80.0
12	75.0	70.0	63.0	67.0	65.0	61.0	61.0	63.0	64.0	70.0	75.0	80.0
13	75.0	70.0	63.0	72.0	65.0	61.0	61.0	63.0	64.0	69.0	75.0	82.0
14	75.0	70.0	63.0	69.0	65.0	61.0	61.0	63.0	65.0	70.0	73.0	84.0
15	76.0	68.0	64.0	64.0	65.0	61.0	61.0	62.0	65.0	71.0	72.0	83.0
16	75.0	67.0	65.0	64.0	64.0	61.0	60.0	63.0	65.0	71.0	72.0	83.0
17	75.0	67.0	65.0	64.0	64.0	61.0	60.0	63.0	66.0	68.0	72.0	83.0
18	74.0	67.0	64.0	64.0	63.0	60.0	60.0	63.0	65.0	69.0	73.0	85.0
19	74.0	66.0	64.0	64.0	62.0	60.0	60.0	63.0	64.0	70.0	74.0	86.0
20	74.0	67.0	65.0	63.0	62.0	60.0	60.0	62.0	64.0	68.0	74.0	86.0
21	74.0	66.0	65.0	63.0	62.0	60.0	60.0	64.0	64.0	68.0	74.0	83.0
22	74.0	67.0	65.0	63.0	61.0	60.0	61.0	65.0	66.0	67.0	74.0	82.0
23	74.0	66.0	64.0	62.0	61.0	60.0	60.0	65.0	67.0	67.0	74.0	81.0
24	74.0	66.0	63.0	62.0	62.0	60.0	63.0	65.0	68.0	68.0	74.0	81.0
25	73.0	66.0	63.0	62.0	62.0	61.0	64.0	65.0	69.0	70.0	75.0	81.0
26	73.0	66.0	63.0	63.0	63.0	60.0	64.0	67.0	68.0	72.0	75.0	81.0
27	73.0	66.0	63.0	62.0	62.0	60.0	63.0	69.0	69.0	72.0	75.0	81.0
28	72.0	66.0	63.0	62.0	62.0	60.0	63.0	70.0	70.0	72.0	75.0	81.0
29	72.0	65.0	63.0	62.0	---	61.0	63.0	71.0	68.0	72.0	75.0	82.0
30	72.0	65.0	63.0	62.0	---	61.0	62.0	71.0	68.0	72.0	75.0	82.0
31	72.0	---	63.0	62.0	---	61.0	---	71.0	---	72.0	76.0	---
TOTAL	2286	2046	1976	1987	1756	1884	1843	1984	2047	2166	2280	2417
MEAN	73.8	68.2	63.8	64.1	62.7	60.9	61.5	64.0	68.2	69.9	73.6	80.6
MAX	76.0	71.0	65.0	72.0	65.0	62.0	64.0	71.0	77.0	73.0	76.0	86.0
MIN	70.0	65.0	63.0	62.0	61.0	60.0	60.0	61.0	64.0	67.0	71.0	75.0
AC-FT	4534	4058	3919	3941	3483	3737	3656	3935	4060	4296	4522	4794

Values For Period

TOTAL 24672 **MEAN** 67.6 **MAX** 86.0 **MIN** 60.0 **AC-FT** 48940

GRAHAM MATTHEWS & ASSOCIATES

Hydrology -- Geomorphology -- Stream Restoration

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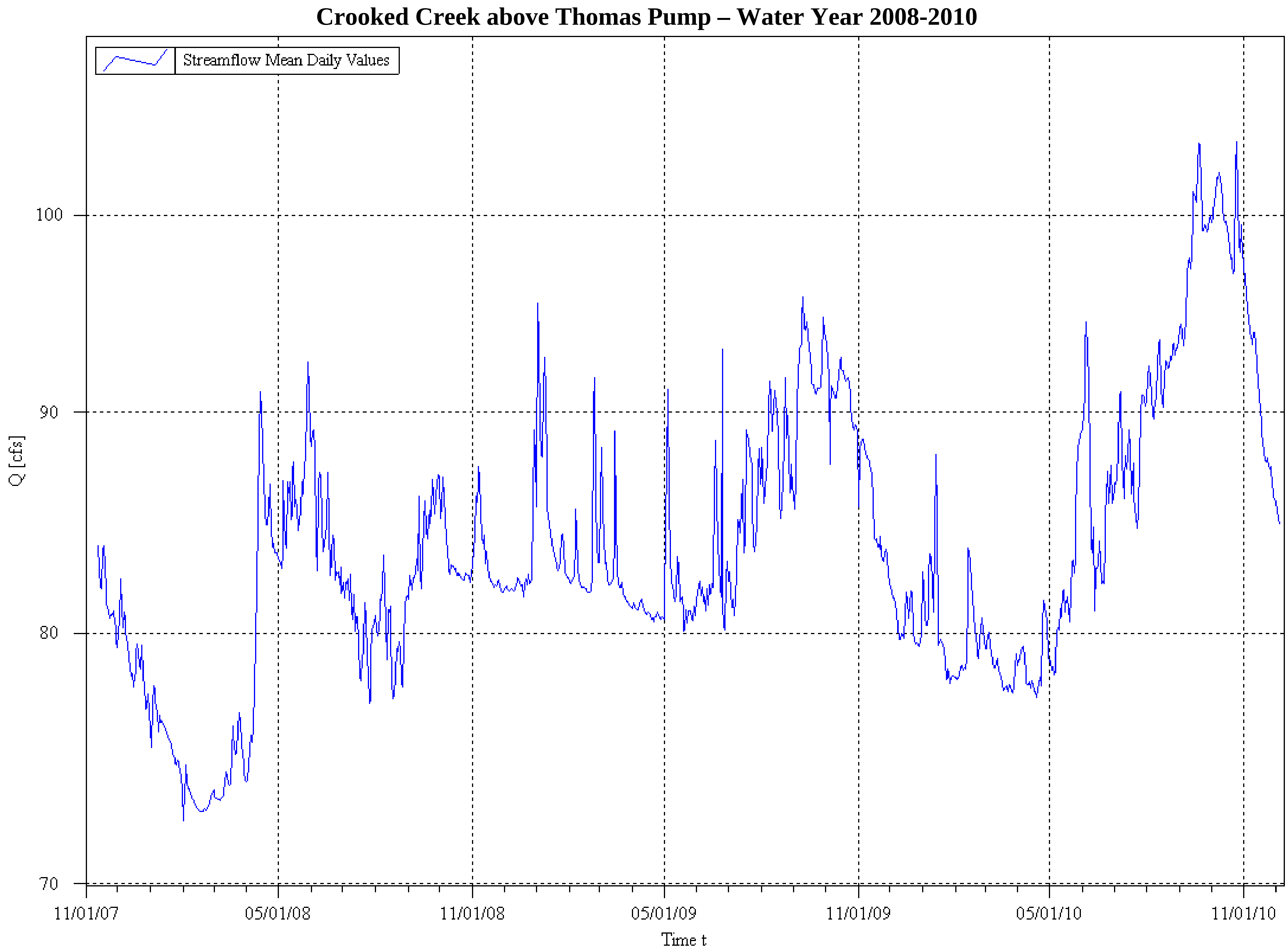
DISCHARGE SUMMARY SHEET

LOCATION: CROOKED CREEK AT THOMAS PUMP **WATER YEAR:** 2008-2010

STATION NUMBER: GMA0591010

Measurement Number	WY Msmt #	Date	Made By:	Width (feet)	Mean Depth (feet)	Area (ft2)	Mean Velocity (ft/sec)	Stage Height (feet)	Gage Height (feet)	Discharge (cfs)	Rating __N/A___ Comp. Shift (feet)	Used Shift (feet)	% Diff.	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	GZF	Notes
1	2008-01	04/07/2008	M. Anderson	37.3	3.18	118.7	0.80	---	---	94.4	---	---	---	Bridge	25	16:03		Fair		
2	2008-02	05/15/2008	M. Anderson	37.3	3.23	120.6	0.76	---	---	91.5	---	---	---	Bridge	23	19:35		Good		
3	2008-03	06/26/2008	M. Anderson	37.4	3.19	119.2	0.68	---	---	81.3	---	---	---	Bridge	23	18:00		Good		
4	2009-01	05/29/2009	M. Anderson	37.3	3.57	133.2	0.64	---	---	85.7	---	---	---	Bridge	31	13:09		Good		
5	2010-01	06/30/2010	M. Anderson	---	---	---	---	---	---	88.4	---	---	---	Bridge	---	13:02		Fair		Do not have Data File
6	2010-02	09/24/2010	M. Anderson	37.3	2.29	85.4	1.15	---	---	97.891	---	---	---	Bridge	30	16:47		Good		



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

Klamath Basin Rangeland Trust

GMA

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APPENDIX

3-7

CROOKED CREEK ABOVE THOMAS PUMP
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2007 TO 9/30/2008
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	78	---	79e	76e	72e	74e	74e	83e	88e	82e	81e	81e
2	86	---	80e	75e	74e	73e	74e	83e	89e	82e	80e	83e
3	86	---	81e	77e	73e	73e	75e	83e	89e	82e	80e	82e
4	86	---	82e	78e	75e	73e	75e	83e	89e	82e	80e	82e
5	86	---	81e	78e	74e	73e	76e	83e	88e	82e	81e	82e
6	86	---	80e	77e	74e	73e	75e	87e	84e	82e	81e	82e
7	86	---	81e	77e	74e	73e	76e	85e	83e	81e	81e	82e
8	86	---	81e	77e	73e	73e	76e	84e	87e	82e	82e	83e
9	87	---	80e	76e	73e	73e	78e	84e	87e	83e	83e	83e
10	88	---	80e	77e	73e	73e	80e	87e	87e	81e	82e	83e
11	88	---	80e	76e	73e	74e	82e	86e	85e	81e	80e	86e
12	88	---	79e	76e	73e	74e	85e	87e	85e	82e	79e	85e
13	88	84e	79e	76e	73e	74e	89e	85e	84e	80e	81e	82e
14	88	83e	78e	76e	73e	74e	91e	85e	84e	81e	81e	82e
15	88	82e	78e	76e	73e	74e	90e	87e	84e	81e	81e	83e
16	86	82e	78e	76e	73e	74e	88e	88e	85e	80e	80e	85e
17	86	84e	78e	76e	73e	74e	88e	86e	87e	78e	78e	86e
18	87	84e	78e	76e	73e	75e	87e	86e	85e	78e	77e	85e
19	93	83e	79e	76e	73e	76e	85e	86e	82e	78e	77e	84e
20	96	82e	80e	76e	73e	76e	85e	85e	83e	79e	78e	85e
21	94	81e	79e	75e	73e	75e	85e	85e	84e	80e	79e	85e
22	87	81e	79e	75e	73e	75e	85e	85e	84e	81e	79e	85e
23	---	81e	78e	75e	73e	75e	87e	87e	84e	81e	80e	85e
24	---	81e	79e	75e	73e	76e	84e	87e	82e	79e	79e	87e
25	---	81e	78e	75e	73e	77e	84e	86e	83e	78e	79e	86e
26	---	81e	78e	75e	73e	76e	84e	88e	83e	77e	78e	85e
27	---	81e	77e	75e	73e	75e	84e	88e	83e	77e	78e	86e
28	---	80e	77e	75e	73e	75e	84e	90e	82e	79e	80e	87e
29	---	80e	77e	74e	73e	75e	83e	92e	83e	80e	81e	87e
30	---	80e	77e	74e	---	74e	84e	91e	82e	80e	82e	87e
31	---	---	77e	74e	---	74e	---	89e	---	80e	82e	---
TOTAL	1924	1471	2448	2350	2122	2303	2473	2671	2545	2489	2480	2526
MEAN	87.4	81.7	79	75.7	73.2	74.4	82.4	86.1	84.8	80.3	80.1	84.3
MAX	96	84	82	78	75	77	91	92	89	83	83	87
MIN	78	80	77	74	72	73	74	83	82	77	77	81
AC-FT	3816	2918	4856	4661	4209	4568	4905	5298	5048	4937	4919	5010

Values For Period

TOTAL 27802 **MEAN** 80.6 **MAX** 96 **MIN** 72 **AC-FT** 55140

CROOKED CREEK ABOVE THOMAS PUMP
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2008 TO 9/30/2009
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	87e	83e	82e	86e	82e	83e	81e	81e	82e	82e	87e	86e
2	85e	84e	82e	95e	82e	86e	81e	81e	82e	83e	88e	85e
3	86e	84e	82e	94e	82e	88e	81e	85e	82e	82e	87e	87e
4	87e	86e	82e	89e	82e	86e	81e	87e	82e	81e	86e	91e
5	86e	86e	82e	88e	82e	84e	81e	91e	82e	81e	86e	92e
6	85e	87e	82e	88e	84e	83e	81e	86e	82e	81e	87e	93e
7	84e	87e	82e	91e	85e	83e	81e	83e	81e	81e	88e	93e
8	84e	87e	82e	93e	84e	83e	81e	82e	81e	81e	90e	93e
9	83e	85e	82e	91e	83e	82e	81e	82e	82e	83e	92e	95e
10	83e	84e	82e	87e	82e	82e	81e	82e	81e	85e	91e	96e
11	83e	84e	82e	86e	82e	82e	81e	82e	82e	85e	89e	94e
12	83e	84e	82e	85e	82e	82e	81e	81e	81e	84e	89e	94e
13	83e	83e	82e	85e	82e	82e	81e	82e	82e	86e	90e	94e
14	83e	84e	82e	84e	82e	82e	81e	83e	82e	87e	91e	94e
15	83e	83e	82e	84e	82e	84e	81e	83e	82e	86e	90e	93e
16	83e	83e	82e	84e	82e	89e	81e	81e	82e	83e	90e	93e
17	82e	83e	82e	83e	82e	85e	81e	82e	82e	84e	89e	92e
18	83e	82e	82e	83e	82e	83e	81e	82e	86e	89e	86e	91e
19	83e	82e	82e	83e	82e	82e	81e	81e	89e	89e	85e	91e
20	83e	82e	82e	83e	82e	82e	81e	80e	86e	89e	86e	91e
21	82e	82e	82e	83e	82e	82e	81e	80e	84e	88e	86e	91e
22	82e	82e	82e	83e	82e	82e	81e	81e	83e	88e	87e	91e
23	82e	82e	82e	83e	90e	82e	81e	80e	82e	88e	89e	91e
24	82e	82e	83e	84e	92e	82e	81e	81e	82e	86e	92e	91e
25	83e	82e	82e	84e	86e	82e	81e	81e	93e	84e	89e	91e
26	83e	82e	82e	84e	86e	81e	81e	81e	81e	84e	90e	91e
27	83e	82e	82e	83e	84e	81e	81e	81e	80e	84e	88e	91e
28	82e	82e	86e	83e	83e	81e	81e	81e	80e	85e	86e	92e
29	82e	82e	89e	83e	---	81e	81e	81e	82e	87e	87e	95e
30	82e	82e	88e	82e	---	81e	81e	81e	83e	88e	88e	94e
31	83e	---	86e	82e	---	81e	---	81e	---	87e	86e	---
TOTAL	2585	2503	2564	2656	2333	2569	2430	2546	2481	2631	2735	2756
MEAN	83.3	83.4	82.7	85.7	83.4	83	80.9	82.1	82.7	84.9	88.2	91.9
MAX	87	87	89	95	92	89	81	91	93	89	92	96
MIN	82	82	82	82	82	81	81	80	80	81	85	85
AC-FT	5127	4965	5086	5268	4627	5096	4820	5050	4921	5219	5425	5466

Values For Period

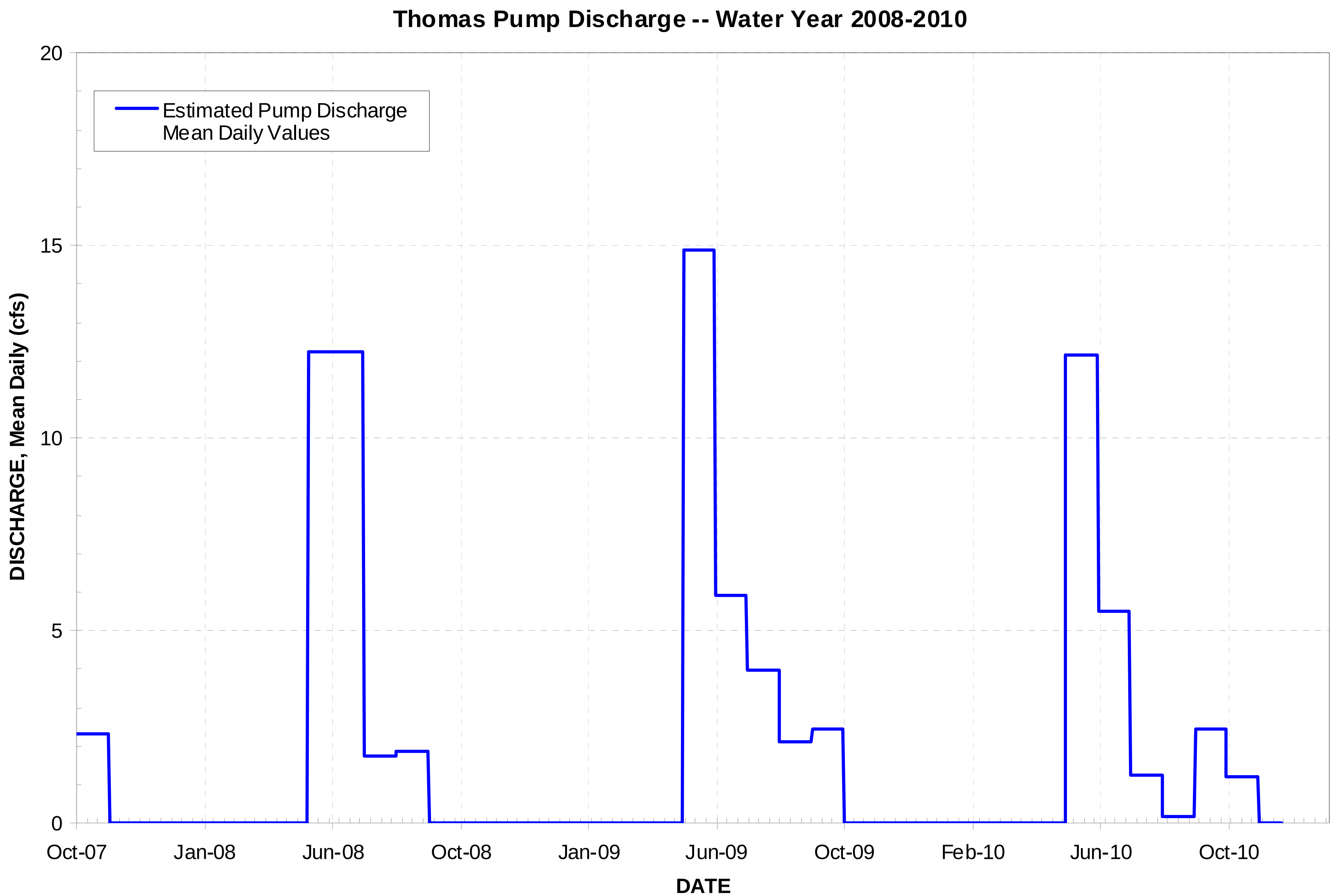
TOTAL 30789 **MEAN** 84.4 **MAX** 96 **MIN** 80 **AC-FT** 61070

CROOKED CREEK ABOVE THOMAS PUMP
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2009 TO 9/30/2010
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	94e	86e	82e	83e	78e	79e	79e	79e	89e	86e	91e	94e
2	93e	88e	82e	82e	78e	79e	79e	79e	90e	87e	92e	94e
3	93e	88e	82e	81e	78e	79e	79e	78e	91e	87e	92e	94e
4	92e	88e	82e	80e	78e	80e	79e	79e	93e	87e	92e	93e
5	88e	89e	82e	80e	78e	80e	79e	78e	94e	88e	91e	93e
6	90e	89e	81e	81e	79e	79e	79e	78e	93e	91e	90e	94e
7	91e	88e	81e	83e	79e	79e	79e	79e	92e	91e	90e	95e
8	91e	88e	80e	83e	78e	79e	78e	80e	87e	88e	90e	97e
9	91e	88e	80e	83e	79e	79e	78e	80e	84e	87e	90e	97e
10	91e	88e	80e	82e	78e	79e	78e	80e	83e	86e	91e	98e
11	91e	88e	80e	81e	79e	79e	78e	81e	85e	87e	92e	97e
12	91e	87e	80e	84e	82e	79e	78e	81e	81e	88e	93e	98e
13	92e	87e	80e	88e	84e	79e	78e	82e	81e	87e	94e	100e
14	93e	87e	80e	85e	84e	78e	78e	82e	83e	88e	91e	101e
15	93e	86e	81e	80e	83e	78e	78e	81e	83e	89e	91e	101e
16	92e	84e	82e	80e	82e	78e	78e	81e	83e	88e	90e	101e
17	92e	84e	81e	80e	82e	78e	78e	81e	84e	86e	91e	101e
18	92e	84e	81e	80e	81e	78e	77e	82e	83e	87e	92e	103e
19	92e	84e	81e	80e	80e	78e	77e	81e	82e	88e	92e	104e
20	92e	84e	81e	80e	80e	78e	78e	81e	82e	86e	92e	104e
21	92e	84e	82e	79e	79e	78e	78e	82e	82e	85e	92e	101e
22	92e	84e	82e	79e	79e	78e	78e	83e	84e	85e	92e	100e
23	91e	84e	80e	78e	79e	78e	78e	83e	85e	85e	93e	99e
24	91e	83e	80e	78e	80e	78e	80e	83e	86e	85e	93e	99e
25	90e	83e	80e	79e	80e	78e	81e	83e	87e	88e	93e	99e
26	90e	83e	80e	78e	81e	78e	81e	85e	86e	90e	93e	99e
27	89e	84e	80e	78e	80e	77e	81e	87e	87e	91e	93e	99e
28	89e	83e	79e	78e	80e	78e	81e	88e	88e	91e	93e	99e
29	89e	83e	79e	78e	---	79e	80e	89e	86e	91e	93e	100e
30	89e	82e	80e	78e	---	79e	79e	89e	86e	91e	93e	100e
31	89e	---	80e	78e	---	79e	---	89e	---	90e	94e	---
TOTAL	2825	2568	2501	2497	2238	2435	2362	2544	2580	2724	2849	2954
MEAN	91.1	85.6	80.6	80.5	79.9	78.5	78.7	82.1	86	87.8	91.9	98.5
MAX	94	89	82	88	84	80	81	89	94	91	94	104
MIN	88	82	79	78	78	77	77	78	81	85	90	93
AC-FT	5603	5094	4961	4953	4439	4830	4685	5046	5117	5403	5651	5859

Values For Period

TOTAL 31077 **MEAN** 85.1 **MAX** 104 **MIN** 77 **AC-FT** 61640



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

Klamath Basin Rangeland Trust

GMA

Hydrology | Geomorphology | Stream Restoration

APPENDIX

4-7

THOMAS PUMP DITCH
DISCHARGE, CFS, 10/1/2007 TO 9/30/2008
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	2.3	0	0	0	0	0	0	0	12.24	1.76	1.87	0
2	2.3	0	0	0	0	0	0	0	12.24	1.76	1.87	0
3	2.3	0	0	0	0	0	0	0	12.24	1.76	1.87	0
4	2.3	0	0	0	0	0	0	0	12.24	1.76	1.87	0
5	2.3	0	0	0	0	0	0	0	12.24	1.76	1.87	0
6	2.3	0	0	0	0	0	0	0	12.24	1.76	1.87	0
7	2.3	0	0	0	0	0	0	0	12.24	1.76	1.87	0
8	2.3	0	0	0	0	0	0	0	12.24	1.76	1.87	0
9	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
10	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
11	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
12	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
13	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
14	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
15	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
16	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
17	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
18	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
19	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
20	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
21	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
22	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
23	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
24	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
25	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
26	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
27	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
28	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
29	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
30	2.3	0	0	0	---	0	0	12.24	12.24	1.76	1.87	0
31	2.3	---	0	0	---	0	---	12.24	---	1.76	1.87	---
TOTAL	71	0	0	0	0	0	0	282	367	55	58	0
MEAN	2.3	0	0	0	0	0	0	9.08	12.24	1.76	1.87	0
MAX	2.3	0	0	0	0	0	0	12.24	12.24	1.76	1.87	0
MIN	2.3	0	0	0	0	0	0	0.0	12.24	1.76	1.87	0

THOMAS PUMP DITCH
DISCHARGE, CFS, 10/1/2008 TO 9/30/2009
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
2	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
3	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
4	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
5	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
6	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
7	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
8	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
9	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
10	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
11	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
12	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
13	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
14	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
15	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
16	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
17	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
18	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
19	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
20	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
21	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
22	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
23	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
24	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
25	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
26	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
27	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
28	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
29	0	0	0	0	---	0	0	14.88	5.91	3.97	2.11	2.46
30	0	0	0	0	---	0	0	14.88	5.91	3.97	2.11	2.46
31	0	---	0	0	---	0	---	14.88	---	3.97	2.11	---
TOTAL	0	0	0	0	0	0	0	461	177	123	65	74
MEAN	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
MAX	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46
MIN	0	0	0	0	0	0	0	14.88	5.91	3.97	2.11	2.46

THOMAS PUMP DITCH
DISCHARGE, CFS, 10/1/2009 TO 9/30/2010
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
2	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
3	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
4	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
5	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
6	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
7	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
8	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
9	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
10	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
11	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
12	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
13	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
14	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
15	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
16	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
17	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
18	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
19	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
20	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
21	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
22	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
23	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
24	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
25	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
26	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
27	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
28	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
29	0	0	0	0	---	0	0	12.17	5.52	1.23	0.19	2.46
30	0	0	0	0	---	0	0	12.17	5.52	1.23	0.19	2.46
31	0	---	0	0	---	0	---	12.17	---	1.23	0.19	---
TOTAL	0	0	0	0	0	0	0	377	166	38	6	74
MEAN	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
MAX	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46
MIN	0	0	0	0	0	0	0	12.17	5.52	1.23	0.19	2.46

Description of Gaging Station on: *Sevenmile Creek at Sevenmile Road*

Drainage Basin: *Sevenmile/Fourmile*

1. **Location**

Lat. 42° 40' 6.62"N, Long. 122° 04' 20.07"W (NAD 27), W ½ , Sec. 36, T33S, R6E, Klamath County. The elevation of the gage is 4148.71 ft (NAVD 88). The gage can be reached by traveling 13.79 miles north on Highway 62 to Fort Klamath from the intersection of Highway 62 and Highway 97. Turn left on Weed road and drive 1.76 miles south. Turn left on Sevenmile Road and travel 4.09 miles to a bridge over Sevenmile Creek. The gage is located under the bridge on the left bank.

2. **Hydrologic Conditions**

The upper Klamath Basin primarily consists of agricultural lands interspersed with wetlands on the basin floor rising to evergreen forests on the basin slopes. Geology in the basin results from past volcanic events in the surrounding area. Average temperatures in the basin range from 17.2°F to 80.7°F based on 13 years of record from the National Weather Service station in Chiloquin. Precipitation averages 20.69 inches per year and is produced in a combination of snow and rain. Peak flows are generated from rain-on-snow events and spring snowmelt.

3. **Establishment and History**

Graham Matthews & Associates performed periodic discharge measurements at this site from 1998-2000. On September 5, 2002 the site was upgraded to a continuous station by GMA for the Klamath Basin Rangeland Trust.

4. **Gage**

A Design Analysis H-310 pressure transducer and Campbell Scientific Inc. CR510 datalogger were installed on October 6, 2004. A Van Essen Instruments Diver pressure transducer/datalogger serves as a backup. The staff plate is mounted near the left bank downstream of the Sevenmile Road Bridge.
Inside recording gage: Less than or equal to 0.02% of full scale output (FSO) over temperature range referenced (0 to 40° C) to a straight line stretched from zero psi to maximum pressure (15 psi).
Outside staff gage: One USGS style C staff gage is mounted on the left bank. Limits 0.00 ft to 3.33 ft. Staff heights over 3.33 ft. require use of an engineer's tape that is used to measure from the top of the staff plate to the water surface.

View across channel at gage section, and staff gage, LB

View upstream through gage section and bridge

5. **Reference Marks (RM)**

The reference mark at the gage is a PK nail near the Sevenmile Road Bridge on right bank upstream side adjacent to the second wood post from the end of guardrail. The elevation of the reference mark is 4157.803 ft (NAVD 88).

6. **Control**

The water elevation at the site is controlled by the roughness of the channel. Growth of Aquatic vegetation downstream of the gaging cross-section causes shifting of the stage discharge relationship

7. **Discharge Measurements**

Wading measurement are taken just downstream of the bridge during most of the year. The measurements are made with a Price AA current meter, top-set rod, and AquaCalc streamflow computer. Higher flows require a bridge measurement on the downstream side of the bridge.

Channel Conditions At Measurement Section

The channel bed at the measurement section is composed of firm sands and small gravel. In late summer aquatic vegetation grows from the bottom of the channel 10 ft downstream of the measurement cross section

Horizontal Angle Corrections

Horizontal corrections are not required at the site.

Flow Conditions

Flow lines are parallel, and perpendicular to the cross section. A slackwater area exists on the right bank during certain flows.

8. Floods

No floods have occurred at the site since the establishment of the gage. The largest flood since 1992 probably occurred on December 30, 1995 based on upstream gage records.

9. Point of Zero Flow

Unknown.

10. Winter Flow

Typical winter flows are derived from rain and/or snowmelt. Rain-on-snow events are responsible for most of the extreme flood events on the stream. Flows at the gage are not likely to be affected by ice except during extremely cold winters.

11. Regulation

None.

12. Diversion

A large portion of the streamflow in Sevenmile Creek and its tributaries is diverted at numerous locations upstream during a portion of the year for agricultural purposes.

13. Accuracy

The accuracy of the record at this site is considered fair.

14. Cooperation

None.

15. Land Ownership

The gage is located on public property within the easement for Sevenmile Road.

16. Purpose of Record

The purpose of the record is to study streamflow along with sediment and nutrient transport in the reach of Sevenmile Creek below Blue Springs.

17. Cross Section Survey History

None.

19. Photo History

GMA has taken photographs of the site since 1998.

View downstream along creek from bridge

View upstream from bridge to large diversion structure

GRAHAM MATTHEWS & ASSOCIATES

Hydrology -- Geomorphology -- Stream Restoration

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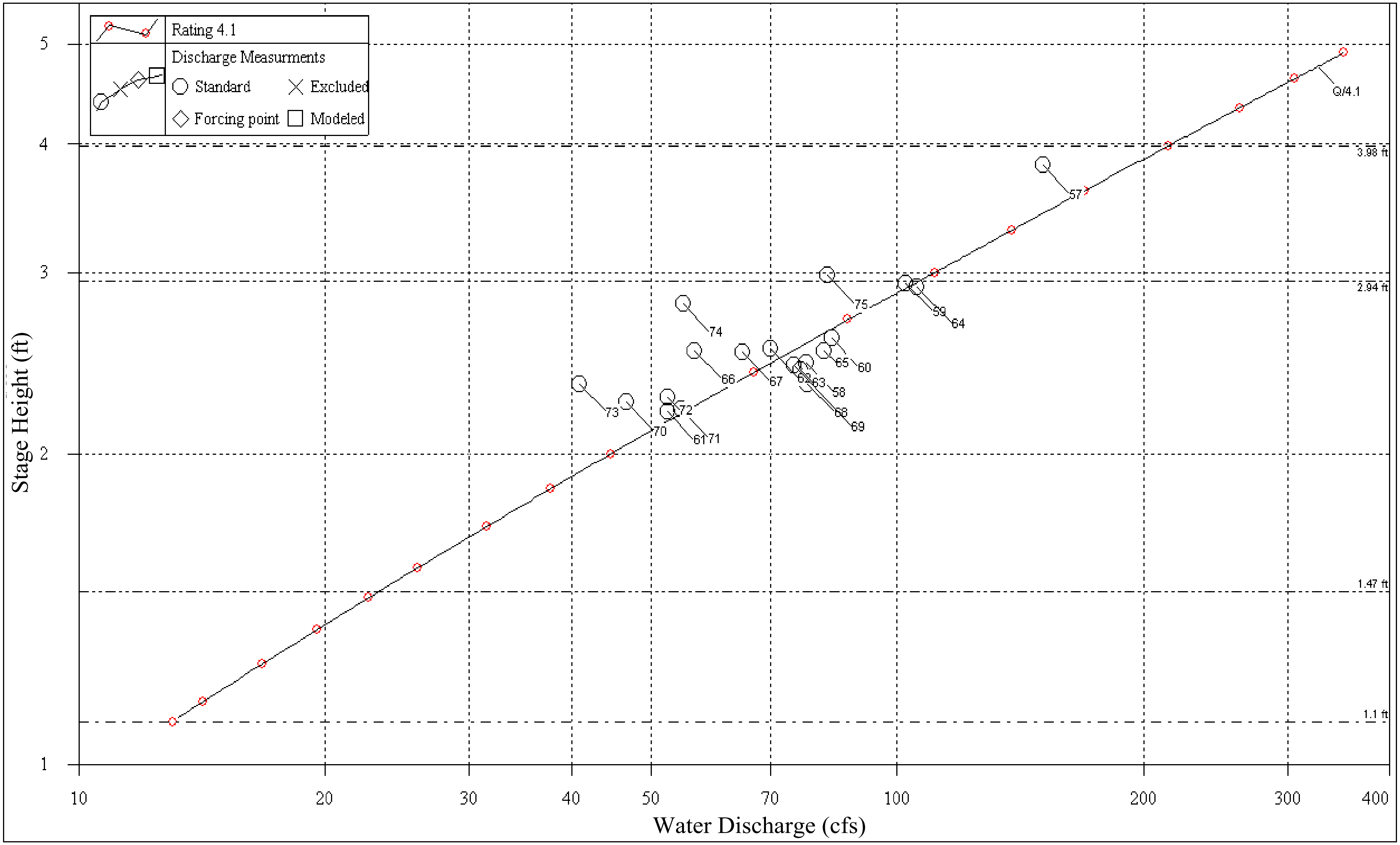
DISCHARGE SUMMARY SHEET

LOCATION: SEVENMILE CREEK at SEVENMILE ROAD **WATER YEAR:** 2007-2010
STATION NUMBER: GMA0592100

Measurement Number	WY Msmt #	Date	Made By:	Width (feet)	Mean Depth (feet)	Area (ft2)	Mean Velocity (ft/sec)	Stage Height (feet)	Gage Height (feet)	Discharge (cfs)	Rating __4.1__ Comp. Shift (feet)	Used Shift (feet)	% Diff.	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	GZF	Notes
56	2007-01	10/30/2006	M Anderson	31.0	2.48	76.90	0.75	2.58	2.58	57.7	-0.33	-0.33	0	Bridge	22	12:52	13:51	Fair		
57	2007-02	12/14/2006	M Anderson	39.5	3.04	120.00	1.25	3.79	3.81	151	-0.39	-0.33	-4	Bridge	24	10:03	11:09	Fair		Many Abnormal velocity profiles
58	2007-03	01/19/2007	M Anderson	30.0	2.37	71.10	1.09	2.45	2.45	77.4	0.11	0.11	0	Bridge	24	14:26	15:59	Fair		Many Abnormal and Turbulent velocity profiles
59	2007-04	02/16/2007	M Anderson	32.6	2.64	85.90	1.19	2.92	2.93	102	-0.03	0.00	-3	Bridge	24	16:13	17:36	Good		Many Abnormal and Turbulent velocity profiles
60	2007-05	04/20/2007	M Anderson	31.5	2.31	72.85	1.14	2.60	2.59	83.2	0.06	0.00	5	Bridge	24	12:49	13:57	Good		
61	2007-06	05/25/2007	M Anderson	30.5	1.94	59.30	0.88	2.20	2.20	52.4	-0.05	0.00	5	Bridge	27	12:58	13:57	Good		
62	2008-01	12/14/2007	M Anderson	31.0	1.96	60.70	1.16	2.54	2.53	70.1	-0.08	0.00	-7	Bridge	26	15:30	16:45	Fair		Time is approx. Time and date on AQUA file is wrong. Shape of X-sec. and control looks like it has changed due to veg. and erosion.
63	2008-02	01/24/2008	M Anderson	29.3	1.96	54.40	1.40	2.39	2.41	76.3	0.14	0.14	0	Wading	25	15:51	16:26	Good		
64	2008-03	05/30/2008	M Anderson	31.6	2.25	71.20	1.49	2.91	2.91	106	0.03	0.00	2	Bridge	29	14:00	14:58	Good		
65	2008-04	06/16/2008	M Anderson	31.0	1.95	60.40	1.35	2.52	2.52	81.4	0.10	0.10	0	Bridge	25	15:53	16:41	Good		
66	2008-05	08/18/2008	M Anderson	29.5	1.94	57.30	0.99	2.50	2.52	56.6	-0.29	-0.29	0	Wading	25	13:53	14:32	Good		
67	2009-01	10/24/2008	M. Anderson	30.0	2.08	62.38	1.04	2.51	2.51	64.8	-0.14	-0.14	0	Bridge	24	12:30	13:36	Good		
68	2009-02	02/19/2009	M. Anderson	29.8	2.17	64.55	1.20	2.31	2.34	77.8	0.26	0.26	0	Bridge	25	15:26	16:46	Fair		
69	2009-03	05/27/2009	M. Anderson	31.0	2.17	67.12	1.12	2.44	2.43	74.9	0.09	0.09	0	Bridge	24	13:08	14:24	Fair		
70	2009-04	08/12/2009	M. Anderson	29.5	2.05	60.61	0.77	2.24	2.25	46.7	-0.20	-0.20	0	Bridge	25	13:17	14:08	Fair		
71	2010-01	11/04/2009	M. Anderson	29.5	1.98	58.50	0.93	2.19	2.21	54.6	-0.02	0.00	2	Bridge	25	16:01	16:48	Good		
72	2010-02	04/06/2010	M. Anderson	29.3	2.09	61.10	0.86	2.27	---	52.5	-0.12	---	---	Wading	26	12:51	14:04	Good		Do not have Data File
73	2010-03	06/30/2010	M. Anderson	29.5	2.13	62.80	0.65	2.34	2.34	40.9	-0.42	-0.42	0	Wading	27	12:50	13:57	Good		Do not have Data File
74	2010-04	09/28/2010	M. Anderson	31.5	2.42	76.35	0.72	2.79	2.80	54.8	-0.61	-0.61	0	Wading	26	13:55	14:54	Good		



