United States Department of the Interior
BUREAU OF RECLAMATION
Great Plains Region
Montana Area Office
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Billings, Montana 59107-0137

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MT-745
ENV-2.00

APR 17 2007

Mr. Jeff Hagener, Director
Montana Fish, Wildlife, and Parks
1420 E 6th Ave.
Helena, MT 59620-0701

Subject: Warm Springs Creek, Flow and Sediment Project

Dear Mr. Hagener:

A two-year project funded by the Bureau of Reclamation has recently been completed by Montana State University (MSU), Extension Water Quality Program. Enclosed are two reports written by MSU which summarize the information collected during the 2005 and 2006 irrigation seasons. The completion of these reports fulfills Reclamation's commitment under a mitigation measure contained in the Finding of No Significant Impact (FONSI), reference number MT-231-05-01F, completed by Reclamation.

The FONSI contains several mitigation measures, one of which is related to an investigation of measures to avoid and/or minimize return flow issues that may be limiting the fishery potential of Warm Springs Creek. The Environmental Assessment and FONSI were related to the conversion of long-term water service contracts to repayment contracts for the Helena Valley Irrigation District, the Toston Irrigation District (TID), and the City of Helena.

The project completed by MSU was the result of a meeting in January, 2005, between representatives of Reclamation, TID, Montana Fish, Wildlife and Parks (FWP), and MSU to discuss concerns TID had with water conservation and management, as well as concerns FWP had with sediment in the Warm Springs Creek and the related fishery.

If you have any questions or comments regarding the reports, please contact Clayton Jordan at 406-247-7665.

Sincerely,

Dan Jewell
Area Manager

COPY

Enclosures

cc: Mr. Bill Jones, Manager
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Ms. Amber Kirkpatrick
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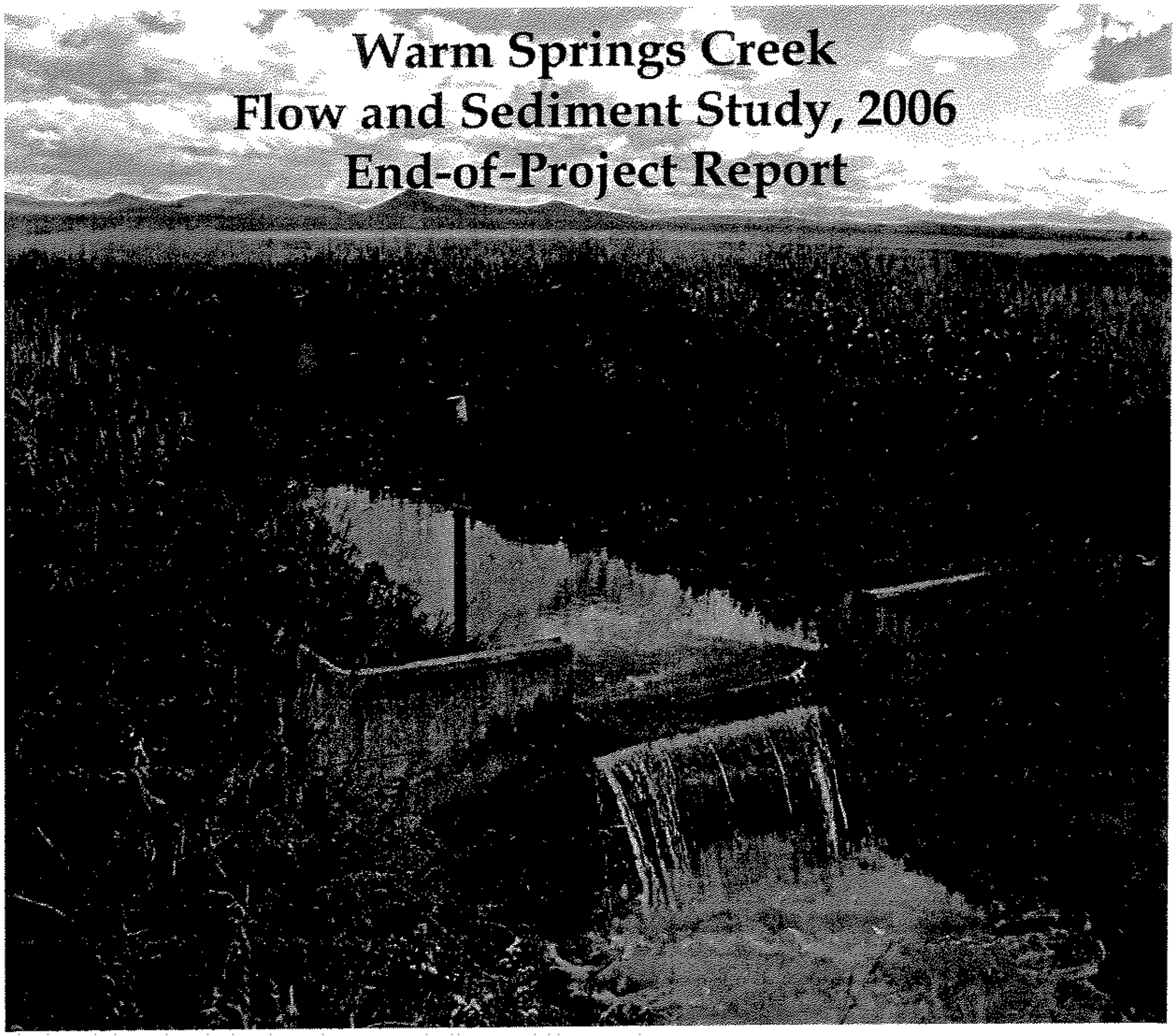
Warm Springs Creek
Flow and Sediment Study, 2006
End-of-Project Report



Prepared for:
USBR – Great Plains Office
Cooperative Agreement #06-FC-60-2128

Prepared by:
Amber Kirkpatrick
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February, 2007

Warm Springs Creek Flow and Sediment Study, 2006
End-of-Project Report

Overview

The Toston Irrigation District (TID), located about six miles southwest of Toston, Montana, comprises approximately 6,500 acres of full irrigation service lands in Broadwater County. Warm Springs Creek runs along the western edge of the district and the Toston Canal runs along the south-eastern portion. Most of Broadwater County is an intermountain basin known as the Townsend Basin, flanked by the Elkhorn Mountains on the west and the Big Belt Mountains on the east. Flood plains, terraces, and fans comprise the Townsend Basin around Toston. Erosion of local mountains consisting of sandstone, shale, limestone, andesite and basalt, along with volcanic ash and breccia from Yellowstone National Park, provide sediments for the Madison and Missouri Rivers and their tributaries to transport.

The parent material, derived from a variety of sources, consists mainly of alluvial deposits of the Missouri River and its tributary streams, with some loess on upper terraces and hills. Soils of the flood plains and low terraces are formed by the rivers while the higher terraces and fans are formed by tributaries.

Soils in the TID are characterized by nearly level to steep, deep, well-drained Mollisols, Entisols and Inceptisols. In general, soils of the district are sandy loams to silty clay loams. Silt loams and silty clay loams are distributed throughout the district but are concentrated along Warm Springs Creek north of Lone Mountain Road. Loams and sandy loams are found along the Toston Canal and Warm Springs Creek below Lone Mountain Road as well as in the north-eastern portion of the TID.

Average annual rainfall for the TID is 11.4 inches, with an average annual temperature of 43 degrees Fahrenheit, and elevations between 3,940 - 4,120 feet above sea level. Principal crops are alfalfa, cereal crops, seed potatoes and pasture.

Preface

TID pumps approximately 16,800 acre/feet of water per season. Water for irrigation is diverted to the project from the Missouri River by way of a pumping station and is typically delivered April through October. Water is diverted from the river downstream of the headwaters and above Toston Dam at the Crow Creek pumping plant. The Crow Creek Pumping Plant consists of three turbines which pump water up to the Toston Bench via the Toston Tunnel where it is delivered to individual farm units through the Toston Canal and lateral pipelines.

In 1987 most of the area was gravity irrigated and contour ditches, border dikes, and furrow systems were common. Gravity irrigation is typically equated with low on-farm efficiencies, with tail water running into downstream ditches where it is re-used. Although inefficient, gravity irrigation allowed water to make its way back to the river via Warm Springs Creek.

More recently, there has been a shift to more efficient sprinkler, center pivot, and side-roll irrigation systems. Estimates suggest that as much as 80% of irrigated acreage is now managed under sprinkler irrigation. Increased efficiency means less water makes its way back to the river, but it also means less water needs to be diverted. This could translate to savings for the TID in the form of lower energy costs for pump operation. Another management tool the TID has implemented is the conversion of all lateral delivery canals to pipelines, which increased delivery system efficiency by reducing loss through evaporation and seep.

The U.S. Bureau of Reclamation (Reclamation) completed an Environmental Assessment (EA) and signed a Finding of No Significant Impact (FONSI) in December 2004 related to the conversion of long-term water service contracts to repayment contracts for the Helena Valley Irrigation District, Toston Irrigation District, and the City of Helena. The FONSI (reference number MT-231-05-01F) contained mitigation measures, one of which is related to an investigation of measures to avoid and/or minimize return flow issues that may be limiting the Warm Springs Creek fishery.

Project Goal and Approach

Reclamation has initiated compliance with mitigation measures outlined by the FONSI and undertaken efforts to assess current flow and sediment patterns in the TID. At the request of Reclamation, the TID hosted a meeting with representatives from Reclamation, Fish-Wildlife and Parks (FWP) and Montana State University Extension Water Quality (MSUEWQ) in January 2005. The purpose of the meeting was to discuss concerns the irrigation district had with water conservation and management as well as concerns FWP had with sediment in the Warm Springs Creek fishery.

The overall goal of the project which evolved from that meeting was to attempt to measure or estimate irrigation season amounts of water and sediment contributed to Warm Springs Creek by the TID.

A secondary goal established in July 2005 was to attempt to define fluctuations within the Toston Canal itself. The TID has concerns about water loss from the Toston Canal and downstream erosion in the event of a power outage. When power is lost (due primarily from electrical storms), individual pumps go offline and all the water in the canal is discharged into Warm Springs Creek. This has two consequences, loss of water to individual units and a potentially damaging surge of water in Warm Springs Creek.

Data collected in 2005 showed the greatest water level fluctuations occurring in the lower section of the canal (lower canal), just before it empties into Warm Springs Creek. Historically, the TID operated the Toston Canal to spill approximately 6 cfs of water into Warm Springs Creek for delivery to a district water user. However, there have been times when the district was not able to maintain that flow. In hopes of assuring water allotments and preventing damaging surges in Warm Springs Creek and loss of district water, TID constructed a holding pond along the lower section of the Toston Canal prior to the 2006 irrigation season.

Goals for the 2006 season included determining sediment amounts in Warm Springs Creek attributed to the project; ascertaining irrigation season and non-irrigation (baseline) flow and sediment loads for Warm Springs Creek; establishing new datum points and installing permanent staff gages at the Tunnel and Main Canal stations; and defining (if possible) groundwater contributions to Warm Springs Creek leaving the district.

To accomplish these goals, ten sites were selected to monitor flow and sediment between March and October, 2006 (Fig 1). Irrigation and non-irrigation seasonal flow (Acre feet) and sediment load (tons) were calculated for each location. Note: End of Canal is where the Toston Canal discharges into Warm Springs Creek (WSC), which is coming in from the southwest.

The ten monitoring sites established for this study include:

- Tunnel - top of canal
- Lower Canal - pivot bridge on west canal
- End of canal – Canal empties into WSC
- WSC @ Arnies Drain – WSC crossing Lone Mountain Road
- Spring Creek - coming in from Plunket Lake (SW of TID) ♦
- WSC B4 WSwamp – WSC before Willow Swamp Canal (WSwamp) conf. ♦
- Muddy Lane Ditch (MLD) – surface drain before WSwamp confl. ♦
- WSC @ WSwamp – WSC downstream of WSwamp confl. ♦
- WSC @ End of Line (EOL) – Warm Springs Creek leaves the TID
- Oil Road Xing - outside TID and after Marsh Creek confl. w/ WSC

♦ Stations installed to account for off-project flow and sediment contributions to WSC. Subtracting WSC B4 WSwamp and MLD from WSC @ WSwamp gave a rough approximation of flow and sediment contributions to Warm Springs Creek from Willow Swamp Canal.

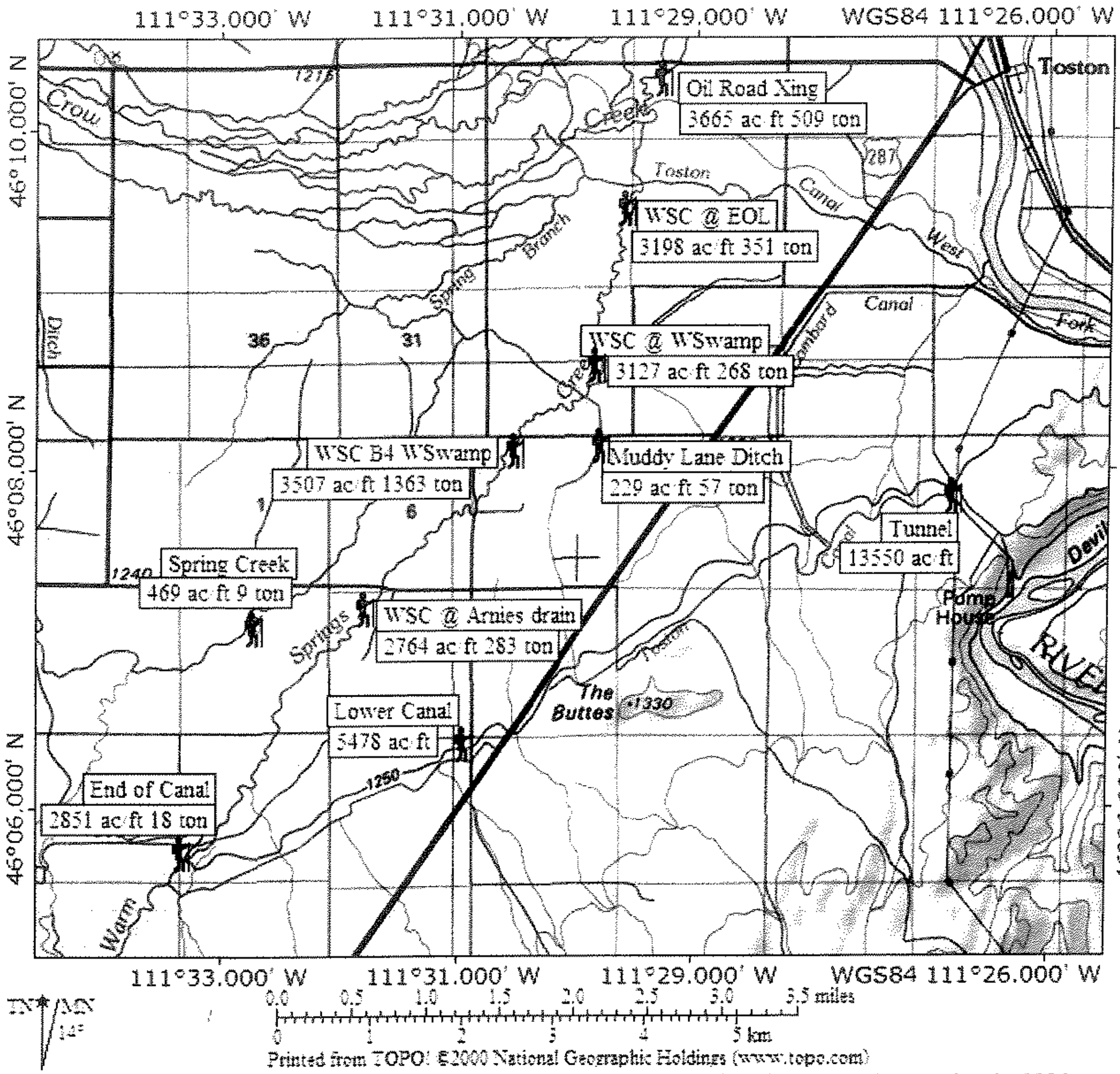


Figure 1. Map of the Toston Irrigation District showing location of each monitoring station in 2006. Monitoring season was 3/22 – 11/2 and irrigation season was 4/29 – 10/7. Irrigation season acre feet of water and sediment loads (where appropriate) are listed next to each station.

A Trutrack was installed in a stilling well at each monitoring site. Trutracks measure water height (stage) and water and air temperature on a continuous basis, and record (log) data on pre-set intervals. For this project, Trutracks were set to log stream height and air and water temperature every hour. Trutracks were installed in March and the TID began pumping water into the canal on April 29. The period of record reported in this study runs from March 22 through November 2, and irrigation season ran from April 29 to October 7, 2006.

Beginning March 22 and throughout the summer, gauging stations were visited approximately every three weeks. Sediment grab samples were collected periodically at all sites along Warm Springs Creek, and flow was measured at all sites using a Marsh-McBirney Model 2000 Flo-Mate portable flow meter. Flow measurements made with the flow meter were correlated with Trutrack stage data to develop rating curves for data collected by the Trutracks.

Rating curves were developed for each gauging station (Appendix A). Average daily flows (cfs) and seasonal acre feet of water were calculated for each station. Sediment X flow relationships were also developed (Appendix B) and used to calculate average daily sediment concentrations (mg/L) and seasonal sediment loads (ton/season). Due to non-fluctuating flows and/or backwater conditions flow and sediment loads were averaged for Muddy Lane Ditch. Additionally, sediment concentration and loads for WSC @ WSwamp, Spring Creek and End of Canal were averaged because of poor flow X sediment concentration relationships.

Observations and Measurements

Flow Patterns

Hourly Trutrack data was used to calculate average daily flow (cfs and Acft) and total flow (Acft) for each station during the monitoring season (March 22 to November 2, 2006). Note: period of record for Tunnel, Lower Canal and End of Canal was April 29 to October 7. Table 1 provides flow summaries (Acft) and minimum and maximum cfs for each station in 2006. Table 1 also contains estimated base flow (Acft) of Warm Springs Creek, and gains (inflow/return flow) or losses (diversion/loss) between stations. To estimate base flow in Warm Springs Creek and distinguish base flow from TID contributions, flow in WSC @ Arnies Drain was measured when there was no water in the Toston Canal (March 22 – April 28 and Oct 8 – November 2, 2006). This was averaged over the monitoring season to provide irrigation season base flow in Warm Springs Creek. Estimating base flow in Warm Springs Creek at EOL was accomplished in the same way except only pre-irrigation season flow were used as post-irrigation season flow could be influenced by irrigation return flow.

Table 1. Non-irrigation and Irrigation season flow (acft), irrigation season gains/losses (acft), minimum/maximum cfs and in-project water consumption for 2006. Irrigation season was April 29 to Oct 7. Non-irrigation totals calculated from data collected before and after irrigation season (March 22–April 28 and Oct 8–Nov 2). Total period of record for each station is in parenthesis. Min/max cfs was taken from average daily cfs for each station.

Station	NON-IRR (Acft)	IRR season (Acft)	IRR season Gain(+) or loss(-) (Acft)	Min cfs	Max cfs
Tunnel (4/29 – 10/7)	N/A	13,550		0.0	92.8
Lower Canal (6/6 – 10/7)	N/A	5,478	N/A	0.0	31.5
End of Canal (4/29 – 10/7)	N/A	2,851	N/A	0.0	16.9
WSC @ Arnies Drain (3/22 – 11/2)	54	2,764	-87	0.2	17.1
Spring Creek Canal (SC) (4/26 – 11/2)	191	469	INFLOW	0.0	3.5
WSC B4 WSwamp (4/4 – 11/2)	403	3,507	+743	2.2	26.4
Muddy Lane Ditch (4/4 – 11/2)	70	229	W/IN PROJ	n/a	n/a
WSC @ WSwamp (3/22 – 11/2)	829	3,127	-380	0.0	16.2
WSC @ EOL (3/22 – 11/2)	842	3,198	+71	4.4	22.9
Oil Road Xing (3/22 – 11/2)	1,883	3,665	+467	0.0	57.6
Willow Swamp Canal (WSwamp)	N/A	609			
Baseflow of WSC at Arnies Drain	21	55			
Baseflow of WSC at EOL	805	2,082			

Figures 2 through 11 are hydrographs of selected gauging stations comparing average daily flows (cfs) between stations for the 2006 season.

Figure 2 compares flow for the Tunnel and End of Canal stations from April 29 to October 7, 2006. The difference in flow between the tunnel and the end of the canal provides an indication of how much water is being pumped out of the main canal before it reaches WSC. Based on our data, it appears that the majority of water pumped into the Toston Canal is being diverted to lateral pipelines before it enters Warm Springs Creek at the End of Canal. For most of the irrigation season, water pumped into the canal is used within the TID. However, there are times when over 1/3 of the pumped water shows up at the end of the canal. A comparison of flows at End of Canal and EOL indicates over half of the flow in WSC is contributed by the canal although large fluctuations at EOL are mostly a function of precipitation events.

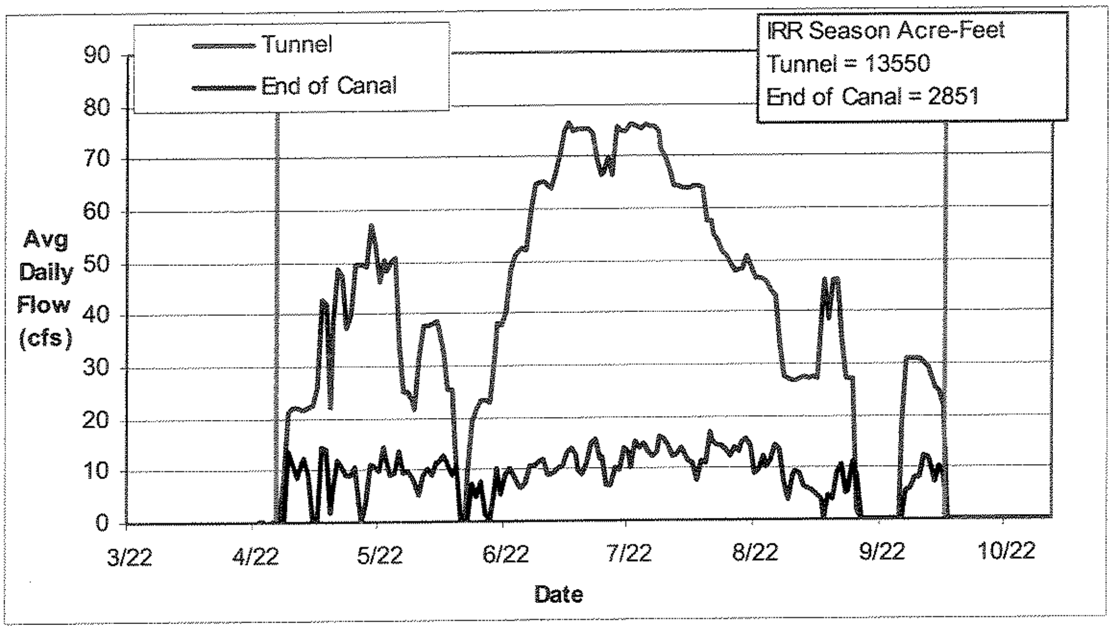
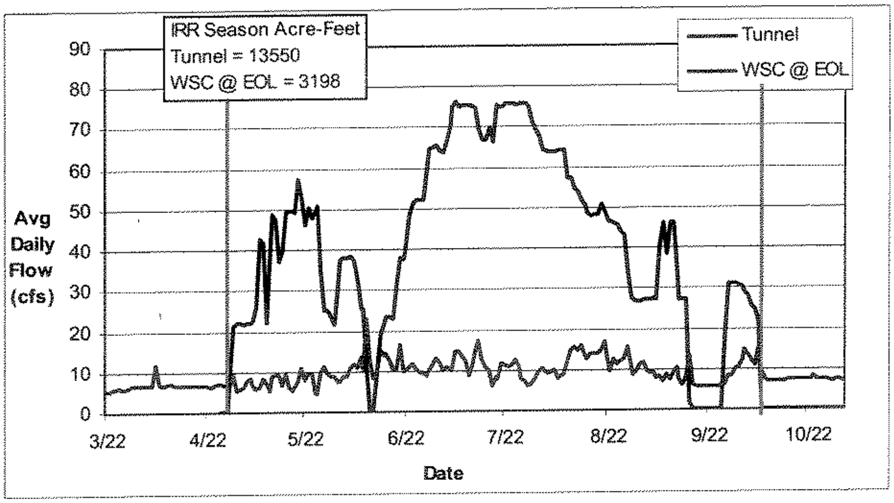
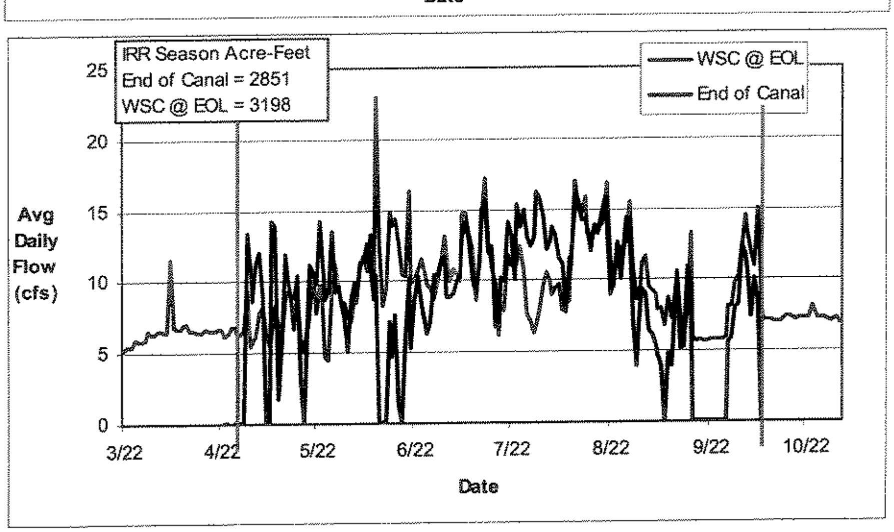


Figure 2. Average daily flows (cfs) at the Tunnel and End of Canal stations for the period May 29 - October 7, 2006. Vertical green lines indicate beginning and end of canal operation.