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

Klamath Basin Rangeland Trust

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APPENDIX

5-3

Graham Matthews & Associates

SEVENMILE CREEK at SEVENMILE ROAD

RATING TABLE NO. 4.1 -- Begin Date 3/23/04

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
0.0	---	---	*0.01*	*0.01*	*0.02*	*0.03*	*0.05*	*0.06*	*0.08*	*0.10*		
0.1	*0.12*	*0.15*	*0.18*	*0.21*	*0.24*	*0.27*	*0.31*	*0.35*	*0.39*	*0.43*	0.3	
0.2	*0.48*	*0.52*	*0.57*	*0.62*	*0.68*	*0.73*	*0.79*	*0.85*	*0.91*	*0.98*	0.6	0.22
0.3	*1.05*	*1.11*	*1.18*	*1.18*	*1.26*	*1.41*	*1.49*	*1.57*	*1.65*	*1.74*	0.8	0.21
0.4	*1.83*	*1.92*	*2.01*	*2.10*	*2.20*	*2.30*	*2.40*	*2.50*	*2.60*	*2.71*	1.0	0.21
0.5	*2.82*	*2.93*	*3.04*	*3.16*	*3.27*	*3.39*	*3.51*	*3.63*	*3.76*	*3.89*	1.2	0.21
0.6	*4.02*	*4.15*	*4.28*	*4.41*	*4.55*	*4.69*	*4.69*	*4.83*	*4.98*	*5.27*	1.4	0.20
0.7	*5.42*	*5.57*	*5.72*	*5.88*	*6.03*	*6.19*	*6.36*	*6.52*	*6.52*	*6.68*	1.4	0.03
0.8	*7.02*	*7.19*	*7.37*	*7.54*	*7.72*	*7.90*	*8.08*	*8.26*	*8.45*	*8.64*	2.0	0.55
0.9	*8.82*	*9.02*	*9.21*	*9.40*	*9.60*	*9.80*	*10.0*	*10.2*	*10.4*	*10.6*	2.0	0.00
1.0	*10.8*	*11.0*	*11.3*	*11.5*	*11.7*	*11.9*	*12.1*	*12.3*	*12.6*	*12.8*	2.2	0.24
1.1	*13.0*	*13.3*	*13.5*	*13.7*	*14.0*	*14.2*	*14.4*	*14.7*	*14.9*	*15.2*	2.4	0.20
1.2	*15.4*	*15.7*	*16.0*	*16.2*	*16.5*	*16.7*	*17.0*	*17.3*	*17.6*	*17.8*	2.6	0.20
1.3	*18.1*	*18.4*	*18.7*	*19.0*	*19.3*	*19.5*	*19.8*	*20.1*	*20.4*	*20.7*	2.9	0.30
1.4	*21.0*	*21.4*	*21.7*	*22.0*	*22.3*	*22.6*	22.9	23.3	23.6	23.9	3.2	0.30
1.5	24.3	24.6	24.9	25.3	25.6	26.0	26.3	26.7	27.0	27.4	3.5	0.30
1.6	27.7	28.1	28.5	28.9	29.2	29.6	30.0	30.4	30.7	31.1	3.7	0.20
1.7	31.5	31.9	32.3	32.7	33.1	33.5	33.9	34.4	34.8	35.2	4.1	0.40
1.8	35.6	36.0	36.5	36.9	37.3	37.8	38.2	38.6	39.1	39.5	4.3	0.20
1.9	40.0	40.5	40.9	41.4	41.8	42.3	42.8	43.2	43.7	44.2	4.7	0.40
2.0	44.7	45.2	45.7	46.2	46.7	47.2	47.7	48.2	48.7	49.2	5.0	0.30
2.1	49.7	50.3	50.8	51.3	51.8	52.4	52.9	53.4	54.0	54.5	5.3	0.30
2.2	55.1	55.6	56.2	56.8	57.3	57.9	58.5	59.0	59.6	60.2	5.7	0.40
2.3	60.8	60.8	62.0	62.0	63.2	63.2	64.4	64.4	65.6	65.6	5.4	-0.30
2.4	66.8	66.8	68.1	68.1	69.4	69.4	70.6	70.6	71.9	71.9	6.3	0.90

Graham Matthews & Associates

SEVENMILE CREEK at SEVENMILE ROAD

RATING TABLE NO. 4.1 -- Begin Date 3/23/04

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
2.5	73.3	73.9	74.6	75.3	75.9	76.6	77.3	78.0	78.6	79.3	7.4	1.10
2.6	80.0	80.7	81.4	82.1	82.8	83.5	84.2	85.0	85.7	86.4	7.1	-0.30
2.7	87.1	87.9	88.6	89.4	90.1	90.9	91.7	92.5	93.2	94.0	7.6	0.50
2.8	94.8	94.8	96.4	96.4	98.0	98.0	99.6	99.6	101	101	7.0	-0.60
2.9	103	103	104	104	106	*106*	*108*	*108*	*110*	*110*	9.0	2.00
3.0	*111*	*112*	*113*	*114*	*115*	*116*	*116*	*117*	*118*	*119*	9.0	0.00
3.1	*120*	*121*	*122*	*123*	*124*	*124*	*125*	*126*	*127*	*128*	9.0	0.00
3.2	*129*	*130*	*131*	*132*	*133*	*134*	*135*	*136*	*136*	*137*	9.0	0.00
3.3	*138*	*138*	*140*	*140*	*142*	*142*	*144*	*144*	*146*	*146*	9.0	0.00
3.4	*148*	*148*	*150*	*150*	*152*	*152*	*155*	*155*	*157*	*157*	11.0	2.00
3.5	*159*	*160*	*161*	*162*	*163*	*164*	*165*	*166*	*167*	*168*	11.0	0.00
3.6	*169*	*171*	*172*	*173*	*174*	*175*	*176*	*177*	*178*	*180*	12.0	1.00
3.7	*181*	*182*	*183*	*184*	*185*	*186*	*188*	*189*	*190*	*191*	11.0	-1.00
3.8	*192*	*192*	*195*	*195*	*197*	*197*	*200*	*200*	*202*	*202*	11.0	0.00
3.9	*204*	*204*	*207*	*207*	*209*	*209*	*212*	*212*	*214*	*214*	12.0	1.00
4.0	*217*	*218*	*220*	*221*	*222*	*223*	*225*	*226*	*227*	*229*	15.0	3.00
4.1	*230*	*230*	*231*	*234*	*235*	*235*	*237*	*239*	*241*	*241*	12.0	-3.00
4.2	*244*	*245*	*246*	*248*	*249*	*250*	*252*	*253*	*255*	*256*	15.0	3.00
4.3	*257*	*259*	*259*	*262*	*263*	*265*	*265*	*268*	*269*	*270*	14.0	-1.00
4.4	*272*	*273*	*275*	*276*	*278*	*279*	*281*	*282*	*284*	*285*	15.0	1.00
4.5	*287*	*288*	*290*	*291*	*293*	*295*	*296*	*298*	*299*	*301*	16.0	1.00
4.6	*302*	*302*	*304*	*307*	*309*	*309*	*310*	*313*	*315*	*315*	14.0	-2.00
4.7	*318*	*320*	*321*	*323*	*325*	*326*	*328*	*330*	*331*	*333*	18.0	4.00
4.8	*334*	*336*	*336*	*339*	*341*	*343*	*343*	*346*	*348*	*350*	17.0	-1.00
4.9	*351*	---	---	---	---	---	---	---	---	---		

PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

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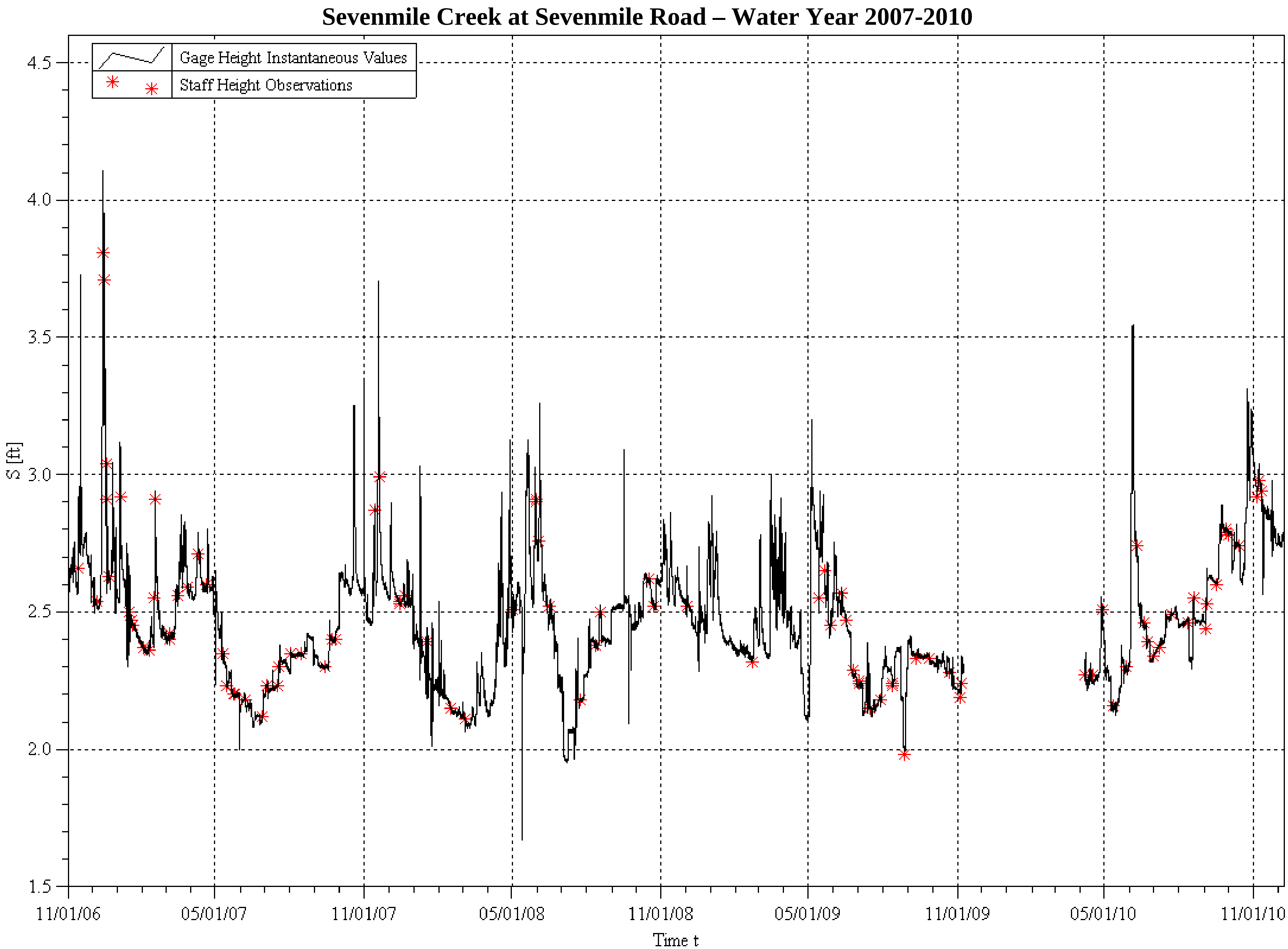
APPENDIX

5-4



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

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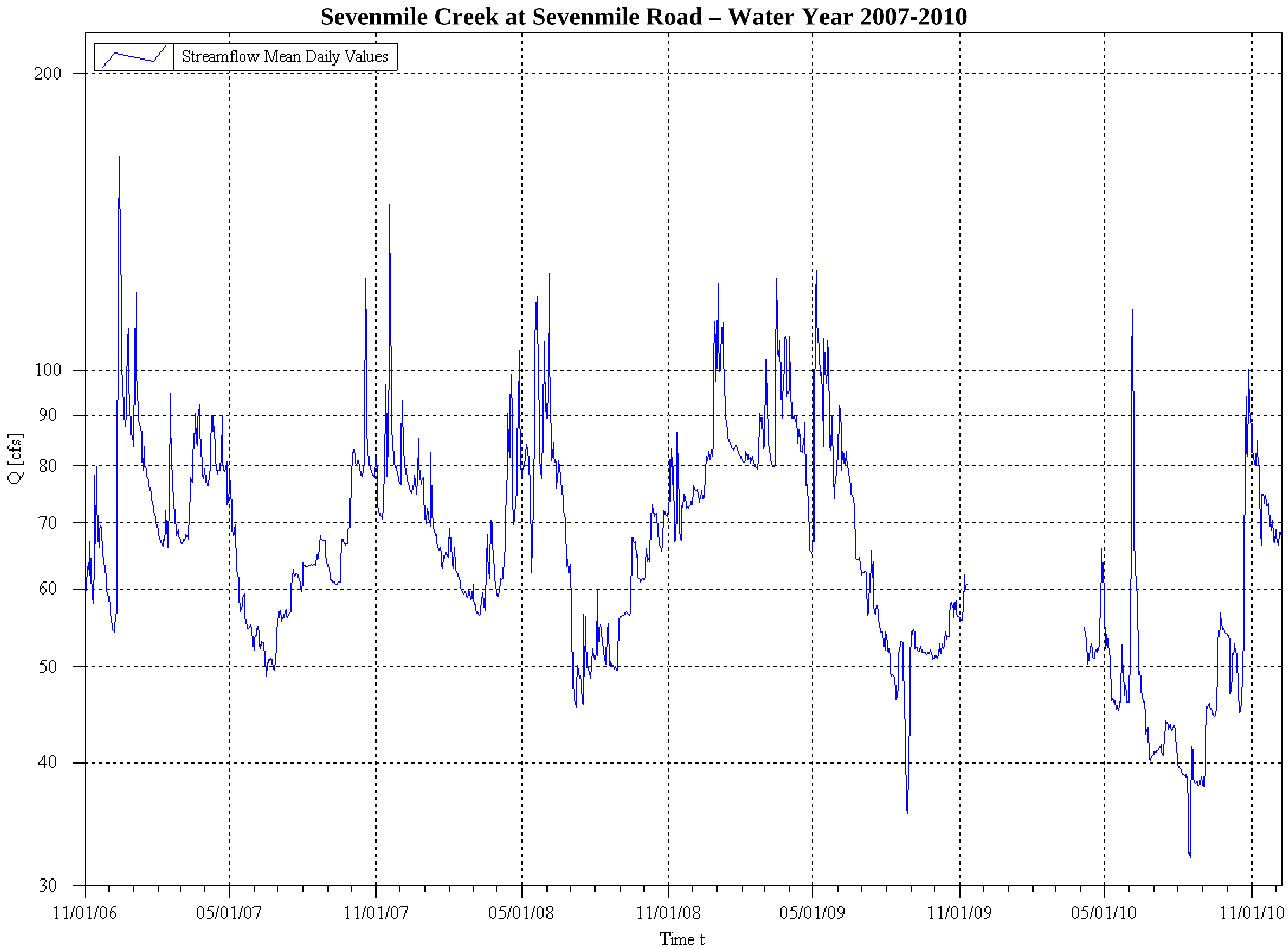
APPENDIX

5-5



PROJECT:

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APPENDIX

5-7

SEVENMILE CREEK AT SEVENMILE ROAD GMA0592100
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2006 TO 9/30/2007
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	65	57	59	84	69	67	79	76	52	55	61	63
2	67	58	58	84	68	67	78	79	53	57	64	63
3	67	61	57	101	68	67	76	76	54	57	63	63
4	67	62	56	120	67	67	76	72	54	57	63	62
5	68	63	55	101	67	67	77	69	55	56	63	61
6	68	64	55	95	66	67	78	68	55	56	63	61
7	68	62	54	92	66	68	80	68	54	56	63	61
8	68	67	54	89	67	68	83	69	53	56	63	61
9	68	62	55	88	67	68	90	70	52	56	63	61
10	68	59	56	88	69	67	90	63	53	57	63	61
11	68	59	57	86	72	68	87	63	53	57	64	61
12	67	58	64	82	69	71	88	62	53	56	64	61
13	62	65	136	79	67	76	83	61	53	56	63	61
14	59	78	165	84	66	78	81	59	53	56	64	61
15	58	67	155	80	75	77	80	57	51	57	64	61
16	60	80	136	80	95	77	79	57	49	57	64	61
17	60	75	115	79	89	80	79	58	49	57	63	61
18	58	68	102	78	82	86	79	59	50	60	63	63
19	58	66	96	78	77	86	79	59	51	61	65	67
20	58	69	92	77	74	91	79	59	50	63	65	67
21	58	69	91	76	74	85	82	56	51	62	64	67
22	58	69	88	76	71	84	90	56	51	62	66	67
23	59	69	90	75	68	89	81	55	51	62	68	66
24	59	65	95	74	68	90	79	55	51	62	68	67
25	59	64	107	73	69	92	79	55	50	62	67	67
26	59	64	110	73	69	87	79	55	50	62	67	67
27	59	63	99	72	68	84	80	55	50	62	67	69
28	59	61	91	71	68	80	81	55	51	61	67	69
29	59	60	88	71	---	78	73	55	52	61	67	69
30	58	59	87	70	---	78	74	55	55	60	65	70
31	58	---	85	70	---	79	---	53	---	60	64	---
TOTAL	1927	1943	2708	2546	1995	2389	2419	1909	1559	1819	1998	1919
MEAN	62.2	64.8	87.3	82.1	71.2	77.1	80.6	61.6	51.9	58.7	64.6	64
MAX	68	80	165	120	95	92	90	79	55	63	68	70
MIN	58	57	54	70	66	67	73	53	49	55	61	61
AC-FT	3822	3854	5371	5050	3957	4739	4798	3786	3092	3608	3963	3806

Values For Period

TOTAL 25131 **MEAN** 68.9 **MAX** 165 **MIN** 49 **AC-FT** 49850

SEVENMILE CREEK AT SEVENMILE ROAD GMA0592100
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2007 TO 9/30/2008
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	78	82	77	72	69	61	59	78	89	64	51	56
2	82	79	77	70	66	59	59	79	90	57	51	56
3	82	73	84	70	68	58	60	80	95	56	52	56
4	83	72	93	72	64	58	61	80	125	48	60	56
5	82	72	83	72	63	57	62	80	105	47	51	56
6	81	71	81	71	63	57	61	82	92	46	55	56
7	80	71	80	70	66	57	62	84	85	46	55	57
8	81	71	79	70	64	57	62	84	81	46	55	57
9	81	71	78	82	63	56	64	83	82	48	54	57
10	81	73	77	71	63	57	67	81	84	50	53	57
11	80	81	77	71	62	57	71	79	82	50	52	57
12	80	77	76	69	62	58	75	78	81	49	52	57
13	79	97	76	69	62	59	80	62	81	49	51	57
14	78	85	75	68	61	59	90	63	76	48	50	56
15	78	78	75	68	60	58	84	66	78	48	50	57
16	79	86	75	67	60	57	82	75	79	46	55	68
17	81	106	76	66	60	57	90	88	81	46	55	67
18	84	147	77	66	60	64	99	104	80	57	55	67
19	124	117	78	66	59	68	89	116	78	49	50	67
20	107	95	77	66	59	65	75	119	77	56	50	67
21	88	88	75	65	60	63	70	117	76	54	51	67
22	83	84	75	63	59	62	70	98	74	50	50	65
23	81	82	78	63	59	63	72	90	72	50	50	65
24	80	80	85	64	59	70	72	82	72	50	50	62
25	80	80	80	65	60	70	77	78	70	49	50	61
26	79	79	78	64	60	67	84	79	63	49	50	61
27	78	80	76	65	59	64	91	78	64	49	50	61
28	78	78	77	65	59	63	105	88	64	50	50	61
29	78	78	78	65	59	62	94	107	62	52	50	61
30	79	77	78	65	---	61	81	103	62	52	50	61
31	78	---	74	66	---	59	---	92	---	51	56	---
TOTAL	2563	2510	2425	2106	1788	1883	2268	2673	2400	1562	1614	1809
MEAN	82.7	83.6	78.3	68	61.5	60.7	75.5	86.1	80	50.4	52.1	60.3
MAX	124	147	93	82	69	70	105	119	125	64	60	68
MIN	78	71	74	63	59	56	59	62	62	46	50	56
AC-FT	5084	4979	4810	4177	3546	3735	4499	5302	4760	3098	3201	3588

Values For Period

TOTAL 25601 **MEAN** 69.9 **MAX** 147 **MIN** 46 **AC-FT** 50780

SEVENMILE CREEK AT SEVENMILE ROAD GMA0592100
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2008 TO 9/30/2009
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	61	72	73	103	81	84	95	66	83	62	54	54
2	62	75	76	122	81	101	108	68	90	62	53	54
3	64	79	76	109	81	102	96	85	92	62	52	54
4	66	83	76	100	81	92	90	118	91	62	52	55
5	64	77	75	100	81	87	89	126	86	63	51	54
6	64	82	76	103	83	85	89	112	79	62	49	52
7	64	78	76	110	82	83	90	109	83	61	49	52
8	64	70	75	112	82	82	89	104	82	56	49	52
9	64	67	74	104	81	81	89	103	81	57	49	52
10	71	67	74	96	81	81	90	100	80	58	49	52
11	73	72	74	92	82	80	85	98	83	61	49	52
12	73	86	75	90	81	80	84	99	82	63	47	52
13	72	78	76	88	81	80	87	94	80	66	46	53
14	71	73	74	87	82	81	85	84	79	62	47	52
15	72	69	74	86	81	98	83	108	78	64	48	52
16	71	67	74	85	81	124	83	101	78	58	51	52
17	71	67	79	84	80	112	82	97	76	57	52	52
18	72	73	82	84	80	104	83	101	75	57	53	52
19	68	73	82	83	79	103	84	107	75	57	53	52
20	67	74	81	83	79	106	86	104	74	58	53	51
21	66	75	82	83	79	107	89	87	74	57	53	52
22	66	74	83	83	81	97	76	84	73	56	53	52
23	66	73	81	83	90	89	77	83	65	55	45	52
24	66	72	83	84	90	94	75	89	65	55	44	52
25	66	73	83	84	89	96	74	90	64	54	42	52
26	72	72	82	83	89	103	67	78	64	54	36	52
27	72	73	84	82	85	108	66	74	64	54	36	51
28	72	73	101	83	83	108	66	76	65	54	36	51
29	71	73	112	82	---	107	65	78	63	53	40	51
30	71	74	106	82	---	94	65	78	62	52	46	51
31	72	---	98	81	---	95	---	80	---	54	50	---
TOTAL	2114	2214	2517	2831	2306	2944	2487	2881	2286	1806	1487	1567
MEAN	68.2	73.9	81.1	91.4	82.4	95	83	92.9	76.2	58.3	47.9	52.2
MAX	73	86	112	122	90	124	108	126	92	66	54	55
MIN	61	67	73	81	79	80	65	66	62	52	36	51
AC-FT	4193	4391	4992	5615	4574	5839	4933	5714	4534	3582	2949	3108

Values For Period

TOTAL 27440 **MEAN** 75.2 **MAX** 126 **MIN** 36 **AC-FT** 54430

SEVENMILE CREEK AT SEVENMILE ROAD GMA0592100
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2009 TO 9/30/2010
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	51	56	---	---	---	---	---	58	47	41	40	38
2	51	56	---	---	---	---	---	52	51	41	40	38
3	51	56	---	---	---	---	---	53	73	41	39	40
4	51	56	---	---	---	---	---	54	102	41	39	42
5	52	57	---	---	---	---	---	53	115	41	39	46
6	53	62	---	---	---	---	55	52	79	41	39	45
7	52	60	---	---	---	---	54	52	68	41	39	46
8	52	60	---	---	---	---	53	51	64	41	39	46
9	53	61	---	---	---	---	51	46	60	41	39	46
10	53	---	---	---	---	---	50	47	61	42	39	46
11	52	---	---	---	---	---	51	46	59	41	39	45
12	53	---	---	---	---	---	52	46	50	41	39	45
13	53	---	---	---	---	---	52	46	49	41	36	45
14	54	---	---	---	---	---	53	46	49	41	32	45
15	54	---	---	---	---	---	52	45	49	42	32	45
16	53	---	---	---	---	---	51	46	48	44	32	45
17	54	---	---	---	---	---	51	46	47	44	35	45
18	54	---	---	---	---	---	51	45	46	44	42	46
19	56	---	---	---	---	---	52	46	46	44	41	50
20	58	---	---	---	---	---	52	46	46	43	39	53
21	58	---	---	---	---	---	52	46	45	43	38	54
22	58	---	---	---	---	---	52	53	43	44	38	55
23	58	---	---	---	---	---	52	51	43	43	38	57
24	58	---	---	---	---	---	53	50	43	43	38	55
25	56	---	---	---	---	---	55	47	43	43	38	55
26	58	---	---	---	---	---	57	48	40	43	38	55
27	58	---	---	---	---	---	65	48	40	44	38	55
28	57	---	---	---	---	---	66	47	40	43	38	54
29	56	---	---	---	---	---	62	46	40	42	38	54
30	56	---	---	---	---	---	60	46	41	42	39	54
31	56	---	---	---	---	---	---	46	---	40	38	---
TOTAL	1689	524	0	0	0	0	1354	1504	1627	1306	1178	1445
MEAN	54.5	58.2	---	---	---	---	54.1	48.5	54.2	42.2	38	48
MAX	58	62	---	---	---	---	66	58	115	44	42	57
MIN	51	56	---	---	---	---	50	45	40	40	32	38
AC-FT	3350	1039	0	0	0	0	2686	2983	3227	2590	2337	2866

Values For Period

TOTAL 10627 **MEAN** 48.7 **MAX** 115 **MIN** 32 **AC-FT** 21080

Description of Gaging Station on: *Sevenmile Creek at USFS Guard Station*

Drainage Basin: *Sevenmile/Fourmile*

1. Location

Lat. 42° 42' 18.49"N, Long. 122° 04' 25.11"W (NAD 27), between SW ¼, SW ¼, Sec. 13, and SE ¼, SE ¼, Sec14, T33S, R6E, Klamath County. The elevation of the gage is 4188.09 ft (NAVD 88). The gage can be reached by traveling 14.04 miles north on Highway 62 from the intersection of Highway 62 and Highway 97. Turn left on Nicholson Road and drive 3.86 miles west. Veer left at Y in road and travel an additional 775 ft. The gage is located on the right bank 20 ft upstream of the bridge.

2. Hydrologic Conditions

The upper Klamath Basin primarily consists of agricultural lands interspersed with wetlands on the basin floor rising to evergreen forests on the basin slopes. Geology in the basin results from past volcanic events in the surrounding area. Average temperatures in the basin range from 17.2°F to 80.7°F based on 13 years of record from the National Weather Service station in Chiloquin. Precipitation averages 20.69 inches per year and is produced in a combination of snow and rain. Peak flows are generated from rain-on-snow events and spring snowmelt.

3. Establishment and History

Graham Matthews & Associates established the gage for the Klamath Basin Rangeland Trust in April 2003

4. Gage

The recording gage is Global Water WL-15 pressure tranducer powered by a 9-volt lithium battery, housed in a 6-inch diameter metal cylinder mounted to a post on the right bank. The pressure transducer orifice is 15 feet streamward of the gage housing; the orifice line is enclosed in a 1¼ inch watertight armored flex conduit.

On July 21, 2010 the Global Water WL-15 pressure transducer was replaced by a Design Analysis H-310 pressure transducer and Campbell Scientific Inc. 510 data collection platform (DCP).
Inside recording gage: Accuracy to 0.03 feet.
Outside staff gage: One enameled section mounted on channel iron driving into streambed, 15 ft from gage; limits 0.00 ft to 3.33 ft.

View of staff gage, RB

View of gage housing prior to 6/21/10

5. **Reference Marks (RM)**

The reference mark is the center of last bolt on right bank, downstream side of 12"x12" wood beam atop the bridge near USFS guard station. The elevation of the reference mark is 4203.714 ft (NAVD 88).

6. **Control**

The control at the site is a cobble riffle 25 ft downstream of the gage. At low water shifts may be caused by accumulation of leaves on control.

7. **Discharge Measurements**

Wading discharge measurements are taken at the cross section 3 ft downstream of the staff. The measurements are made with a pygmy or Price AA current meter, top-set rod, and AquaCalc streamflow computer.

Channel Conditions At Measurement Section

The banks are sloped and covered with grass and bushes. The bottom is fairly flat and is made up of gravel and small cobbles. The channel geometry is uniform.

Horizontal Angle Corrections

No horizontal angle corrections are required at the site.

Flow Conditions

Flow lines are parallel, and perpendicular to the cross section.

8. **Floods**

No floods have occurred since the establishment of the gage.

9. **Point of Zero Flow**

Unknown.

10. **Winter Flow**

Typical winter flows are derived from rain and/or snowmelt. Rain-on-snow events are responsible for most of the extreme flood events on the stream. Ice and snow could affect the quality of data during winter months

11. **Regulation**

None.

12. **Diversion**

A large portion of the streamflow in Sevenmile Creek is diverted upstream of the gage during a portion of the year for agricultural purposes.

13. **Accuracy**

The accuracy is considered fair for this site.

14. **Cooperation**

None.

15. **Land Ownership**

The gage is located on public property managed by the USFS.

16. **Purpose of Record**

The purpose of the record at this gaging site is to study streamflow and sediment transport in Sevenmile Creek below the first major diversion.

17. **Cross Section Survey History**

None.

18. **Rating Table History**

Rating Table #1.2: April 24, 2003 to March 5, 2004.

19. **Photo History**

GMA photographs of site available since 2003.

View upstream through beaver dam and gage section

View downstream under bridge

GRAHAM MATTHEWS & ASSOCIATES

Hydrology -- Geomorphology -- Stream Restoration

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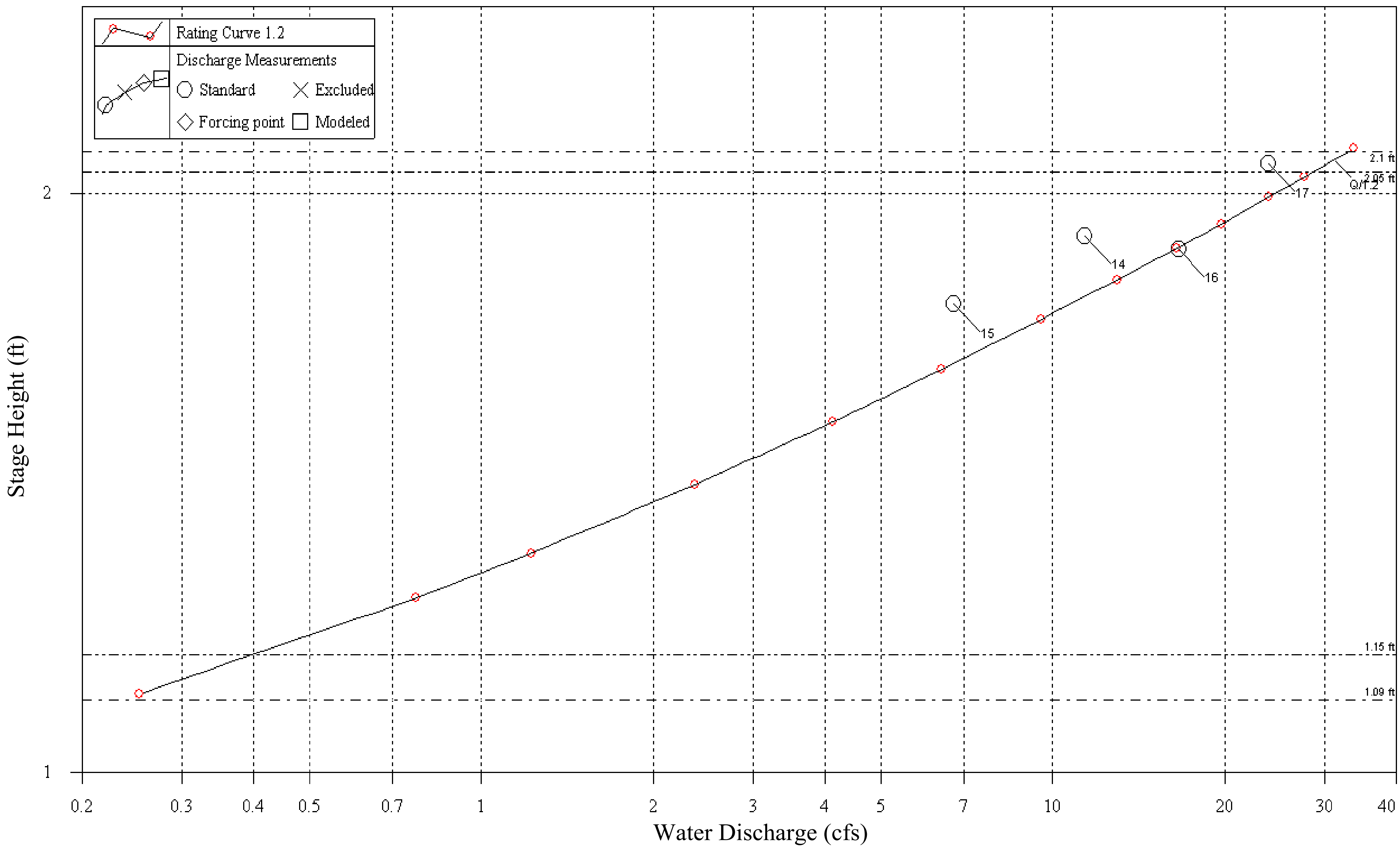
5435 Ericson Way Suite 1, Arcata, CA 95521 Phone: (707) 834-1906; email: cort@gmahydrology.com

DISCHARGE SUMMARY SHEET

LOCATION: SEVENMILE CREEK at GUARD STATION **WATER YEAR:** 2010
STATION NUMBER: GMA0592300

Measurement Number	WY Msmt #	Date	Made By:	Width (feet)	Mean Depth (feet)	Area (ft2)	Mean Velocity (ft/sec)	Stage Height (feet)	Gage Height (feet)	Discharge (cfs)	Rating __1.2___ Comp. Shift (feet)	Used Shift (feet)	% Diff.	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	GZF	Notes
14	**2010-01**	06/21/2010	M. Anderson	18.6	1.53	28.50	0.40	1.89	1.93	11.4	-0.16	-0.16	-1	Wading	24	15:19	16:14	Good		
15	**2010-02**	07/19/2010	M. Anderson	19.2	1.33	25.60	0.26	1.75	1.79	6.72	-0.16	-0.16	1	Wading	28	16:05	17:01	Good		More veg on rocks than previous measurement
16	**2010-03**	09/28/2010	M. Anderson	18.5	1.58	29.30	0.57	1.94	1.87	16.6	0.00	0.00	1	Wading	27	11:50	12:45	Good		



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

Klamath Basin Rangeland Trust

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APPENDIX

6-3

Graham Matthews & Associates

SEVENMILE CREEK AT GUARD STATION

RATING TABLE 1.2 -- Begin Date APRIL 23, 2003

GH	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	1st Diff	2nd Diff
0.0	---	---	---	---	---	---	---	---	---	---		
0.1	---	---	---	---	---	---	---	---	---	---	---	
0.2	---	---	---	---	---	---	---	---	---	---	---	---
0.3	---	---	---	---	---	---	---	---	---	---	---	---
0.4	---	---	---	---	---	---	---	---	---	---	---	---
0.5	---	---	---	---	---	---	---	---	---	---	---	---
0.6	---	---	---	---	---	---	---	---	---	---	---	---
0.7	---	---	---	---	---	---	---	---	---	---	---	---
0.8	---	---	---	---	---	---	---	---	---	---	---	---
0.9	---	---	---	---	---	---	---	---	---	---	---	---
1.0	---	---	---	---	---	---	---	---	---	---	---	---
1.1	*0.26*	*0.28*	*0.31*	*0.33*	*0.36*	*0.4*	0.43	0.47	0.51	0.55	---	---
1.2	0.6	0.65	0.7	0.76	0.82	0.88	0.94	1.01	1.08	1.15	0.6	---
1.3	1.23	1.31	1.39	1.48	1.57	1.66	1.77	1.87	1.99	2.11	1.0	0.36
1.4	2.23	2.36	2.49	2.62	2.76	2.91	3.06	3.22	3.38	3.56	1.5	0.49
1.5	3.74	3.93	4.12	4.32	4.52	4.72	4.94	5.16	5.39	5.64	2.1	0.63
1.6	5.89	6.15	6.42	6.69	6.97	7.26	7.56	7.87	8.19	8.52	2.9	0.80
1.7	8.87	9.22	9.59	9.96	10.34	10.73	11.14	11.56	11.99	12.43	3.9	1.03
1.8	12.89	13.35	13.82	14.31	14.81	15.32	15.85	16.39	16.95	17.52	5.1	1.18
1.9	18.12	18.72	19.35	19.98	20.58	21.2	21.84	22.49	23.15	23.83	6.3	1.22
2.0	24.57	25.32	26.09	26.89	27.7	28.51	*29.34*	*30.19*	*31.06*	*31.96*	8.1	1.82
2.1	*32.87*	---	---	---	---	---	---	---	---	---	---	---
2.2	---	---	---	---	---	---	---	---	---	---	---	---
2.3	---	---	---	---	---	---	---	---	---	---	---	---

PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

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APPENDIX

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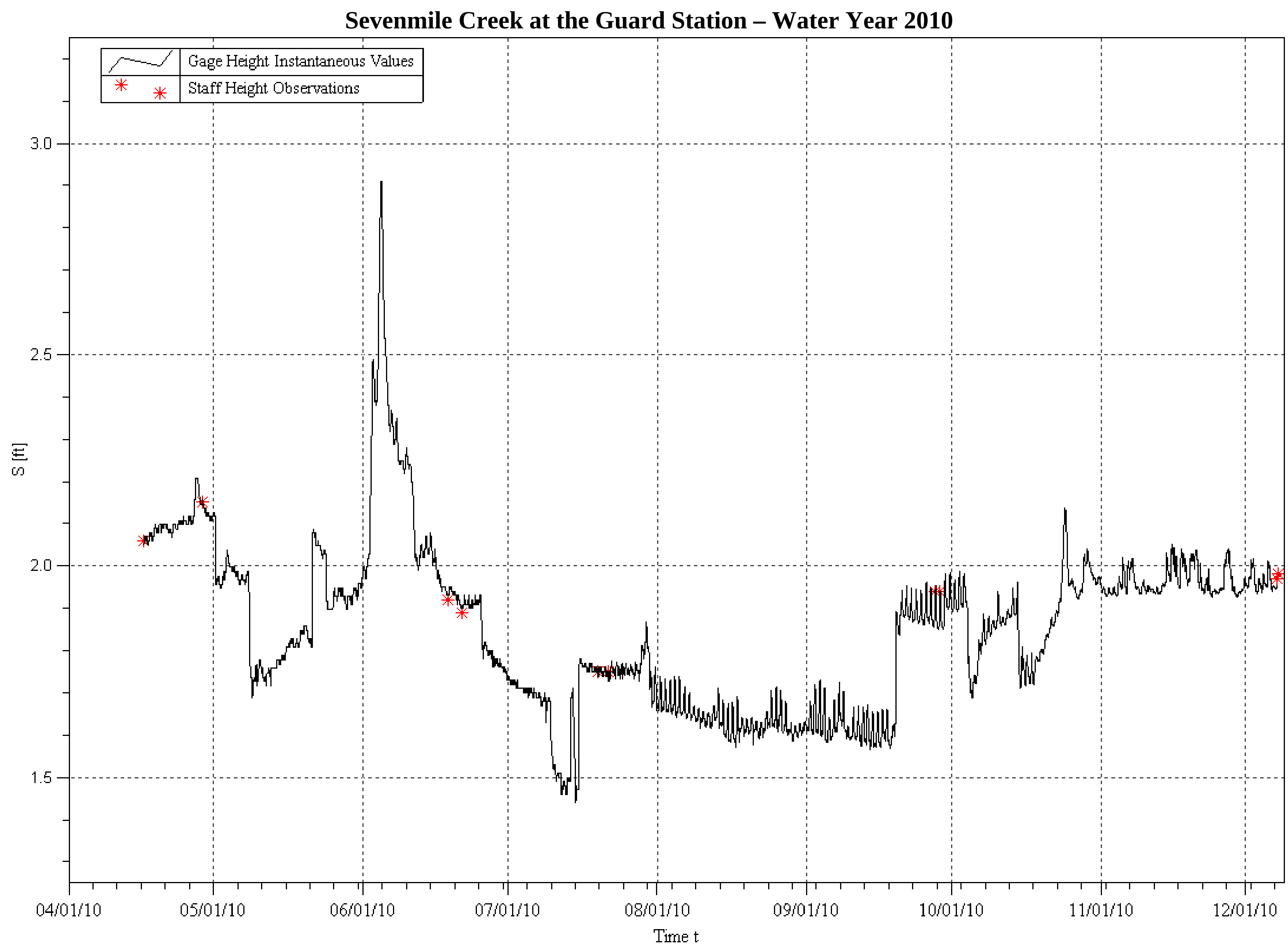