Figures 3 and 4 compare flows at the Tunnel to End of Canal and WSC @ EOL stations and illustrate the difference between water pumped into the canal and water flowing out of the TID. Data presented in Figure 3 suggest the majority of water being pumped into the canal is being used within the irrigation district. Figure 4 shows the WSC @ EOL and End of Canal stations tracking closely while the tunnel has consistently higher flows. The topography of the TID causes water to flow north-west toward Warm Springs Creek, so some of the difference between WSC @ EOL and End of Canal may be a result of irrigation return flow. Additionally, there are two off-project tributaries (Spring Creek, Willow Swamp Canal), two in-project field drains and one surface drain (Muddy Lane Ditch) between the end of the canal and WSC @ EOL which contribute to flow in Warm Springs Creek at the end of the district.





Figures 3 (top) and 4 (bottom). Average daily flows (cfs) at the Tunnel, WSC @ EOL and End of Canal stations for the period March 22 - November 2, 2006. Vertical green lines indicate beginning and end of canal operation.

Figure 5 compares flow for the WSC @ EOL and Oil Road Xing stations and illustrates water loss/gain between the end of the TID and the Oil Road Xing. Marsh Creek is a very braided, meandering stream, one fork of which enters Warm Springs Creek between WSC @ EOL and Oil Road Xing. Because it is a tributary to the Missouri River and provides spawning habitat, regulations mandate flow be maintained in Marsh Creek. This is controlled by a headgate west of the district. One off-project landowner (at the Oil Road Crossing) diverts water into his irrigation ditches from Warm Springs Creek between EOL and Oil Road Crossing. Our data suggest a correlation between flow at WSC @ EOL and Oil Road Xing. Before the canal was operational and after the canal was shut off (March 22-April 28 and Oct 8-Nov2), flow at Oil Road Xing exceeded flow at WSC @ EOL, suggesting off-project water (inflow from the Marsh Creek area), no water being diverted from Warm Springs Creek and irrigation return flow (post-season) as likely causes for this increase. When flow at Oil Road exceeds that of EOL during irrigation season it is likely due to irrigation return flow and no diversion from Warm Springs Creek. When flow at EOL exceeds flow at Oil Road during irrigation season it is likely a factor of increased flow in Warm Springs Creek from canal spill, irrigation diversions from Warm Springs Creek and less inflow from the Marsh Creek area.

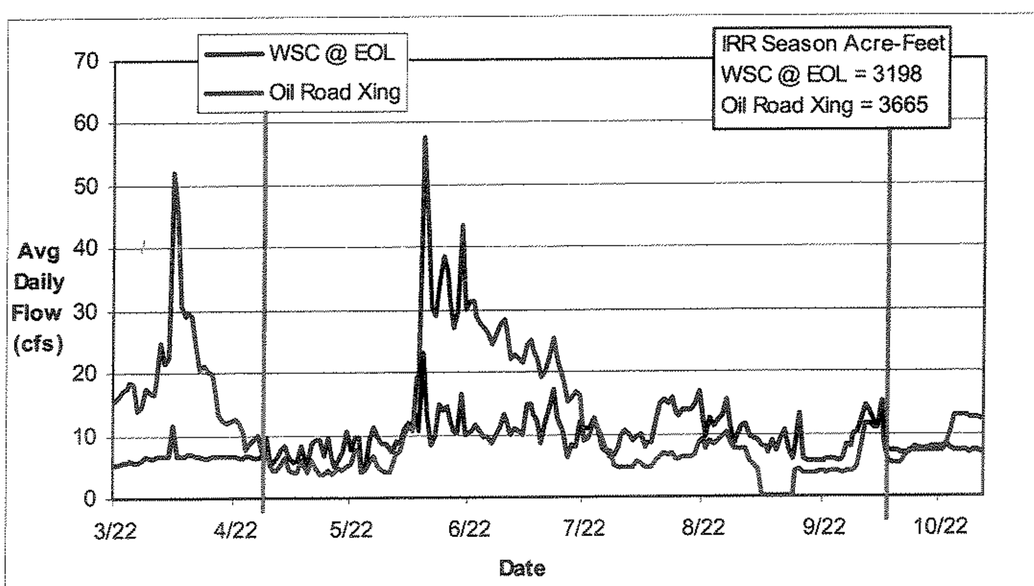


Figure 5. Average daily flow (cfs) at WSC @ EOL and Oil Road Xing stations for the period March 22 - November 2, 2006. Vertical green lines indicate beginning and end of canal operation.

Data suggest precipitation events greater than 0.5 inches have the largest affect on flow and sediment in Warm Springs Creek. Figure 6 is a graph of precipitation data from the area AGRIMET station. Spikes in flow and sediment around April 6-7 and June 9-10 for the Oil Road, EOL and WSC@WSwamp stations correspond to rain events (spikes) on April 6 and June 9 (Figures 3,4,5,6,7,9 and Appendices C,D). Figure 6 indicates the greatest rainfall occurred on May 27 but is not apparent in daily flow and sediment graphs for any stations except WSC @ Arnies drain and WSC B4 WSwamp (Figures 6,8,9,10 and Appendices C,D). Effects of a May 27 rain event are seen at EOL and Oil Road but to a lesser magnitude (Figures 3,4,5,6,7,9 and Appendices C,D). Although a rain event on June 14 are seen at WSC B4 WSwamp, WSC @ WSwamp and EOL (Figures 3,4,5,6,7,9,10 and Appendices C,D) it is not apparent at Oil Road. This could be a factor of diversions between EOL and Oil Road.

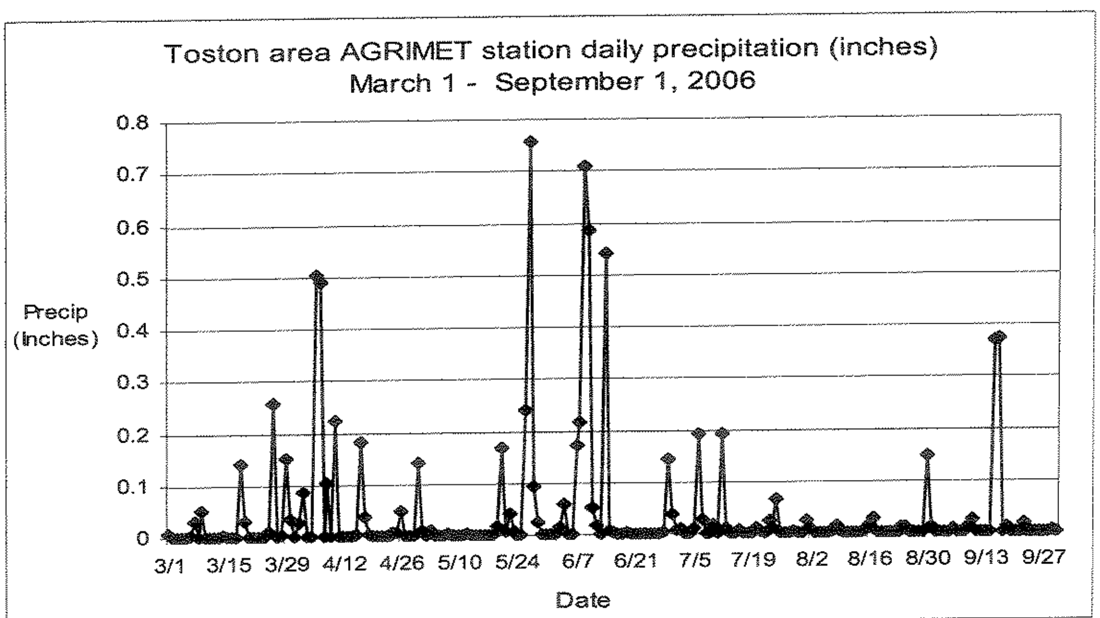


Figure 6. Toston area AGRIMET station precipitation for March 1 - September 30, 2006.

Figure 7 is a graph showing daily gains/losses in flow from WSC @ EOL to Oil Road Xing. This graph reiterates what Figure 5 illustrated. There appears to be a loss of water between WSC @ EOL and Oil Road Xing late April through early June, and again from the end of July until the canal was shut off. This is likely due to pumping and diversions (possibly to Marsh Creek) below WSC @ EOL. In March and April (pre-irrigation season), June - July and October (post-irrigation season), data suggest a gain in water between WSC @ EOL and Oil Road Xing. This is to be expected pre and post-irrigation season as no water is being withdrawn from Warm Springs Creek. Increasing flows in June and July could be due to irrigation return flow as there is still flood irrigation in the northern portion of the district.

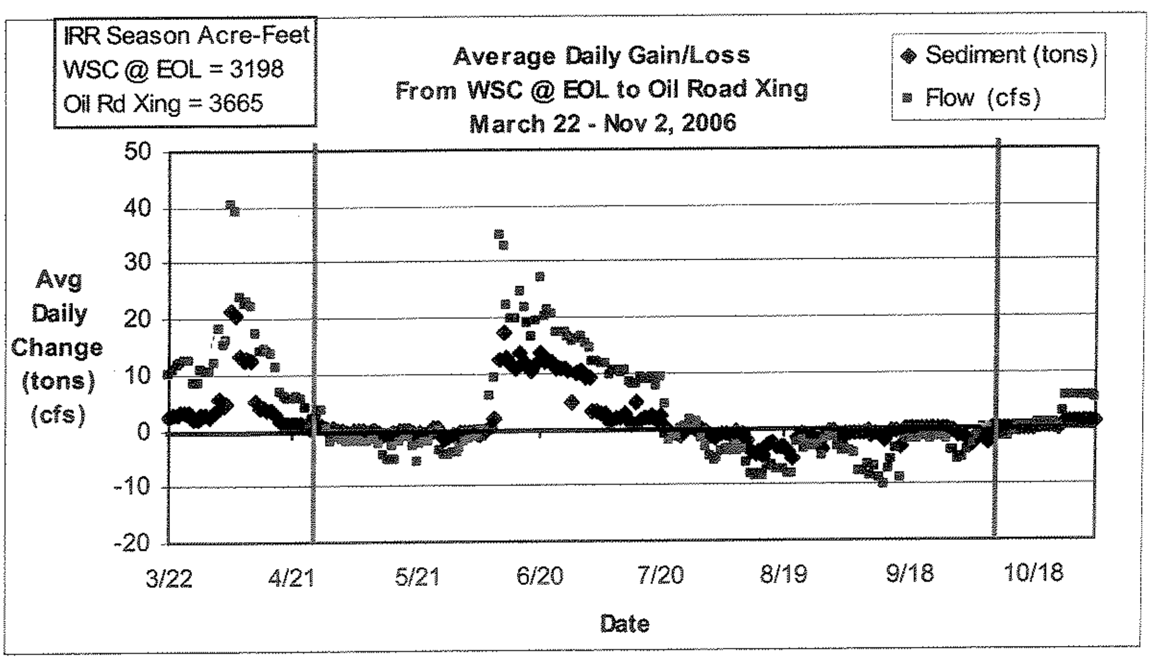


Figure 7. Average daily gain or loss of flow (cfs) and sediment (tons) from WSC @ EOL to Oil Road Xing for the period March 22 - November 2, 2006. In situations where WSC @ EOL – Oil Road Xing = negative, flow or sediment increases from WSC @ EOL to Oil Road Xing. In situations where WSC @ EOL – Oil Road Xing = positive, flow or sediment decreases from WSC @ EOL to Oil Road Xing, likely due to diversions and pumping below WSC @ EOL. Vertical green lines indicate beginning and end of canal operation.

Figure 8 compares flow at the End of Canal to flow in WSC @ Arnies drain and illustrates the amount of water passing through the weir at the end of the canal and into Warm Springs Creek. Flow at WSC @ Arnies drain closely tracks flow at the End of Canal but at Arnies drain flow is, in general, slightly lower. This is likely due to irrigation withdraws and seepage along the southern portion of Warm Springs Creek. Towards the end of the irrigation season, flow in WSC @ Arnies drain increases above that at the End of Canal. This is likely due to irrigation return flow from a field drain near WSC @ Arnies drain.

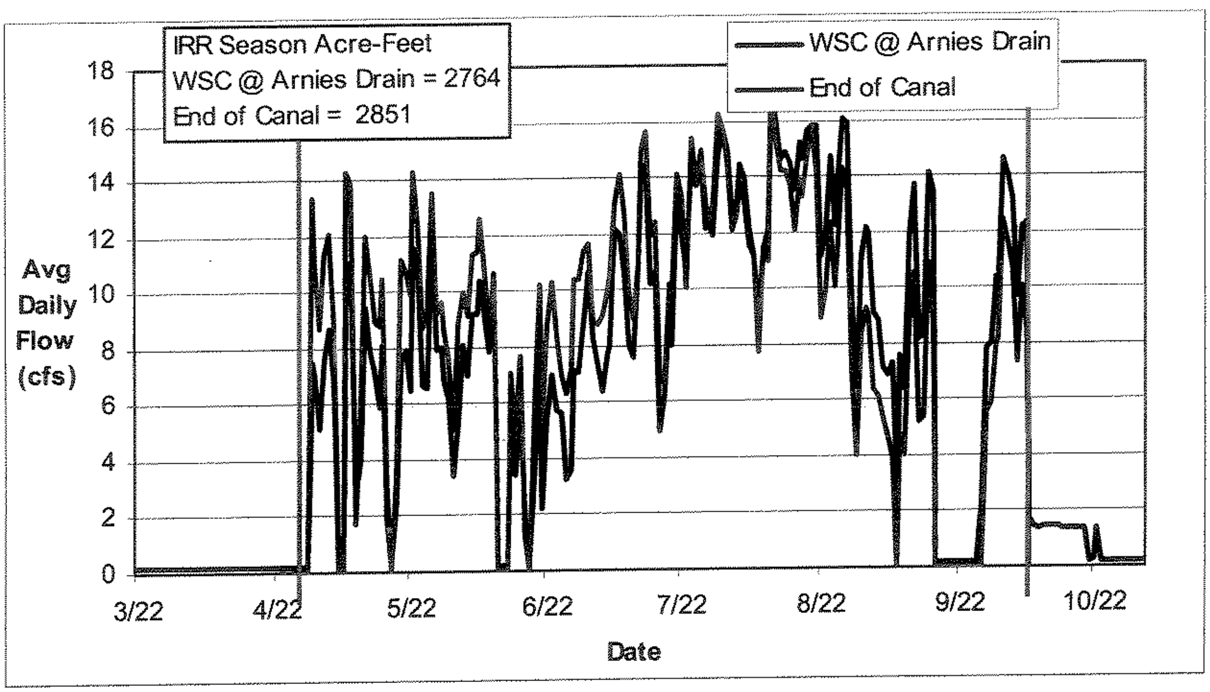


Figure 8. Average daily flows (cfs) for WSC @ Arnies Drain and the End of Canal stations for the period March 22 – November 2, 2006. Vertical green lines indicate beginning and end of canal operation.

Figure 9 compares average daily flow at WSC @ Arnies drain to flow at the end of the district (WSC @ EOL). This graph illustrates the influence of Spring Creek, Willow Swamp Canal and irrigation return flow as Warm Springs Creek moves through the district. Data suggests flow in WSC @ EOL is generally greater than at Arnies drain. Inflow increases flows at WSC @ EOL while diversions for Willow Swamp Canal and flood irrigation in the lower sections of the district decrease flows at WSC @ EOL. As can be seen in Figure 8, contributions from return flow to flow in WSC@ EOL become increasingly more significant as the irrigation season progresses (late July to September).

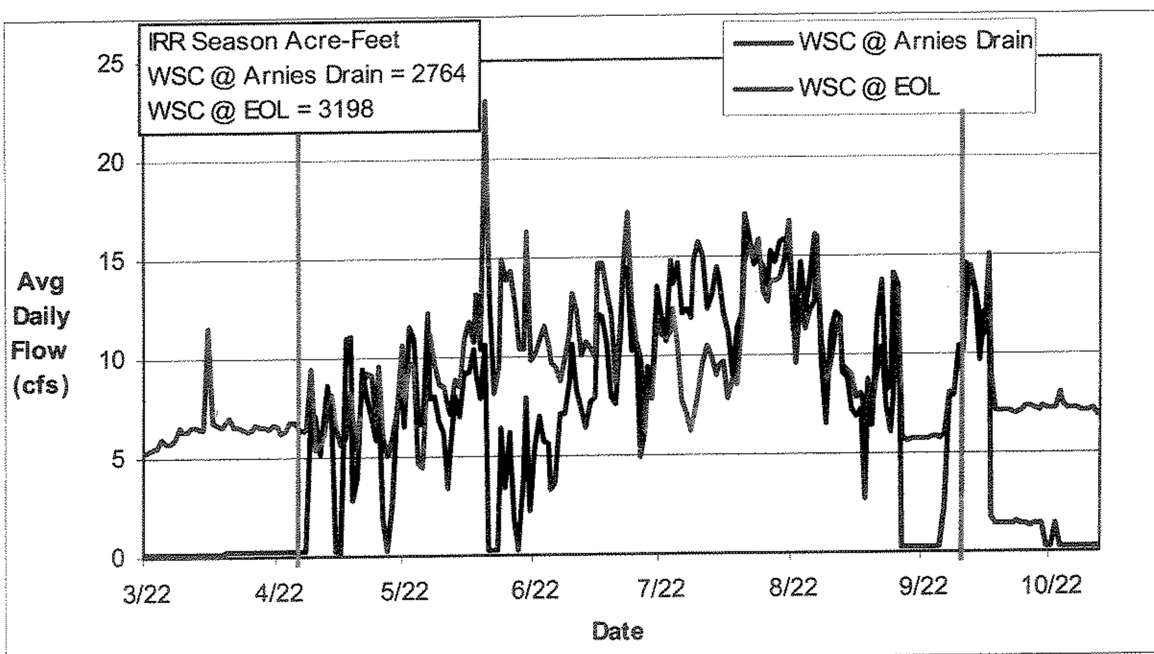


Figure 9. Average daily flows (cfs) for WSC @ Arnies Drain and WSC @ EOL stations for the period March 22 to November 2, 2006. Vertical green lines indicate beginning and end of canal operation.

Figure 10 compares Warm Springs Creek before and after the confluence with Willow Swamp Canal. Subtracting Muddy Lane Ditch and WSC B4 WSwamp from WSC @ WSwamp gives a rough estimate of how much water is being added by Willow Swamp Canal. It was difficult to estimate contributions by Willow Swamp Canal to Warm Springs Creek; there is flood irrigation on some of the fields in this area, Muddy Lane Ditch had backwater conditions most of the season and it was not possible to determine exactly how much water is diverted back into Willow Swamp Canal. Essentially there is no net gain or loss in flow or sediment from Willow Swamp Canal to Warm Springs Creek.

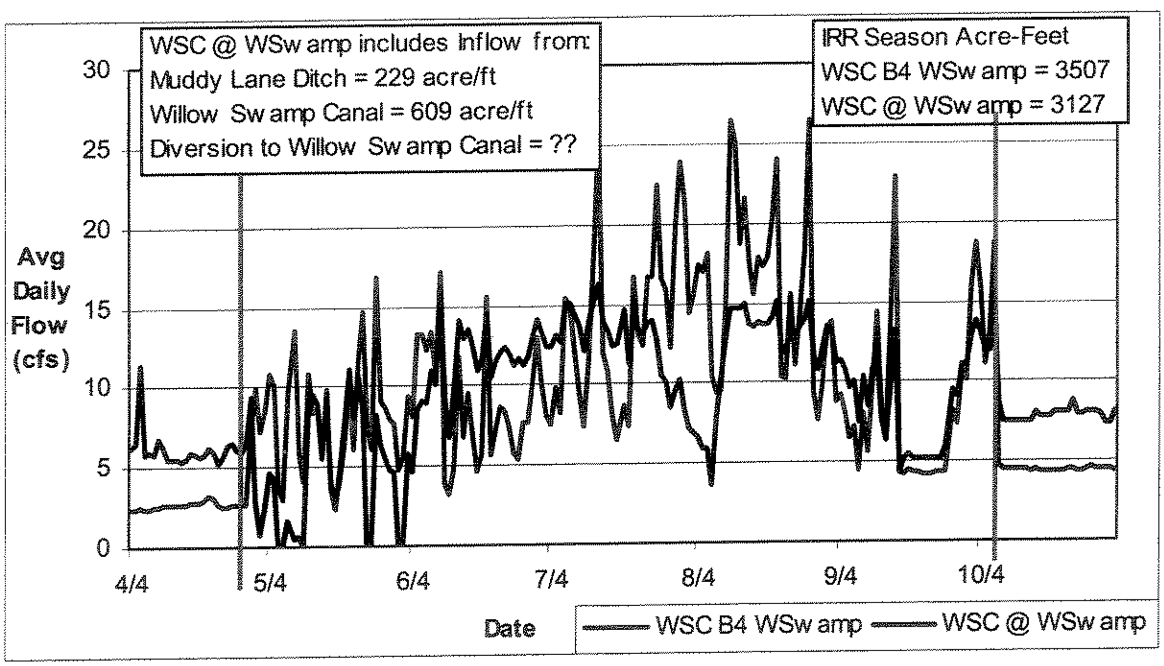


Figure 10. Average daily flows (cfs) in Warm Springs Creek before (WSC B4 WSwamp) and after the Willow Swamp Canal diversion (WSC @ WSwamp) April 4 to November 2, 2006. WSC @ WSwamp includes inflow from Muddy Lane Ditch (300 acft) and Willow Swamp (197 acft). Vertical green lines indicate beginning and end of canal operation.

Figure 11 compares average daily flow at the Tunnel, Lower Canal and End of Canal stations. This graph reiterates what was seen in Figure 3; the majority of water pumped into the canal is diverted in the upper portion of the TID. It also illustrates the impact of diversions between the Lower Canal and End of Canal. Flow at the Tunnel in July decreased while flows in the lower canal increased. This could be due to less water being called for in July (i.e. less water being pumped into canal and less water being diverted from the canal). The TID has three pumps to supply water to the canal and when water needs exceed what one pump can provide, a second (or third) must be operated. This can lead to more water being pumped than is really needed, which could explain higher flows in the lower canal section and lower flows at the tunnel.

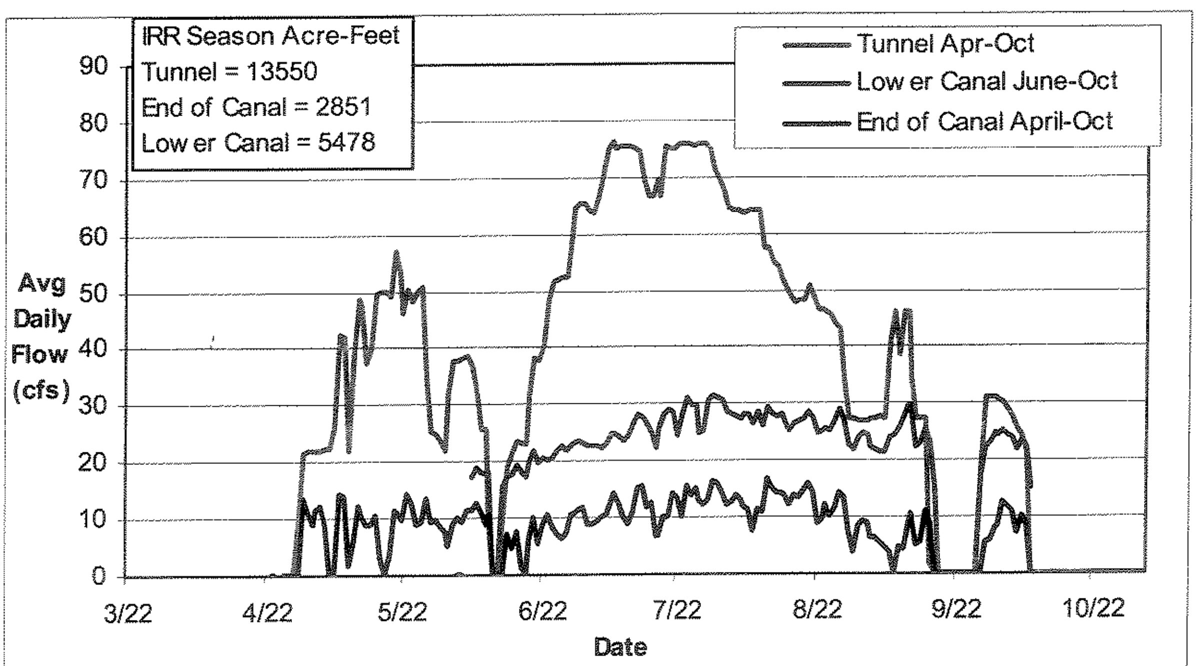


Figure 11. Average daily flows (cfs) at the Tunnel, End of Canal stations for the period April 29 – October 7, 2006. Data for the lower canal station starts at June 6 due to equipment failure and replacement.