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APPENDIX

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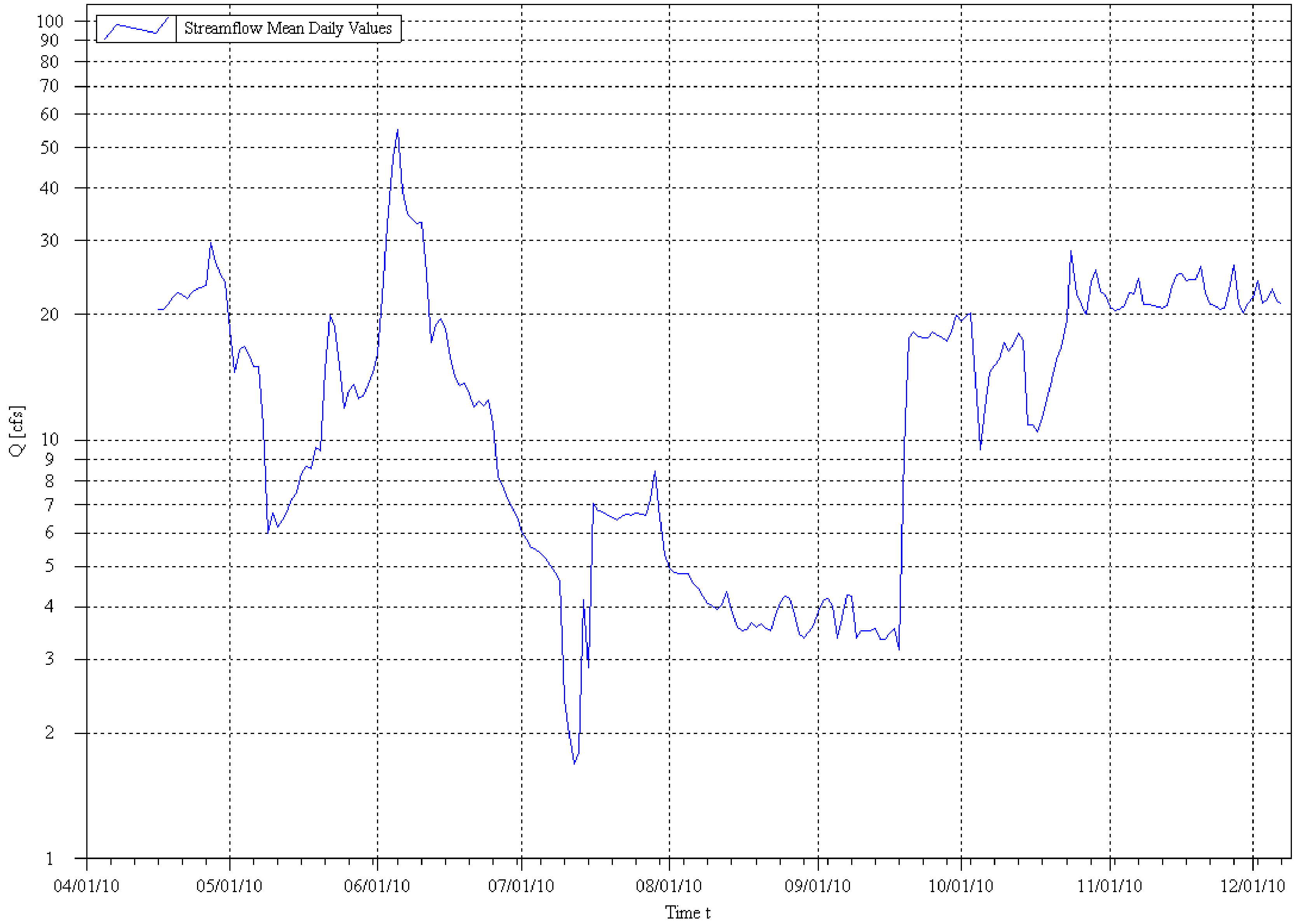
Sevenmile Creek at the Guard Station – Water Year 2010



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APPENDIX

6-7

SEVENMILE CREEK AT GUARD STATION GMA0592300
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2009 TO 9/30/2010
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	7	7.6	---	---	---	---	---	18	16	6	5	3.9
2	6.9	7.4	---	---	---	---	---	15	22e	5.8	4.8	4.1
3	7	7.2	---	---	---	---	---	16	33e	5.5	4.8	4.2
4	7.1	6.8	---	---	---	---	---	17	47e	5.5	4.8	4
5	7	11	---	---	---	---	---	16	55e	5.4	4.8	3.4
6	7.1	12	---	---	---	---	---	15	39e	5.2	4.5	3.8
7	7	12	---	---	---	---	---	15	35e	5	4.4	4.3
8	7.1	13	---	---	---	---	---	11	34e	4.8	4.2	4.2
9	7.1	12	---	---	---	---	---	6	33e	4.6	4.1	3.4
10	7.1	12	---	---	---	---	---	6.7	33	2.4	4	3.5
11	7.1	13	---	---	---	---	---	6.2	25	2	3.9	3.5
12	7.1	---	---	---	---	---	---	6.4	17	1.7	4	3.5
13	8	---	---	---	---	---	---	6.7	19	1.8	4.3	3.6
14	8.3	---	---	---	---	---	---	7.2	20	4.2	3.9	3.4
15	8	---	---	---	---	---	---	7.5	18	2.9	3.6	3.3
16	7.7	---	---	---	---	---	21	8.3	16	7	3.5	3.5
17	7.7	---	---	---	---	---	21	8.6	14	6.8	3.5	3.6
18	7.9	---	---	---	---	---	21	8.6	14	6.7	3.7	3.2
19	7.8	---	---	---	---	---	22	9.6	14	6.6	3.6	9.5
20	7.7	---	---	---	---	---	22	9.4	13	6.5	3.6	18
21	7.5	---	---	---	---	---	22	15	12	6.4	3.5	18
22	7.4	---	---	---	---	---	22	20	12	6.6	3.5	18
23	7.5	---	---	---	---	---	23	19	12	6.7	3.8	18
24	7.7	---	---	---	---	---	23	15	12	6.6	4.1	18
25	7.6	---	---	---	---	---	23	12	11	6.7	4.2	18
26	8.2	---	---	---	---	---	23	13	8.2	6.7	4.2	18
27	8.3	---	---	---	---	---	30	14	7.8	6.6	3.8	18
28	7.6	---	---	---	---	---	27	13	7.3	7.2	3.4	17
29	7.5	---	---	---	---	---	25	13	6.9	8.4	3.4	18
30	7.7	---	---	---	---	---	24	14	6.6	6.5	3.5	20
31	7.6	---	---	---	---	---	---	14	---	5.3	3.6	---
TOTAL	232.3	114	0	0	0	0	349	376.2	612.8	170.1	124	274.9
MEAN	7.5	10.3	---	---	---	---	23.2	12.1	20.4	5.5	4	9.1
MAX	8.3	13	---	---	---	---	30	20	55	8.4	5	20
MIN	6.9	6.8	---	---	---	---	21	6	6.6	1.7	3.4	3.2
AC-FT	461	226	0	0	0	0	692	746	1215	337	246	545

Values For Period

TOTAL 2253 **MEAN** 10.7 **MAX** 55 **MIN** 1.7 **AC-FT** 4469

Description of Gaging Station on: *West Canal Above Sevenmile Canal*

Drainage Basin: *Sevenmile/Fourmile*

1. Location

Lat. 42° 39' 3.62"N, Long. 122° 03' 0.94"W (NAD 27), SW ¼, NW ¼, Sec. 6, T34S, R7 ½E, Klamath County. Gage can be reached by traveling 13.79 miles north on Hwy 62 to Fort Klamath from the intersection of Hwy 62 and Hwy 97. Turn left on Weed road and drive 1.76 miles south. Turn left on Sevenmile Road and travel 2.65 miles. Turn left on McQuiston Road and drive 1.51 miles south. The gaging site is a bridge over the canal on the west side of the road.

2. Hydrologic Conditions

The upper Klamath Basin primarily consists of agricultural lands interspersed with wetlands on the basin floor rising to evergreen forests on the basin slopes. Geology in the basin results from past volcanic events in the surrounding area. Average temperatures in the basin range from 17.2°F to 80.7°F based on 13 years of record from the National Weather Service station in Chiloquin. Precipitation averages 20.69 inches per year and is produced in a combination of snow and rain. Peak flows are generated from rain-on-snow events and spring snowmelt. West Canal receives a significant volume of irrigation tailwater during the irrigation season.

3. Establishment and History

Graham Matthews and Associates established the gaging site for the Klamath Basin Rangeland trust in August, 2003. In June of 2004 the site was upgraded to include measurement of continuous stage and velocity.

4. Gage

A Nortek EZQ is mounted on a piece of channel iron near the left bank. The channel iron is driven into the streambed directly underneath a private bridge that passes over West Canal. Flex conduit runs from the EZQ to a small (1 ft X 1.5 ft) metal enclosure that is chained to the bridge on the left bank. A Global Water WL-14 pressure transducer is also located at the site. The WL-14 pressure transducer is installed in the same conduit that the EZQ wiring is in. The purpose of the WL-14 is used as a backup for stage readings. Both instruments are downloaded and checked from the small enclosure on the left bank.

Inside recording gage: Primary stage accuracy to 0.01 feet; Secondary stage accuracy to 0.03 feet. Velocity accuracy to 1% of the measured value.

Outside Staff gage: Two enameled sections mounted to the bridge retaining wall on the right bank. Limits 3.36 feet to 10.12 feet.

5. Reference Marks (RM)

Three reference marks exist at the site. All reference marks are capped 5/8-inch rebar pounded into the ground. All reference marks can be located by standing on the gravel approach to the bridge and facing east. RM#1 is 27 feet to the north or upstream and is located roughly 3 feet back from the top of the channel. RM#2 is 19 feet to the south or downstream and is located roughly 4 feet back from the top of the channel. RM#3 is located across the bridge and 16 ft to the south or downstream of the bridge. RM#3 is located between the end of the bridge and a telephone pole.

6. Control

The water elevation of Sevenmile Creek as well as the channel roughness are the hydraulic controls at this gage.

7. Discharge Measurements

Discharge measurements are taken off of either the upstream side or downstream side of the bridge using a bridge board, A-reel, Price AA current meter, and an Aquacalc streamflow computer. A 15-lb sounding weight can be used most of the year, but high flow conditions sometimes require the use of a 30-lb sounding weight.

Channel Conditions At Measurement Section
The channel is a semi-trapezoidal man-made channel. The banks are steep, uniformly sloped. Some portions of the bank are unstable.

Horizontal Angle Corrections
No horizontal angle corrections are required at the site.

Flow Conditions
Flow lines are smooth, parallel, and perpendicular to the cross section.

8. Floods
No floods have occurred since the establishment of the gage.

9. Point of Zero Flow
Unknown.

10. Winter Flow
Typical winter flows are derived from rain and/or snowmelt. Rain-on-snow events are responsible for most of the extreme flood events on the stream. Ice is a factor at the site during the winter months.

11. Regulation
None

12. Diversion
A large portion of the streamflow in Sevenmile Creek and its tributaries is diverted at numerous locations upstream during a portion of the year for agricultural purposes.

13. Accuracy
The accuracy at the site is considered good to fair.

14. Cooperation
None.

15. Land Ownership
The gage is located on private property.

16. Purpose of Record
The purpose of the record is to study streamflow and nutrient transport from West Canal into Sevenmile Canal and Fourmile Canal.

17. Cross Section Survey History
Cross Section #1 surveyed: June 2004
Cross Section #1 surveyed: September 2004
Cross Section #1 surveyed: January 2006

18. Rating Table History
NA

19. Photo History
NA

GRAHAM MATTHEWS & ASSOCIATES

Hydrology -- Geomorphology -- Stream Restoration

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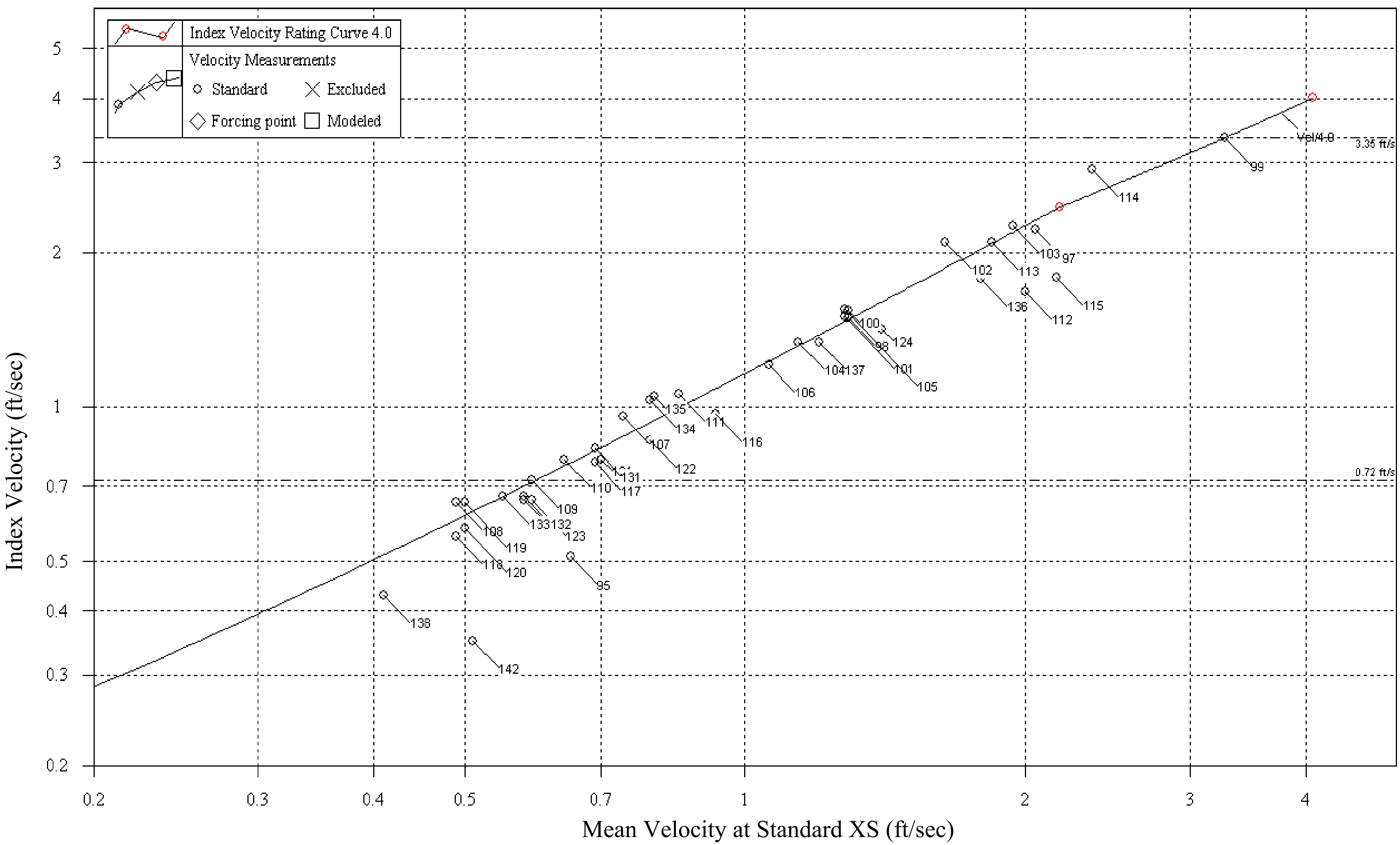
DISCHARGE SUMMARY SHEET

LOCATION: WEST CANAL above SEVENMILE **WATER YEAR:** 2007-2010

STATION NUMBER: GMA0592050

Measurement Number	WY Msmt #	Date	Made By:	Width (feet)	Mean Depth (feet)	Area (ft2)	Mean Velocity (ft/sec)	Stage Height (feet)	Gage Height (feet)	Discharge (cfs)	Rating __3.1___ Comp. Shift (feet)	Used Shift (feet)	% Diff.	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	GZF	Notes
97	2007-03	11/14/2006	M. Anderson	21.6	4.25	91.8	2.21	6.03	6.03	203		0.00	6	Bridge	25	12:00	13:08	Fair		
98	2007-04	12/07/2006	M. Anderson	19.2	1.81	34.8	1.30	3.24	3.23	45.1		0.00	-5	Bridge	26	13:18	14:11	Fair		
											Rating __4.0___									
99	2007-05	12/14/2006	M. Anderson	25.5	5.46	139	3.30	7.56	7.55	459		0.00	1	Bridge	26	8:15	9:17	Fair		Veg. on LB (now under water) prevented 0.2 0.8 msmts.
100	2007-06	01/18/2007	M. Anderson	20.1	1.76	35.3	1.18	3.22	3.23	41.7		0.00	-3	Bridge	25	14:54	15:41	Good		
101	2007-07	02/01/2007	M. Anderson	19.6	1.75	34.3	1.10	3.04	3.06	37.6		0.00	-3	Bridge	23	13:07	13:49	Good		SH Approx. Will not meet 5% rule due to width.
102	2007-08	03/06/2007	M. Anderson	21	1.81	38.1	1.49	3.35	3.37	56.8		-0.20	0	Bridge	26	14:21	15:10	Good		
103	2007-09	03/27/2007	M. Anderson	21.2	2.15	45.7	1.69	3.62	3.61	77.2		0.00	3	Bridge	26	12:28	13:31	Fair		
104	2007-10	05/10/2007	M. Anderson	21.8	2.89	63.1	1.11	4.48	4.55	70.1		0.00	-4	Bridge	25	12:33	13:50	Good		
105	2007-11	05/23/2007	M. Anderson	21.7	2.91	63.1	1.23	4.54	4.53	77.6		-0.05	-2	Bridge	27	14:49	15:54	Good		
106	2007-12	06/06/2007	M. Anderson	21.4	3.56	76.1	1.06	5.13	5.17	80.8		-0.05	6	Bridge	27	15:46	16:57	Fair		
107	2007-13	07/18/2007	M. Anderson	19.8	3.79	75.1	0.80	5.39	5.38	60.5		-0.05	-1	Bridge	23	12:26	13:29	Good		
108	2007-14	08/02/2007	M. Anderson	19.5	3.40	66.4	0.52	4.95	4.89	34.2		-0.05	1	Bridge	24	13:20	14:32	Good		
109	2007-15	08/15/2007	M. Anderson	19.5	3.16	61.6	0.61	4.67	4.68	37.8		0.00	0	Bridge	23	13:31	14:49	Good		
110	2007-16	09/13/2007	M. Anderson	19	3.14	59.7	0.69	4.68	4.68	40.9		-0.05	1	Bridge	22	10:31	11:38	Good		
111	2008-01	12/20/2007	M. Anderson	21.2	2.36	50	0.79	3.91	3.91	39.5		-0.05	-1	Bridge	27	13:00	14:19	Fair		Ice along edges and staff plate had to be broken.
112	2008-02	02/27/2008	M. Anderson	20	1.64	32.9	1.54	2.83	2.86	50.5		---	---	Bridge	26	15:00	16:00	Excluded		SH NA due to snow & ice
113	2008-03	03/12/2008	M. Anderson	20.2	1.85	37.4	1.68	3.31	3.30	62.7		---	---	Bridge	26	15:00	16:30	Good		No Computations Made
114	2008-04	03/27/2008	M. Anderson	21.2	2.88	61.1	2.33	4.53	4.39	143		---	---	Bridge	29	14:18	15:25	Good		No Computations Made
115	2008-05	04/24/2008	M. Anderson	21.7	2.4	52.1	1.98	3.97	3.97	103		---	---	Bridge	29	13:00	15:00	Excluded		No Computations Made
116	2008-06	06/16/2008	M. Anderson	21.8	3.46	75.4	0.89	5.04	---	67.4		---	---	Bridge	26	13:42	15:00	Good		No Record
117	2008-07	07/17/2008	M. Anderson	20.4	3.24	66	0.71	4.82	4.82	46.7		0.06	-1	Bridge	24	9:00	10:40	Good		

118	**2008-08**	07/31/2008	M. Anderson	20.4	3.43	69.9	0.50	4.97	---	34.7		---	---	Bridge	25	12:42	13:54	Good		No GH File
119	**2008-09**	08/13/2008	M. Anderson	20	3.4	68.1	0.52	4.96	---	35.6		---	---	Bridge	25	14:20	15:35	Good		No GH File
120	**2008-10**	08/28/2008	M. Anderson	19	3.41	64.9	0.55	4.97	---	35.5		---	---	Bridge	26	6:54	8:15	Good		No GH File
121	**2008-11**	09/25/2008	M. Anderson	19.9	3.65	72.9	0.73	5.18	---	53.3		---	---	Bridge	22	14:00	15:36	Good		No GH File
122	**2009-01**	10/09/2008	M. Anderson	20.0	3.17	63.4	0.79	4.66	---	50.1		--		Bridge	23	14:22	15:40	Good		No GH File
123	**2009-02**	10/23/2008	M. Anderson	19.8	3.04	59.6	0.59	4.51	4.52	35.4		0.06	-2	Bridge	21	11:51	13:05			
124	**2009-03**	02/19/2009	M. Anderson	20.5	1.83	37.5	1.16	3.13	3.16	43.6		0.06	4	Bridge	25	12:34	13:37	Good		
125	**2009-04**	05/28/2009	M. Anderson	22.5	2.79	62.8	0.58	4.38	4.44	36.2		---	---	Bridge	26	10:54	12:14	Good		No Velocity Data
126	**2009-05**	06/11/2009	M. Anderson	21.9	3.31	72.6	1.30	4.87	4.86	94.5		---	---	Bridge	25	13:25	14:47	Good		No Velocity Data
127	**2009-06**	06/25/2009	M. Anderson	21.3	2.95	62.9	0.88	4.50	4.50	55.2		---	---	Bridge	25	10:22	11:44	Good		No Velocity Data
128	**2009-07**	07/02/2009	M. Anderson	21.1	2.85	60.2	0.60	4.35	4.35	35.9		---	---	Bridge	24	13:34	15:02	Good		No Velocity Data
129	**2009-08**	07/16/2009	M. Anderson	21.2	3.54	75.0	0.60	5.06	5.13	45.3		---	---	Bridge	24	12:53	14:00	Good		No Velocity Data
130	**2009-09**	07/29/2009	M. Anderson	21.3	3.59	76.6	0.46	5.21	5.25	35.1		---	---	Bridge	24	11:10	12:28	Good		No Velocity Data
131	**2009-10**	08/13/2009	M. Anderson	20.3	3.09	62.7	0.71	4.62	4.66	44.2		0.00	2	Bridge	23	11:47	13:11	Fair		A lot of veg. floating DS.
132	**2009-11**	08/27/2009	M. Anderson	20.2	3.57	72.10	0.59	5.03	5.05	42.6		0.00	7	Bridge	22	11:58	13:09	Good		
133	**2009-12**	09/10/2009	M. Anderson	20.6	3.66	75.30	0.56	5.15	5.15	41.9		0.00	0	Bridge	22	13:31	14:49	Good		
134	**2009-13**	10/22/2009	M. Anderson	19.4	2.72	52.7	0.85	4.38	---	44.9		---	---	Bridge	22	14:57	16:18	Fair		No GH Data; I had to change measurement time to 30 sec. on some. The meter was not getting a good reading and resetting.
135	**2010-01**	11/05/2009	M. Anderson	20.2	2.75	55.5	0.78	4.26	---	43.2		---	---	Bridge	21	14:58	16:17	Fair		No GH Data; Flow may be higher than measurement. There was a lot of veg. sticking to the meter and effecting the spin at times.
136	**2010-02**	04/28/2010	M. Anderson	21.5	2.05	44.0	1.60	3.58	3.56	70.2		0.23	0	Bridge	26	16:13	17:22	Good		Do not have Data File
137	**2010-03**	05/12/2010	M. Anderson	22.0	2.67	58.7	1.12	4.30	4.30	65.9		0.00	2	Bridge	25	11:43	12:48	Good		Do not have Data File
138	**2010-04**	07/22/2010	M. Anderson	21.8	3.31	72.1	0.41	4.98	5.00	29.3		0.07	0	Bridge	26	12:22	13:43	Good		Do not have Data File
139	**2010-05**	08/11/2010	M. Anderson	21.8	3.16	68.9	0.50	4.92	4.94	34.4		---	---	Bridge	23	16:29	17:40	Good		No Velocity Data; Do not have Data File, SH +/- 0.02 due to Wind
140	**2010-06**	08/19/2010	M. Anderson	21.8	3.33	72.6	0.51	4.97	5.04	36.9		---	---	Bridge	22	10:12	11:18	Good		No Velocity Data; Do not have Data File, SH +/- 0.01
141	**2010-07**	09/02/2010	M. Anderson	21.8	3.17	69.2	0.65	4.87	4.88	45.1		---	---	Bridge	25	12:45	13:55	Good		No Velocity Data; SH +/- 0.01
142	**2010-08**	09/30/2010	M. Anderson	21.7	2.64	57.3	0.46	4.15	4.13	26.4		0.24	1	Bridge	22	16:29	17:27	Good		SH +/- 0.01



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

Klamath Basin Rangeland Trust

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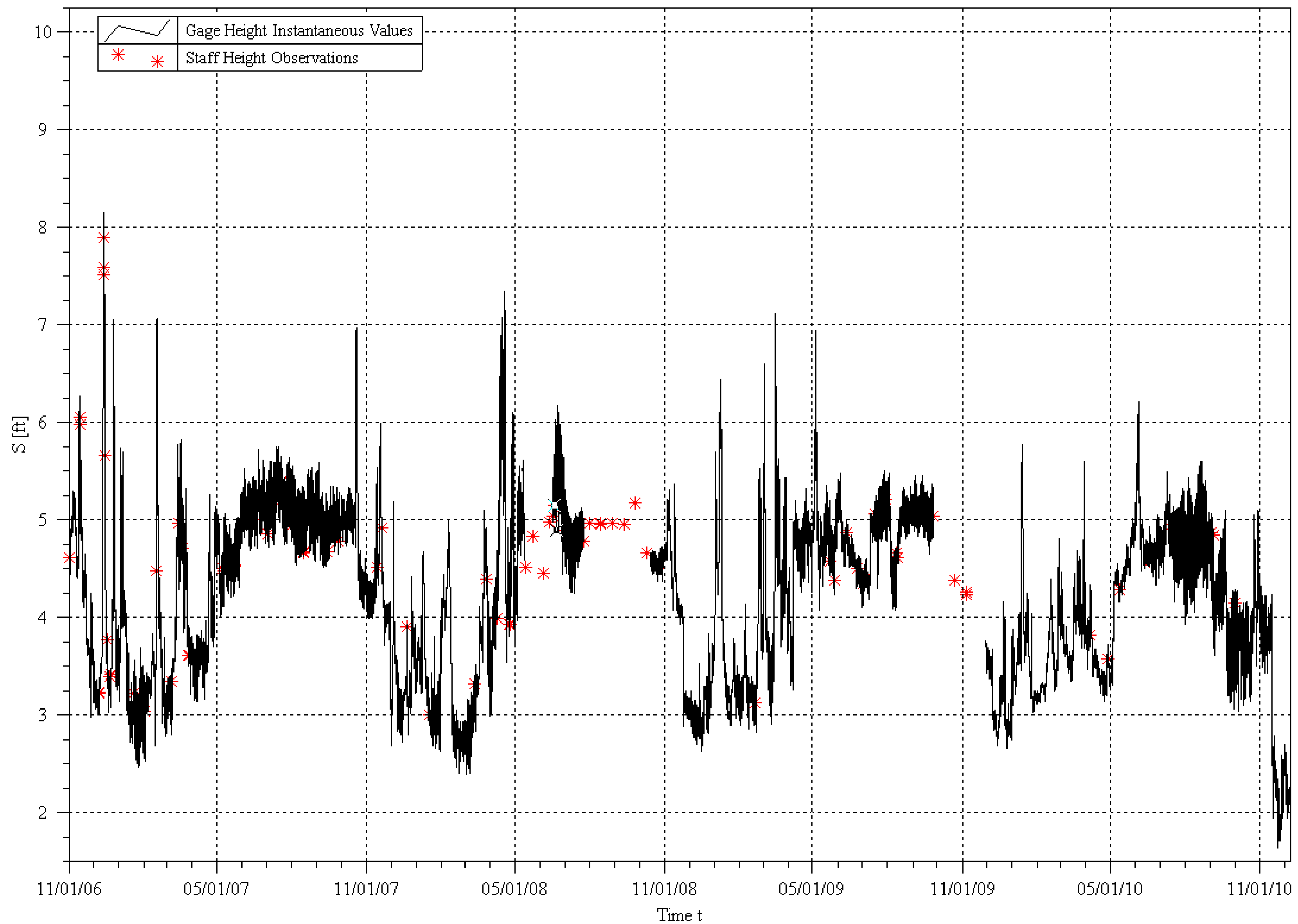
APPENDIX

7-3

West Canal above Sevenmile Creek – Water Year 2007-2010



PROJECT:

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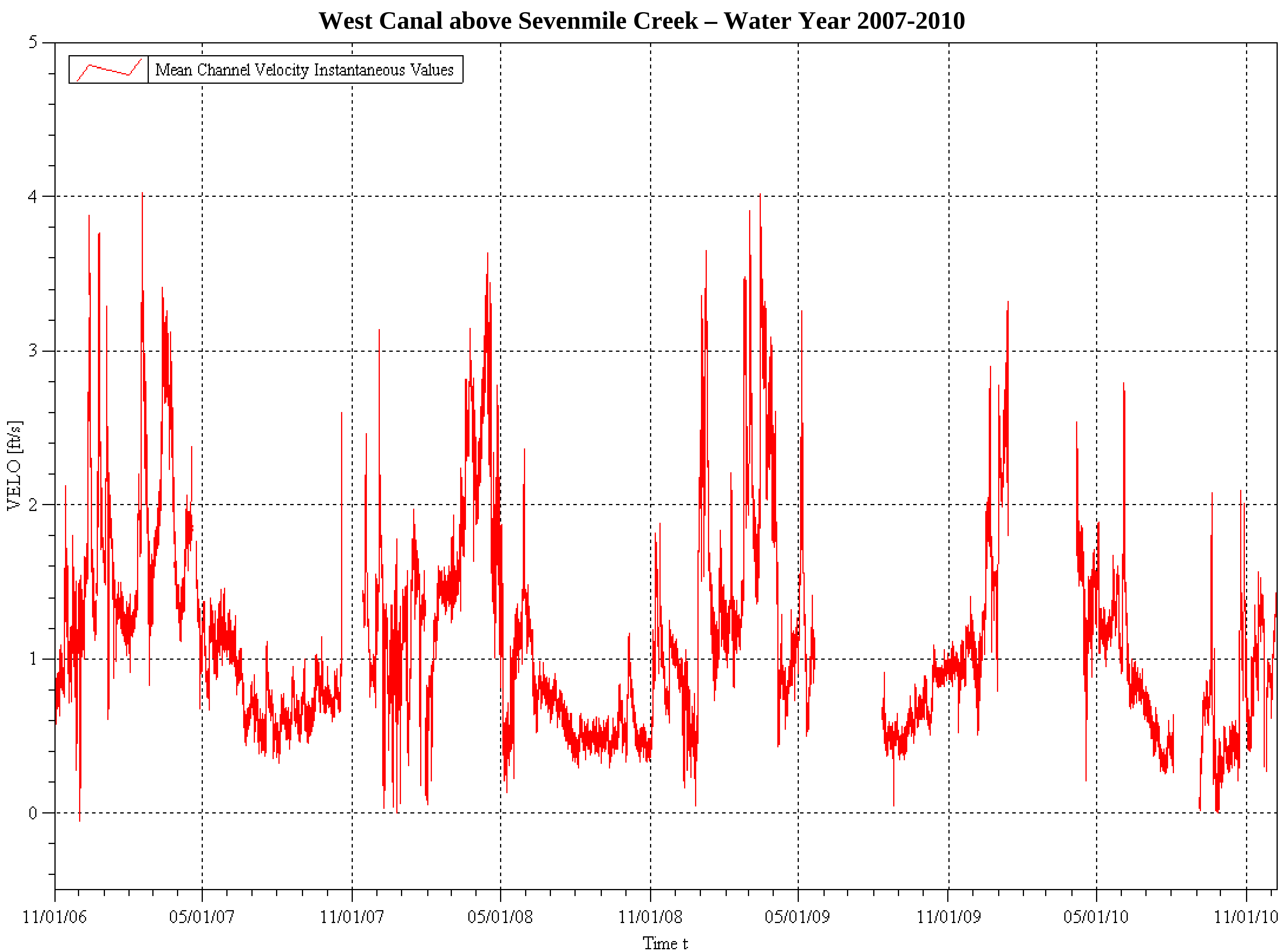
APPENDIX

7-5



PROJECT:
WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING
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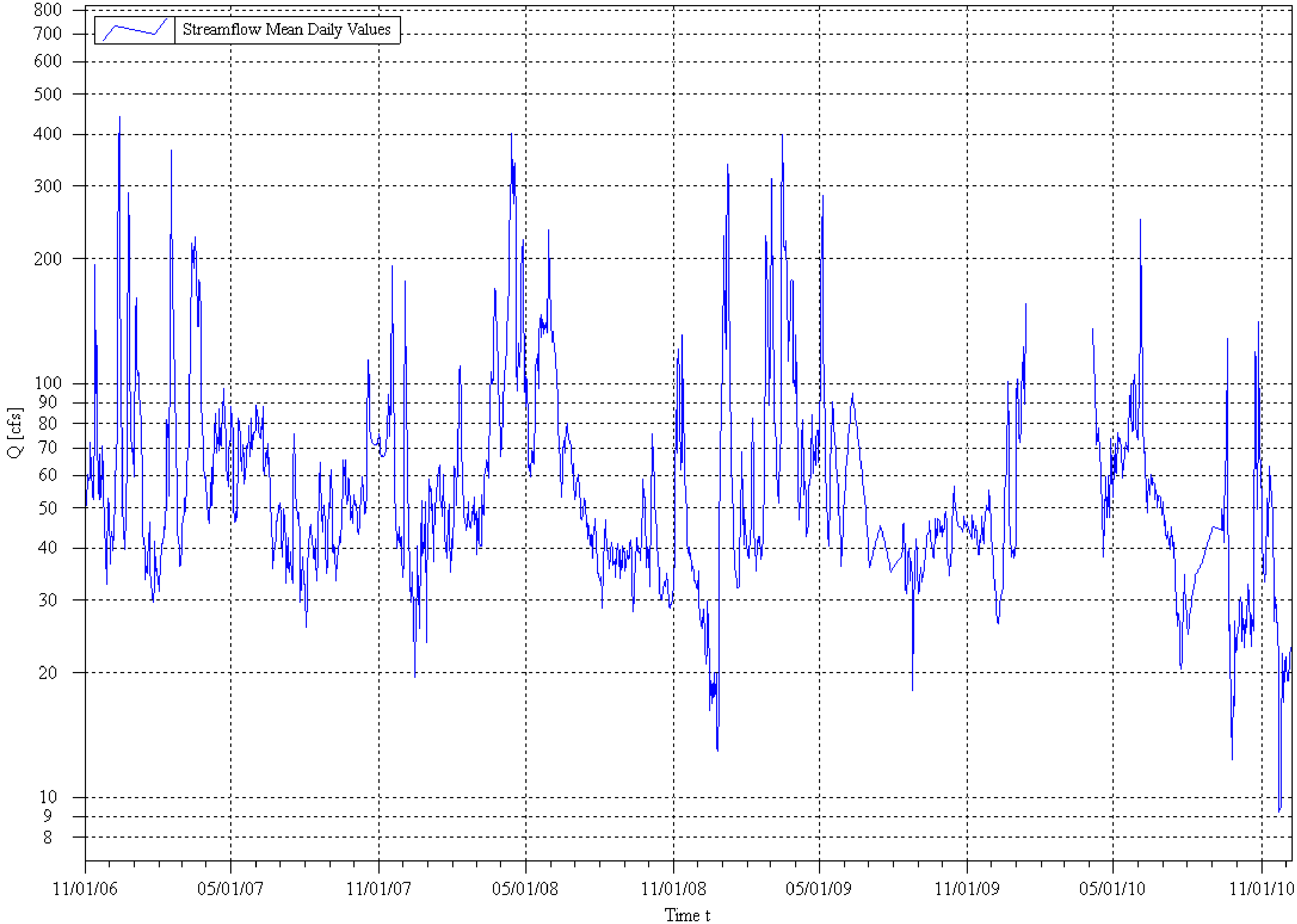
APPENDIX
7-6

West Canal above Sevenmile Creek – Water Year 2007-2010



PROJECT:

WOOD RIVER VALLEY SURFACE WATER AND WATER QUALITY MONITORING

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APPENDIX

7-7

WEST CANAL ABOVE SEVENMILE CREEK GMA0592050
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2006 TO 9/30/2007
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	50	38	50	59	32	40	58	72	78	51	33	50
2	51	48	37	62	31	45	52	88	88	48	31	58
3	51	53	41	148	38	47	47	83	85	42	26	62
4	48	58	44	161	40	48	46	74	82	38	30	51
5	48	60	42	111	41	53	47	51	78	46	36	39
6	44	58	40	105	41	49	53	46	74	50	40	41
7	40	59	44	106	43	58	63	47	74	47	45	37
8	39	72	53	96	45	61	51	49	79	41	46	40
9	39	61	59	87	44	69	64	47	78	33	45	33
10	42	55	64	81	55	71	71	69	88	39	42	38
11	38	54	79	56	82	88	75	82	62	42	39	38
12	34	52	182	43	79	126	85	81	60	36	38	39
13	44	85	370	42	69	208	68	74	66	35	38	42
14	47	193	443	39	54	219	74	68	68	39	42	43
15	45	94	218	34	144	203	74	62	66	39	37	41
16	52	123	95	36	367	190	69	71	72	34	33	48
17	51	76	65	35	263	203	87	65	64	33	38	58
18	50	56	51	37	190	226	71	57	66	60	42	65
19	39	52	44	41	121	194	71e	60	53	76	57	60
20	39	67	40	46	109	194	76e	65	53	61	65	65
21	41	53	43	36	102	138	84e	71	45	56	60	56
22	39	64	44	32	71	137	97e	70	40	50	49	51
23	35	71	74	32	55	178	93e	74	36	49	44	53
24	38	60	96	31	44	175	84	79	39	47	46	59
25	40	42	288	30	42	143	72	67	40	49	51	59
26	40	46	226	33	40	94	63	73	43	42	45	49
27	40	39	119	42	36	77	60	82	47	30	41	47
28	39	33	77	35	36	74	56	69	46	34	35	49
29	34	36	68	35	---	64	68	76	51	37	37	46
30	39	53	71	36	---	59	73	76	49	38	43	48
31	37	---	69	33	---	60	---	76	---	33	51	---
TOTAL	1313	1911	3236	1800	2314	3591	2052	2124	1870	1355	1305	1465
MEAN	42.3	63.8	104.4	58.1	82.6	115.9	68.4	68.5	62.3	43.7	42.1	48.8
MAX	52	193	443	161	367	226	97	88	88	76	65	65
MIN	34	33	37	30	31	40	46	46	36	30	26	33
AC-FT	2604	3790	6419	3570	4590	7123	4070	4213	3709	2688	2588	2906

Values For Period

TOTAL 24336 **MEAN** 66.7 **MAX** 443 **MIN** 26 **AC-FT** 48270

WEST CANAL ABOVE SEVENMILE CREEK GMA0592050
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2007 TO 9/30/2008
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	54	76e	34	41	42	49	67	88	148e	52	33e	39e
2	51	73e	37	52	48	39	71	104	144e	54	34e	35e
3	51	68e	70	59	63	45	86	102	126e	57	34e	36e
4	51	67e	177	55	62	50	107	79	134e	59	31e	39e
5	47	67e	87	56	57	41	104	63	132e	60	29e	39e
6	44	67e	69	49	51	40	111	64	120e	60	37e	38e
7	43	67e	58	51	69	40	123	60	118e	55	42e	38e
8	46	67e	46	37	87	54	132	60	111e	51	47e	41e
9	46	67e	34	40	107	48	150	69	107e	47	44e	42e
10	56	69e	33	51	110	48	175	68	88e	47	41e	39e
11	57	78e	30	52	90	58	224	64	79e	48	38e	33e
12	59	74e	35	53	71	62	274	64e	71e	48	39e	28e
13	55	94e	33	59	59	63	334	90e	65e	53	36e	31e
14	49	83e	29	62	49	65	401	110e	63e	51	38e	34e
15	49	74	19	64	48	64	306	112e	53e	52	39e	36e
16	49	94	20	53	47	59	271	118e	61e	45	41e	42e
17	55	185	28	51	44	60	328	97e	68e	46	39e	39e
18	74e	193	33	49	44	92	342	130e	73e	42	36e	39e
19	114e	102	40	48	46	107	239	142e	68	45	37e	39e
20	98e	71	29	60	52	106	112	146e	71	41	38e	39e
21	79e	55	29	45	48	100	96	129e	77	43	34e	37e
22	74e	48	26	42	45	103	125	143e	80	43	39e	43e
23	73e	41	41	41	45	125	117	138e	78	38e	41e	52e
24	72e	40	52	38	48	170	109	132e	75	42e	40e	59e
25	72e	43	38	38	49	168	129	138e	72	44e	39e	53e
26	71e	41	39	48	49	147	185	139e	71	46e	34e	53e
27	71e	45	44	51	53	137	207	140e	67	47e	40e	51e
28	71e	41	40	44	46	106	224	133e	61	41e	36e	36e
29	71e	43	52	35	48	99	171	193e	64	37e	36e	39e
30	72e	39	24	42	---	90	103	236e	58	35e	40e	40e
31	72e	---	34	37	---	70	---	172e	---	35e	39e	---
TOTAL	1946	2172	1360	1503	1677	2505	5423	3523	2603	1464	1171	1209
MEAN	62.8	72.3	43.9	48.5	57.8	80.7	180.8	113.6	86.8	47.3	37.7	40.4
MAX	114	193	177	64	110	170	401	236	148	60	47	59
MIN	43	39	19	35	42	39	67	60	53	35	29	28
AC-FT	3860	4308	2698	2981	3326	4969	10760	6988	5163	2904	2323	2398