Sediment Patterns

Sediment loads (ton) were determined by relating daily flow data (cfs) to sediment concentration (mg/L) as a function of flow. A sediment sample was collected each time a flow measurement was taken for the entire season and flow x sediment relationships were developed for all stations along Warm Springs Creek (Appendix B). Relating average daily flow velocities to sediment concentrations provided a mechanism for calculating sediment loads at each station as a function of flow. Calculations made were for total sediment load (tons) and sediment concentration (tons/acre-feet). Table 2 illustrates cumulative sediment load (tons), seasonal acre feet of water and sediment concentration (tons/acre ft) for each station along Warm Springs Creek (Table 2). Due to non-fluctuating flows at Muddy Lane Ditch, sediment concentration (mg/L) and load (tons) were averaged. Recall, sediment concentration (mg/L) and load (tons) for WSC @ WSwamp, Spring Creek and End of Canal were also averaged because of poor flow X sediment concentration relationships.

Table 2. Irrigation season (April 29 – October 7, 2006) sediment loads (tons), acre-feet of water and average sediment concentrations (tons/acft) at each station along WSC.

Station	IRR season Sediment (Tons)	IRR season Acft	IRR season (Tons/Acft)
End of Canal	18	2,851	0.01
WSC @ Arnies Drain	283	2,764	0.10
Spring Creek	9	469	0.02
WSC B4 WSwamp	1,363	3,507	0.39
Muddy Lane Ditch	57	229	0.25
WSC @ WSwamp	268	3,127	0.09
WSC @ EOL	351	3,198	0.11
Oil Road Xing	509	3,665	0.14

Table 3 shows irrigation season sediment (tons) for each station along Warm Springs Creek, and how much sediment was lost or gained between stations during the 2006 irrigation season. From this table one can see the impact of the check dam at Willow Swamp Canal and get an idea of reaches where sediment is being transported and deposited in Warm Springs Creek.

Table 3. Sediment gains/losses (tons) for each station on Warm Springs Creek during the 2006 irrigation season.

Station	SEDIMENT	GAIN	LOSS
	Tons		
End of Canal	18	18	
WSC @ Arnies Drain	283	265	
Spring Creek	9	off-project source	
WSC B4 WSwamp	1,363	1,071	
Muddy Lane Ditch	57	surface drain	
WSC @ WSwamp	268		1,152
WSC @ EOL	351	83	
Oil Road Xing	509	158	

Figures 12 and 13 illustrate sediment loads for select monitoring stations along Warm Springs Creek and downstream of the TID (Oil Road Xing). Figure 12 shows data collected during the irrigation season (April 29 – October 7, 2006) and figure 13 shows data collected before and after the canal was operational (March 22 – April 28 and October 8 – November 2, 2006). During irrigation season, data indicate that the check dam at Willow Swamp Canal is acting as a sediment sink, and suggests sediment in Warm Springs Creek, Muddy Lane Ditch and Willow Swamp Canal is settling out before the check dam at Willow Swamp Canal (Fig. 12). Sediment loads of 1300 ton before the Willow Swamp Canal dropped to less than 300 ton after. Muddy Lane Ditch and WSC B4 WSwamp stations were not operational until the beginning of April so it was not possible to make the same inferences about pre and post irrigation season sediment after the check dam at Willow Swamp Canal (Fig. 13).

Increasing sediment between the end of TID (WSC @ EOL) and Oil Road Xing is evident regardless of irrigation (Figs 12, 13). This suggests off-project sources, groundwater and/or irrigation return flow are contributing sediment after Warm Springs Creek leaves the TID. However, it was not possible to determine the exact source of increased sediment because there are multiple factors (soil type, irrigation, off-project sources, animal presence) influencing sediment in the northern portion of TID.

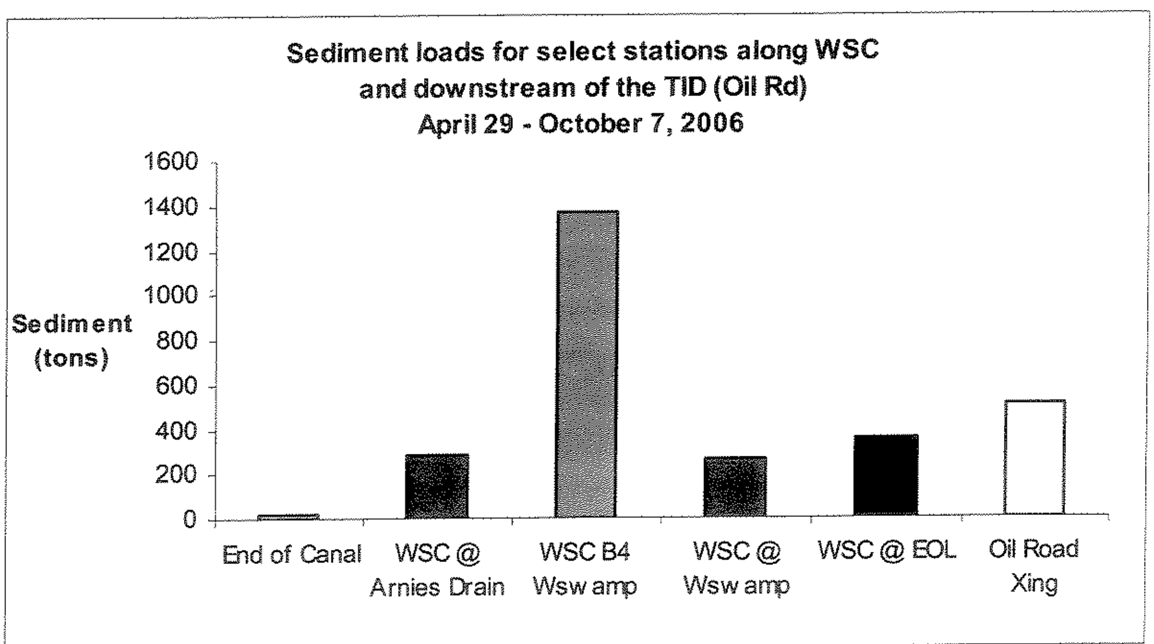


Figure 12. Sediment loads for select stations along Warm Springs Creek and downstream of the TID (Oil Road Xing) for the period April 29 through October 7, 2006.

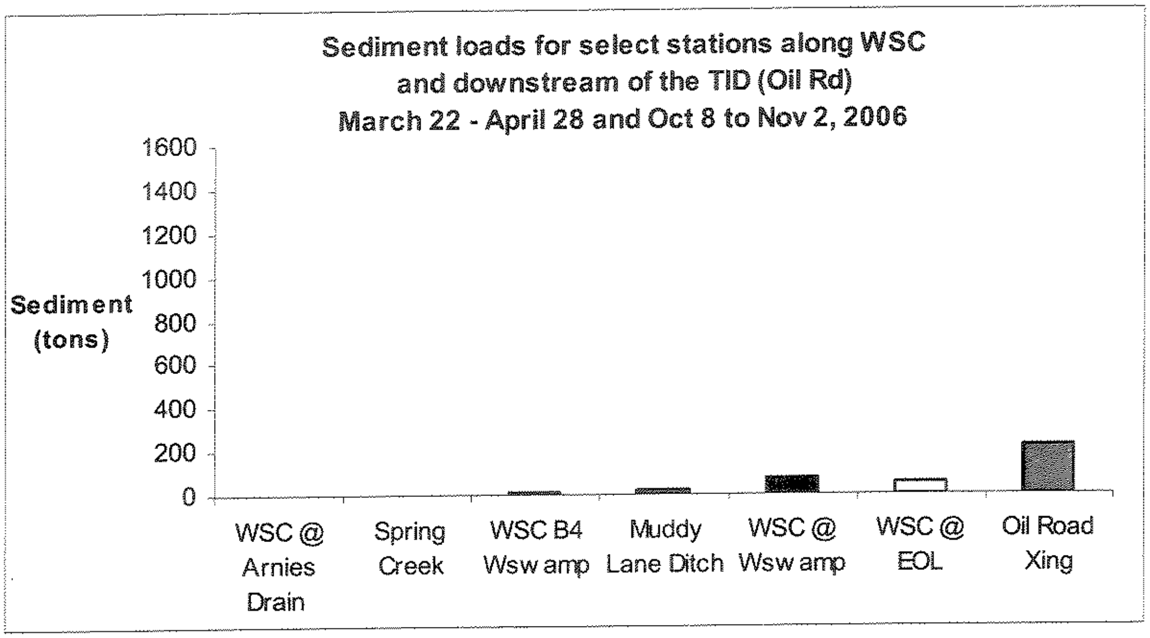


Figure 13. Sediment loads for select stations along Warm Springs Creek and downstream of the TID (Oil Road Xing) for the period March 22 to April 28 and October 8 to November 2, 2006.

Sediment is difficult to estimate based on flow alone and robust flow X sediment relationships were difficult to attain. There are multiple variables to consider including, but not limited to, changes in-channel, bank stability (soil types) and height, presence/absence of vegetation, presence/absence of animals and accessibility to stream channel. Data collected during 2005 and 2006 suggest the biggest factors influencing sediment in the TID section of Warm Springs Creek are not irrigation practices but soil type and animals. Spring Creek, WSC B4 WSwamp, Muddy Lane Ditch and WSC @ EOL were affected by animal presence upstream of sampling sites on June 6, 27 and July 18, 2006. Even with duplicate samples, sediment concentrations were unusually high and skewed flow X sediment relationships.

Soil types change from loams and sandy loams to silt loams and silty clay loams north of Lone Mountain Road (north of WSC @ Arnies drain) (Fig. 14). These changes coincide with increased sediment loads in Warm Springs Creek downstream of Arnies drain (Fig. 12 and Table 3).

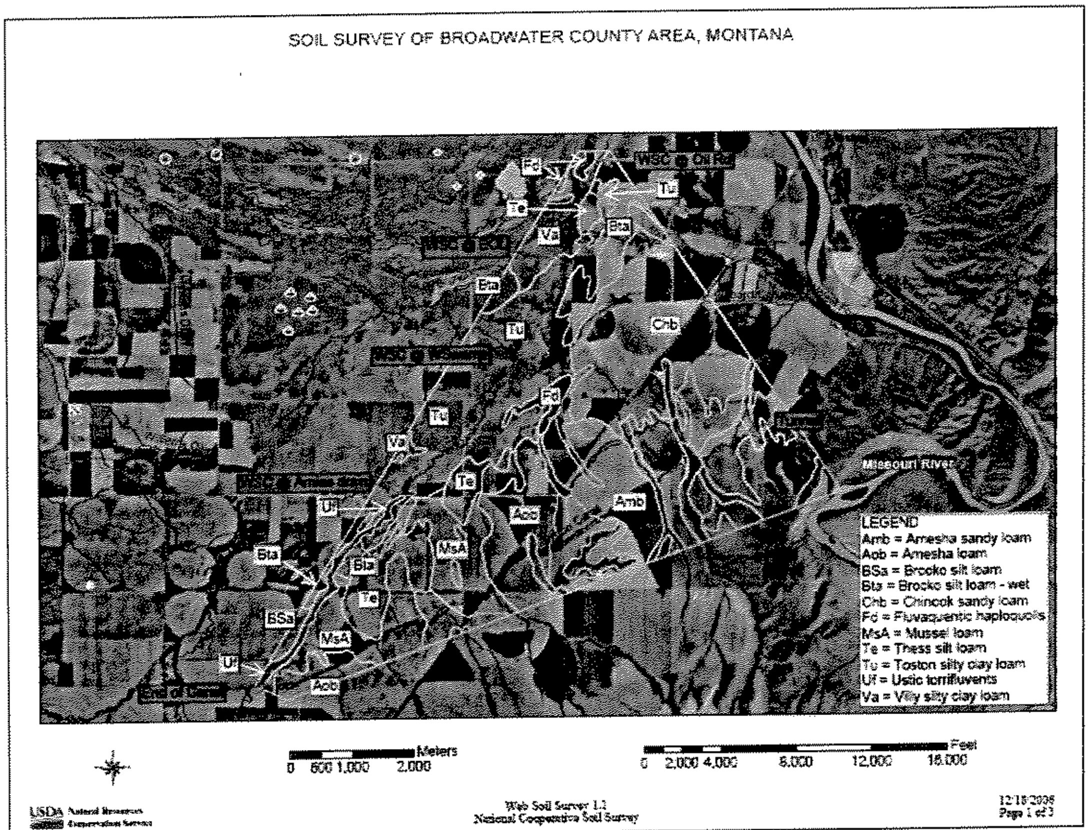


Figure 14. Soils map for the Toston Irrigation District. Soil types are in yellow and select monitoring stations are shown in orange.

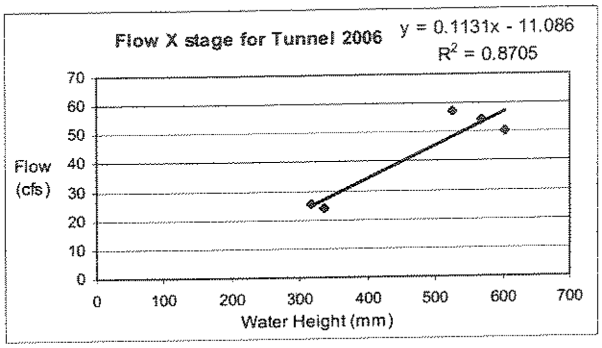
Summary

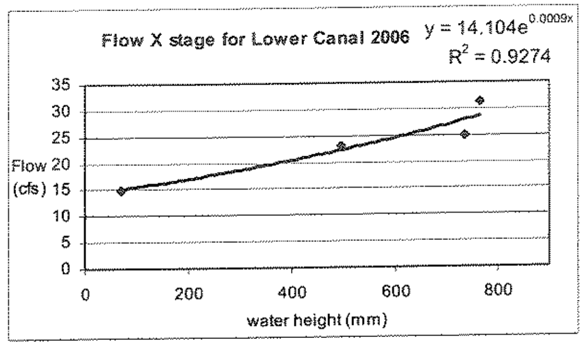
The majority of water diverted from the Missouri River into the Toston Canal is diverted from the canal along the upper reaches of the district. Therefore, a significantly smaller quantity of diverted water actually makes it into Warm Springs Creek via the Toston Canal under normal circumstances. However, WSC @ EOL had greater seasonal flow than End of Canal. This is likely due to contributions to Warm Springs Creek from Spring Creek, Willow Swamp Canal and TID return flow.

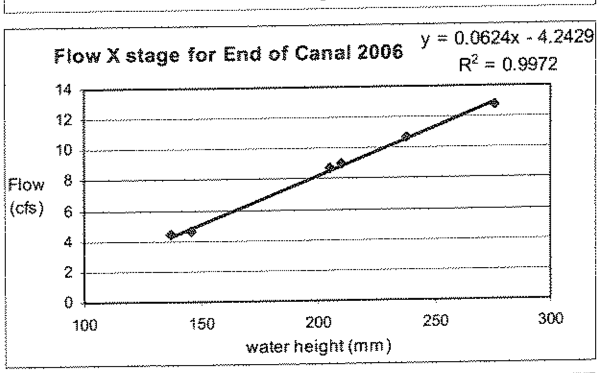
Defining base flow of Warm Springs Creek and non-irrigation and irrigation season flow and sediment loads, allowed us to more accurately define contributions to Warm Springs Creek from the TID on a yearly basis. Increasing sediment loads downstream of WSC @ Arnies drain are more likely a result of changing soil types, increased muskrat activity and livestock access to Warm Springs Creek than irrigation practices. A similar trend of increasing sediment after Warm Springs Creek leaves the TID is seen regardless of irrigation. However, during irrigation, the diversion dam at Willow Swamp Canal acts as a sediment sink, effectively trapping a majority of the sediment before it leaves the district. Although the TID is not a major source of sediment it is a contributor of flows in Warm Springs Creek. EOL vs. End of Canal data suggest the canal contributes over half the flow in Warm Springs Creek. However, large fluctuations at EOL are more likely a factor of precipitation events.

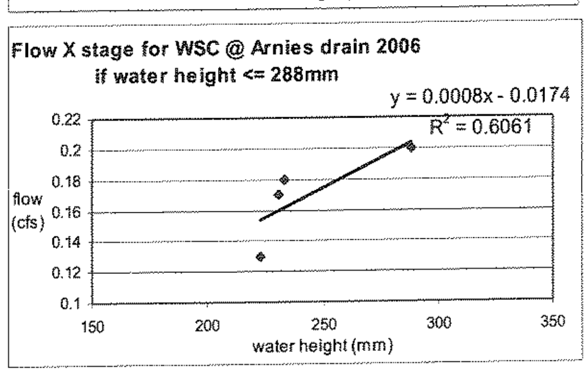
TID is making modifications to their pumping plant to refine water delivery. More accurate delivery to the canal and use of use of the detention pond may result in reduced flow fluctuations in Warm Springs Creek and reserve TID water for on-project use. Other management options for minimizing flow and sediment in Warm Springs Creek within the TID: establish vegetative buffer strips, reclaim riparian areas and limit livestock stream access.

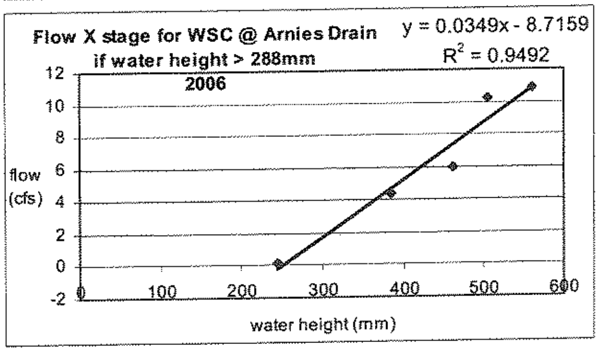
APPENDIX A. Flow (cfs) by stage (mm) rating curves for each station in 2006.

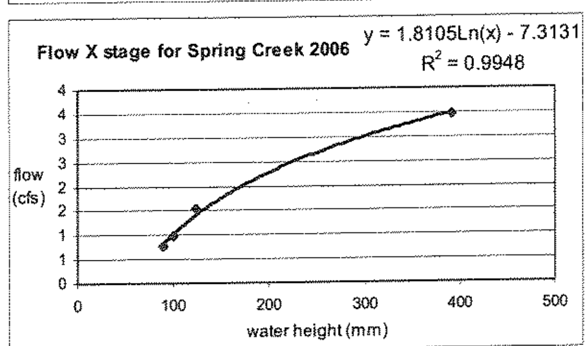




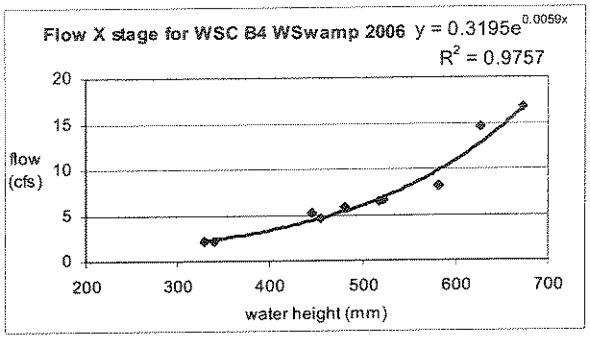


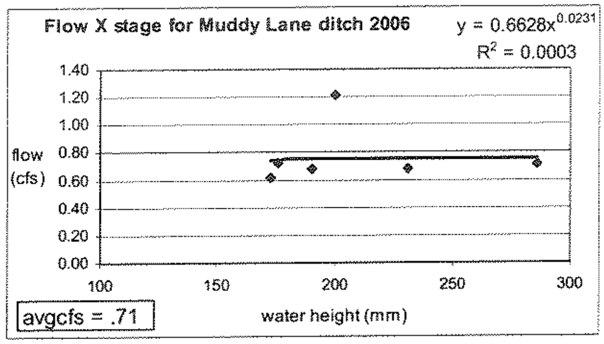


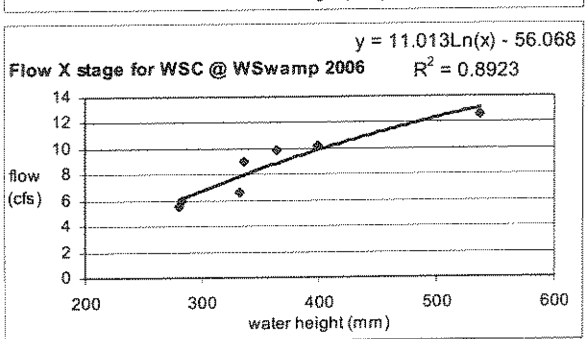


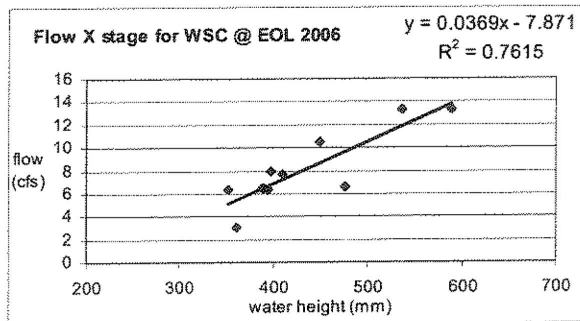


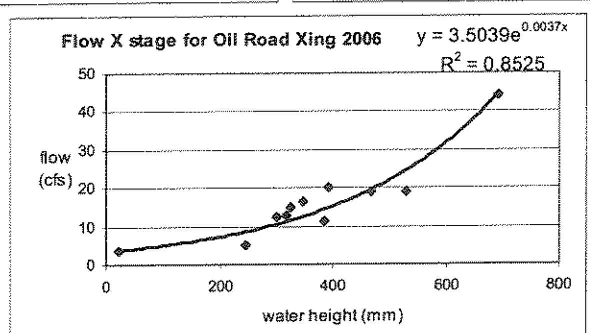
APPENDIX A (con't). Flow (cfs) by stage (mm) rating curves for each station in 2006.



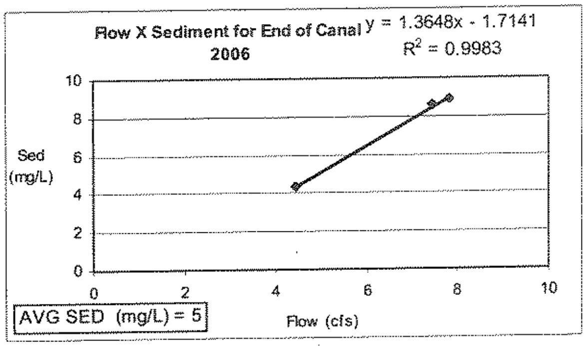


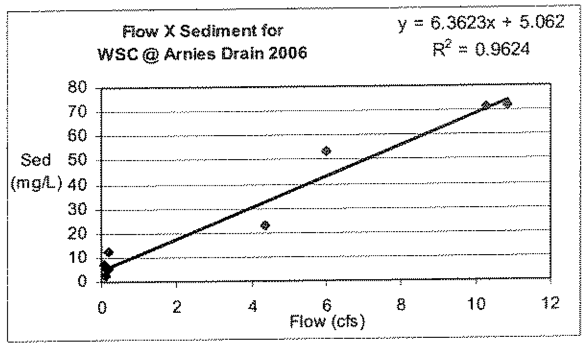


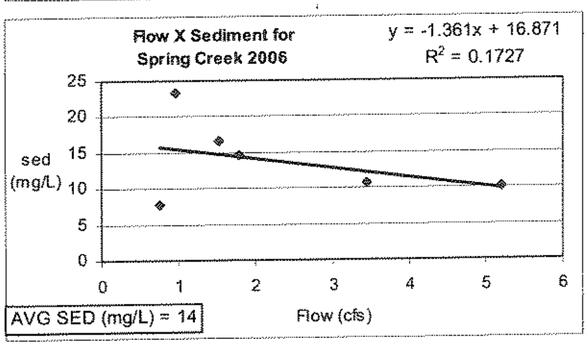


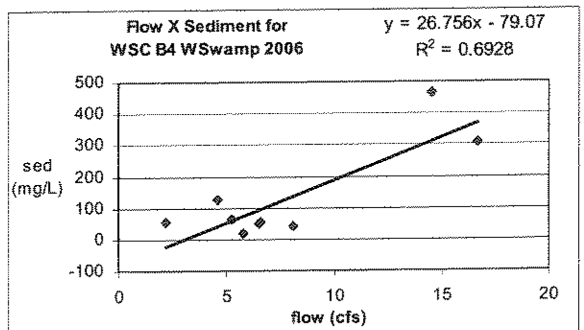


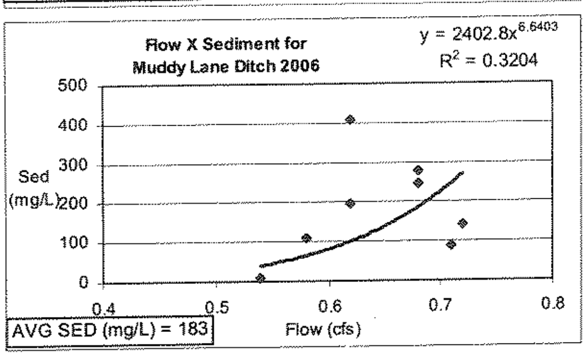
APPENDIX B. Flow (cfs) by sediment (mg/L) relationships for sediment monitoring stations in 2006.