Values For Period

TOTAL 26556 **MEAN** 72.6 **MAX** 401 **MIN** 19 **AC-FT** 52670

WEST CANAL ABOVE SEVENMILE CREEK GMA0592050
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2008 TO 9/30/2009
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	40e	32	32	104	39	119	95	80	53e	39e	36e	31
2	32e	40	35	228	38	313	131	103	57e	36e	36e	31
3	34e	55	30	195	39	278	97	177	61e	37e	36e	33
4	49e	86	27	146	42	150	63	225	65e	37e	37e	36
5	73e	68	26	121	46	98	57	286	70e	38e	37e	34
6	76e	110	26	192	63	87	47	125	74e	39e	37e	33
7	66e	121	26	339	83	75	53	100	78e	39e	37e	35
8	58e	103	28	306	64	74	59	76	82e	40e	38e	35
9	50e	85	25	196	47	61	73	63	86e	41e	38e	36
10	49e	62	23	103	38	56	82	52	90e	41e	38e	39
11	43e	67	21	71	38	51	59	47	95e	42e	38	41
12	40e	131	23	64	35	57	54	44	92e	43e	40	43
13	38e	81	30	55	42	65	58	40	89e	43e	45	44
14	34e	72	26	48	41	78	54	54	86e	44e	46	44
15	32e	60	20	43	43	236	43	66	83e	45e	37	47
16	31e	54	16	36	43	400	44	70	80e	45e	32	42
17	30	49	19	35	38	293	46	90	78e	45e	31	40
18	30	42	19	33e	38	219	57	85	75e	44e	34	40
19	32	39	17	32	39	211	57	80	72e	43e	39	38
20	33	38	18	32	43	218	61	73	69e	42e	40	38
21	33	40	20	32	47	222	65	69	66e	41e	36	44
22	32	38	18	37	55	179	84	65e	64e	41e	33	47
23	35	37	18	48	158	113	61	60e	61e	40e	37	42
24	34	35	20	64	228	120	71	55e	58e	39e	33	43
25	33	36	13	69	215	133	66	50e	55e	38e	18	47
26	29	35	13	51	149	151	63	46e	52e	37e	27	47e
27	29	33	17	41	101	175	72	41e	50e	37e	37	46e
28	29	33	37	50	88	178	77	36e	47e	36e	37	44e
29	29	32	73	44	---	177	77	40e	44e	35e	42	45e
30	30	32	80	42	---	101	64	45e	41e	35e	39	43e
31	31	---	96	41	---	102	---	49e	---	36e	36	---
TOTAL	1214	1746	892	2898	1940	4790	1990	2492	2073	1238	1127	1208
MEAN	39.1	58.3	28.8	93.5	69.3	154.5	66.3	80.3	69.1	39.9	36.4	40.3
MAX	76	131	96	339	228	400	131	286	95	45	46	47
MIN	29	32	13	32	35	51	43	36	41	35	18	31
AC-FT	2408	3463	1769	5748	3848	9501	3947	4943	4112	2456	2235	2396

Values For Period

TOTAL 23608 **MEAN** 64.7 **MAX** 400 **MIN** 13 **AC-FT** 46830

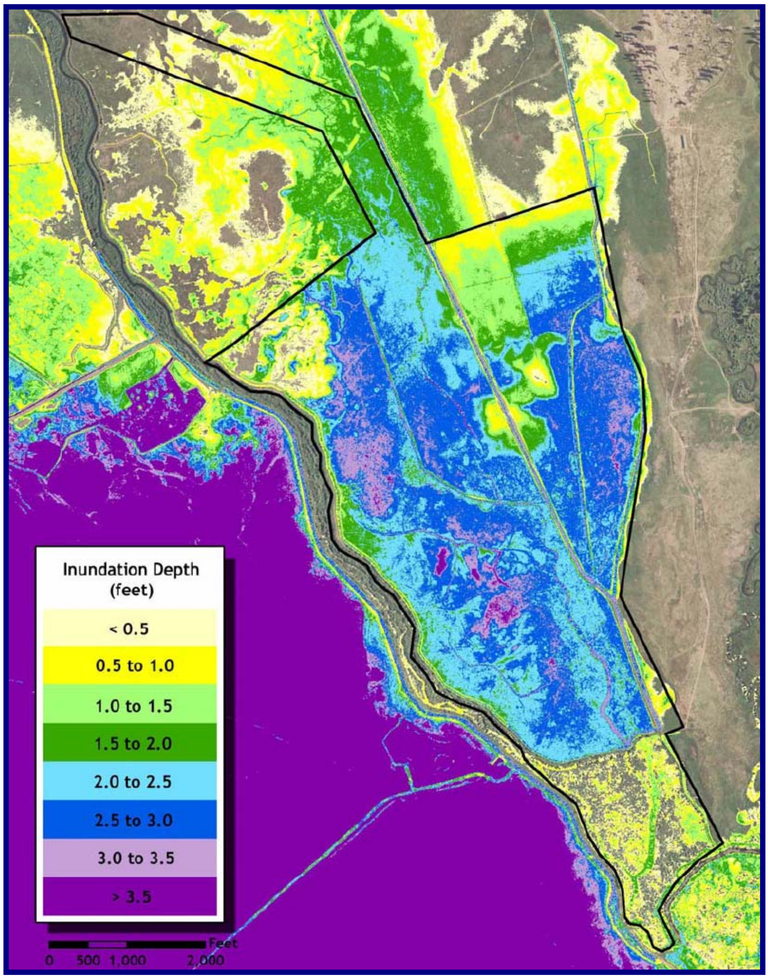
WEST CANAL ABOVE SEVENMILE CREEK GMA0592050
DISCHARGE, CUBIC FEET PER SECOND, 10/1/2009 TO 9/30/2010
MEAN DAILY DISCHARGE VALUES

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	45e	46e	43	92	---	---	---	54	74	52	26	45e
2	44e	45e	40	103	---	---	---	63	102	52	25	45e
3	45e	44e	37	83	---	---	---	71	136	45	26	45e
4	48e	44e	35	74	---	---	---	61	249	46	27e	45e
5	49e	43e	33	72	---	---	---	61	150	44	28e	45e
6	46e	42e	31	79	---	---	135	75	100	42	29e	45e
7	38e	48e	29	98	---	---	114	76	82	44	30e	45e
8	38e	46e	26	104	---	---	99	73	68	43	31e	45e
9	35e	44e	26	123	---	---	78	72	68	42	32e	44e
10	34e	42e	28	105	---	---	71	74	63	40	33e	44e
11	38e	45e	29	89	---	---	73	70	55	41	34e	44e
12	40e	43e	30	157	---	---	78	59	49	45	35e	44
13	44e	43e	31	---	---	---	74	59	52	40	35e	50
14	52e	39e	31	---	---	---	71	65	59	43	35e	47
15	56e	39e	32	---	---	---	59	67	54	40	36e	41
16	53e	42e	52	---	---	---	57	69	54	36	36e	49
17	50e	41e	56	---	---	---	52	72	60	34	36e	59
18	48e	45e	57	---	---	---	38	70	58	29	37e	72
19	47e	48e	63	---	---	---	39	69	57	26	37e	129
20	46e	42e	62	---	---	---	46	77	58	28	37e	74
21	45e	41e	101	---	---	---	59	88	57	28	38e	25
22	45e	45e	74	---	---	---	57	99	52	26	39e	26
23	45e	48e	49	---	---	---	47	86	55	21	39e	24
24	45e	50e	42	---	---	---	60	77	53	20	40e	16
25	45e	51e	39	---	---	---	53	77	50	22	40e	12
26	44e	50e	38	---	---	---	47	99	53	25	41e	14
27	45e	49e	39	---	---	---	68	105	53	28	42e	18
28	48e	55e	40	---	---	---	73	95	53	35	42e	17
29	46e	52e	38	---	---	---	61	80	52	32	43e	27
30	45e	45e	39	---	---	---	53	75	48	30	43e	22
31	46e	---	42	---	---	---	---	73	---	27	44e	---
TOTAL	1395	1357	1312	1179	0	0	1662	2311	2174	1106	1096	1258
MEAN	45	45.2	42.4	98.3	---	---	66.6	74.5	72.5	35.6	35.4	41.9
MAX	56	55	101	157	---	---	135	105	249	52	44	129
MIN	34	39	26	72	---	---	38	54	48	20	25	12
AC-FT	2767	2692	2602	2339	0	0	3297	4584	4312	2194	2174	2495

Values For Period

TOTAL 14850 **MEAN** 52.7 **MAX** 249 **MIN** 12 **AC-FT** 29450

AGENCY RANCH WRP
WATER QUALITY MONITORING, 2008-2010



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AGENCY RANCH WRP
2008-2010 WATER QUALITY MONITORING

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AGENCY RANCH WRP
2008-2010 WATER QUALITY MONITORING PROGRAM

1.0 INTRODUCTION

1.1 Project Setting and Overview

The Upper Klamath Basin once supported nearly 200,000 acres of shallow lakes and freshwater marshes (USGS 2004). These extensive wetlands and associated waterways attracted, at times, more than six million waterfowl. Today, over 75 percent of historic wetlands, marshes, and streams have been converted to agricultural uses. To facilitate cattle grazing and other agriculture land uses, wetlands were ditched, drained, and diked, which subsequently destroyed water fowl habitat, diminished water quality, and reduced overall water storage in the basin. As a result, multiple agencies and stakeholders agree there is a need to restore wetland function to improve water fowl habitat, improve water quality, expand wetland hydrology, and increase water storage.

The purpose of the Agency Ranch WRP Project is to restore 700 acres of lake-fringe wetland to a proper functioning state in the most feasible manner that will best benefit both habitat and water quality. This pasture has been actively grazed by cattle for the last century. Historically, Agency Ranch has pumped water off of its land every spring in order to graze cattle, and throughout the season, pumped irrigation tailwater from properties up-gradient of them off of their land and into Crooked Creek, where it mixes with better quality creek water before joining the Wood River, and finally entering Agency lake. The owners of Agency Ranch intend to return their ranch to its historic wetland state and have applied for a permanent easement through the Wetland Reserve Program.

This project is located adjacent to the Bureau of Land Management (BLM) Wood River Wetland and in proximity to the Klamath Basin National Wildlife Refuge Complex. Irrigation tailwater from hundreds of acres pass through the ranch, offering a superb opportunity to improve the water quality before it empties into Agency Lake. The tailwater will now be retained and naturally treated in the 700-acre wetlands before reaching Agency Lake.

To achieve project goals, irrigation ditches were plugged and swales and slough channels were excavated throughout the project area. A water control structure was installed, exclusively for the restoration effort, to maintain semi-permanent water conditions and to manage water for treatment within the restoration project area. Loafing islands and riparian mounds were constructed with spoil from swale and ditch excavation. Riparian habitat was restored by planting willow and cottonwood trees on the riparian mounds and along the restored slough channel. Project construction took place from August through November of 2009 and is now managed and protected by permanent easement with the Natural Resources Conservation Service - Wetland Reserve Program. For the first few years, water levels will be closely managed to encourage wetland vegetation establishment.

1.2 Scope and Objectives

The wetland project design and water quality monitoring have been undertaken by the Klamath Basin Rangeland Trust (KBRT). KBRT has been involved in a large-scale irrigation forbearance project in the Wood River Valley since 2002. Associated activities have involved an extensive monitoring program to establish baseline water quality conditions in the overall project area. Such baseline conditions are intended to facilitate comparison of possible water quality changes induced by increased stream flow and cattle reduction/management strategies, as well as any future channel restoration activities. Changes in water quality from increased flows, cattle management (e.g., riparian fencing), and stream restoration may respond in the short-term, but are more likely to become detectable within a 5-10 year time span.

At the Agency Ranch, water quality monitoring was incorporated into the original project proposal in order to develop baseline data which would be used to evaluate project performance.

2.0 WATER QUALITY MONITORING PROGRAM

2.1 2008-2010 Program

The water quality monitoring program to date for the Agency Ranch WRP Project was undertaken by KBRT in 2008 through 2010. The data collection conducted in this period involved streamflow monitoring and standard nutrient sampling for nitrogen and phosphorus species.

The following 3 sites were monitored between April 2008 and November 2010:

- Wood River at Weed Road (WRWR)
- Crooked Creek above Thomas Pump Ditch (CCATP)
- Thomas Pump Ditch (TPD)

The WRWR site was initially incorporated into the project scope to assess the extent of impact from the wetland project on the larger river system (to which Crooked Creek is a tributary) which then provides significant inflow into Agency Lake. The WRWR site is the longest running streamflow station in the Wood River Valley (1991-present).

Biweekly nutrient measurements were collected at these 3 sites from late April to late October. All of these sites were co-located with surface-water gages so that nutrient loads may be calculated.

Major nutrient parameters (total phosphorus and total nitrogen) were monitored on an approximately biweekly basis at each site. In addition, either continuous or manual discharge measurements were made by GMA. Streamflow details are presented in a separate report for the 2007-2010 period (GMA 2011). Computation of daily nutrient loads for TP and TN was undertaken for the May 1 – October 31 period for each year, based on available streamflow and nutrient data.

3.0 METHODS

3.1 Streamflow Measurements and Records

Stage at continuous gaging sites is measured by a Campbell datalogger combined with a Design Analysis H-310 pressure transducer. Stage is recorded at 30-minute intervals. Gaging stations are typically visited and downloaded monthly.

Discharge measurements were made periodically during the season, with the number depending on the variation in stage and stability of the discharge rating at the site. The measurements were made following standard hydrologic practice using standard stream gaging equipment. Most measurements were performed by wading at the gage location, however at the WRWR and CCATP sites, measurements were taken from bridges.

After collection of the discharge measurements, a discharge-rating curve was developed for each station by plotting the stage/discharge pairs and electronically hand fitting a curve. Stage/discharge pairs were evaluated and ratings developed within the WISKI Suite of software. The WISKI suite was used to develop all rating tables and performed all computations for continuous surface water gaging stations.

Continuous streamflow records were not measured at CCATP, as this site lies with the backwater of Agency Lake and establishing and maintaining an index velocity station was beyond the scope of this project. Instead, streamflow records were developed for the Crooked Creek above Agency gage (CCAA) and summed with measured flows in Agency Creek and Agency Ditch to produce a continuous flow record at CCATP. Periodic discharge measurements at CCATP were collected to verify and slightly adjust the summed flows due to water use from the ditch. Most of the ditch water returns to Crooked Creek via Ranch Creek on the Root Ranch, but there is up to several cfs of consumptive use on other properties.

3.2 Water Quality Measurements

Nutrient samples (Total-P and Total-N) were collected on an approximately biweekly sample schedule, from late April through late October or early November of each year. Nutrient sampling was conducted by collecting a grab sample at the channel edge. In 2008 and 2009, samples were overnighted to the Aquatic Research, Inc. laboratory in Seattle. In 2010, samples were delivered to the Klamath Tribes Sprague River Water Quality Lab in Chiloquin.

3.3 Nutrient Loading

Continuous stream discharge records produced by GMA were used to compute daily loads for TP and TN during the irrigation season. Daily loads are computed by multiplying mean daily discharge by the daily nutrient concentration to obtain kilograms per day for each parameter.

At continuous discharge sites (WRWR and CCATP), the mean daily flow for a sample date was multiplied by measured concentration on that date, with daily concentration values obtained by linear interpolation between the roughly bi-weekly samples (every 12-16 days). The daily values are summed to produce either monthly or total loading for the period. In 2008-2010, daily loading records were computed for all three sites (except WRWR in 2010 where nutrient data were not collected) for the period of May 1 to October 31 (to enable comparison with previous water years).

For the Thomas Pump, average daily discharge for the billing period was computed by the power consumption method, which uses engineering information about the pump and its power consumption to estimate the total amount of water pumped in a given billing period, typically monthly. The mean daily pump discharge is then computed by dividing the total pumped by the interval. It should be noted that this method is an approximation, but one that provides for the relative difference between pumping in different years.

4.0 2008-2010 RESULTS

4.1 Streamflow

Figure 3 shows the 2008-2010 annual hydrographs at the Wood River at Weed Road site. In general, winter baseflow (~400 cfs) and irrigation season flows (~200 cfs) are similar between the three years, with variability associated with individual winter storms or snowmelt runoff. Figure 4 provides a close-up of the May-Oct period of the WQ investigation, which highlights the variability of spring and early summer flows and the consistency of flows from July through October. 2010 was a bit different from mid-September through mid-October, when a bench around 325 cfs occurred.

In contrast, the streamflow records for Crooked Creek above Agency Creek (Figure 5) show the summer and fall flows for 2009 and 2010 increasing substantially over previous years, with the departure for 2010 being the most pronounced. Streamflows were between 15 and 20 cfs higher in 2010 than in 2003-2005 and 2008. 2009 flows were intermediate between the two groups. At present, no explanation for this substantial increase is known, but it seems it must be related to greater spring flows, as Crooked Creek is essentially entirely fed by a series of springs. Why this would not be reflected in the flows that drive the Wood River is unknown, as that system is also primarily spring-fed in the summer and fall.

In any case, flows at CCATP where nutrient loading are computed ranged from 77 to 104 cfs in the study period, roughly 20% of the WRWR flows in the non-irrigation season and 30-60% of the WRWR flows during the main portion of the irrigation season, mid June through early September. Thus, at least during irrigation season, changes in nutrient loads from Crooked Creek could have an important effect on the quality of Wood River water reaching Agency Lake.

4.1 Nutrient Concentrations

4.1.1 Nutrient Sample Summary

Table 1 summarizes the nutrient samples collected by site over the course of the 2008 to 2010 study period. 10-14 samples were collected each year at each site, with the exception of WRWR in 2010 when only 2 samples were collected and then data collection was stopped at that site.

AGENCY RANCH WRP PROJECT Water Quality Data Collection Summary -- 2008-2010					
		2008	2009	2010	Total
Site	**Site Acronym**	**# Nutrient Msmts**	**# Nutrient Msmts**	**# Nutrient Msmts**	**Site Project Total**
Wood River at Weed Road	WRWR	14	12	2	28
Crooked Creek above Thomas Ditch	CCATP	12	12	10	34
Thomas Pump Ditch	TPD	13	12	11	36
Total by Year		39	36	23	98

Table 1: Summary of Nutrient Measurements by Site, 2008-2010

A total of 98 nutrient measurements were collected at the three sites over the 3-year period. Figure 6 plots all of the nutrient data over the study period by site. Note that the scale is 10x for the Thomas Pump samples compared to the other sites. These results are discussed in the following sections.

4.1.2 Wood River at Weed Road (WRWR)

Figure 7 plots TP and TN concentrations at WRWR for 2008 and 2009. The upper plot shows TP, with the two years overlaid on the same date axis. TP is generally fairly consistent in the range of 0.08-0.09 mg/l. A few small spikes up or down have occurred, but the bulk of the data identify a well defined relationship, especially in the summer months (both years) and in 2009.

For TN, there is considerably more scatter between measurements and an overall trend of declining TN concentrations is apparent in the data from both years. In the spring and early summer, concentrations are generally in 0.10 to 0.17 mg/l range, with variations of 0.05 mg/l or more between the bi-weekly samples. Beginning in mid-June, both years exhibit a gradual decline that continues into the fall. Note also that several samples (plotted at 0.025 mg/l) are below the detection limit of the laboratory analysis. Since very little tailwater reaches the Wood River system (GMA 2003, 2007) this decline suggest that higher flows in the spring are able to entrain TN from tributaries sources (e.g. Annie Creek), or groundwater returns but are depleted as these sources decline in importance compared to base springflow.

4.1.3 Crooked Creek above Thomas Pump (CCATP)

The Crooked Creek above Thomas Pumps reflects the flow and nutrient loading from the entire Crooked Creek watershed, with the exception of field runoff that mostly ends up at the topographic low point where the Thomas Pump sits. Thus, nutrient loading in Crooked Creek is primarily from background spring nutrient loads with some contributions from the State Fish Hatchery located neat Tecumseh Springs just East of Highway 62.

Figure 8 plots TP and TN concentrations at CCATP for 2008-2010. The upper plot shows TP, with the three years overlaid on the same date axis. TP is consistent in the range of 0.10-0.12 mg/l. Similar to WRWR, an occasional small spikes up or down occurred, but the bulk of the data identify a well defined relationship, especially in the summer months. A slight, but apparent seasonal decline occurs for TP for spring through fall, with the Aug-Oct TP values all very close to 0.10 mg/l. All TP data for all three years were all similar.

For TN, a slightly different seasonal pattern occurs, with higher values early, 0.2-0.3 mg/l (April and May) and then generally steady values for mid-May through the beginning of October. However, 2010 saw somewhat higher values (0.09 to 0.15) than in 2008 and 2009 which were in the 0.07 to 0.10 mg/l range. One large spike occurred in September 2008 (a five-fold increase), for an unknown reason, as there was no change in streamflow in that period.

4.1.4 Thomas Pump (TPD)

Nutrient concentrations at the Thomas Pump discharge are substantially elevated from the other sites. Note that the scale of the axes (Figure 9) is more than 10x greater than for either WRWR or CCATP.

TP concentrations are much more variable at TPD than the other sites. Spikes occur in every season and are highly variable between years. There does not appear to be any seasonal pattern. TP concentrations varied from 0.2 to 1.4 mg/l in 2008, from 0.35 to 13.7 mg/l in 2009, and from 0.3 to 1.1 mg/l in 2010. The October 2009 spike dwarfs all other data, although a second spike from 0.5 to 2.0 mg/l occurred in July 2009. Since 2009 was the construction year, it is possible that these spikes could have been related to ground disturbance during construction activities. TP concentrations in 2010 were lower in the first half of the season than 2008, but higher from August on.

TN concentrations are also substantially elevated compared to the other sites. Spikes also occurred with varying timing and generally followed the spikes in TP. TN concentrations seem to be normally in the 1.0-2.0 mg/l range, but spikes over 4 occurred in 2008 and 2010, and the largest spike to 30.7 mg/l occurred in October 2009. 2008 showed an increase during the initial pump down period, followed by a decline through Fall. 2009 values were more consistent until the large spike in October. 2010 were consistent early in the season, then spiked in September.

4.2 2008-2010 Nutrient Loading

Nutrient loads for the Total Phosphorus (TP) and Total Nitrogen (TN) parameters were computed for the three monitoring sites (WRWR, CCATP, and TPD) for the 2008-2010 irrigation seasons. Nutrient loading computations are summarized in Tables 2-4 and in Figures 10-12.

4.2.1 Wood River at Weed Road (WRWR)

Table 2 shows the computed nutrient loads for WRWR for TP and TN for the 2008 and 2009 years. Overall, both the loads are very consistent between years, with 9,588 kg in 2008 and 9,878 kg in 2009 for TP, and 10,297 and 10,186 kg for TN, Thus TN loads are slightly higher. Mean monthly loads for both parameters are 1,600 to 1,700 kg. There is, however, considerable seasonal variation, with the highest TP loads in Oct as the irrigations season ends and flows increase towards winter baseflow. In contrast, TN loads were highest in either May or June, depending on year, with much lower values in August or September, reflecting the decrease in concentrations identified previously (Figure 7). The lowest loads during the low summer flows in August were about 20% of the highest loads in June. The monthly loads are plotted in Figure 10. Of particular importance is the relative consistency between 2008 and 2009 at this site.

4.2.2 Crooked Creek above Thomas Pump (CCATP)

For the CCATP site, TP loading is even more consistently distributed through the year than WRWR, reflecting the more constant streamflows from the spring-fed system (Table 2, Figure 11). TN loading is more variable reflecting the greater seasonal variation in TN concentrations and the large spike in September 2008. Overall, CCATP produced 3,843, 4,100, and 4,650 kg of TP in 2008, 2009, and 2010, respectively. Of interest is the increase in TP loading which tracked the increase in streamflow in 2009 and 2010.

Similar to WRWR, TN loads are also more variable at CCATP, but only by a factor of perhaps 2 (other than the September 2008 spike). Total TN loading was computed to be 4,729 kg in 2008, 3,168 kg in 2009, and 5,414 kg in 2010.

Mean monthly loading for TP ranged from 641kg in 2008 to 775kg in 2010, while the mean monthly TN loads ranged from 528 kg in 2009 to 902 kg in 2010.

4.2.3 Thomas Pump (TPD)

TP loading from the Thomas Pump is dependent on the pump discharge, and is, therefore highly variable from high values during early season pump down to zero values when there was no pump discharge. Individual months ranged from 0 to 948 kg (Table 2, Figure 12). Mean monthly TP loading was 250 kg in 2008, 266 kg in 2009, and 147 kg in 2010.

TN loads are much greater than TP loads, typically 2-3 times greater. Strong seasonal variation occurred, depending on pumping volumes. Monthly TN loading varied from 0 to 2,748 kg (June 2008). Mean monthly TN loading was 732 kg in 2008, 585 kg in 2009, and 496 kg in 2010.

4.2.4 Comparison of 2008, 2009, and 2010 Nutrient Loading during Irrigation Season

Table 3 compares the computed monthly and seasonal loading values for each site by year. For example in 2008 for TP, WRWR produced 9,588 kg while CCATP had 3,843, and TPD was 1,502. Thus, WRWR was about 2.5 times CCATP and 6 times TPD in terms of overall loading. In 2009, there was a similar relationship between total loading at the three sites. In 2010, TP loading at CCATP increased, while it decreased substantially at TPD.

For TN loading, WRWR produced somewhat over twice what CCATP and TPD did. In 2009, the factor was about 3 times, while TPD produced more than CCATP. In 2010, CCATP increased significantly, while TPD decreased.

4.2.5 Comparison of 2008, 2009, and 2010 Volume Weighted Nutrient Loading

Previous discussions included either only total seasonal load or monthly loads. Given the wide disparity of streamflows at the three sites, computation of volume weighted mean concentration is an appropriate metric for comparison both between sites and between years at a given site. Table 4 and Figure 13 present the results of this analysis.

The volume weighted mean concentrations for WRWR for TP and TN are both consistent, 0.081 and 0.087 in 2008, and 0.083 and 0.086 in 2009. CCATP is similar for TP in 2008 and 2009, 0.103 and 0.105, with 2010 at 0.114, while TN in 2008 was 0.127, in 2009 was 0.081, and in 2010 was 0.132. Why the TN concentration dropped so much in 2009 is not known, nor what caused its rebound in 2010. TPD shows the most change in volume-weighted mean concentration: for TP in 2008 it was .805, in 2009 0.729, and in 2010 0.523, thus showing a decline each year. For TN, the value was 2.357 in 2008, 1.599 in 2009, and 1.751 in 2010. Volume-weighted mean concentrations for TPD compared to the other two sites are 5-8 times for TP and 15-20 times for TN.

Table 4 also presents the percentage change of the volume-weighted mean concentration, nutrient loading and water yield from the baseline year which is 2008. For volume-weighted mean concentration in 2009, TP increased slightly for WRWR and CCATP (2.0% and 2.4%), while TPD decreased 9.5%. For TN in 2009, WRWR decreased 2%, CCATP decreased 35.7% and TPD decreased 32.2%. In 2010 for TP, CCATP increased 10.5%, while TPD decreased 35.1%. For TN, CCATP increased 4.4%, while TPD decreased 26.7%.

Percentage changes in nutrient loading from the baseline year show increases in TP in 2009 for all three sites (WRWR, CCATP, and TPD) of 3.0%, 6.8%, and 6.7%, while TN declined 1.0%, 33%, and 20%. In 2010, both TP and TN increased from 2008 at CCATP (21.1% and 14.4%), while declining at TPD (41.7% and 32.1%).

Finally, for water yield, in 2009 all three sites showed increases compared to 2008 of 1% for WRWR, 4.3% for CCATP, and 17.9% for TPD. In 2010, CCATP increased 9.6% compared to 2008, while TPD decreased 8.6%.

4.2.6 Discussion of Nutrient Loading during 2008-2010

Significant changes in nutrient loading occurred in the project area in the study period, with results suggesting a highly positive and very rapid response to project implementation. However, it should be apparent that having a single year of pre-project data limits the strength of the conclusions. Without multiple years of pre-project data, there is no information on the variability of the TPD discharge, with or without management changes.

The reasons for believing that actual positive change has occurred include the following:

1. Pumping volumes at TPD declined in 2010 while streamflow increased at CCATP.
2. Volume-weighted mean concentrations of TP and TN declined substantially at TPD in both 2009 and 2010 while those at WRWR and CCATP increased.
3. Nutrient loading from TPD declined substantially in 2010 while CCATP increased.

Thus, virtually all data suggest highly positive trends, including 25-35% reductions in volume-weighed TP and TN concentrations and 32-40% reductions in nutrient loading from TPD in 2010 compared to the baseline year. If concentrations and pump discharge volumes continue to decline over several more years, a remarkable success story will emerge.

5.0 CONCLUSIONS

Taken together, the data from the Agency Ranch WRP project indicate that large scale wetland restoration has the potential to substantially decrease downstream nutrient export to Upper Klamath Lake. Pump-down discharges from former wetlands converted to agriculture around the lake margins have long been known to be a substantial contributor of elevated nutrient loading.

Continued monitoring of water quality and flow will provide valuable information to guide treatment wetland strategies, as well as provide useful information to other project elements such as the location and design of stream channel restoration projects, in order to achieve, for example, the greatest potential improvement in water quality. Clearly, development of new strategies to minimize, recycle, or treat return flows in the Wood River Valley have the greatest potential for reductions in downstream nutrient export.

6.0 RECOMMENDATIONS

It is recommended that 1-2 additional years of post-project streamflow and water quality monitoring occur to bolster the observations seen in this study. It would be difficult to scale back the study beyond the 2010 scope (which eliminated WRWR nutrient sampling) and still produce meaningful data.

NUTRIENT LOADING BY SITE, 2008-2010

Monthly Computed Total Phosphorus and Total Nitrogen Loading by Site for the May-Oct Period of 2008-2010

TOTAL PHOSPHORUS

MONTH	WRWR			MONTH	CCATP			MONTH	TPD		
	2008	2009	2010		2008	2009	2010		2008	2009	2010
	TP (kg)				TP (kg)				TP (kg)		
May	1,848	1,820	0	May	706	725	707	May	366	429	443
Jun	1,221	1,716	0	Jun	670	643	739	Jun	948	261	181
Jul	1,258	1,327	0	Jul	630	673	852	Jul	107	343	58
Aug	1,388	1,144	0	Aug	568	696	831	Aug	81	79	13
Sep	1,580	1,367	0	Sep	618	677	724	Sep	0	485	140
Oct	2,293	2,503	0	Oct	651	685	797	Oct	0	0	49
Total Load	9,588	9,878	0	**Total Load**	3,843	4,100	4,650	**Total Load**	1,502	1,598	885
Mean Monthly Load	1,598	1,646	0	**Mean Monthly Load**	641	683	775	**Mean Monthly Load**	250	266	147

TOTAL NITROGEN

MONTH	WRWR			MONTH	CCATP			MONTH	TPD		
	2008	2009	2010		2008	2009	2010		2008	2009	2010
	TN (kg)				TN (kg)				TN (kg)		
May	2,939	2,554	0	May	908	491	730	May	1,164	1,069	1,513
Jun	1,908	2,901	0	Jun	495	609	809	Jun	2,748	577	561
Jul	1,369	1,455	0	Jul	494	410	747	Jul	242	535	221
Aug	1,162	629	0	Aug	542	569	887	Aug	229	220	51
Sep	1,342	893	0	Sep	1,597	671	1,059	Sep	10	1,110	511
Oct	1,578	1,755	0	Oct	692	419	1,183	Oct	0	0	120
Total Load	10,297	10,186	0	**Total Load**	4,729	3,168	5,414	**Total Load**	4,393	3,511	2,978
Mean Monthly Load	1,716	1,698	0	**Mean Monthly Load**	788	528	902	**Mean Monthly Load**	732	585	496

WOOD-CROOKED SYSTEM NUTRIENT LOADING BY SITE BY YEAR

TOTAL PHOSPHORUS

IRRIGATION SEASON 2008	WRWR	CCATP	TPD	IRRIGATION SEASON 2009	WRWR	CCATP	TPD	IRRIGATION SEASON 2010	WRWR	CCATP	TPD
MONTH	TP (kg)			MONTH	TP (kg)			MONTH	TP (kg)		
May-08	1,848	706	366	May-09	1,820	725	429	May-10	0	707	443
Jun-08	1,221	670	948	Jun-09	1,716	643	261	Jun-10	0	739	181
Jul-08	1,258	630	107	Jul-09	1,327	673	343	Jul-10	0	852	58
Aug-08	1,388	568	81	Aug-09	1,144	696	79	Aug-10	0	831	13
Sep-08	1,580	618	0	Sep-09	1,367	677	485	Sep-10	0	724	140
Oct-08	2,293	651	0	Oct-09	2,503	685	0	Oct-10	0	797	49
Total Load	9,588	3,843	1,502	Total Load	9,878	4,100	1,598	Total Load	0	4,650	885
Mean Monthly Load	1,598	641	250	Mean Monthly Load	1,646	683	266	Mean Monthly Load	0	775	147

TOTAL NITROGEN

IRRIGATION SEASON 2008	WRWR	CCATP	TPD	IRRIGATION SEASON 2009	WRWR	CCATP	TPD	IRRIGATION SEASON 2010	WRWR	CCATP	TPD
MONTH	TN (kg)			MONTH	TN (kg)			MONTH	TN (kg)		
May-08	2,939	908	1,164	May-09	2,554	491	1,069	May-10	0	730	1,513
Jun-08	1,908	495	2,748	Jun-09	2,901	609	577	Jun-10	0	809	561
Jul-08	1,369	494	242	Jul-09	1,455	410	535	Jul-10	0	747	221
Aug-08	1,162	542	229	Aug-09	629	569	220	Aug-10	0	887	51
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Total Load	10,297	4,729	4,393	Total Load	10,186	3,168	3,511	Total Load	0	5,414	2,978
Mean Monthly Load	1,716	788	732	Mean Monthly Load	1,698	528	585	Mean Monthly Load	0	902	496

Notes: No WRWR nutrient data available for 2010

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TABLE

3

SUMMARY OF WATER QUALITY LOADING COMPUTATIONS, 2008-2010

Volume-Weighted Mean Concentration (May 1-Oct 31), Nutrient Loading, and Water Yield

	VOLUME WEIGHTED MEAN CONCENTRATION, May 1-Oct 31		VOL. WEIGHTED MEAN CONC. PERCENT OF BASELINE YEAR (2008)		NUTRIENT LOADING, May 1-Oct 31		NUTRIENT LOADING PERCENT OF BASELINE YEAR (2008)		WATER YIELD May 1-Oct 31	PERCENT OF BASELINE YEAR (2008)
	TP (mg/l)	TN (mg/l)	TP (mg/l)	TN (mg/l)	TP (kg)	TN (kg)	TP (kg)	TN (kg)	(ac-ft)	(ac-ft)
2008										
Wood River at Weed Road	0.081	0.087	Baseline Year		9,590	10,300	Baseline Year		95,700	Baseline Year
Crooked Creek above Thomas Pump Ditch	0.103	0.127	Baseline Year		3,840	4,730	Baseline Year		30,300	Baseline Year
Thomas Pump Ditch	0.805	2.357	Baseline Year		1,500	4,390	Baseline Year		1,510	Baseline Year
2009										
Wood River at Weed Road	0.083	0.086	102.0%	98.0%	9,880	10,200	103.0%	99.0%	96,700	101.0%
Crooked Creek above Thomas Pump Ditch	0.105	0.081	102.4%	64.3%	4,100	3,170	106.8%	67.0%	31,600	104.3%
Thomas Pump Ditch	0.729	1.599	90.5%	67.8%	1,600	3,510	106.7%	80.0%	1,780	117.9%
2010										
Wood River at Weed Road	-na-	-na-			-na-	-na-			-	
Crooked Creek above Thomas Pump Ditch	0.114	0.132	110.5%	104.4%	4,650	5,410	121.1%	114.4%	33,200	109.6%
Thomas Pump Ditch	0.523	1.751	64.9%	74.3%	890	2,980	59.3%	67.9%	1,380	91.4%

Notes: All values rounded to 3 significant figures

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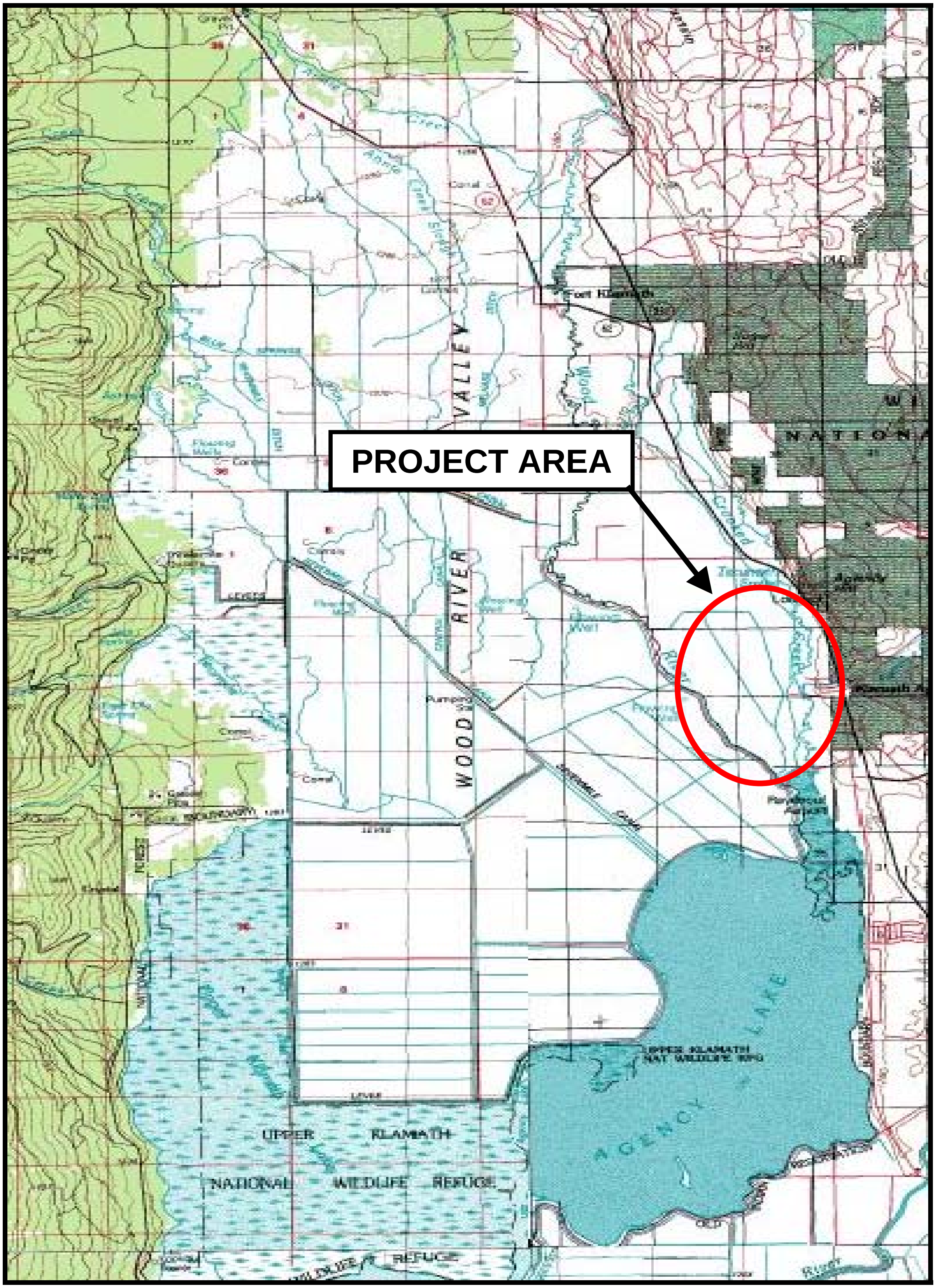
TABLE

4

MAP OF PROJECT LOCATION



AGENCY RANCH WRP **Klamath Basin Rangeland Trust** **Water Quality Monitoring, 2008-2010**	GMA Hydrology | Geomorphology | Stream Restoration	**FIGURE** **1**