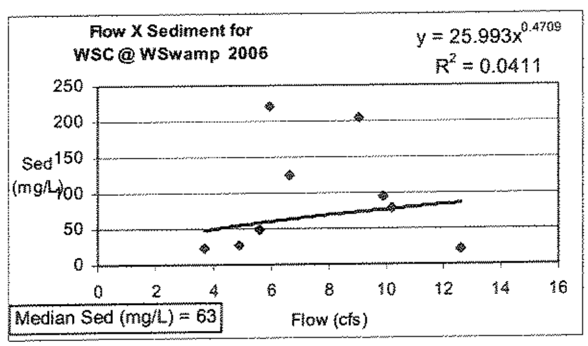


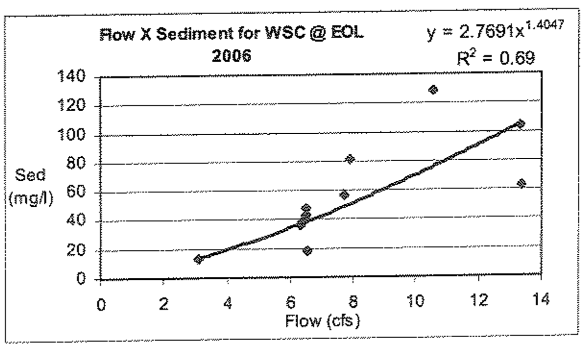


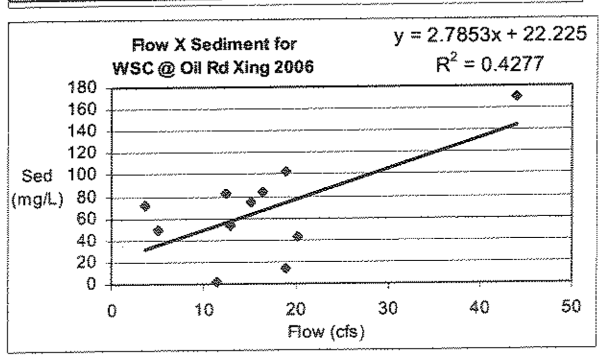




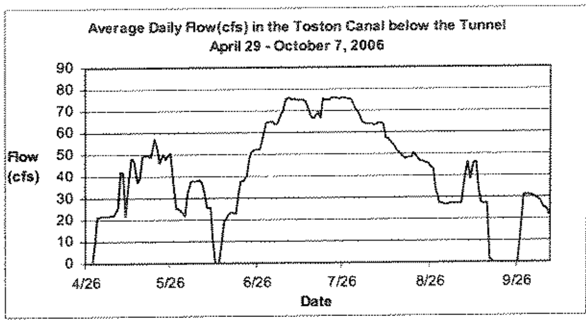


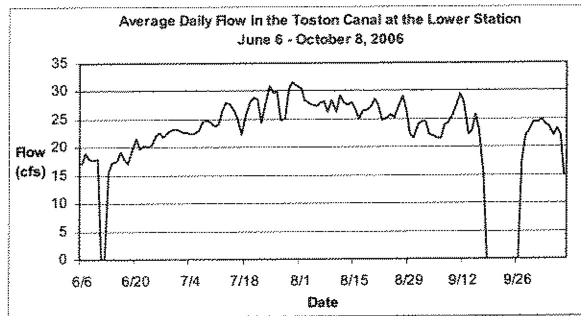


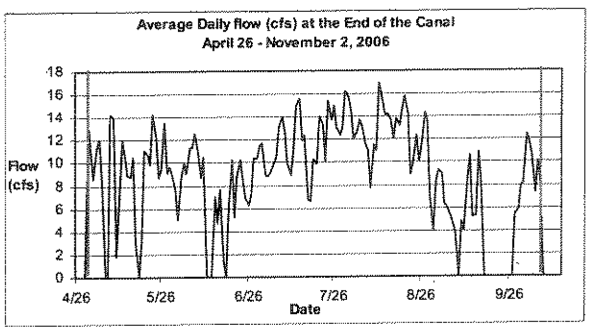


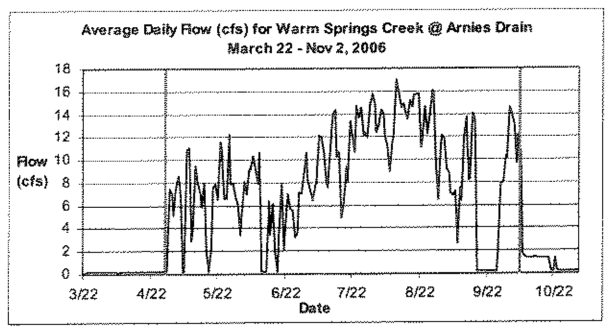


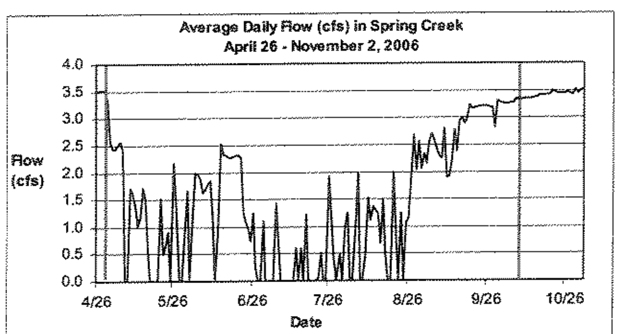
APPENDIX C. Average daily flow (cfs) for each station in the TID in 2006.
Note: Flows for Muddy Lane Ditch were averaged for the entire season so were not included in this appendix. Vertical green lines indicate irrigation season (Apr 29–Oct 7).



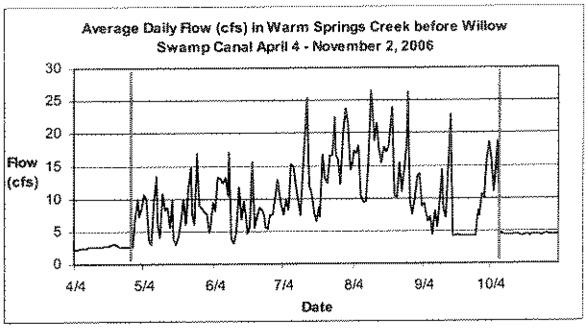


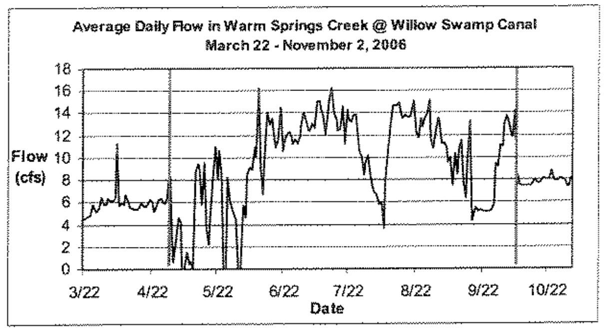


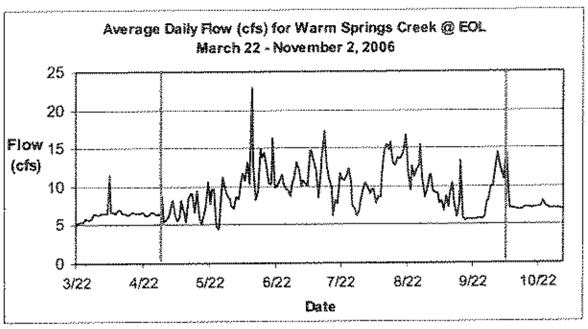


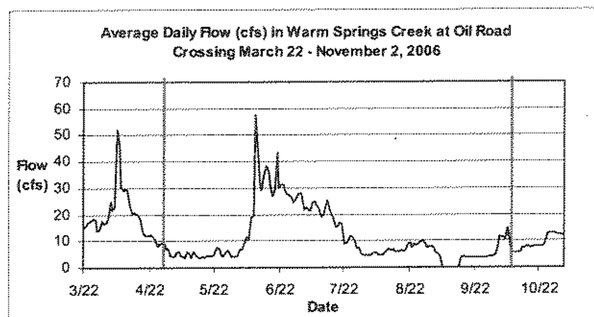


APPENDIX C (con't). Average daily flow (cfs) for each station in the TID in 2006. Note: Flows for Muddy Lane Ditch were averaged for the entire season so were not included in this appendix. Vertical green lines indicate irrigation season (Apr 29–Oct 7).

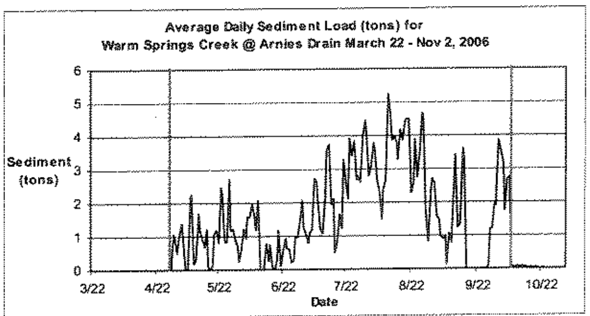


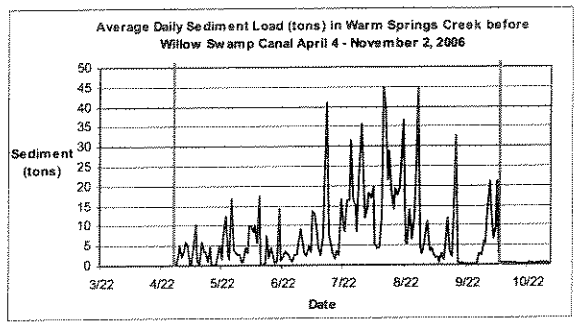


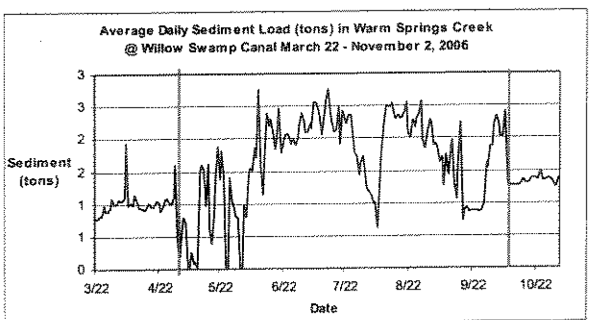


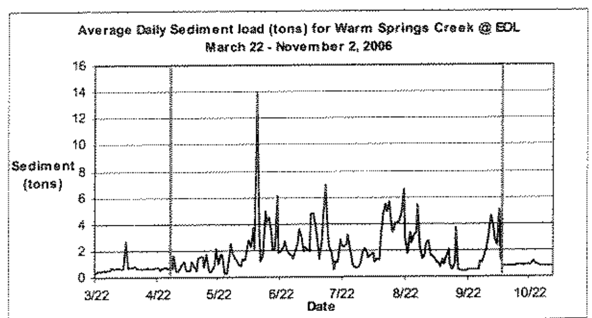


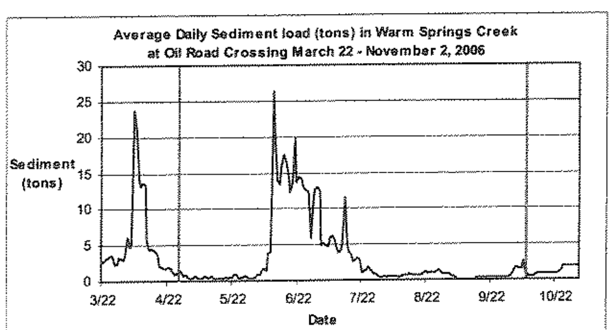
APPENDIX D. Average daily sediment load (tons) for each station in the TID in 2006. Note: Sediment loads for Muddy Lane Ditch, Spring Creek and End of Canal were averaged for the entire season so were not included in this appendix. Vertical green lines indicate irrigation season (Apr 29–Oct 7).