LOCATION OF MONITORING SITES

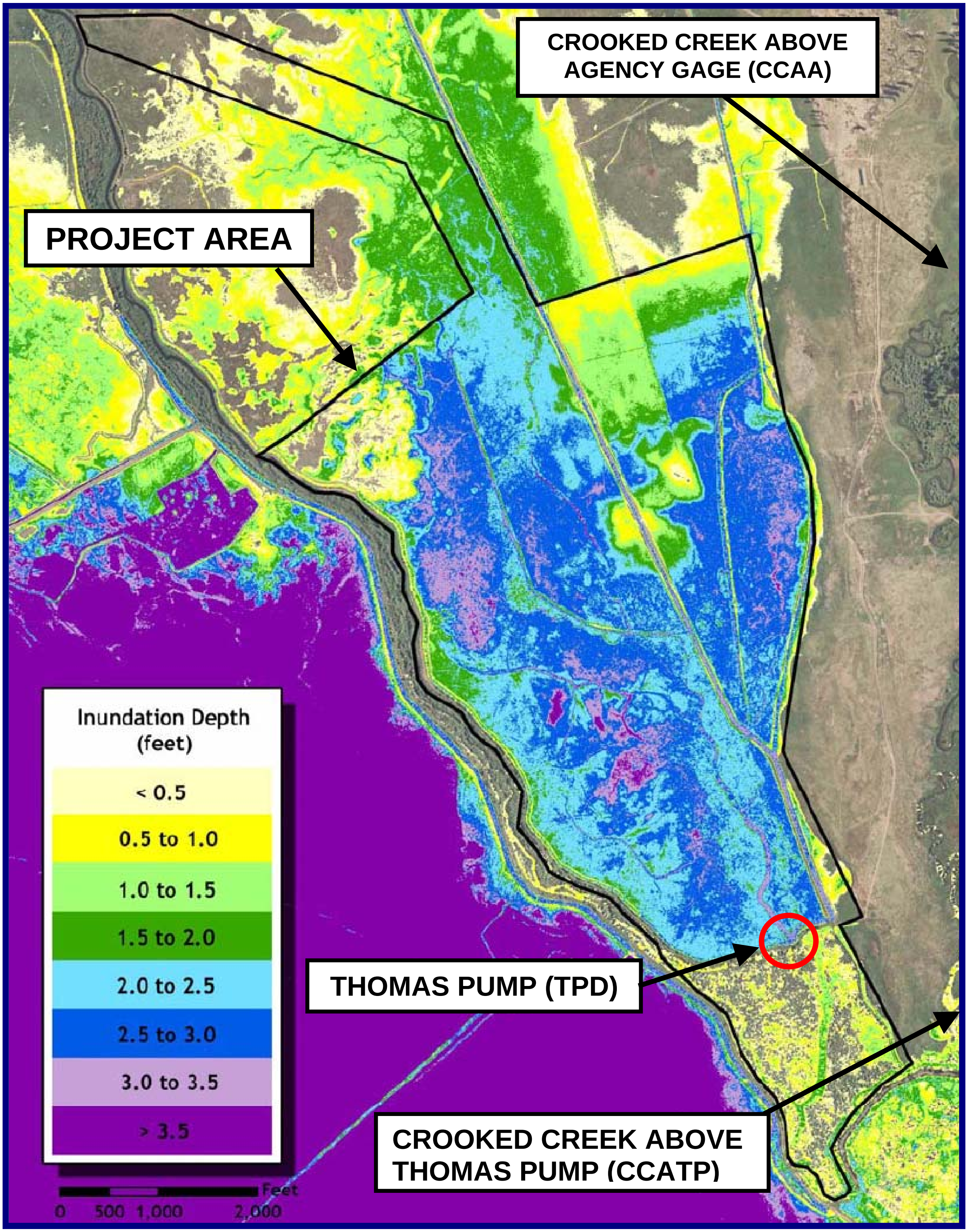


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FIGURE

2

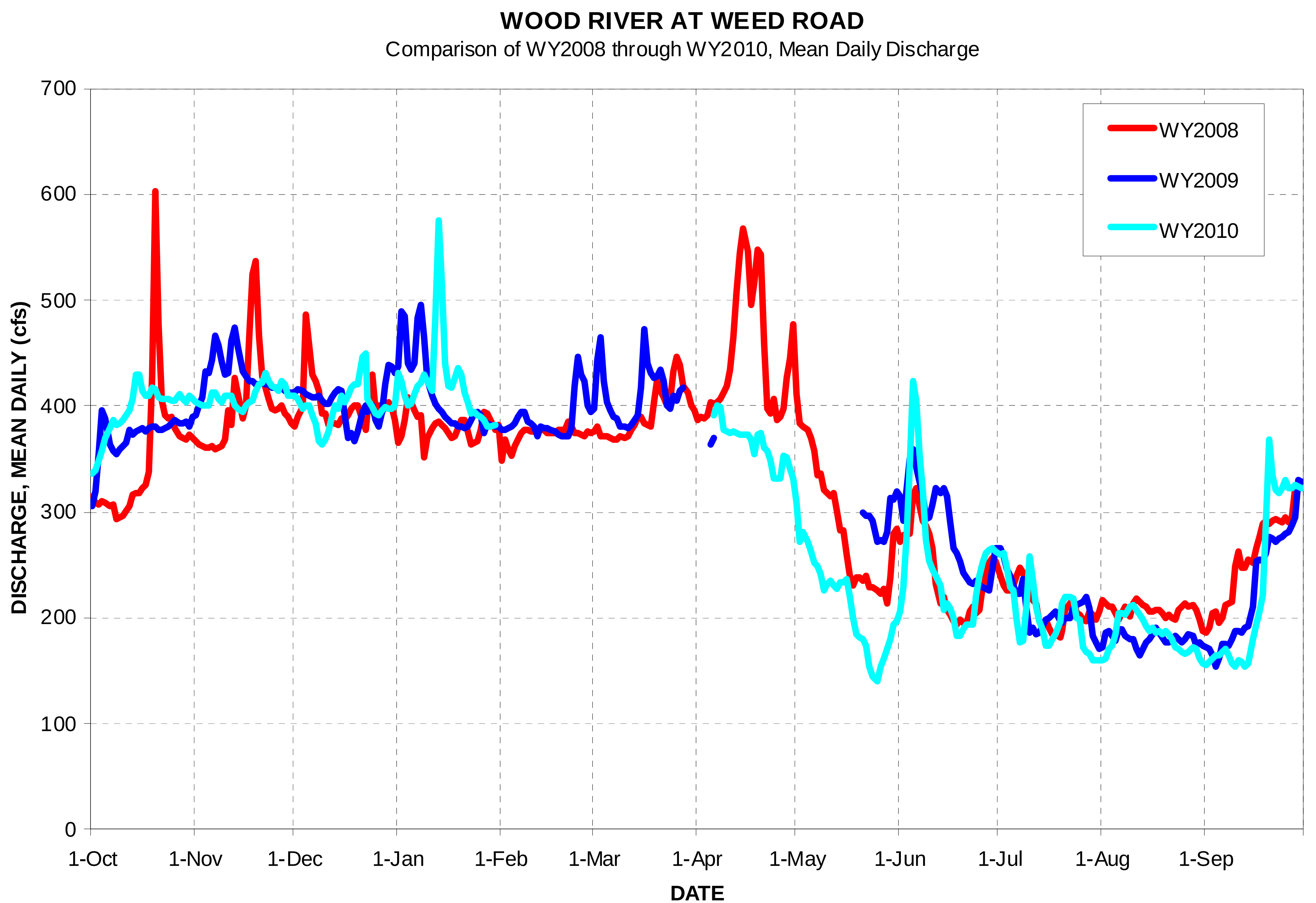

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FIGURE

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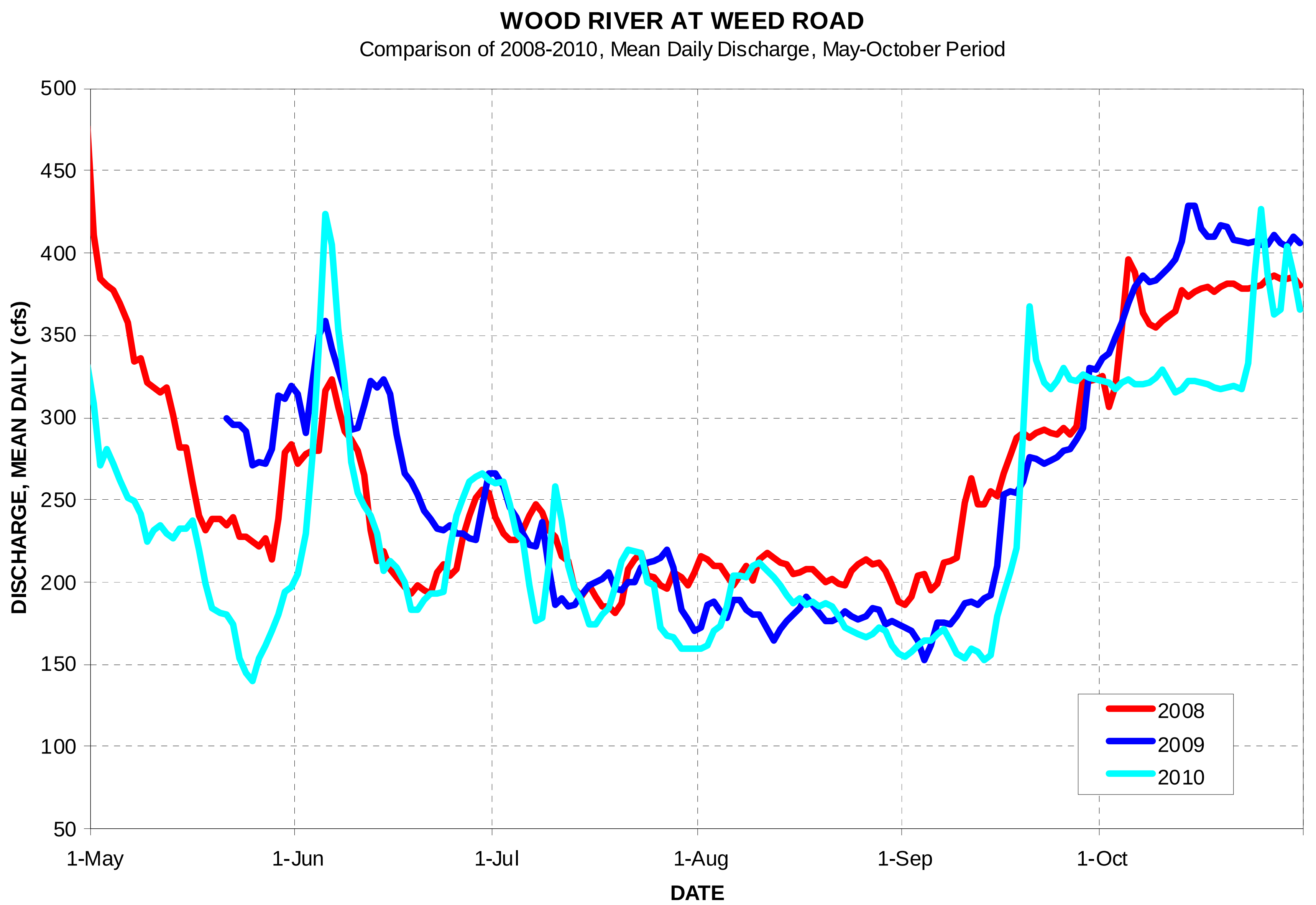

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FIGURE

4

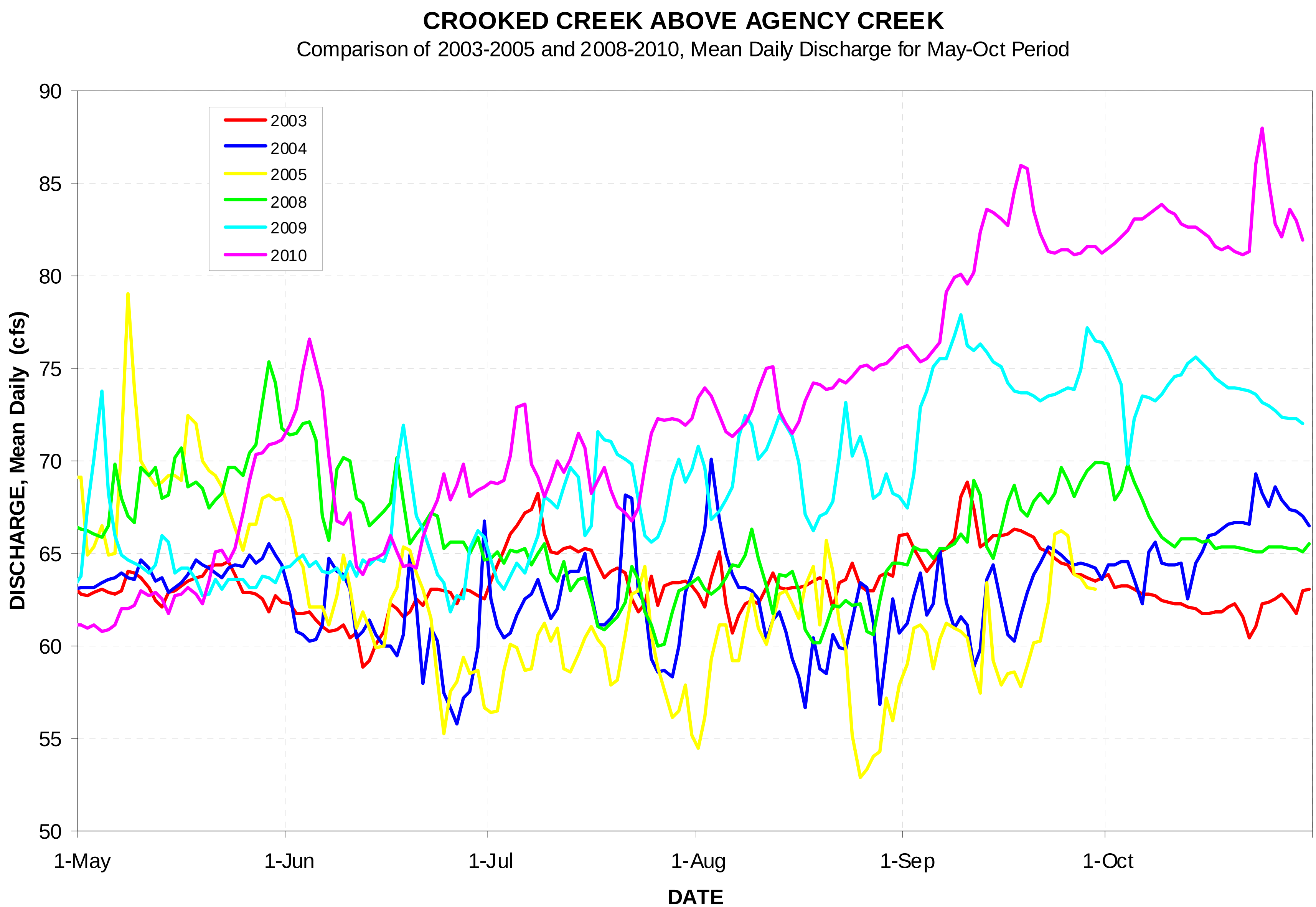

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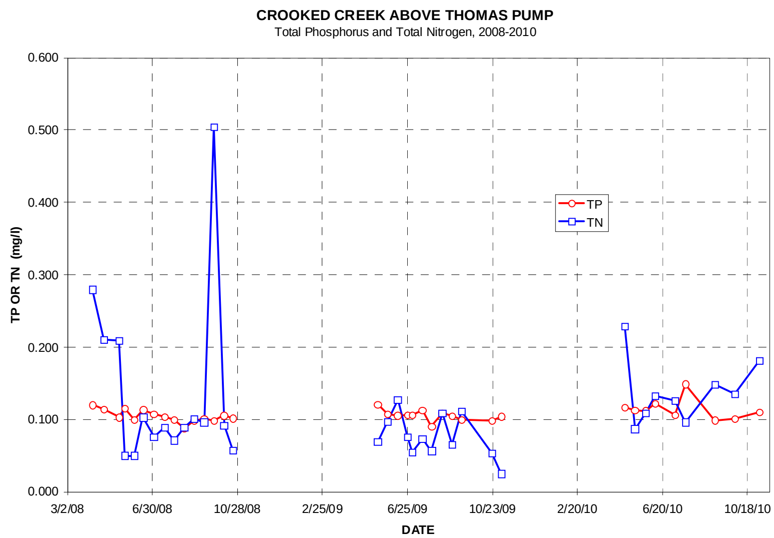
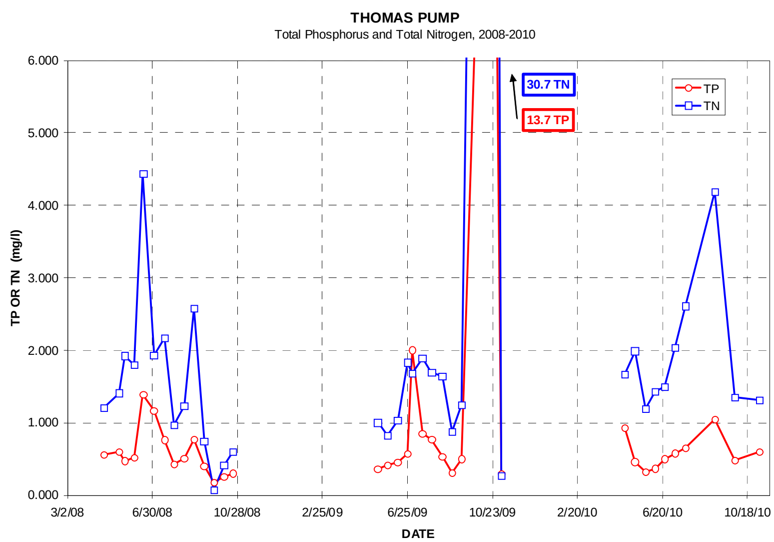
FIGURE

5

TP AND TN CONCENTRATIONS BY SITE, 2008-2010





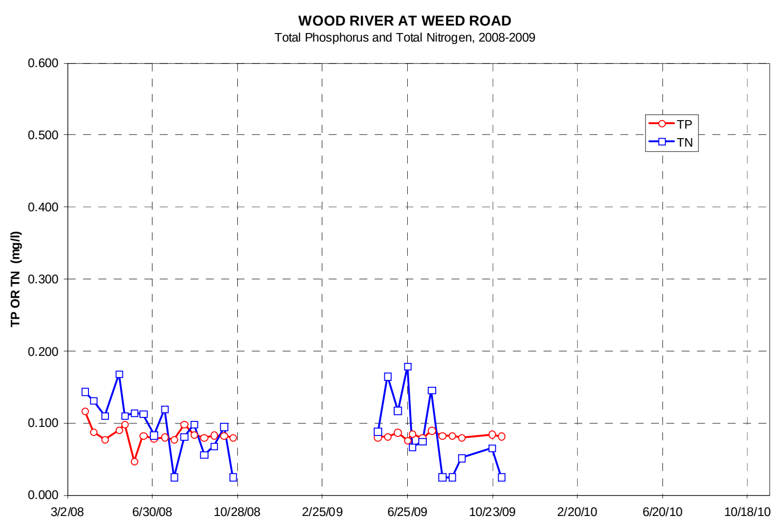


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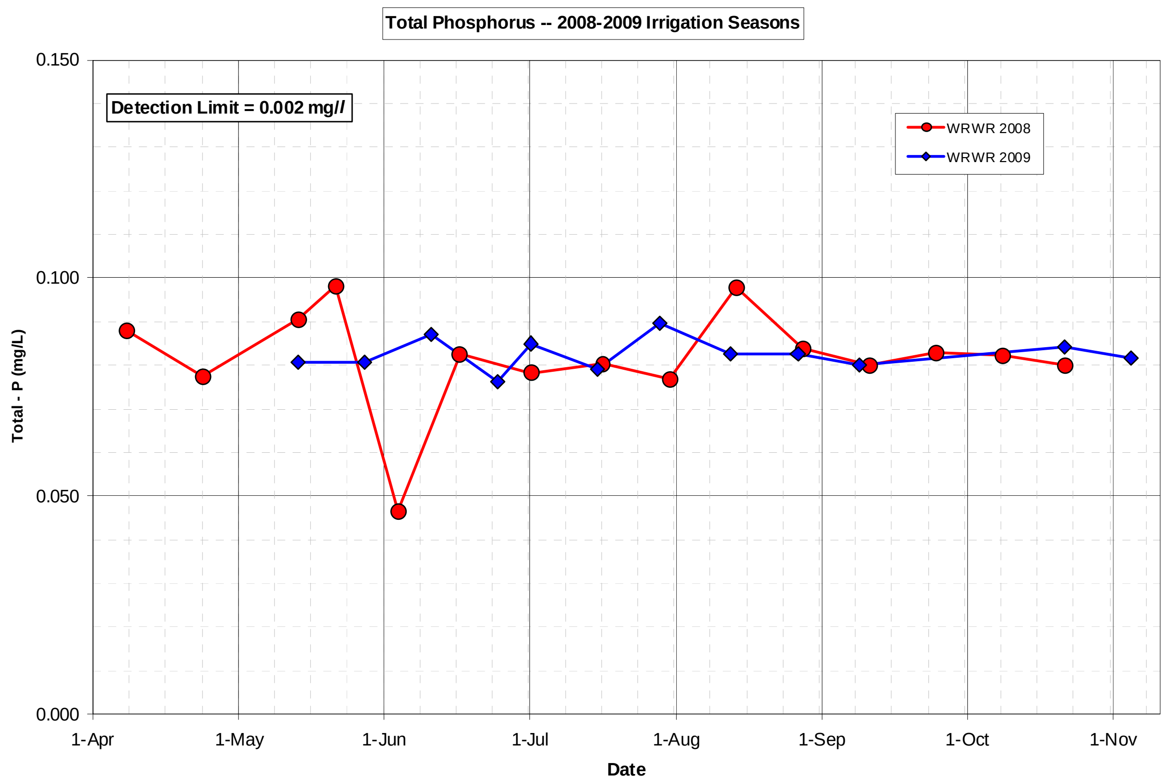
FIGURE

6

WOOD RIVER AT WEED ROAD: TP AND TN CONCENTRATIONS, 2008-2010



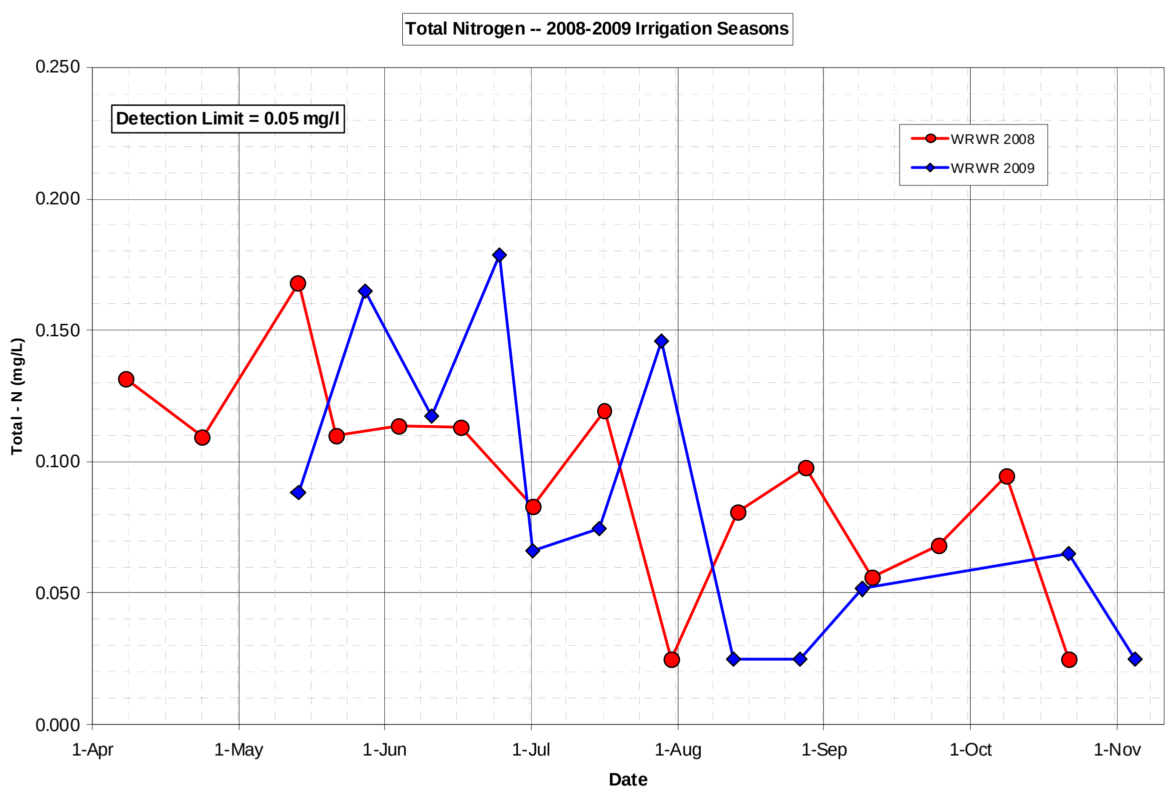


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FIGURE

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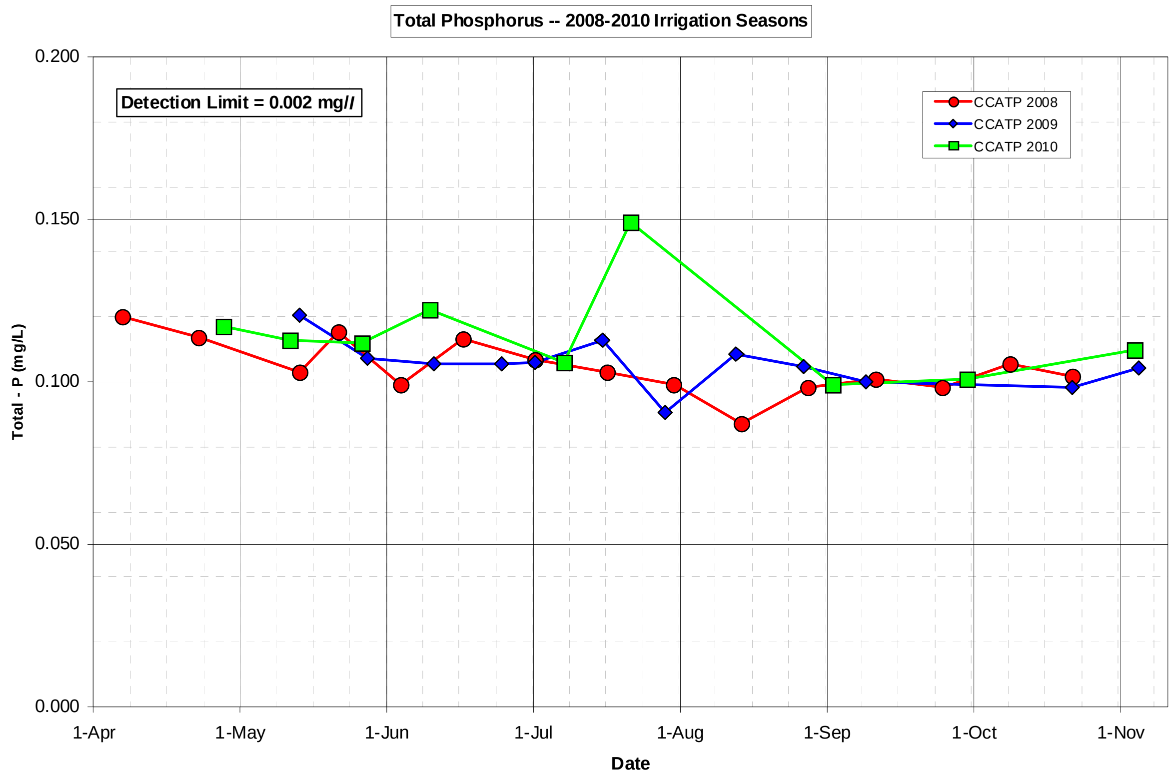
CROOKED CREEK ABOVE THOMAS PUMP: TP AND TN CONCENTRATIONS, 2008-2010



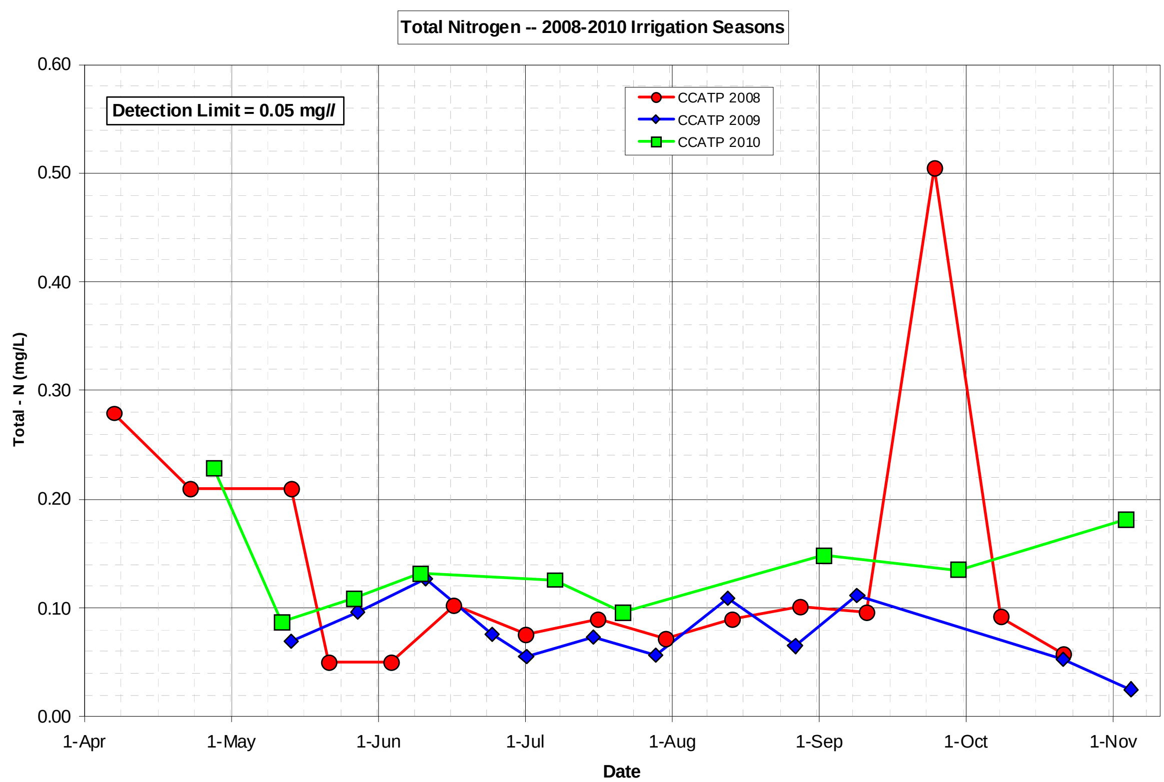


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FIGURE

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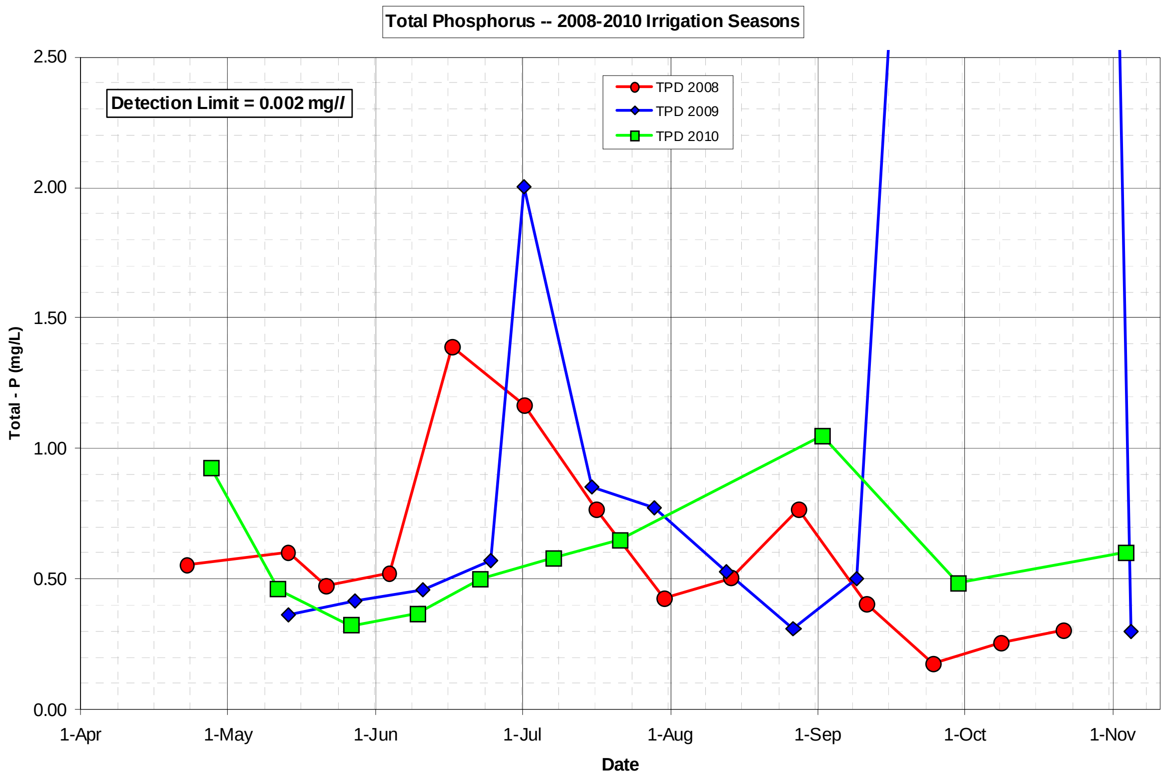
THOMAS PUMP: TP AND TN CONCENTRATIONS, 2008-2010



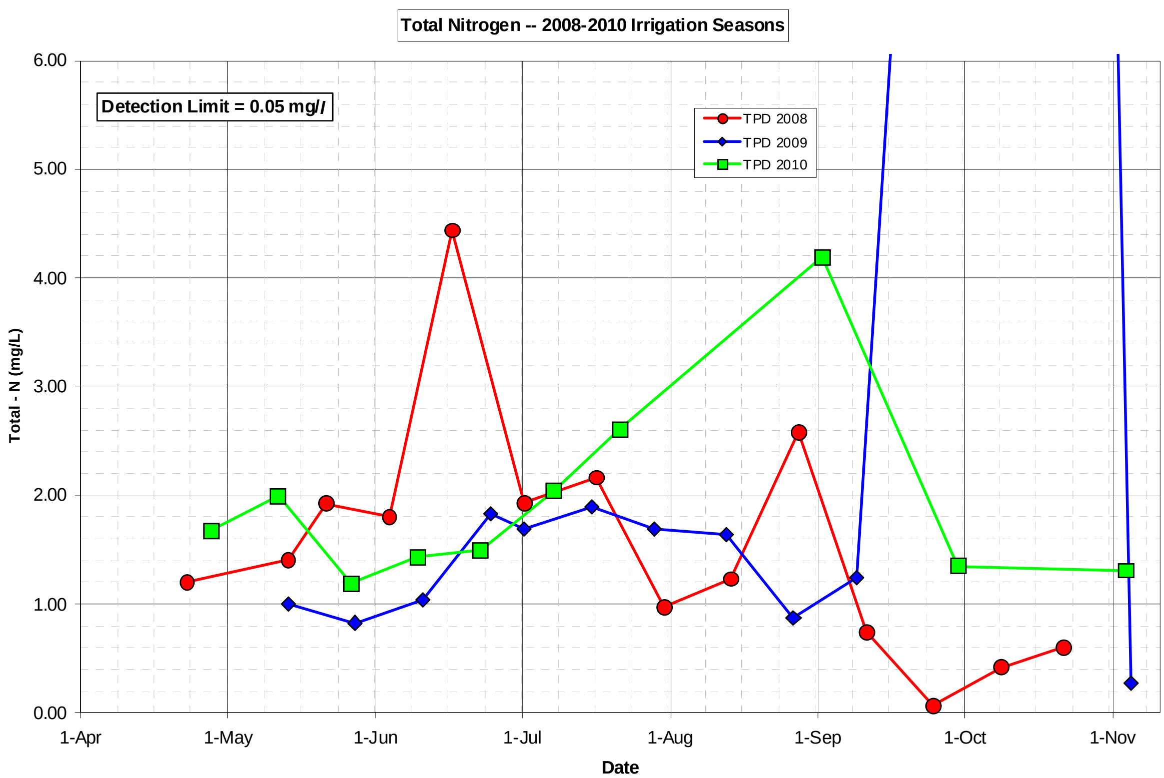


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FIGURE

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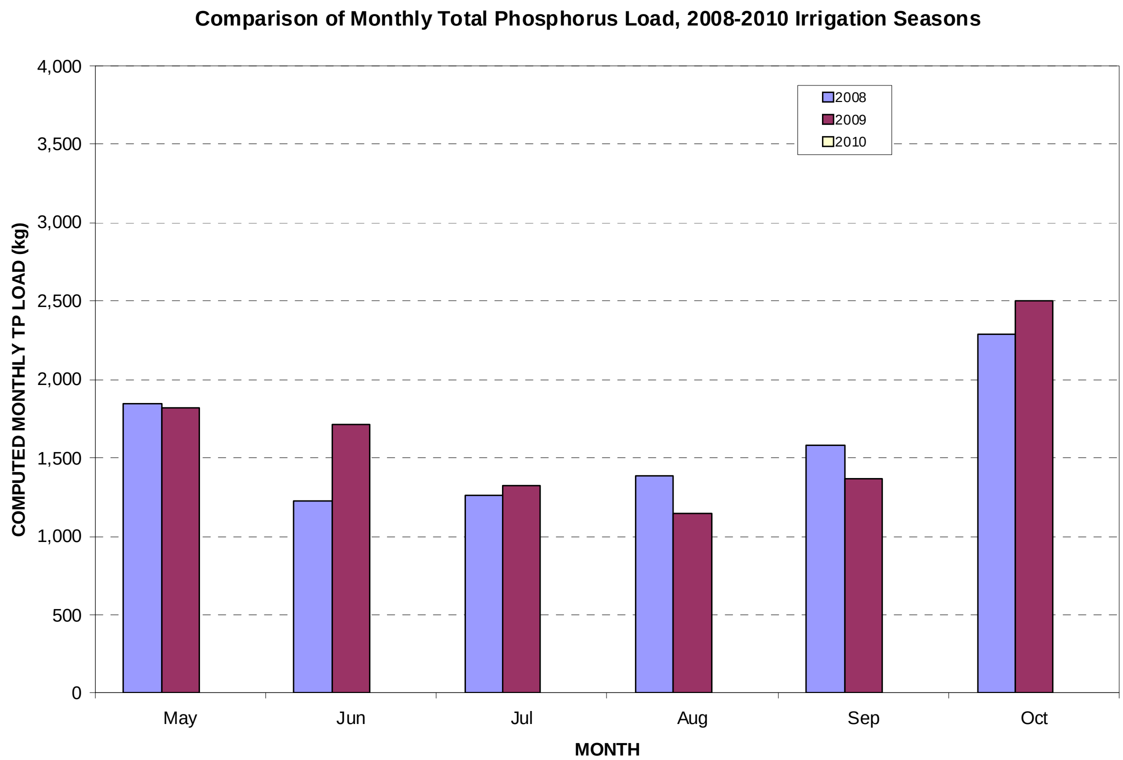
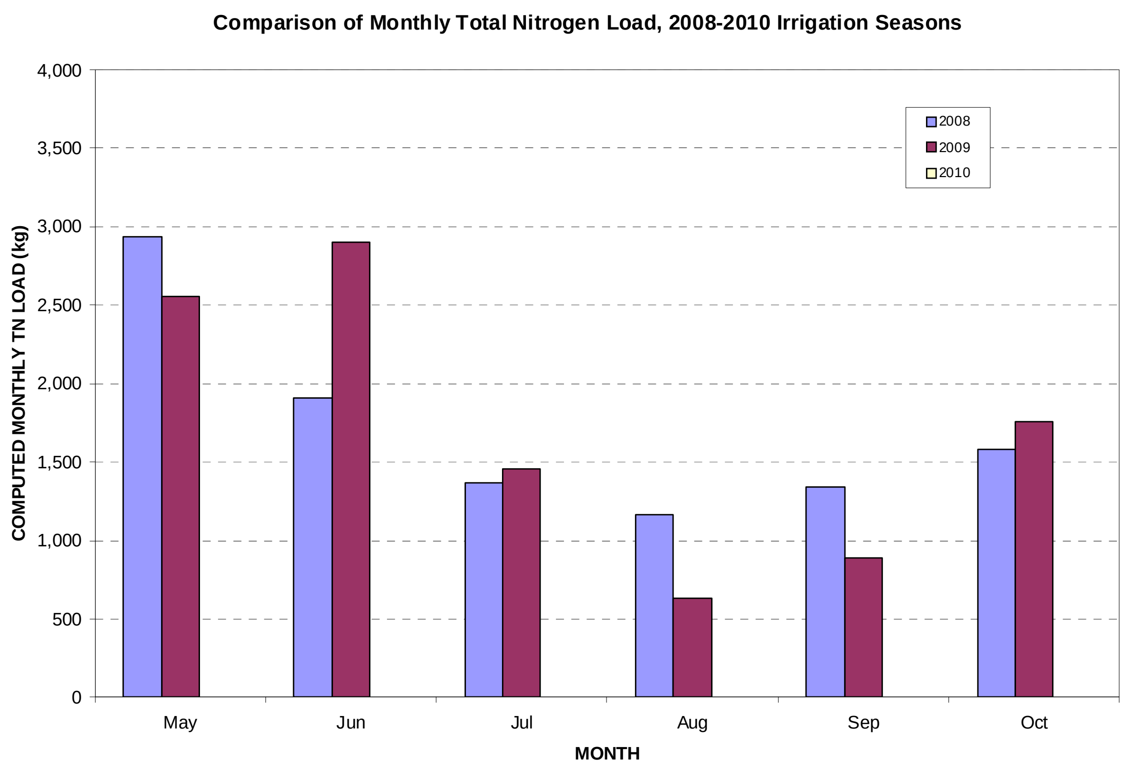
WOOD RIVER AT WEED ROAD: TP AND TN LOADING BY MONTH, 2008-2010





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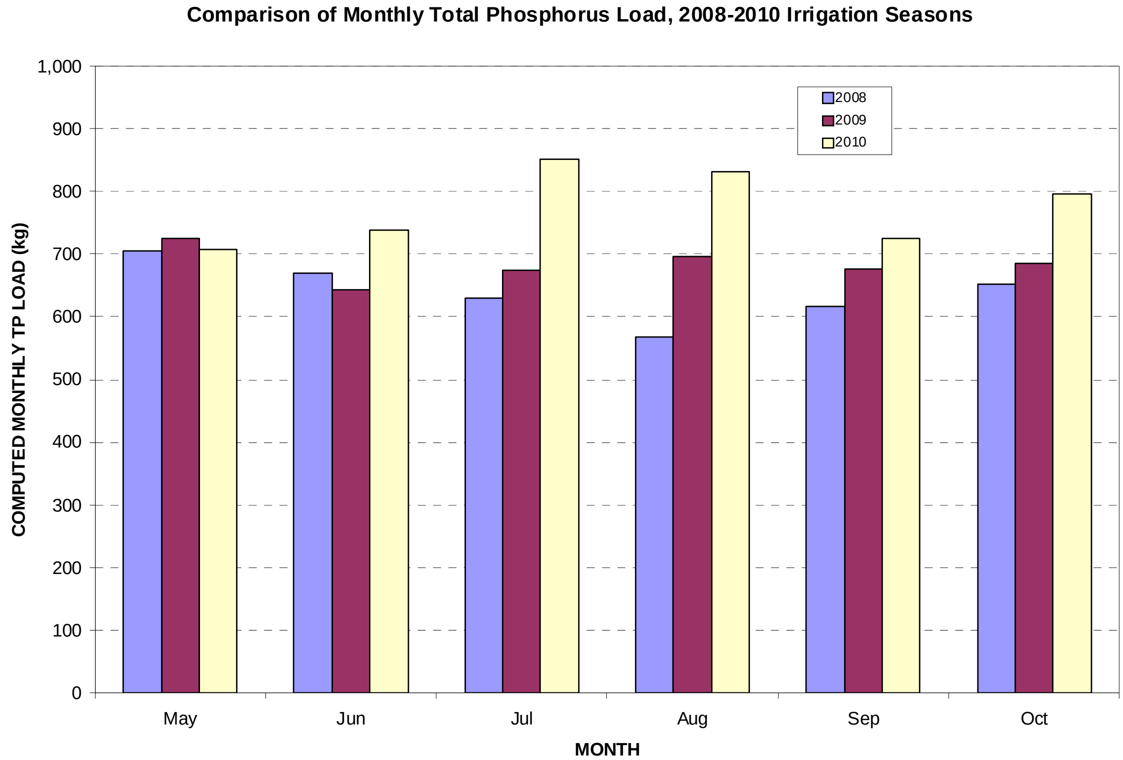
CROOKED CREEK ABOVE THOMAS PUMP: TP AND TN MONTHLY LOADING, 2008-2010



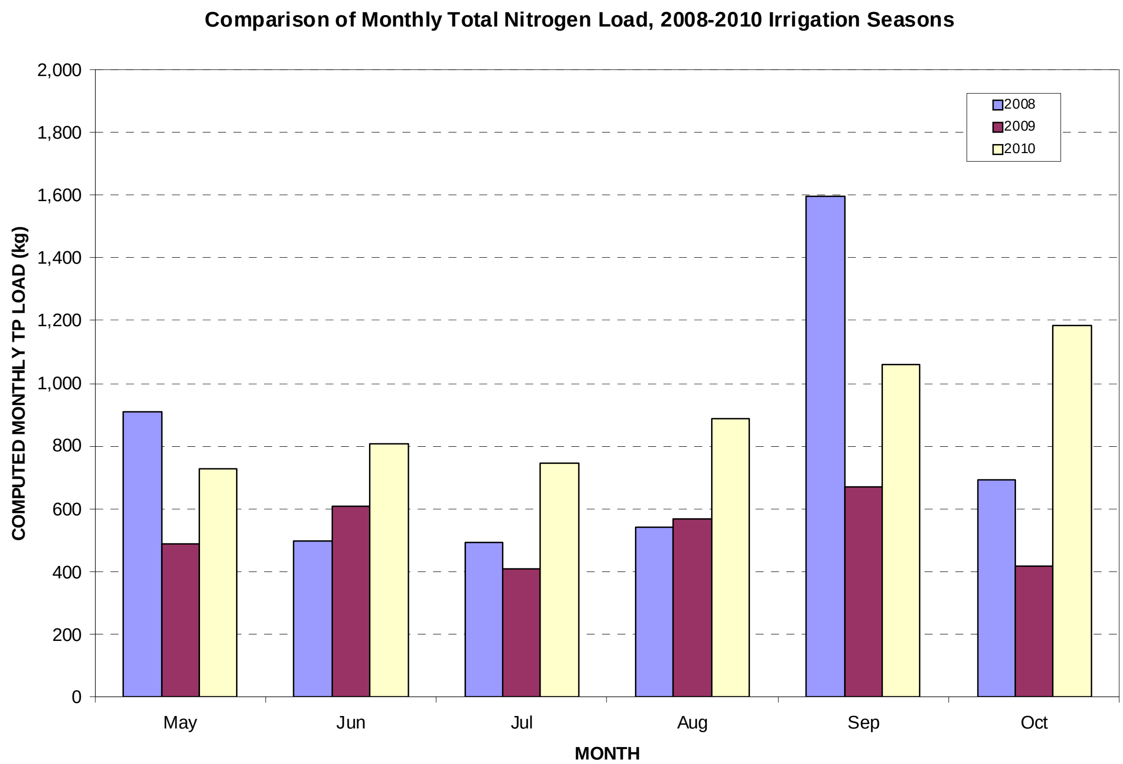


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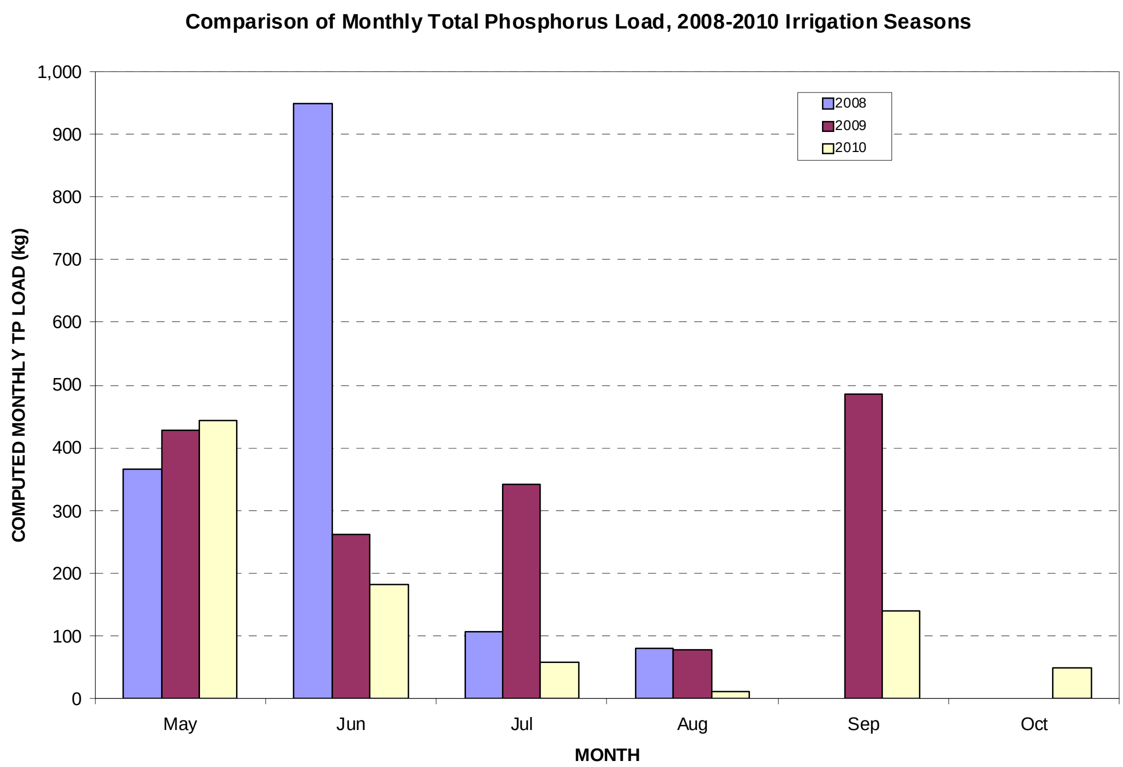
FIGURE

11

THOMAS PUMP: TP AND TN MONTHLY LOADING, 2008-2010



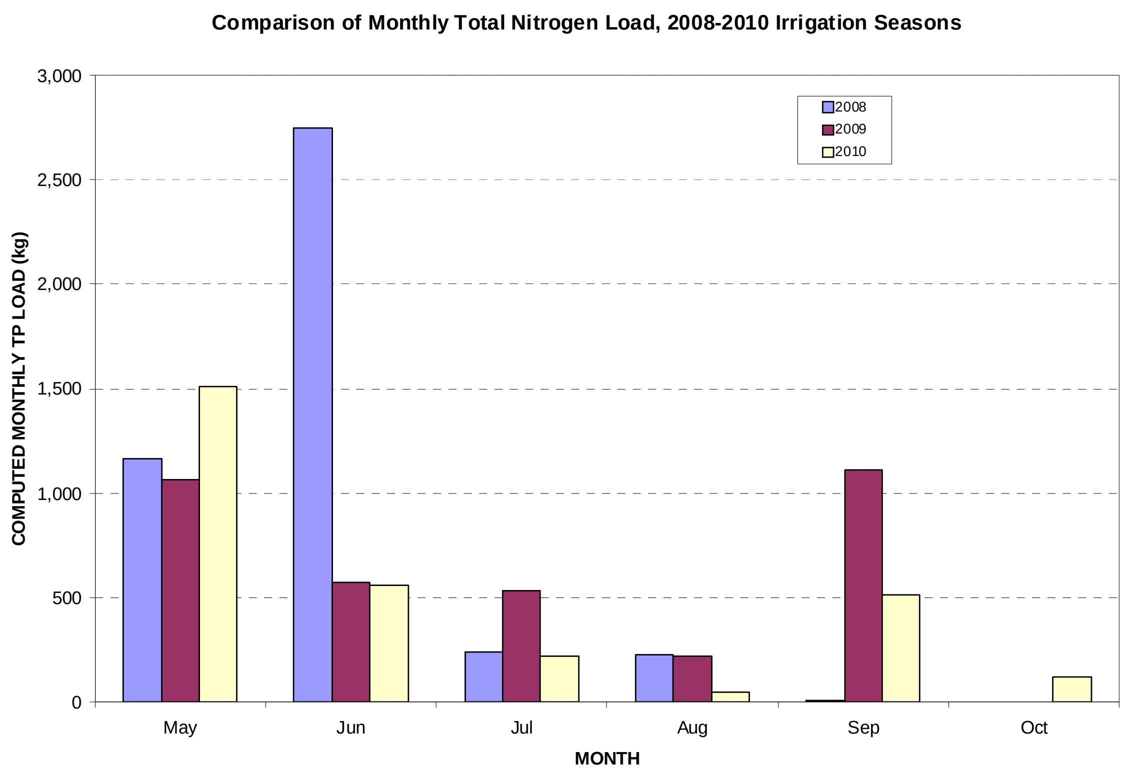


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FIGURE

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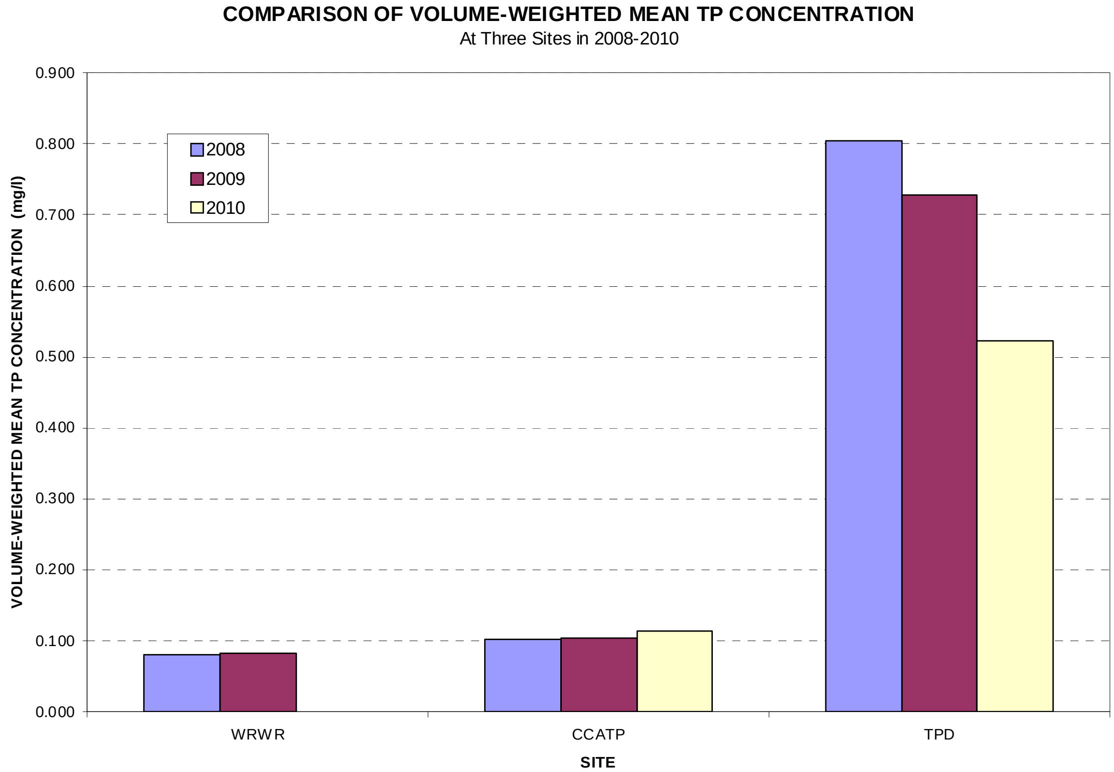
COMPARSON OF VOLUME-WEIGHTED MEAN CONCENTRATIONS, 2008-2010



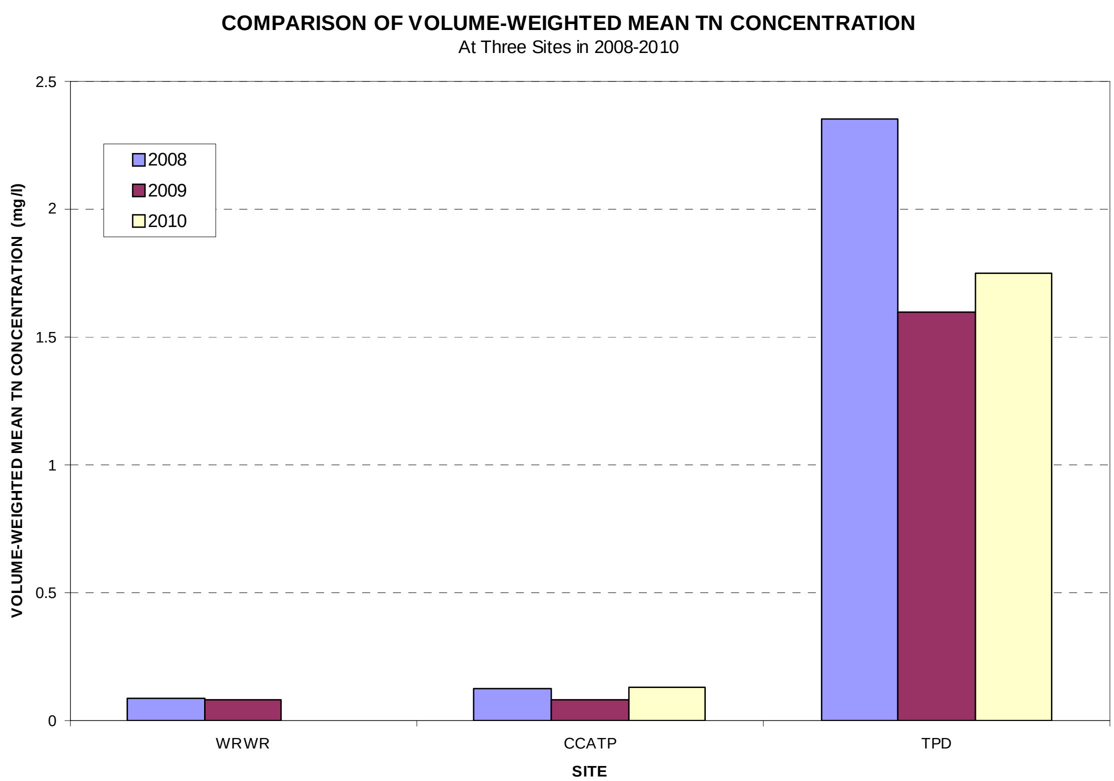


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FIGURE

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WOOD RIVER VALLEY TREATMENT WETLAND ASSESSMENT PROJECT




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January 2010

WOOD RIVER VALLEY
TREATMENT WETLANDS ASSESSMENT PROJECT

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WOOD RIVER VALLEY
TREATMENT WETLANDS ASSESSMENT PROJECT

1.0 INTRODUCTION

1.1 Background

Over the last 100 years, Upper Klamath Lake has degraded to a hypereutrophic state characterized by excessive levels of blue-green alga *Aphanizomenon flos-aquae.* Excessive algae levels can result in numerous water quality concerns including increased turbidity, elevated ammonia levels, decreased dissolved oxygen levels and high pH levels (> 9.5). High nutrient loading promotes correspondingly high production of algae, which, in turn, modifies physical and chemical water quality characteristics that can directly diminish the survival and production of fish populations, including endangered short-nosed suckers and Lost River suckers (ODEQ, 2002). One generally accepted theory as to the rise in algae levels in the lake is that there has been an increase in the nutrient concentrations (primarily phosphorus) in inflows to Upper Klamath Lake.

The increase in nutrient loading likely results from many causes, including deforestation due to logging, conversion of wetlands to agriculture, runoff from agricultural fields, and degradation of riparian areas due to uncontrolled grazing pressure. These modifications in land form and land use have contributed to degradation in habitat conditions, both in stream channels, and downstream in Upper Klamath Lake.

To enhance water quality within Upper Klamath Lake and improve habitat for native fish and wetland dependent species, substantial efforts are being undertaken to correct some of the water quality issues within the upper Klamath River Watershed. In the 5-Year Plan for Restoration of the Upper Klamath Basin, the Hatfield Restoration Science Team lists restoration of historic wetlands and construction of treatment wetlands as one of the top priorities for Upper Klamath Lake.

The Wood River Valley once contained over 60,000 acres of wetlands; however, throughout the last century most of its marshes and stream systems have been modified or eliminated as a result of diking, draining, channelization, irrigation diversion and other activities primarily associated with agricultural practices. By the early 1990s, the wetland area had been reduced to about 44,000 acres, mostly through losses to margin wetlands around Agency Lake, which had been converted to agricultural lands through diking and draining in the 1960s-1970s. In addition, , wetlands and floodplains adjacent to stream channels had historically removed sediments and nutrients by slowing down peak flows, which allowed particulates to settle out, and allowed soluble nutrients to be taken up by wetland plant species. Disassociation of stream channels with adjacent wetlands and floodplains – through channelization, diking, or channel incision -- has reduced the capacity of the riparian zone to filter out sediments and nutrients.

Unfortunately, the reduction in wetland filtering capacity has also been accompanied by increased concentrations of nutrients and sediment loading, resulting from the introduction of more intensive land uses such as livestock production and flood irrigation.

The design and construction of treatment wetlands has been shown to be an effective response to the circumstances described above. Such wetlands allow for existing (if modified) land uses while reducing and mitigating for the impacts of those uses.

1.2 Flow and Nutrient Loading

Using the mass balance developed by Kann and Walker (2001), the Williamson River and Sprague River subbasins contribute 51% of the annual flow input to Upper Klamath Lake. The Wood River and Seven Mile Creek account for 16% and 7% of the flow inputs, respectively. Other flow inputs to the lake include agricultural pumps (3%), springs and ungaged tributaries (16%) and precipitation received by the lake (7%). Roughly half of the external phosphorus loading to Upper Klamath Lake is derived from the Williamson River and Sprague River subbasins. The Wood River contributes 19% of the external total phosphorus load. Other external total phosphorus sources include Seven-Mile Canal (9%), springs and ungaged tributaries (10%), agricultural pumps (11%) and precipitation (3%). Point sources apparently account for a very small portion of the external total phosphorus loading to Upper Klamath Lake.

The Williamson River subbasin delivers a large external phosphorus load to Upper Klamath Lake (86.4 metric tons per year) when compared to that contributed from Seven-Mile Creek (16.5 metric tons per year). However, the drainage area of the Williamson River subbasin is very large (3501 km^2), while the drainage area of Seven Mile Creek is comparatively small (106 km^2). When the production of annual external phosphorus loading is considered as a unit area load, the Williamson River subbasin contributes considerably less phosphorus per square kilometer (11 kg/ km^2/yr), while the Seven Mile Creek drainage contributes a high rate of loading per unit area (156 kg/ km^2/yr). Areas with high unit loads are more likely candidates for restoration.

Total phosphorus load reduction is the primary mechanism to attain water quality standards for pH, dissolved oxygen and algal biomass in Upper Klamath Lake and Agency Lake. Seasonal maximum algal growth rates in Klamath and Agency Lakes, and its subsequent impact on elevated pH and low dissolved oxygen levels, are controlled primarily by phosphorus and secondarily by light and temperature. High nutrient loading promotes correspondingly high production of algae, which, in turn, modifies physical and chemical water quality characteristics that can directly diminish the survival and production of fish populations. The TMDL targets a 40% external total phosphorus loading reduction to Upper Klamath and Agency Lakes (Walker 2001).

2.0 SCOPE AND OBJECTIVES

The Wood River Valley Treatment Wetlands Assessment Project has been undertaken to prioritize potential locations of constructed wetlands as a treatment method to reduce nutrient loads in the Wood River Valley. The project area includes all accessible ditches that contribute to the nutrient load in West Canal. West Canal has been documented (KBRT 2003, 2004, 2005, 2006, and 2008) to deliver most of the nutrient loads from the upper and middle reaches of the Wood River Valley, and is, therefore, the primary source of nutrients for the Sevenmile Creek system.

The goal of the assessment is to determine which ditches in the Wood River Valley are contributing large amounts of nutrients to West Canal and to prioritize potential treatment wetland sites based on field data collection and LiDAR analysis.

The project involved the collection of nutrient concentration samples and discharge at a variety of ditches in the Wood River Valley in order to estimate typical nutrient loads during the irrigation season. Field data were analyzed to determine the discharge and nutrient load in various sampled ditches as a method of prioritizing the location and size of potential treatment wetlands. The percentage of West Canal nutrient load provided by each sampling location was used as a primary factor in prioritizing possible treatment locations.

This report summarizes the results of the field data collection and prioritizes potential treatment wetland sites by nutrient load and relative feasibility. It does not purport to be a design document and additional site investigation and treatment wetland design must occur prior to any implementation.

3.0 METHODS

3.1 Field Data Collection

Two types of field data were collected during irrigation season at various sites within the Wood River Valley: discharge measurements and nutrient concentration samples. Sampling sites that contributed to the flow at the West Canal gaging station were selected on air photos prior to sampling days and sample site locations were then refined in the field based on accessibility and flow direction. Accessibility was a limiting factor when choosing sampling locations. Sampling took place during two days, July 17, 2008 and August 28, 2008. The locations of all sampling sites are shown in Figure 1.

Water quality samples (Total-P and Total-N) were collected using either a US DH-48 Depth Integrated Sampler or a Van Dorn Horizontal Type Alpha Sampler. Samples were collected using the single vertical method, with DH-48 samples being depth integrated while Van Dorn samples were limited to a single depth. Sample bottles were labeled, stored on ice, and transferred via overnight courier to the laboratory (Aquatic Research Incorporated, Seattle, WA) for analysis. At each sampling site the following information was collected and recorded; discharge (measured or estimated), time, location description, and photographs. The locations of sampling points were hand drawn on field maps for transfer into a GIS database during office analysis.

When access to the full channel was available, discharge measurements were made using standard and accepted hydrologic protocols. All measurements were performed by wading, with a few exceptions where, due to water depth or accessibility, bridge measurements were the more practical form of measurement. Streamflow equipment for wading measurements included a 4ft top-set wading rod, JBS Instruments AquaCalc Pro, and a Price AA or Pygmy current meter. Streamflow equipment for bridge measurements included a bridge board, JBS Instruments AquaCalc Pro, Price AA current meter, A-Reel, and a 15 lb. Columbus sounding weight. All measurements were made with the magnetic head version of the Price AA or Pygmy meter. Where access to the channel was unavailable a visual estimate of discharge was recorded.

3.2 Data Analysis

Field data results were analyzed to determine the discharge and nutrient load in the various sampled ditches. Nutrient load (tons/day) for TP and TN at each sampled site were calculated assuming that the instantaneous discharge and nutrient concentration measurements were daily averages. The results were also expressed as a percentage of nutrient loads at the West Canal gaging station.

Approximate sampling locations were digitized using ArcMap 9.3 GIS software. Each sampling location was attributed with discharge and method of discharge measurement (measured or estimated) for each sampling day.

As a method of determining feasibility of constructing treatment wetlands at each sampling location, the water surface elevation of each location was compared to its surrounding valley floor elevation using the Wood River Valley LiDAR data. Within ArcMap, elevations were determined using the LiDAR’s 1 meter resolution digital elevation model (DEM). Five points were chosen at random, inside the channel, approximately 20 ft upstream of each sampling location; and the average elevation was reported. In addition, five points were chosen at random, outside of the channel, approximately 20 ft upstream and 50 ft away from the channel; and the average was reported. The difference between the two average elevations was calculated at each location. Levees were excluded from the out of channel elevation average calculations.

At some locations it was difficult to determine from the LiDAR data alone if the in channel elevations were water surface elevation or bed elevation. If, at the time of the LiDAR flight, there was little or no water in the channels, the elevations pulled were likely bed elevations. However, without performing cross sectional analysis and aerial photo investigations, which were not included in the scope of this project, it is difficult to determine if that is the case. For the purposes of this report it is assumed that the average in-channel elevations were water surface elevations.

4.0 RESULTS

4.1 Nutrient Concentration Data

During the first sampling event on July 17, 2008, 30 nutrient samples and discharge measurements were collected. During the second sampling event on August 28, 2008, 28 samples and discharge measurements were collected. Six sites which were sampled in July were excluded from August sampling for one of three reasons: (1) it was determined that the site was not contributing to the nutrient load at West Canal, (2) the results from July sampling showed that the nutrient load at the site was very low, or (3) the irrigation ditch was dry during the August sampling day. In August, four additional sites were sampled. In total, 34 sites were sampled at least once during July or August of 2008. Raw data results for Total P and Total N were received from the laboratory and are presented in Appendix A.

Table 1 contains the basic data collected during the field portion of the study. It includes site number, how discharge was measured at each site, a brief description of the location of each site, and TP and TN concentrations for each of the sampling events. On July 17, 2008 TP concentrations ranged from 0.032 (Site #37) to 1.27 mg/l (Site #44). For reference, the TP concentration at West Canal at the gage was 0.157 mg/l. TN concentrations ranged from below the lab detection limit of 0.050 mg/l (Site #1 and #23) to 3.74 mg/l (Site #44). For reference, the TN concentration of West Canal at the gage was 0.474 mg/l

On August 28, 2008, TP concentrations ranged from 0.065 (BLSB and BLSD) to 1.274 mg/l (Site #41). For reference, the TP concentration at West Canal at the gage was 0.155 mg/l. TN concentrations ranged from below the lab detection limit of 0.050 mg/l (BLSB and BLSD) to 2.132 mg/l (Site #41). For reference, the TN concentration of West Canal at the gage was 0.472 mg/l.

The wide range of discharges and nutrient concentrations provides a useful indication of just how complex the irrigation and drainage network is within the project area.

4.2 Discharge and Nutrient Load Data

Tables 2 and Table 3 show the measured and computed data on both sampling days. Site numbers, discharge, TP and TN concentrations, computed loads for TP and TN, and the percentage of nutrient load for each sampling location compared to the measured load of West Canal for that same date are included.

On July 17, 2008, discharges ranged from 1 (Site #23 and #26) to 46.7 cfs (West Canal). TP loads ranged from 0.0001 (Sites #23 and #37) to 0.0138 tons/day (Site #2). The TP load at the West Canal gage was 0.0199 that day. TN loads ranged from 0.0001 (Site #23) to 0.0452 tons/day (Site #2). The TN load at the West Canal gage was 0.0598 tons/day on that day. Percentages of the TP load at the sites compared to the TP load at the West Canal gage varied from 0.57% to 69.34%. Percentages of the TN load at the sites compared to the TN load at the West Canal gage varied from 0.11% to 75.63%. The percentages do not add up to 100% of West Canal because a number of the sites measure the same or somewhat different (increased or decreased) flow.

On August 28, 2008, discharges ranged from 0.49 (Site #25) to 35.5 cfs (West Canal). TP loads ranged from 0.0001 (Site #25) to 0.0175 tons/day (Site #39). The TP load at the West Canal gage was 0.0149 that day. TN loads ranged from 0.0004 (Site #25) to 0.0371 (Site #2). The TN load at the West Canal gage was 0.0452 tons/day on that day. Percentages of the TP load at the sites compared to the TP load at the West Canal gage varied from 0.81% to 117%. Percentages of the TN load at the sites compared to the TN load at the West Canal gage varied from 0.83% to 82.08%.

Table 4 shows the average concentration, discharge, and nutrient load at the various sites. Most of these had samples taken during both sampling days but a few were single values. Average discharges ranged from 0.985 (Site #25) to 29.67 cfs (Site #42). Average TP loads ranged from 0.0001 (Site #37) to 0.0141 tons/day (Site #39). The average TP load at the West Canal gage was 0.0174 tons/day. Average TN loads ranged from 0.0001 (Site #23) to 0.0411 (Site #2). The TN load at the West Canal gage was 0.0525 tons/day on that day. Percentages of the TP load at the sites compared to the TP load at the West

Canal gage varied from 0.65% to 81.29%. Percentages of the TN load at the sites compared to the TN load at the West Canal gage varied from 0.13% to 78.29%.

4.3 Variability between Sampling Dates

Given the limited sampling that was able to occur in this assessment, an important question concerns how variable are the sampling data from the two sampling events in the summer of 2008. Table 5 compares the TP, TN, and discharge values for the two sampling dates and ranks them by the percent change. Slightly more than one-half the sites increased in TP between the sampling dates, with 6 showing increases of almost 300% or more. Only two sites declined by over 50%, but those two sites had some of the highest concentrations on the July 17 sampling. For TN, about two-thirds of the sites showed an increase, with 8 of them 200% or more. Again, two sites declined by over 50% and these were two of the highest values. In terms of discharge, the majority of the sites showed decreases and several (3) were dry in the August sampling. Only one site showed an increase of 50% or more. Generally, it appears that less irrigation water is used later in the summer, and, as a result, the flow of West Canal at the gage fell from 46.7 to 35.5 cfs. The increases in TP and TN probably reflect increased duration of seasonal grazing by late in the summer.

This analysis of variability highlights some of the limitations of the dataset collected for this assessment. More data, or even continuous gages, would greatly assist in the accurate determination of the distribution of discharge and nutrient loads in the complicated drainage network of the Wood River valley.

4.4 Upstream to Downstream Analysis

At several pairs of sites, a simple upstream to downstream analysis was performed as the same ditch crossed both Nicholson Road and Sevenmile Road. Table 6 compares five pairs of samples that could be examined in this way. Both TP and TN, as well as discharge were compared. On July 17, 2008, 3 pairs of sites showed large increases in discharge, while two pairs showed large decreases. This undoubtedly reflects either the usage of water (flood irrigating) or the movement of water from one channel to another. TP declined at two pairs and increased in 3 pairs, though the changes were not linked to changes in discharge. For TN, 3 pairs decreased while 2 pairs increased. Most of the changes, whether an increase or decrease were a substantial change from the upstream site. The unit change (mg/l/mile) based on the channel distance between the two sites of each pair was also computed to investigate whether longitudinal changes were consistent in any way. Overall, the unit changes were quite variable. Field loading would appear to be a variable and quite site specific. Table 7 computes the same parameters based on the average of the parameters. In this case 4 of the 5 pairs showed an average increase in TP and TN in the downstream direction.

This analysis does indicate that intermediate areas in the valley are probably the most effective location for treatment wetlands, as many of the ditches gain in nutrients as they move down gradient.

4.5 Ranking by Phosphorus Concentration and Load

Although nitrogen is an important structuring component of the algal communities and often determines biomass types, phosphorus reduction has been shown to be the most effective and practical long-term nutrient management option to control algal biomass (Sas 1989). This is especially true of nitrogen fixing species such as *Aphanizomenon*, which can augment their nitrogen needs in what may otherwise be a nitrogen limiting system. While nitrogen limitations may be a factor later in the growing season, there is no evidence that the energy requirement for nitrogen fixation is actually limiting algal densities during the critical months of June and July, when energy supply (solar radiation), algal growth rates, and pH excursion frequencies are highest.

Because of the primary importance of phosphorus, a preliminary ranking of potential treatment sites was developed based TP concentrations and loads. Table 8 stratified TP concentrations from the two sample events and their average into 4 bins: high TP (>0.5 mg/l) which is 7x or more of background levels, Moderate TP (0.5>TP>0.15 mg/l) which is 2x-7x background, low TP (0.15>TP>0.07 mg/l), and Background TP (<0.07 mg/l). Based on the average of the two sampling events, 3 sites were classified into the High TP category, 12 sites into the moderate, 10 into the low, and 9 were essentially background. As the arrows show in Table 8, many individual sites shifted between bins on the different sampling days. Figures 4-6 graphically depict the categories into which each site was classified with color coding.

Although ranking by TP concentration has its uses (those sites with highest concentrations have the greatest potential for nutrient reduction by treatment wetlands), a more useful classification is one that is based on a ranking by load, as this factors in discharge and can easily be related to the load at the West Canal gage, which represents the export location of the drainage system. Tables 9-11 rank the sites based on the TP load as a percentage of that at the West Canal gage for each of the sample days and for the average of the two days.

4.6 Elevation Analysis from LiDAR Data

An important consideration in the assessment of potential treatment wetland locations is the relative site elevations between water in the channel or ditch and the general valley floor where a treatment wetland would need to be located. For deeper ditches or drains, the cost or potential impacts of raising the water in the ditch sufficiently to enter a treatment wetland is likely to be a significant limitation for implementation at those sites. Impacts could involve flooding of adjacent roads unless structures were developed that could be lowered during the winter. Fall storms are often deliver large quantities of nutrients, so failure to operate a treatment wetland during these events would certainly reduce the effectiveness. Pumping ditch water into a treatment wetland would likely be far too expensive. Thus, the most feasible sites are ones where flows are near the valley floor surface and only berming or minor grading would be needed to construct the physical features of the treatment wetland.

To assess the elevation difference between water in channel and the out of channel surface t each sample locations, LiDAR data were analyzed. The results are shown in Table and the elevation differences range from -0.2 ft to 9.9 ft. In some cases, ditch channel are elevated above the valley floor with small berms. Sites with elevation differences of no more than 1-2 feet are considered highly feasible. As the site photos in Appendix B indicate, many of these sites could have treatment wetlands constructed with very limited grading. On the other hand, at the deeper drain channels closer to the West

Canal gage (Sites #1, 2, 3, and 41), it would be very difficult to implement treatment wetlands, given the height that flows would need to be raised to, or the amount of excavation that would be necessary to build a treatment wetland at the current water surface elevations.

4.7 Prioritization of Sites

Finally, a relative priority of potential sites for treatment wetlands is developed based on a combination of the ranking and analyses contained in previous sections. Criteria for ranking included TP load as a percentage of that at the West Canal gage, discharge, and elevation difference between ditch flow and the adjacent valley floor. Sites with higher TP concentrations and/or TP loads are obvious candidates for treatment. Figures 7-9 graphically depict the relationship between discharge and TP load expressed as a percentage of the West Canal TP load. Figure 7 (July 17, 2008 sampling) shows that most sites have a similar relationship, while 3 sites depart markedly from that relationship, two of which would be considered poor candidates as they have high discharges but a relatively low percentage of the West Canal load. One site (#44) would have a high priority, as it has a relatively low discharge (2 cfs) but has 35% of the West Canal load. The data from the second sampling day are shown in Figure 8. In this case, two sites would have the highest priority, two would have high priority, and one would be a poor candidate. The reason the discharge is factored into the ranking is that higher flows will take considerably larger treatment wetland surface areas to achieve the same level of nutrient reduction. Thus, the greatest efficiency (most treatment potential for least implementation dollars) should be obtained in small to medium sized treatment wetlands.

Figure 9 based on the average of the two sample days highlights 5 candidate sites that should have the highest priority for implementation. Table 13 ranks the sites in tabular form.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions have been developed as a result of the data collection and analysis performed in this project:

1. There are a wide range of nutrient concentrations present in irrigation ditches and drains within the Wood River Valley, most of which are elevated in TP and TN from background conditions.

2. Potential treatment wetland sites should be located where existing ditches are relatively shallow, currently convey a substantial percentage of the net export from West Canal, and have low to moderate discharge.

3. Since many of the ditches gain nutrients as they travel down-gradient, the most effective locations are in the middle of the valley (around Sevenmile Road), but before the drains become so deep that it would be difficult to move the water out of the ditch into a treatment wetland.

4. Based on the review of the sites monitored in this assessment, implementing a number of treatment wetlands appears highly feasible, assuming cooperation of the property owners is obtained. Treatment wetlands would need to be fenced and thus existing operations would be impacted as a small percentage of the land would need to be removed from agricultural production.

The following recommendations are made:

1. Although construction of pilot treatment wetlands could occur for several of the sites that obtained the highest rankings from this assessment, collection of additional nutrient loading data would be useful to refine this prioritization. However, not as many sites would need to be monitored, as this study provides sufficient information to eliminate a number of sites from further consideration.

2. Further design efforts would likely define the expected benefits (nutrient reduction levels) from various sizes of treatment wetlands, and monitoring of pilot projects could quantify the load reductions. The literature reports a wide range of potential reductions, based on many site specific factors.

6.0 REFERENCES

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TREATMENT WETLAND ASSESSMENT SAMPLING SITES AND DATA

Site Numbers, Q Measurement Type, Location, and Sample results for July and August 2008 Sampling

			JULY 17, 2008 SAMPLING			AUGUST 28, 2008 SAMPLING		
Site #	Q_Type	Location	Sample ID	Total-P (mg/l)	Total-N (mg/l)	Sample ID	Total-P (mg/l)	Total-N (mg/l)
1	Measured	West Branch of West Canal, just N of McQuiston	1	0.124	<0.050*	1	0.076	0.082
2	Measured	Main Channel of West Canal, upstream McQuiston	2	0.171	0.560	2	0.152	0.533
3	Measured	Channel along W. Side of McQuiston	3	0.143	0.462	3	0.145	0.467
20	EstimateD	N. Side of SMR	20			20	Not Sampled	
21	Measured	N. Side of SMR	21	0.105	0.150	21	0.662	1.23
22	Measured	N. Side of SMR	22	0.112	0.119	22	0.609	1.14
23	Estimated	N. Side of SMR	23	0.049	<0.050*	23	Not Sampled	
24	Measured	Blue Springs Ditch on W Side of Hackler Road	24	0.071	0.060	24	0.084	0.240
25	Measured	N/S Ditch along Hackler just N. of Von Sl Driveway	25	0.060	0.078	25	0.091	0.328
26	Estimated	N. Side of Nicholson Road	26	0.232	0.466	26	0.104	0.226
27	Measured	Corner of SMR and Weed Road, W. Side of Weed	27	0.224	0.486	27	0.147	0.614
28	Estimated	N. Side of SMR	28	0.061	0.060	28	0.070	0.152
29	Measured	N. Side of SMR	29	0.176	0.566	29	0.095	0.308
30	Measured	N. Side of SMR	30	0.235	0.703	30	0.154	0.652
31	Estimated	S. Side of Nicholson Road	31	0.057	0.107	31	0.224	0.470
32	Estimated	East Channel above confluence on N. Side of road	32	0.145	2.03	32	0.160	1.61
33	Estimated	S. Side of Nicholson Road below confluence	33	0.091	0.869	33	0.361	1.48
34	Estimated	N. Side of Nicholson Road	34	0.069	0.179	34	0.079	0.308
35	Estimated	S. Side of Nicholson Road	35	0.069	0.101	35	0.069	0.055
36	Estimated	S. Side of Loosley, N/S ditch	36	0.083	0.127	36	Not Sampled	
37	Measured	N. Side of Loosley, E/W ditch	37	0.032	0.239	37	Not Sampled	
38	Measured	N. Side of Loosley, N/S ditch	38	0.093	0.141	38	Not Sampled	
39	Estimated	West Side of Weed Road, just N of road bend	39	0.177	0.392	39	1.17	1.61
40	Measured	East Side of Weed Road, just N of road bend	40	0.197	0.378	40	0.181	0.598
41	Measured	W. Side of Weed, North Ditch flowing west	41	0.241	0.704	41	1.25	2.13
42	Measured	W. Side of Weed, South Ditch flowing west	42	0.068	0.055	42	Not Sampled	
43	Measured	E. Side of Weed Road	43	0.066	0.080	43	Not Sampled	
44	Estimated	Corner of SMR and Weed Road, E. Side of Weed	44	1.27	3.74	44	0.301	1.34
45	Estimated	S. Side of Nicholson Road	45	0.070	0.127	45	0.099	0.227
WCAS	Measured	West Canal at gage	WCAS	0.157	0.474	WCAS	0.155	0.472
46	Measured	W. Side of Weed Road, N. of Sevenmile Rd	46	Not Sampled		46	0.239	0.514
47	Measured		47	Not Sampled		47	0.495	0.481
BLSB	Measured	Blue Springs bypass channel	BLSB	Not Sampled		BLSB	0.065	<0.050
BLSD	Measured	Blue Springs Ditch just east of spring	BLSD	Not Sampled		BLSD	0.065	<0.050
SMSR	Measured	Sevenmile Creek at Sevenmile Road at gage	SMSR	Not Sampled		SMSR	0.068	<0.050

KLAMATH BASIN RANGELAND TRUST

WOOD RIVER VALLEY TREATMENT WETLAND ASSESSMENT PROJECT

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TABLE

1

July 17, 2008 Sampling Event							
Sample ID	Total-P (mg/l)	Total-N (mg/l)	Discharge (cfs)	Total-P Load (tons/day)	Total-N Load (tons/day)	Percent of Total P at WCAS (%)	Percent of Total N at WCAS (%)
1	0.124	<0.050*	8.98	0.0030	0.0006	15.10%	1.01%
2	0.171	0.560	29.9	0.0138	0.0452	69.34%	75.63%
3	0.143	0.462	7.81	0.0030	0.0097	15.18%	16.30%
21	0.105	0.150	6.66	0.0019	0.0027	9.51%	4.51%
22	0.112	0.119	7.55	0.0023	0.0024	11.46%	4.06%
23	0.049	<0.050*	1	0.0001	0.0001	0.67%	0.11%
24	0.071	0.060	8.28	0.0016	0.0013	8.00%	2.23%
25	0.060	0.078	1.48	0.0002	0.0003	1.21%	0.52%
26	0.232	0.466	1	0.0006	0.0013	3.16%	2.10%
27	0.224	0.486	15.2	0.0092	0.0199	46.26%	33.34%
28	0.061	0.060	10	0.0017	0.0016	8.35%	2.72%
29	0.176	0.566	5.21	0.0025	0.0080	12.47%	13.30%
30	0.235	0.703	17.6	0.0112	0.0334	56.25%	55.89%
31	0.057	0.107	10	0.0015	0.0029	7.78%	4.85%
32	0.145	2.03	2	0.0008	0.0110	3.95%	18.34%
33	0.091	0.869	4	0.0010	0.0094	4.93%	15.69%
34	0.069	0.179	5	0.0009	0.0024	4.72%	4.04%
35	0.069	0.101	20	0.0038	0.0054	18.90%	9.08%
36	0.083	0.127	7	0.0016	0.0024	7.95%	4.00%
37	0.032	0.239	1.32	0.0001	0.0009	0.57%	1.43%
38	0.093	0.141	7.4	0.0019	0.0028	9.39%	4.72%
39	0.177	0.392	10	0.0048	0.0106	24.01%	17.72%
40	0.197	0.378	8.2	0.0044	0.0084	21.99%	14.00%
41	0.241	0.704	9.95	0.0065	0.0189	32.67%	31.65%
42	0.068	0.055	29.67	0.0054	0.0044	N/A	N/A
43	0.066	0.080	20	0.0035	0.0043	N/A	N/A
44	1.27	3.74	2	0.0069	0.0202	34.68%	33.73%
45	0.070	0.127	25	0.0047	0.0085	23.86%	14.28%
46	New sites added for second sampling effort						
47	New sites added for second sampling effort						
BLSB	New sites added for second sampling effort						
BLSD	New sites added for second sampling effort						
SMSR	0.061	<0.050*	45.9	0.0076	0.0031	N/A	N/A
WCAS	0.157	0.474	46.7	0.0199	0.0598	100.00%	100.00%

*For samples reported as being under the detection limit of 0.05 mg/l, 0.025 mg/l was used to calculate loads.

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TABLE 2

August 28, 2008 Sampling Event							
Sample ID	**Total-P (mg/l)**	**Total-N (mg/l)**	**Discharge (cfs)**	**Total-P Load (tons/day)**	**Total-N Load (tons/day)**	**Percent of Total P at WCAS (%)**	**Percent of Total N at WCAS (%)**
1	0.076	0.082	4.33	0.0009	0.0010	5.97%	2.12%
2	0.152	0.533	25.8	0.0106	0.0371	71.02%	82.08%
3	0.145	0.467	5.4	0.0021	0.0068	14.16%	14.98%
21	0.662	1.225	2.23	0.0040	0.0074	26.75%	16.32%
22	0.609	1.144	9.34	0.0154	0.0288	103.15%	63.79%
23	Not Sampled due to low nutrient concentration in first sampling effort						
24	0.084	0.240	9.920	0.0022	0.0064	15.07%	14.22%
25	0.091	0.328	0.49	0.0001	0.0004	0.81%	0.96%
26	0.104	0.226	1.000	0.0003	0.0006	1.89%	1.35%
27	0.147	0.614	5.250	0.0021	0.0087	13.98%	19.24%
28	0.070	0.152	10.00	0.0019	0.0041	12.72%	9.07%
29	0.095	0.308	5.340	0.0014	0.0044	9.19%	9.83%
30	0.154	0.652	20.300	0.0084	0.0358	56.54%	79.09%
31	0.224	0.470	7.000	0.0042	0.0089	28.47%	19.64%
32	0.160	1.609	1.5	0.0006	0.0065	4.36%	14.42%
33	0.361	1.48	2.50	0.0024	0.0100	16.36%	22.14%
34	0.079	0.308	2.00	0.0004	0.0017	2.85%	3.68%
35	0.069	0.055	35.00	0.0065	0.0052	43.82%	11.47%
36	No water in channel						
37	No water in channel						
38	No water in channel						
39	1.167	1.613	5.6	0.0175	0.0242	117.61%	53.56%
40	0.181	0.598	2.98	0.0015	0.0048	9.79%	10.63%
41	1.254	2.132	0.100	0.0003	0.0006	2.27%	1.27%
42	Not Sampled because determined not to contribute to WCAS nutrient load						
43	Not Sampled because determined not to contribute to WCAS nutrient load						
44	0.301	1.335	2.25	0.0018	0.0081	12.29%	17.94%
45	0.099	0.227	20.0	0.0053	0.0122	35.89%	27.07%
46	0.239	0.514	2.25	0.0015	0.0031	9.76%	6.91%
47	0.495	0.481	1.240	0.0017	0.0016	11.14%	3.56%
BLSB	0.065	<0.050	5.540	0.0010	0.0004	6.56%	0.83%
BLSD	0.065	<0.050	13.600	0.0024	0.0009	16.04%	2.03%
SMSR	0.068	<0.050	49.700	0.0091	0.0034	N/A	N/A
WCAS	0.155	0.472	35.500	0.0149	0.0452	100.00%	100.00%

*For samples reported as being under the detection limit of 0.05 mg/l, 0.025 mg/l was used to calculate loads.

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TABLE

3

Average Values for July and August 2008 Sampling Events

Sample ID	Total-P (mg/l)	Total-N (mg/l)	Discharge (cfs)	Total-P Load (tons/day)	Total-N Load (tons/day)	Percent of Total P at WCAS (%)	Percent of Total N at WCAS (%)
1	0.100	0.082	6.655	0.0018	0.0015	10.34%	2.80%
2	0.161	0.547	27.850	0.0121	0.0411	69.83%	78.29%
3	0.144	0.465	6.590	0.0026	0.0083	14.78%	15.75%
21	0.383	0.688	4.445	0.0046	0.0083	26.50%	15.72%
22	0.360	0.631	8.445	0.0082	0.0144	47.34%	27.43%
23	0.049	<0.05	1.000	0.0001	0.0001	0.77%	0.13%
24	0.077	0.150	9.100	0.0019	0.0037	10.95%	7.01%
25	0.075	0.203	0.985	0.0002	0.0005	1.16%	1.03%
26	0.168	0.346	1.000	0.0005	0.0009	2.62%	1.78%
27	0.185	0.550	10.225	0.0051	0.0152	29.48%	28.92%
28	0.066	0.106	10.000	0.0018	0.0029	10.23%	5.46%
29	0.135	0.437	5.275	0.0019	0.0062	11.11%	11.86%
30	0.194	0.678	18.950	0.0099	0.0347	57.28%	66.08%
31	0.141	0.289	8.500	0.0032	0.0066	18.61%	12.62%
32	0.153	1.820	1.750	0.0007	0.0086	4.16%	16.39%
33	0.226	1.176	3.250	0.0020	0.0103	11.42%	19.65%
34	0.074	0.243	3.500	0.0007	0.0023	4.03%	4.38%
35	0.069	0.078	27.500	0.0051	0.0058	29.63%	10.99%
36	0.083	0.127	7.000	0.0016	0.0024	9.09%	4.56%
37	0.032	0.239	1.320	0.0001	0.0009	0.65%	1.62%
38	0.093	0.141	7.400	0.0019	0.0028	10.74%	5.37%
39	0.672	1.003	7.780	0.0141	0.0211	81.29%	40.13%
40	0.189	0.488	5.590	0.0029	0.0074	16.45%	14.03%
41	0.748	1.418	5.025	0.0101	0.0192	58.44%	36.66%
42	0.068	0.055	29.670	0.0054	0.0044	31.22%	8.44%
43	0.066	0.080	20.000	0.0035	0.0043	20.44%	8.22%
44	0.788	2.535	2.125	0.0045	0.0145	26.05%	27.71%
45	0.085	0.177	22.500	0.0051	0.0107	29.60%	20.44%
46	0.239	0.514	2.250	0.0015	0.0031	8.38%	5.95%
47	0.495	0.481	1.240	0.0017	0.0016	9.56%	3.07%
BLSB	0.065	<0.05	5.540	0.0010	0.0004	5.63%	0.71%
BLSD	0.065	<0.05	13.600	0.0024	0.0009	13.76%	1.75%
SMSR	0.064	<0.05	47.800	0.0083	0.0032	N/A	N/A
WCAS	0.156	0.473	41.100	0.0174	0.0525	100.00%	100.00%

*For samples reported as being under the detection limit of 0.05 mg/l, 0.025 mg/l was used to calculate loads.

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TABLE

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COMPARISON OF SITES BY SAMPLE DATE AND PARAMETER RANKED BY PERCENT CHANGE

Total Phosphorus			
Site	**7/08 TP**	**8/08 TP**	**% Change**
39	0.177	1.167	561%
21	0.105	0.662	530%
22	0.112	0.609	446%
41	0.241	1.254	419%
33	0.091	0.361	298%
31	0.057	0.224	292%
25	0.060	0.091	51%
45	0.070	0.099	41%
24	0.071	0.084	18%
28	0.061	0.070	14%
34	0.069	0.079	13%
32	0.145	0.160	10%
3	0.143	0.145	2%
35	0.069	0.069	-1%
40	0.197	0.181	-8%
2	0.171	0.152	-11%
27	0.224	0.147	-34%
30	0.235	0.154	-35%
1	0.124	0.076	-38%
29	0.176	0.095	-46%
26	0.232	0.104	-55%
44	1.27	0.301	-76%
23	0.049	---	N/A
36	0.083	---	N/A
37	0.032	---	N/A
38	0.093	---	N/A
42	0.068	---	N/A
43	0.066	---	N/A
46	---	0.239	N/A
47	---	0.495	N/A
BLSB	---	0.065	N/A
BLSD	---	0.065	N/A
WCAS	0.157	0.155	-1%
SMSR	0.061	0.068	11%

Total Nitrogen			
Site	**7/08 TN**	**8/08 TN**	**% Change**
22	0.119	1.144	860%
21	0.150	1.225	717%
31	0.107	0.470	338%
25	0.078	0.328	322%
39	0.392	1.613	311%
24	0.060	0.240	303%
1	0.025	0.082	228%
41	0.704	2.132	203%
28	0.060	0.152	152%
45	0.127	0.227	79%
34	0.179	0.308	72%
33	0.869	1.483	71%
40	0.378	0.598	58%
27	0.486	0.614	26%
3	0.462	0.467	1%
2	0.560	0.533	-5%
30	0.703	0.652	-7%
32	2.03	1.609	-21%
35	0.101	0.055	-45%
29	0.566	0.308	-45%
26	0.466	0.226	-51%
44	3.74	1.335	-64%
23	0.025	---	N/A
36	0.127	---	N/A
37	0.239	---	N/A
38	0.141	---	N/A
42	0.055	---	N/A
43	0.080	---	N/A
46	---	0.514	N/A
47	---	0.481	N/A
BLSB	---	0.025	N/A
BLSD	---	0.025	N/A
WCAS	0.474	0.472	-1%
SMSR	0.025	0.025	0%

Discharge			
Site	**7/08 Q**	**8/08 Q**	**% Change**
35	20	35	75%
22	7.55	9.34	24%
24	8.28	9.92	20%
30	17.6	20.3	15%
44	2	2.25	13%
29	5.21	5.34	2%
26	1	1	0%
28	10	10	0%
2	29.9	25.8	-14%
45	25	20	-20%
32	2	1.5	-25%
31	10	7.0	-30%
3	7.81	5.4	-31%
33	4	2.50	-38%
39	10	5.6	-44%
1	8.98	4.33	-52%
34	5	2	-60%
40	8.2	2.98	-64%
27	15.2	5.25	-65%
21	6.66	2.23	-67%
25	1.48	0.49	-67%
41	9.95	0.10	-99%
36	7.0	0.0	-100%
37	1.32	0.0	-100%
38	7.4	0.0	-100%
23	1	---	N/A
42	29.7	---	N/A
43	20	---	N/A
46	---	2.25	N/A
47	---	1.24	N/A
BLSB	---	5.54	N/A
BLSD	---	13.6	N/A
WCAS	46.7	35.5	-24%
SMSR	45.9	49.7	8%

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TABLE

5

UPSTREAM-DOWNSTREAM SITE RELATIONSHIPS AND UNIT CHANGE

SAMPLE DATE: 7/17/2008

Total Phosphorus

		U/S Sites		D/S Sites		Change		Unit Change
Sites (U/S to D/S)	Distance (miles)	Total P (mg/l)	Q (cfs)	Total P (mg/l)	Q (cfs)	Total P (mg/l)	Q (cfs)	Total P (mg/l/mile)
26 to 22	2.67	0.232	1.0	0.112	7.6	-0.121	6.6	-0.045
32 to 30	2.68	0.145	2.0	0.235	17.6	0.090	15.6	0.033
25 to 3	1.12	0.060	1.5	0.143	7.8	0.083	6.3	0.074
45 to 29	2.56	0.070	25.0	0.176	5.2	0.106	-19.8	0.041
35 to 28	2.33	0.069	20.0	0.061	10.0	-0.008	-10.0	-0.003

Total Nitrogen

		U/S Sites		D/S Sites		Change		Unit Change
Sites (U/S to D/S)	Distance (miles)	Total N (mg/l)	Q (cfs)	Total N (mg/l)	Q (cfs)	Total N (mg/l)	Q (cfs)	Total N (mg/l/mile)
26 to 22	2.67	0.466	1.0	0.119	7.6	-0.346	6.6	-0.130
32 to 30	2.68	2.03	2.0	0.703	17.6	-1.328	15.6	-0.496
25 to 3	1.12	0.078	1.5	0.462	7.8	0.384	6.3	0.343
45 to 29	2.56	0.127	25.0	0.566	5.2	0.439	-19.8	0.172
35 to 28	2.33	0.101	20.0	0.060	10.0	-0.040	-10.0	-0.017

SAMPLE DATE: 8/28/2008

		U/S Sites		D/S Sites		Change		Unit Change
Sites (U/S to D/S)	Distance (miles)	Total P (mg/l)	Q (cfs)	Total P (mg/l)	Q (cfs)	Total P (mg/l)	Q (cfs)	Total P (mg/l/mile)
26 to 22	2.67	0.104	1.0	0.609	9.3	0.505	8.3	0.189
32 to 30	2.68	0.160	1.5	0.154	20.3	-0.007	18.8	-0.002
25 to 3	1.12	0.091	0.5	0.145	5.4	0.055	4.9	0.049
45 to 29	2.56	0.099	20.0	0.095	5.3	-0.004	-14.7	-0.002
35 to 28	2.33	0.069	35.0	0.070	10.0	0.001	-25.0	0.000

		U/S Sites		D/S Sites		Change		Unit Change
Sites (U/S to D/S)	Distance (miles)	Total N (mg/l)	Q (cfs)	Total N (mg/l)	Q (cfs)	Total N (mg/l)	Q (cfs)	Total N (mg/l/mile)
26 to 22	2.67	0.226	1.00	1.144	9.34	0.918	8.340	0.344
32 to 30	2.68	1.609	1.50	0.652	20.3	-0.957	18.800	-0.357
25 to 3	1.12	0.328	0.49	0.467	5.37	0.139	4.880	0.124
45 to 29	2.56	0.227	20.0	0.308	5.34	0.082	-14.660	0.032
35 to 28	2.33	0.055	35.0	0.152	10.00	0.097	-25.000	0.042

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TABLE

6

UPSTREAM-DOWNSTREAM SITE RELATIONSHIPS AND UNIT CHANGE

AVERAGE OF JULY-AUGUST SAMPLING

		U/S Sites		D/S Sites		Change		Unit Change
Sites (U/S to D/S)	Distance (miles)	Total P (mg/l)	Q (cfs)	Total P (mg/l)	Q (cfs)	Total P (mg/l)	Q (cfs)	Total P (mg/l/mile)
26-22	2.67	0.168	1.0	0.360	8.4	0.192	7.4	0.072
32-30	2.68	0.153	1.8	0.194	19.0	0.042	17.2	0.016
25-3	1.12	0.075	1.0	0.144	6.6	0.069	5.6	0.061
45-29	2.56	0.085	22.5	0.135	5.3	0.051	-17.2	0.020
35-28	2.33	0.069	27.5	0.066	10.0	-0.003	-17.5	-0.001

		U/S Sites		D/S Sites		Change		Unit Change
Sites (U/S to D/S)	Distance (miles)	Total N (mg/l)	Q (cfs)	Total N (mg/l)	Q (cfs)	Total N (mg/l)	Q (cfs)	Total N (mg/l/mile)
26-22	2.67	0.346	1.00	0.631	8.45	0.286	7.445	0.107
32-30	2.68	1.820	1.75	0.678	19.0	-1.142	17.200	-0.427
25-3	1.12	0.203	0.99	0.465	6.59	0.262	5.605	0.234
45-29	2.56	0.177	22.5	0.437	5.28	0.260	-17.225	0.102
35-28	2.33	0.078	27.5	0.106	10.00	0.028	-17.500	0.012

STRATIFICATION OF SAMPLE SITES BY TOTAL-P CONCENTRATIONS

July Samples

Sample ID	Total-P (mg/l)
High TP	
44	1.27
Moderate TP	
41	0.241
30	0.235
26	0.232
27	0.224
40	0.197
39	0.177
29	0.176
2	0.171
WCAS	0.157
Low TP	
32	0.145
3	0.143
1	0.124
22	0.112
21	0.105
38	0.093
33	0.091
36	0.083
24	0.071
45	0.070
Background TP	
35	0.069
34	0.069
42	0.068
43	0.066
28	0.061
25	0.060
31	0.057
23	0.049
37	0.032

August Samples

Sample ID	Total-P (mg/l)
High TP	
41	1.254
39	1.167
21	0.662
22	0.609
Moderate TP	
47	0.495
33	0.361
44	0.301
46	0.239
31	0.224
40	0.181
32	0.160
WCAS	0.155
30	0.154
2	0.152
Low TP	
27	0.147
3	0.145
26	0.104
45	0.099
29	0.095
25	0.091
24	0.084
34	0.079
1	0.076
28	0.070
Background TP	
35	0.069
SMSR	0.068
BLSB	0.065
BLSD	0.065

Average

Sample ID	Total-P (mg/l)
High TP	
44	0.788
41	0.748
39	0.672
Moderate TP	
47	0.495
21	0.383
22	0.360
46	0.239
33	0.226
30	0.194
40	0.189
27	0.185
26	0.168
2	0.161
WCAS	0.156
32	0.153
Low TP	
3	0.144
31	0.141
29	0.135
1	0.100
38	0.093
45	0.085
36	0.083
24	0.077
25	0.075
34	0.074
Background TP	
35	0.069
42	0.068
28	0.066
43	0.066
BLSB	0.065
BLSD	0.065
SMSR	0.064
23	0.049
37	0.032

Classification Bins

TP Range	Notes
TP > 0.5 mg/l	Greater than 7x Background
0.5 > TP > 0.15 mg/l	2x-7x Background
0.15 > TP > 0.07 mg/l	1x-2x Background
TP < 0.07 mg/l	Essentially Background

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TABLE 8

July 17, 2008 Sampling Event with Sites Ranked by Percentage of Total-P Load at West Canal					
Sample ID	**Discharge (cfs)**	**Total-P Load (tons/day)**	**Total-N Load (tons/day)**	**Percent of Total P at WCAS (%)**	**Percent of Total N at WCAS (%)**
2	29.9	0.0138	0.0452	69.34%	75.63%
30	17.6	0.0112	0.0334	56.25%	55.89%
27	15.2	0.0092	0.0199	46.26%	33.34%
44	2.0	0.0069	0.0202	34.68%	33.73%
41	10.0	0.0065	0.0189	32.67%	31.65%
39	10.0	0.0048	0.0106	24.01%	17.72%
45	25.0	0.0047	0.0085	23.86%	14.28%
40	8.2	0.0044	0.0084	21.99%	14.00%
35	20.0	0.0038	0.0054	18.90%	9.08%
3	7.8	0.0030	0.0097	15.18%	16.30%
1	9.0	0.0030	0.0006	15.10%	1.01%
29	5.2	0.0025	0.0080	12.47%	13.30%
22	7.6	0.0023	0.0024	11.46%	4.06%
21	6.7	0.0019	0.0027	9.51%	4.51%
38	7.4	0.0019	0.0028	9.39%	4.72%
28	10.0	0.0017	0.0016	8.35%	2.72%
24	8.3	0.0016	0.0013	8.00%	2.23%
36	7.0	0.0016	0.0024	7.95%	4.00%
31	10.0	0.0015	0.0029	7.78%	4.85%
33	4.0	0.0010	0.0094	4.93%	15.69%
34	5.0	0.0009	0.0024	4.72%	4.04%
32	2.0	0.0008	0.0110	3.95%	18.34%
26	1.0	0.0006	0.0013	3.16%	2.10%
25	1.5	0.0002	0.0003	1.21%	0.52%
23	1.0	0.0001	0.0001	0.67%	0.11%
37	1.3	0.0001	0.0009	0.57%	1.43%
42	29.7	0.0054	0.0044	N/A	N/A
43	20.0	0.0035	0.0043	N/A	N/A
SMSR	45.9	0.0076	0.0031	N/A	N/A
46	New sites added for second sampling effort				
47	New sites added for second sampling effort				
BLSB	New sites added for second sampling effort				
BLSD	New sites added for second sampling effort				
WCAS	46.7	0.0199	0.0598	100.00%	100.00%

*For samples reported as being under the detection limit of 0.05 mg/l, 0.025 mg/l was used to calculate loads.

August 18, 2008 Sampling Event with Sites Ranked by Percentage of Total-P Load at West Canal					
Sample ID	**Discharge (cfs)**	**Total-P Load (tons/day)**	**Total-N Load (tons/day)**	**Percent of Total P at WCAS (%)**	**Percent of Total N at WCAS (%)**
39	5.6	0.0175	0.0242	117.61%	53.56%
22	9.34	0.0154	0.0288	103.15%	63.79%
2	25.8	0.0106	0.0371	71.02%	82.08%
30	20.3	0.0084	0.0358	56.54%	79.09%
35	35.0	0.0065	0.0052	43.82%	11.47%
45	20.0	0.0053	0.0122	35.89%	27.07%
31	7.0	0.0042	0.0089	28.47%	19.64%
21	2.2	0.0040	0.0074	26.75%	16.32%
33	2.5	0.0024	0.0100	16.36%	22.14%
BLSD	13.6	0.0024	0.0009	16.04%	2.03%
24	9.9	0.0022	0.0064	15.07%	14.22%
3	5.4	0.0021	0.0068	14.16%	14.98%
27	5.3	0.0021	0.0087	13.98%	19.24%
28	10.0	0.0019	0.0041	12.72%	9.07%
44	2.3	0.0018	0.0081	12.29%	17.94%
47	1.2	0.0017	0.0016	11.14%	3.56%
40	3.0	0.0015	0.0048	9.79%	10.63%
46	2.3	0.0015	0.0031	9.76%	6.91%
29	5.3	0.0014	0.0044	9.19%	9.83%
BLSB	5.5	0.0010	0.0004	6.56%	0.83%
1	4.3	0.0009	0.0010	5.97%	2.12%
32	1.5	0.0006	0.0065	4.36%	14.42%
34	2.0	0.0004	0.0017	2.85%	3.68%
41	0.1	0.0003	0.0006	2.27%	1.27%
26	1.0	0.0003	0.0006	1.89%	1.35%
25	0.5	0.0001	0.0004	0.81%	0.96%
23	Not Sampled due to low nutrient concentration in first sampling effort				
36	No water in channel				
37	No water in channel				
	No water in channel				
42	Not Sampled because determined not to contribute to WCAS nutrient load				
43	Not Sampled because determined not to contribute to WCAS nutrient load				
SMSR	49.7	0.0091	0.0034	N/A	N/A
WCAS	35.5	0.0149	0.0452	100.00%	100.00%

*For samples reported as being under the detection limit of 0.05 mg/l, 0.025 mg/l was used to calculate loads.

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WOOD RIVER VALLEY TREATMENT WETLANDASSESSMENT PROJECT

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TABLE

10

Average Values for July and August Sampling Events with Sites Ranked by Percentage of Total-P Load at West Canal					
Sample ID	Discharge (cfs)	Total-P Load (tons/day)	Total-N Load (tons/day)	Percent of Total P at WCAS (%)	Percent of Total N at WCAS (%)
39	7.8	0.0141	0.0211	81.29%	40.13%
2	27.9	0.0121	0.0411	69.83%	78.29%
41	5.0	0.0101	0.0192	58.44%	36.66%
30	19.0	0.0099	0.0347	57.28%	66.08%
22	8.4	0.0082	0.0144	47.34%	27.43%
42	29.7	0.0054	0.0044	31.22%	8.44%
35	27.5	0.0051	0.0058	29.63%	10.99%
45	22.5	0.0051	0.0107	29.60%	20.44%
27	10.2	0.0051	0.0152	29.48%	28.92%
21	4.4	0.0046	0.0083	26.50%	15.72%
44	2.1	0.0045	0.0145	26.05%	27.71%
43	20.0	0.0035	0.0043	20.44%	8.22%
31	8.5	0.0032	0.0066	18.61%	12.62%
40	5.6	0.0029	0.0074	16.45%	14.03%
3	6.6	0.0026	0.0083	14.78%	15.75%
BLSD	13.600	0.0024	0.0009	13.76%	1.75%
33	3.3	0.0020	0.0103	11.42%	19.65%
29	5.3	0.0019	0.0062	11.11%	11.86%
24	9.1	0.0019	0.0037	10.95%	7.01%
38	7.4	0.0019	0.0028	10.74%	5.37%
1	6.66	0.0018	0.0015	10.34%	2.80%
28	10.0	0.0018	0.0029	10.23%	5.46%
47	1.240	0.0017	0.0016	9.56%	3.07%
36	7.0	0.0016	0.0024	9.09%	4.56%
46	2.3	0.0015	0.0031	8.38%	5.95%
BLSB	5.540	0.0010	0.0004	5.63%	0.71%
32	1.8	0.0007	0.0086	4.16%	16.39%
34	3.5	0.0007	0.0023	4.03%	4.38%
26	1.0	0.0005	0.0009	2.62%	1.78%
25	1.0	0.0002	0.0005	1.16%	1.03%
23	1.0	0.0001	0.0001	0.77%	0.13%
37	1.3	0.0001	0.0009	0.65%	1.62%
SMSR	47.800	0.0083	0.0032	N/A	N/A
WCAS	41.100	0.0174	0.0525	100.00%	100.00%

*For samples reported as being under the detection limit of 0.05 mg/l, 0.025 mg/l was used to calculate loads.

COMPARISON OF CHANNEL WATER SURFACE AND TYPICAL VALLEY FLOOR ELEVATIONS AT SAMPLE SITES

Sample ID	In Channel Water Surface Elevation (ft)	Valley Floor Surface Elevation (ft)	Elevation Difference (ft)
1	4148.0	4154.8	6.8
2	4148.8	4151.8	3.0
3	4148.5	4151.9	3.4
21	4155.2	4155.3	0.1
22	4152.8	4154.9	2.1
23	4156.9	4157.0	0.1
24	4171.2	4171.8	0.6
25	4162.7	4162.8	0.1
26	4192.2	4195.5	3.3
27	4162.0	4163.8	1.8
28	4165.5	4166.8	1.3
29	4156.6	4158.5	1.9
30	4153.0	4155.2	2.2
31	4195.5	4196.8	1.3
32	4192.7	4193.2	0.5
33	4190.3	4192.4	2.1
34	4186.2	4186.9	0.7
35	4183.0	4185.1	2.1
36	4160.2	4160.5	0.3
37	4159.6	4160.4	0.8
38	4162.6	4162.8	0.2
39	4154.8	4155.7	0.9
40	4156.5	4156.9	0.4
41	4150.1	4154.5	4.4
42	4153.7	4153.5	-0.2
43	4150.0	4152.7	2.7
44	4162.9	4163.2	0.3
45	4188.0	4190.1	2.1
46	4161.5	4163.5	2.0
47	4160.5	4162.8	2.3
BLSB	4171.1	4181.0	9.9
BLSD	4178.9	4182.0	3.1
SMSR	4150.8	4155.5	4.7
WCAS	4148.5	4155.5	7.0
*Elevations estimated from Wood River Valley LiDAR			
*Elevation Datum: NAVD 88 feet			

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TABLE

12

Average Values for July and August Sampling Events with Sites Ranked by Percentage of Total-P Load at West Canal

Sample ID	Discharge (cfs)	Total-P Load (tons/day)	Total-N Load (tons/day)	Percent of Total P at WCAS (%)	Percent of Total N at WCAS (%)
Highest Priority					
39	7.8	0.0141	0.0211	81.29%	40.13%
Higher Priority					
41	5.0	0.0101	0.0192	58.44%	36.66%
22	8.4	0.0082	0.0144	47.34%	27.43%
21	4.4	0.0046	0.0083	26.50%	15.72%
44	2.1	0.0045	0.0145	26.05%	27.71%
High Priority					
27	10.2	0.0051	0.0152	29.48%	28.92%
31	8.5	0.0032	0.0066	18.61%	12.62%
40	5.6	0.0029	0.0074	16.45%	14.03%
3	6.6	0.0026	0.0083	14.78%	15.75%
Medium Priority due to Volume of Flow					
2	27.9	0.0121	0.0411	69.83%	78.29%
30	19.0	0.0099	0.0347	57.28%	66.08%
42	29.7	0.0054	0.0044	31.22%	8.44%
35	27.5	0.0051	0.0058	29.63%	10.99%
45	22.5	0.0051	0.0107	29.60%	20.44%
43	20.0	0.0035	0.0043	20.44%	8.22%
Low Priority					
33	3.3	0.0020	0.0103	11.42%	19.65%
29	5.3	0.0019	0.0062	11.11%	11.86%
24	9.1	0.0019	0.0037	10.95%	7.01%
38	7.4	0.0019	0.0028	10.74%	5.37%
1	6.66	0.0018	0.0015	10.34%	2.80%
28	10.0	0.0018	0.0029	10.23%	5.46%
47	1.24	0.0017	0.0016	9.56%	3.07%
36	7.0	0.0016	0.0024	9.09%	4.56%
46	2.3	0.0015	0.0031	8.38%	5.95%
Insignificant or Close to Background					
32	1.8	0.0007	0.0086	4.16%	16.39%
34	3.5	0.0007	0.0023	4.03%	4.38%
26	1.0	0.0005	0.0009	2.62%	1.78%
25	1.0	0.0002	0.0005	1.16%	1.03%
23	1.0	0.0001	0.0001	0.77%	0.13%
37	1.3	0.0001	0.0009	0.65%	1.62%

BLSD	13.6	0.0024	0.0009	13.76%	1.75%
BLSB	5.54	0.0010	0.0004	5.63%	0.71%
SMSR	47.8	0.0083	0.0032	N/A	N/A
WCAS	41.1	0.0174	0.0525	100.00%	100.00%

*For samples reported as being under the detection limit of 0.05 mg/l, 0.025 mg/l was used to calculate loads.

KLAMATH BASIN RANGELAND TRUST

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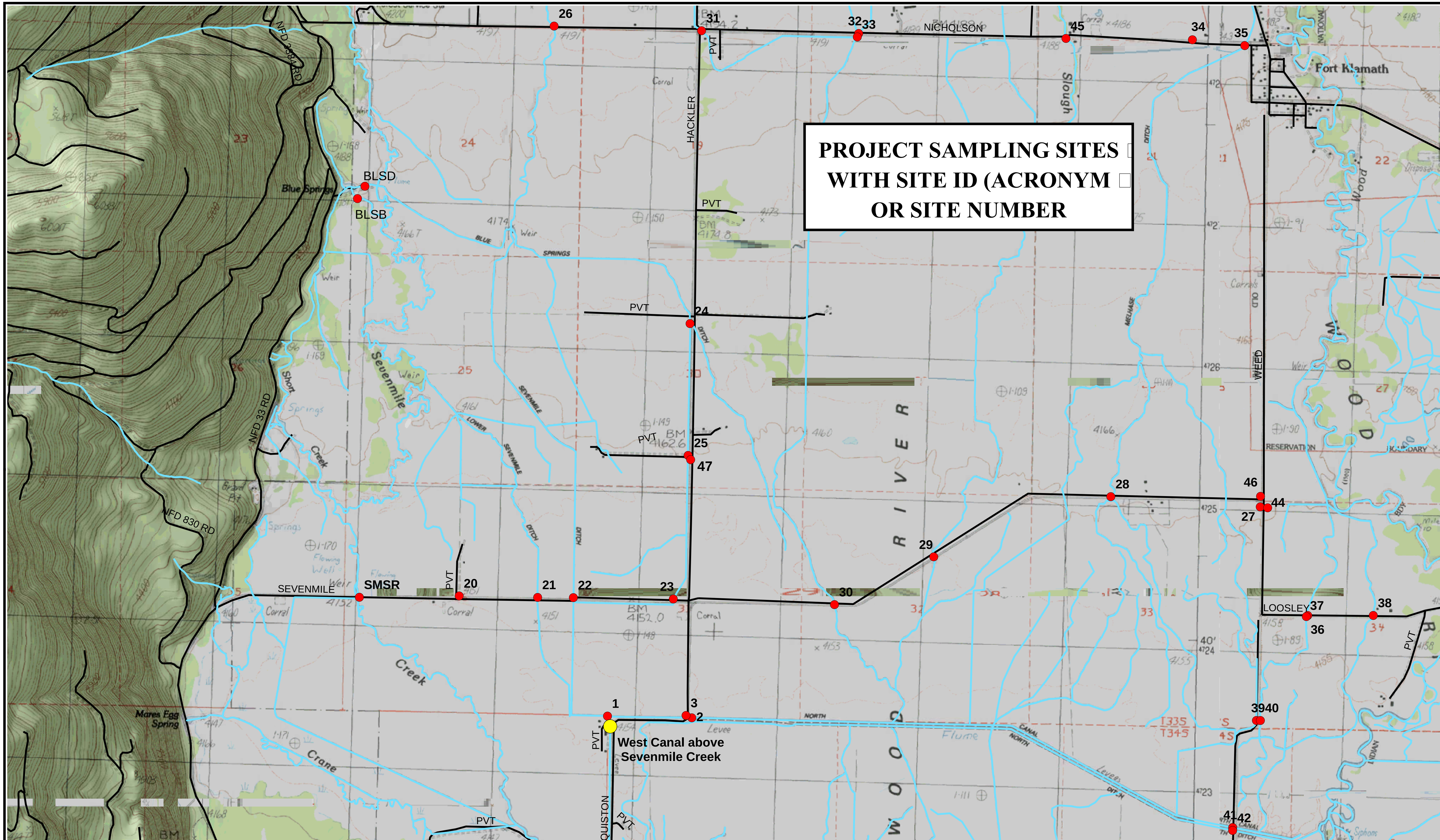
TABLE

13



PROJECT:
WOOD RIVER VALLEY
TREATMENT WETLANDS ASSESSMENT PROJECT
January 2010

N W E S

0 2,500 5,000 Feet

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Figure
1

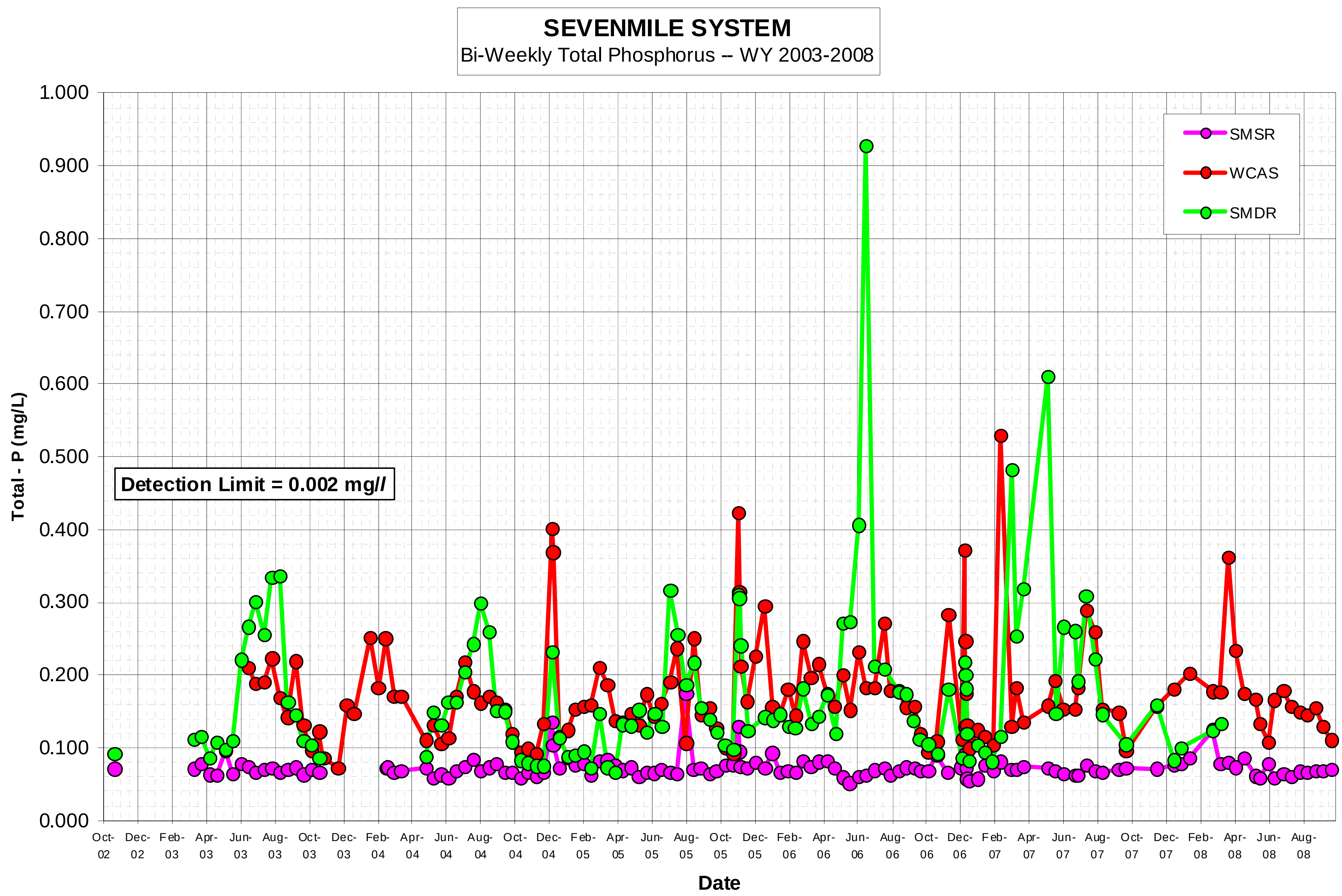

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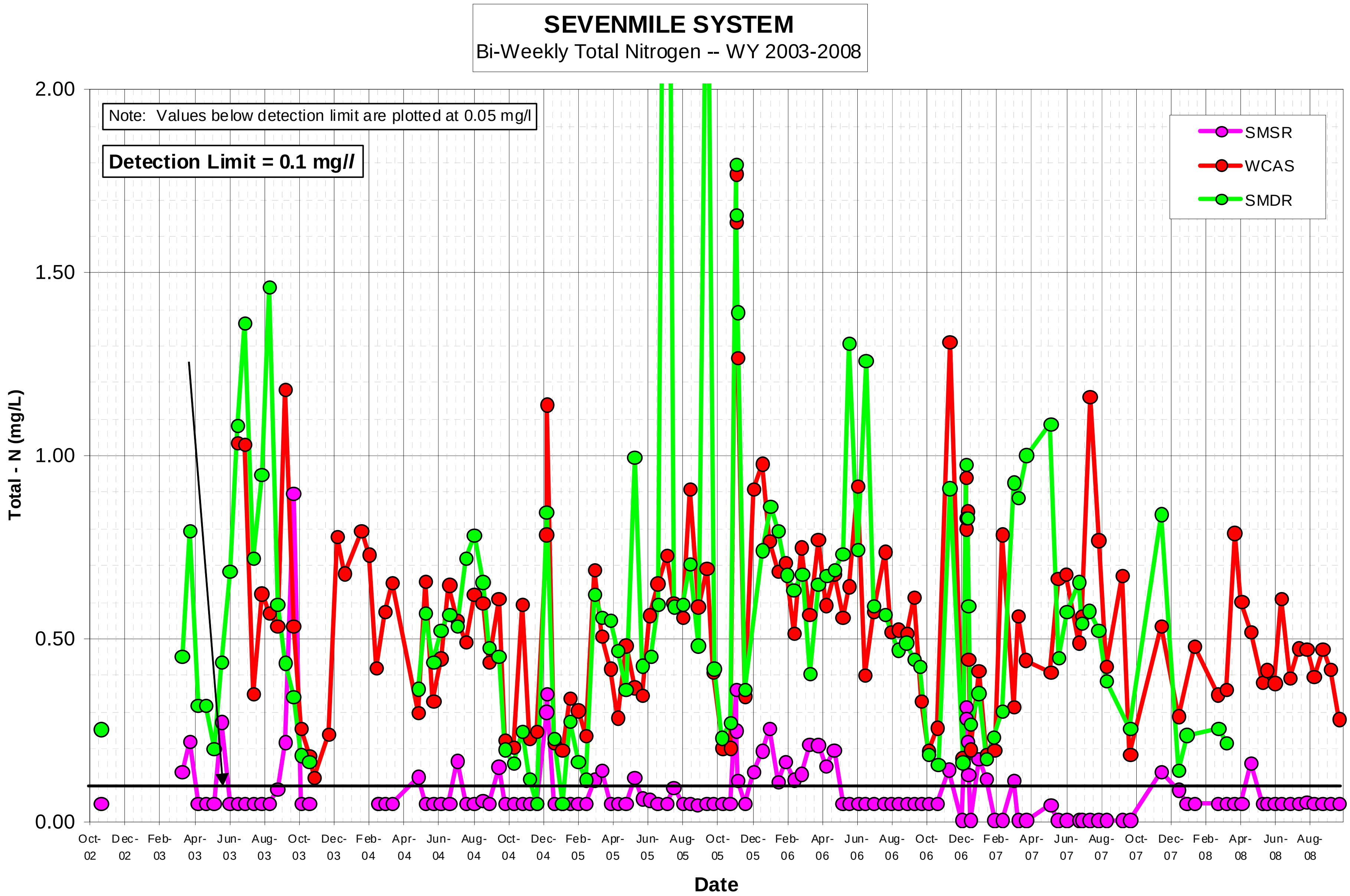
FIGURE

2



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WOOD RIVER VALLEY TREATMENT WETLAND ASSESSMENT PROJECT

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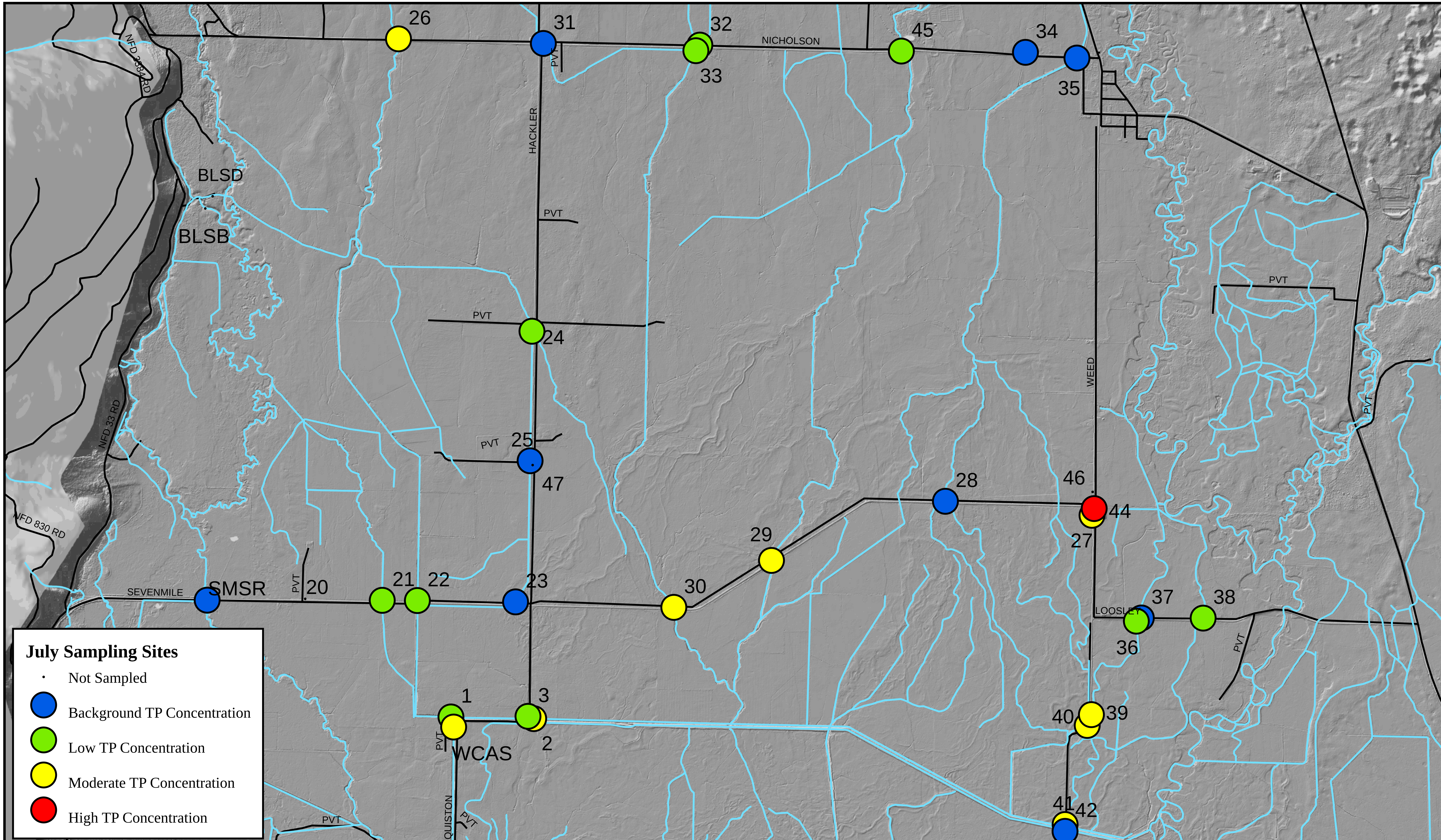
FIGURE

3



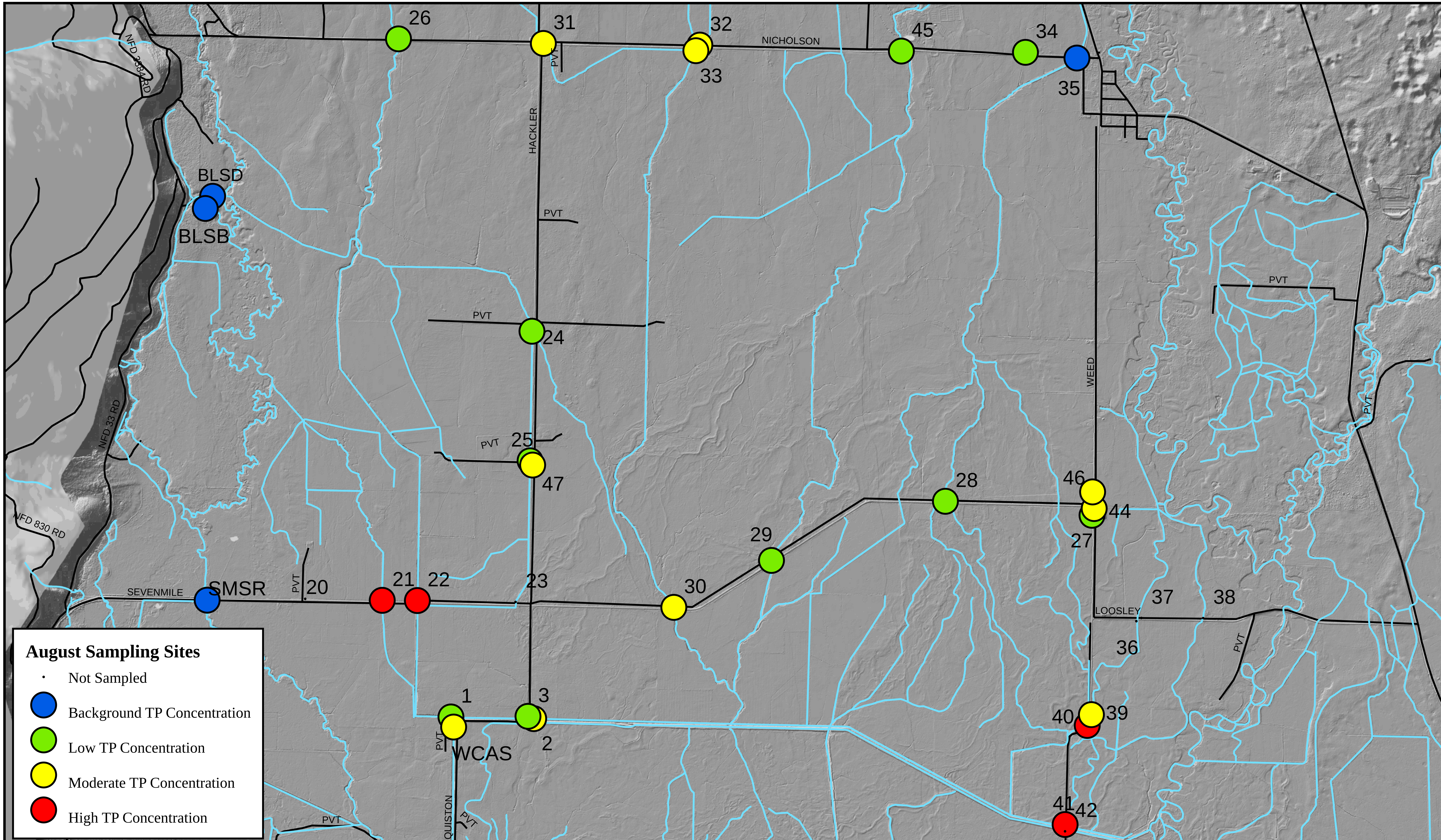
PROJECT:
WOOD RIVER VALLEY
TREATMENT WETLANDS ASSESSMENT PROJECT
January 2010

N W E S

0 2,500 5,000 Feet

Hydrology | Geomorphology | Stream Restoration

Figure 4



PROJECT:
WOOD RIVER VALLEY
TREATMENT WETLANDS ASSESSMENT PROJECT
January 2010

N
W E
S

0 2,500 5,000
Feet

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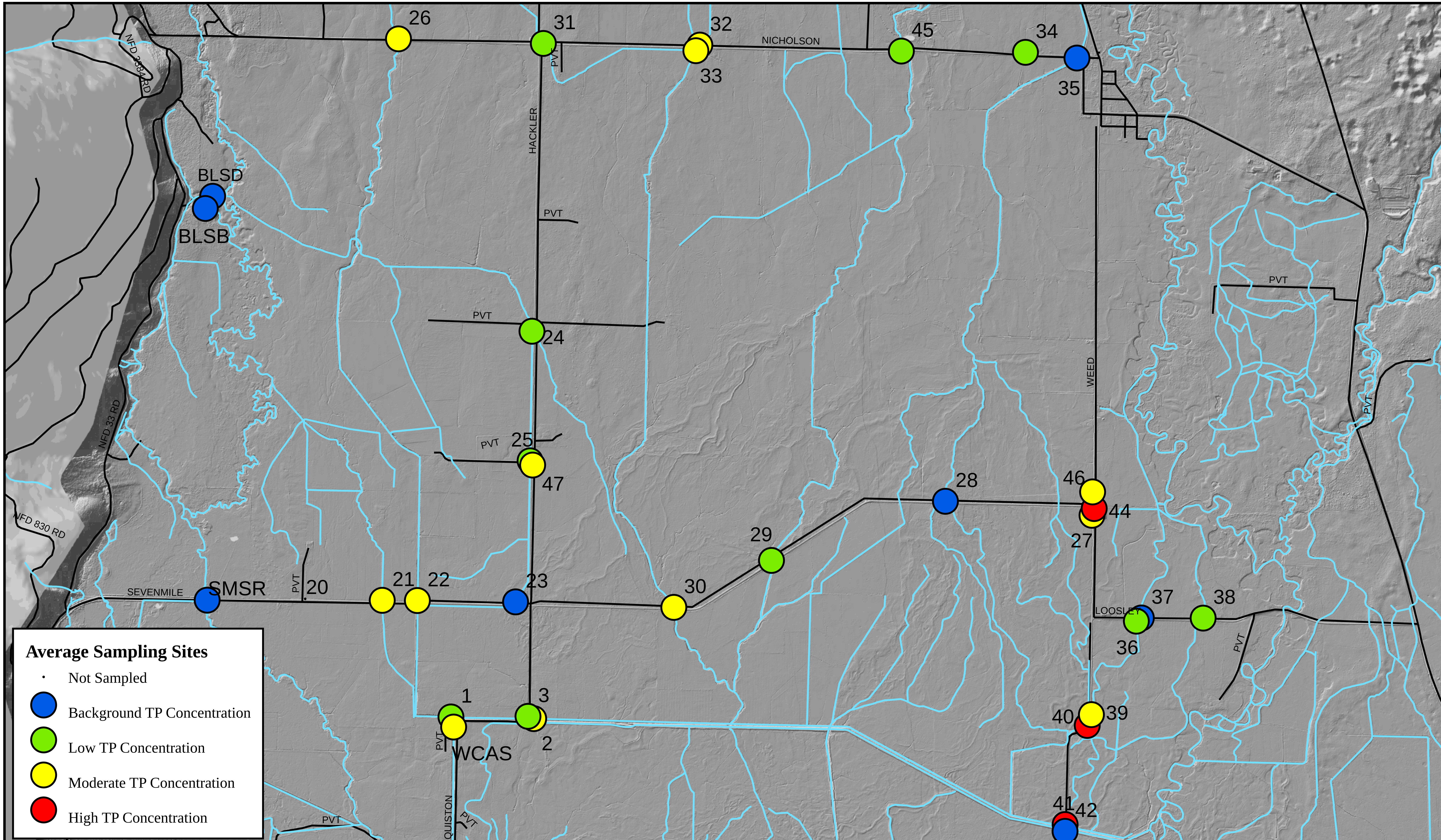
Figure
5



PROJECT:

WOOD RIVER VALLEY

TREATMENT WETLANDS ASSESSMENT PROJECT

January 2010

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Figure 6

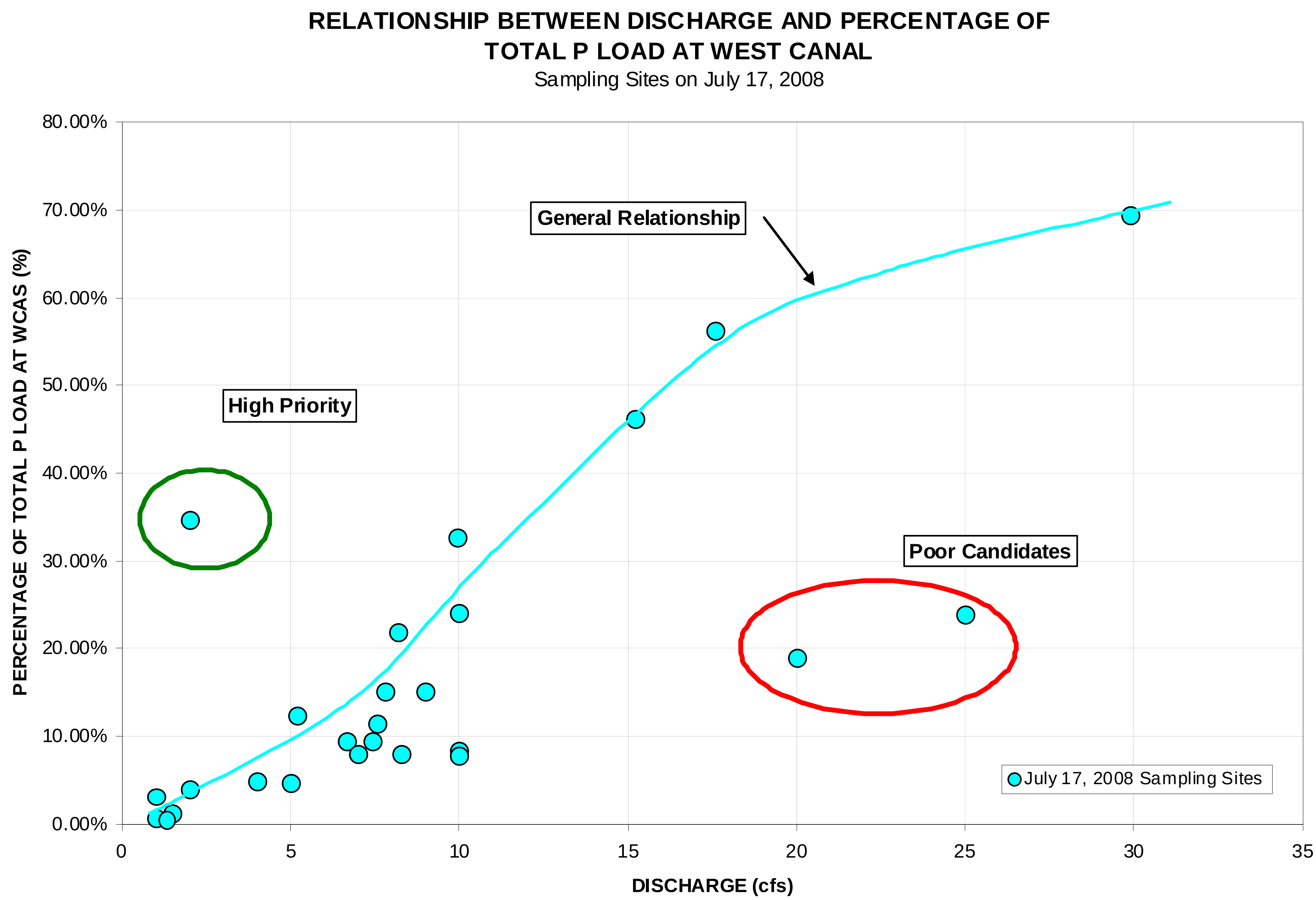

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FIGURE

7

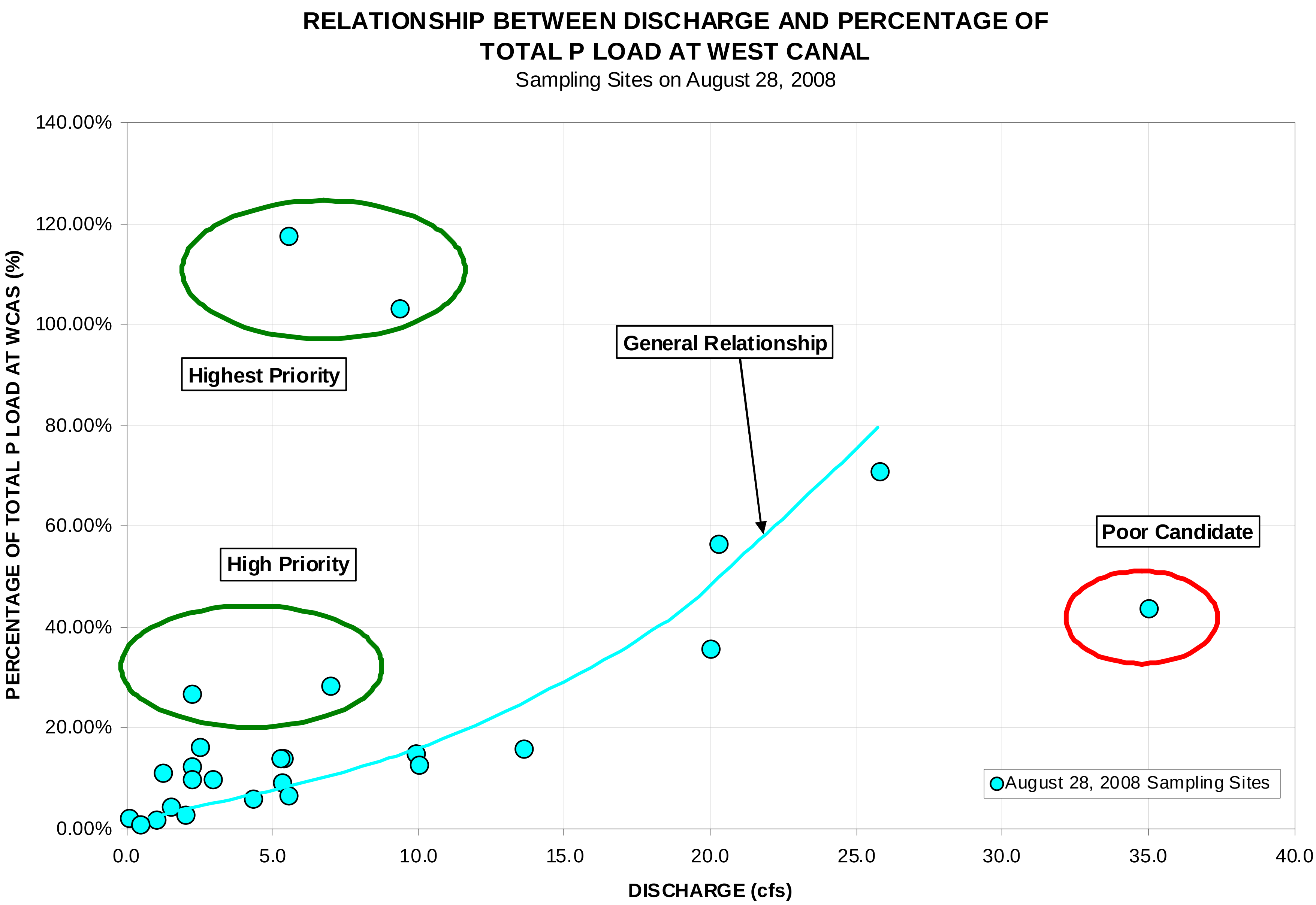

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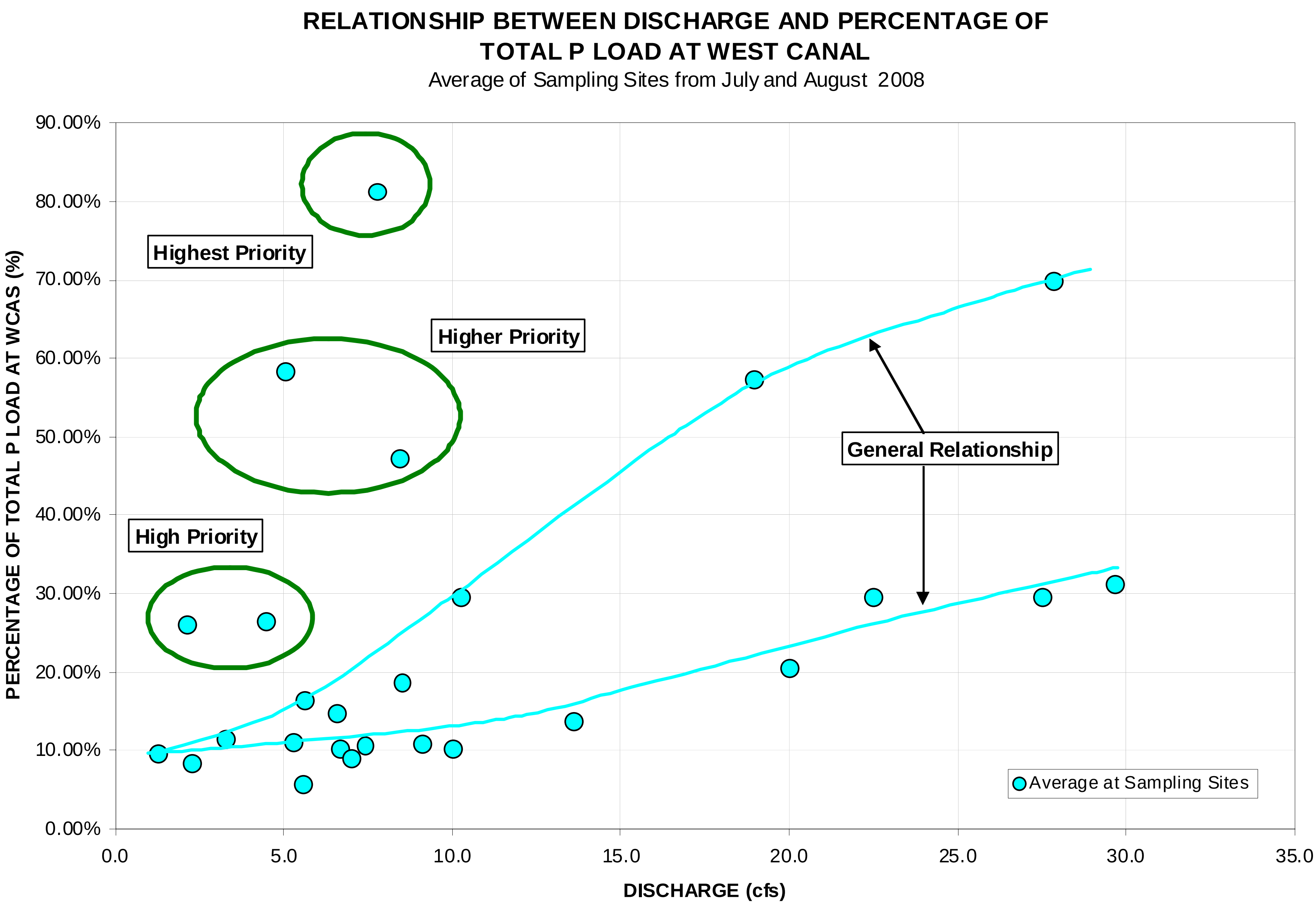
FIGURE

8



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WOOD RIVER VALLEY TREATMENT WETLAND ASSESSMENT PROJECT

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FIGURE

9

AQUATIC RESEARCH INCORPORATED

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: GMA002-81 **PAGE 1**

REPORT DATE: 07/28/08

DATE SAMPLED: 07/17/08 **DATE RECEIVED:** 07/18/08

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GRAHAM MATTHEWS & ASSOCIATES

CASE NARRATIVE

Thirty three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/l)	SRP (mg/l)	AMMONIA (mg/l)	N03+N02 (mg/l)	TOTAL-N (mg/l)
SMSR	0.061	0.059	<0.010	<0.010	<0.050
WCAS	0.157	0.099	<0.010	0.012	0.474
45	0.070				0.127
23	0.049				<0.050
27	0.224				0.486
1	0.124				<0.050
28	0.061				0.060
3	0.143				0.462
2	0.171				0.560
33	0.091				0.869
44	1.27				3.74
43	0.066				0.080
42	0.068				0.055
34	0.069				0.179
31	0.057				0.107
WRWR	0.080				0.119
41	0.241				0.704
TPD	0.766				2.17
25	0.060				0.078
24	0.071				0.060
35	0.069				0.101
22	0.112				0.119
37	0.032				0.239
39	0.177				0.392
40	0.197				0.378
26	0.232				0.466
32	0.145				2.03
29	0.176				0.566
CCATP	0.103				0.089
21	0.105				0.150
38	0.093				0.141
30	0.235				0.703
36	0.083				0.127

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LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **GMA002-81**
REPORT DATE: **07/28/08**
DATE SAMPLED: **07/17/08** **DATE RECEIVED:** **07/18/08**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GRAHAM MATTHEWS & ASSOCIATES

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/l)	SRP (mg/l)	AMMONIA (mg/l)	N03+N02 (mg/l)	TOTAL-N (mg/l)
METHOD	SM18 4500PF	SM18 4500PF	SM184500NH3H	SM184500N03F	SM184500NC
DATE ANALYZED	07/23/08	07/18/08	07/18/08	07/18/08	07/24/08
DETECTION LIMIT	0.002	0.001	0.010	0.010	0.050
DUPLICATE					
SAMPLE ID	WRWR	WCAS	BATCH	BATCH	WRWR
ORIGINAL	0.080	0.099	0.030	0.203	0.119
DUPLICATE	0.080	0.098	0.030	0.203	0.124
RPD	0.11%	0.84%	2.26%	0.03%	3.69%
SPIKE SAMPLE					
SAMPLE ID	WRWR	WCAS	BATCH	BATCH	WRWR
ORIGINAL	0.080	0.099	0.030	0.203	0.119
SPIKED SAMPLE	0.133	0.120	0.242	0.403	1.06
SPIKE ADDED	0.050	0.020	0.200	0.200	1.00
% RECOVERY	106.11%	107.14%	106.04%	99.79%	94.10%
QC CHECK					
FOUND	0.090	0.033	0.320	0.410	0.432
TRUE	0.090	0.033	0.324	0.408	0.435
% RECOVERY	99.86%	100.37%	98.76%	100.48%	99.34%
BLANK	<0.002	<0.001	<0.010	<0.010	<0.050

RPD = RELATIVE PERCENT DIFFERENCE
NA = NOT APPLICABLE OR NOT AVAILABLE
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION

SUBMITTED BY:

Steven Lazoff
Laboratory Director

AQUATIC RESEARCH INCORPORATED
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: GMA002-84 **PAGE 1**
REPORT DATE: 09/08/08
DATE SAMPLED: 08/28/08 **DATE RECEIVED:** 08/29/08
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GRAHAM MATTHEWS & ASSOCIATES

CASE NARRATIVE

Thirty two water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/l)	SRP (mg/l)	AMMONIA (mg/l)	N03+N02 (mg/l)	TOTAL-N (mg/l)
2	0.152				0.533
44	0.301				1.34
27	0.147				0.614
29	0.095				0.308
40	0.181				0.598
TPDI	1.38				2.90
1	0.076				0.082
TPD	0.768				2.58
BLSB	0.065				<0.050
30	0.154				0.652
CCATP	0.098				0.101
25	0.091				0.328
41	1.25				2.13
46	0.239				0.514
31	0.224				0.470
34	0.079				0.308
45	0.099				0.227
21	0.662				1.23
24	0.084				0.240
33	0.361				1.48
22	0.609				1.14
28	0.070				0.152
WRWR	0.084				0.098
47	0.495				0.481
3	0.145				0.467
26	0.104				0.226
32	0.160				1.61
35	0.069				0.055
BLSD	0.065				<0.050
39	1.17				1.61
WCAS	0.155	0.094	0.014	0.010	0.472
SMSR	0.068	0.062	<0.010	<0.010	<0.050

AQUATIC RESEARCH INCORPORATED

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715   FAX: (206) 632-2417

CASE FILE NUMBER: GMA002-84 **PAGE 2**
REPORT DATE: 09/08/08
DATE SAMPLED: 08/28/08 **DATE RECEIVED:** 08/29/08
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GRAHAM MATTHEWS & ASSOCIATES

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/l)	SRP (mg/l)	AMMONIA (mg/l)	N03+N02 (mg/l)	TOTAL-N (mg/l)
METHOD	SM18 4500PF	SM18 4500PF	SM184500NH3H	SM184500N03F	SM184500NC
DATE ANALYZED	09/04/08	08/29/08	08/29/08	08/29/08	09/02/08
DETECTION LIMIT	0.002	0.001	0.010	0.010	0.050
DUPLICATE					
SAMPLE ID	SMSR	SMSR	SMSR	SMSR	34
ORIGINAL	0.068	0.062	<0.010	<0.010	0.308
DUPLICATE	0.067	0.063	<0.010	<0.010	0.267
RPD	1.27%	2.54%	NC	NC	14.06%
SPIKE SAMPLE					
SAMPLE ID	SMSR	SMSR	SMSR	SMSR	34
ORIGINAL	0.068	0.062	<0.010	<0.010	0.308
SPIKED SAMPLE	0.118	0.082	0.212	0.210	1.21
SPIKE ADDED	0.050	0.020	0.200	0.200	1.00
% RECOVERY	100.14%	101.12%	106.12%	105.10%	90.36%
QC CHECK					
FOUND	0.092	0.033	0.318	0.412	0.434
TRUE	0.090	0.033	0.324	0.408	0.435
% RECOVERY	101.90%	100.13%	98.19%	100.89%	99.68%
BLANK	<0.002	<0.001	<0.010	<0.010	<0.050

RPD = RELATIVE PERCENT DIFFERENCE
NA = NOT APPLICABLE OR NOT AVAILABLE
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION

SUBMITTED BY:

Steven Lazoff
Laboratory Director

Sampling Site Photographs
Taken July 17, 2008

Site # 21 -

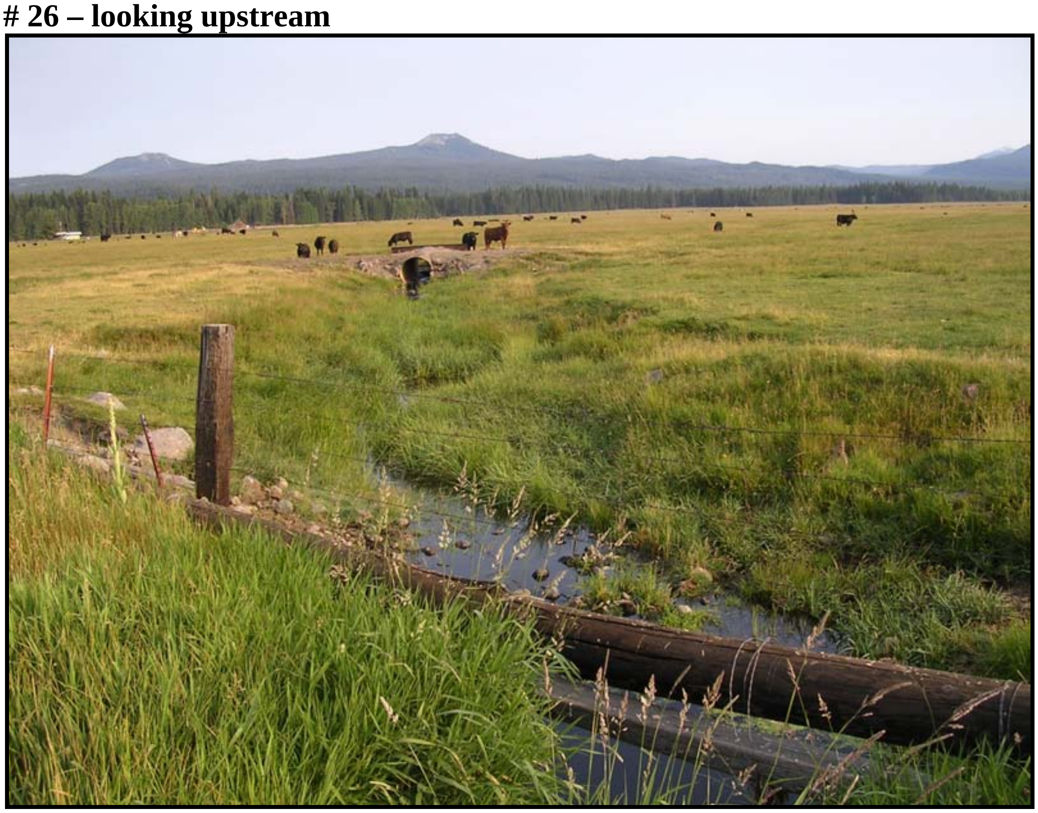
Site # 22 – looking upstream

Site # 22 – looking downstream

Site # 24

Site # 25

Site # 26 – looking upstream



Site # 26 – looking downstream

Site # 28

Site # 29 – looking upstream

Site # 29 – looking downstream

Site # 31 – looking upstream

Site # 31 – looking downstream

Site # 34

Site # 35

Site # 36 – looking upstream

Site # 36 – looking downstream

Site # 37

Site # 38

Site # 39

Site # 40

Site # 41 – looking upstream **Site # 41 – looking downstream**

Site # 42