Warm Springs Creek Flow and Sediment Study
2005 Irrigation Season
Progress Report – Reclamation Cooperative Agreement No. 99FC6011440

Overview

The Toston Irrigation District (TID), located about six miles southwest of Toston, Montana, comprises ~6,200 acres of full irrigation service lands in Broadwater County. Most of Broadwater County is an intermountain basin known as the Townsend Basin, flanked by the Elkhorn Mountains on the west and the Big Belt Mountains on the east. Flood plains, terraces, and fans comprise the Townsend Basin around Toston. Erosion of local mountains, consisting of sandstone, shale, limestone, andesite and basalt, along with volcanic ash and breccia from Yellowstone National Park, provided sediments for the Madison and Missouri Rivers and their tributaries to transport.

The parent material, derived from a variety of sources, consists mainly of alluvial deposits of the Missouri River and its tributary streams with some loess on upper terraces and hills. Soils of the flood plains and low terraces are formed by the rivers while the higher terraces and fans are formed by tributaries.

Soils in the TID are characterized by nearly level to steep, deep, well-drained Mollisols, Entisols and Inceptisols. In general, soils of the district are loams, with sandy loams and loams in the northern portion and silt loams and silty clay loams in the south.

Average annual rainfall for the TID is 11.4 inches, with an average annual temperature of 43 degrees Fahrenheit, and elevations between 3,940 - 4,120 feet above sea level. Principal crops are alfalfa, cereal crops, seed potatoes and pasture.

Preface

Approximately 16,800 acre/feet of water are allotted to the TID per season as per contract terms. Water for irrigation is diverted to the project from the Missouri River by way of a pumping station and water is typically delivered April through October. Water is diverted from the river downstream of the headwaters and above Toston Dam at the Crow Creek pumping plant. The Crow Creek Pumping Plant consists of three turbines which pump water up to the Toston Bench via the Toston Tunnel where it is delivered to individual farm units via the Toston Canal and lateral pipelines.

In 1987 most of the area was gravity irrigated and contour ditches, border dikes, and furrow systems were common. Gravity irrigation is typically equated with low on-farm efficiencies, with tail water running into downstream ditches where it is re-used. Although inefficient, gravity irrigation allowed most of the water to make its way back to the river via Warm Springs Creek.

More recently, there has been a shift to more efficient sprinkler, center pivot, and side-roll irrigation systems. Estimates suggest that as much as 70% of the irrigated acreage is now managed under sprinkler irrigation. Increased efficiency means less water makes its way back to the river but it also means less water needs to be diverted. This could translate to savings for the TID in the form of lower energy costs for pump operation. Another management tool the TID has implemented is the conversion of all lateral delivery canals to pipelines, increasing the efficiency of the delivery system by reducing loss through evaporation and seep.

The U.S. Bureau of Reclamation (Reclamation) completed an Environmental Assessment (EA) and signed a Finding of No Significant Impact (FONSI) in December 2004 related to the conversion of long-term water service contracts to repayment contracts for the Helena Valley Irrigation District, Toston Irrigation District, and the City of Helena. The FONSI (reference number MT-231-05-01F) contained mitigation measures, one of which is related to an investigation of measures to avoid and/or minimize return flow issues that may be limiting the Warm Springs Creek fishery.

Project Goal and Approach

Reclamation has initiated compliance with mitigation measures outlined by the FONSI and undertaken efforts to assess current flow and sediment patterns in the TID. At the request of Reclamation, the TID hosted a meeting with representatives from Reclamation, Fish-Wildlife and Parks (FWP) and Montana State University Extension Water Quality (MSU) in January 2005. The purpose of the meeting was to discuss concerns the irrigation district had with water conservation and management as well as concerns FWP had with sediment in the Warm Springs Creek fishery.

The overall goal of the project which evolved from that meeting was to attempt to measure or estimate irrigation season amounts of water and sediment contributed to Warm Springs Creek by the TID.

A secondary goal established in July 2005 was to attempt to define fluctuations within the Toston Canal itself. The TID has concerns about water loss from the Toston Canal and downstream erosion in the event of a power outage. When power is lost (due primarily from electrical storms), individual pumps go offline and all the water in the canal is discharged into Warm Springs Creek. This has two consequences, loss of water to individual units and a potentially damaging surge of water in Warm Springs Creek. In hopes of preventing both scenarios, the TID is considering constructing a holding pond along the Toston Canal.

To determine irrigation season amounts and sources of surface water and sediment to Warm Springs Creek, ten sites were selected to monitor flow and sediment between March and October, 2005 (Fig 1). In July, two additional monitoring stations (ι) were subsequently installed along the main canal at possible sites for a holding pond (Fig 1).

The twelve monitoring sites established for this study include:

- Tunnel - top of canal
- Upper Canal - human bridge on E Canal
- Lower Canal - pivot bridge on W canal
- Main canal @ Warm Springs Creek (WSC) - bottom of canal
- WSC @ Arnies Drain
- Spring Creek Canal
- Hossfelds Crossing
- Muddy Lane Ditch
- Willow Swamp (WS)
- WSC @ WS
- WSC @ End of Line (EOL)
- Oil Road Xing - outside TID and after Marsh Creek confl. w/ WSC

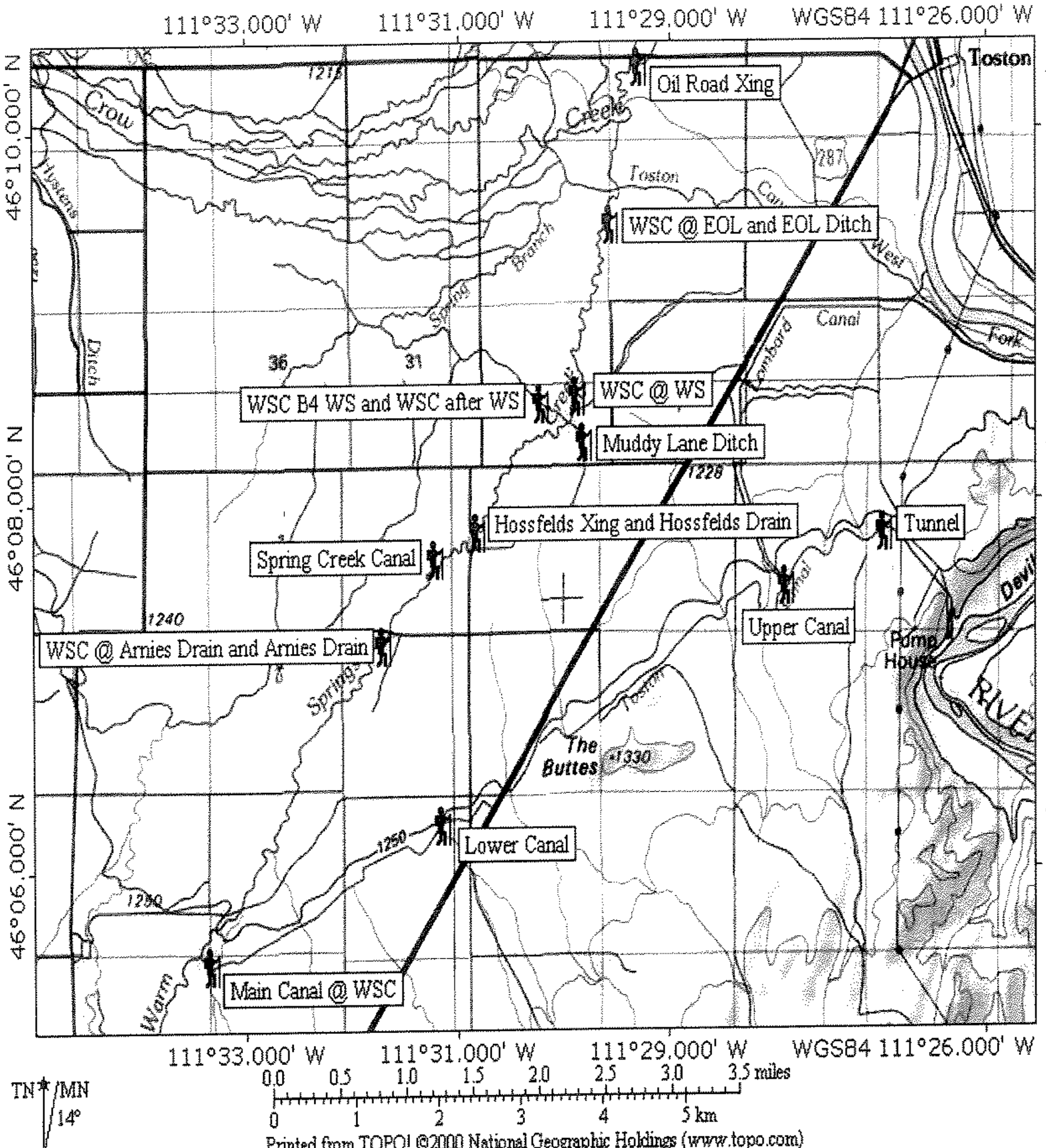


Figure 1. Map of the Toston Irrigation District with locations of monitoring stations for 2005.

A Trutrack or Aquarod was installed in a stilling well at each monitoring site. Aquarods and Trutracks measure water height (stage) and water and air temperature on a continuous basis, and record (log) data on pre-set intervals. For this project, Trutracks and Aquarods were set to log stream height and air and water temperature every hour.

Trutracks and Aquarods were installed in March and the TID began pumping water into the canal in April. The period of record reported in this study runs from May 6 through October 12. Data were collected in March and April, but equipment had to be re-calibrated in May. Therefore, data from the period before re-calibration was not used in rating curves or flow estimates.

Beginning March 23 and throughout the summer, gauging stations were visited approximately every three weeks. Sediment grab samples were collected periodically at all sites along Warm Springs Creek, and flow was measured at all sites using a Marsh-McBirney Model 2000 Flo-Mate portable flow meter. Flow measurements made with the flow meter were correlated with Aquarod and Trutrack stage data to develop rating curves for data collected by the Aquarods and Trutracks. Rating curves were developed for each gauging station (Appendix A). Note that two rating curves were developed for Hossfelds Crossing due to equipment failure and replacement. Halfway through the irrigation season, Willow Swamp (WS) was replaced with WSC B4 WS and WSC after WS (downstream from Willow Swamp Canal) due to problems with backwater in Willow Swamp Canal. Some stations (Spring Creek Canal, Muddy Lane Ditch) have poor rating curves due to non-fluctuating flows and/or backwater conditions.

Average daily flows and sediment concentrations were calculated for these stations, based on collected data. Additionally, some stations recorded sporadic gaps in Trutrack or Aquarod data due to equipment failure and human error. Flows were estimated for these data gaps to obtain a full period of record. Information regarding estimation techniques is available upon request.

Observations and Measurements

Flow Patterns

Hourly Trutrack or Aquarod data was used to calculate average daily flow (cfs and Acft) and total seasonal flow (Acft) for each station for the period of record (May 6 to October 12, 2005). Table 1 provides summaries of seasonal flow (Acft), and seasonal minimum and maximum cfs for each station in 2005. In July, the station at Willow Swamp Canal (WS) was abandoned due to placement difficulties and two stations were added, WSC B4 WS and WSC after WS. Subtracting WSC B4 WS from WSC after WS provides an estimation of flow contributed by Willow Swamp Canal from July - October. Table 1 also contains estimates of seasonal flow (Acft) in the two field drains

(Arnies drain and Hossfelds drain), estimated seasonal base flow (Acft) of Warm Springs Creek, and seasonal flow (Acft) from diversions and tributaries within the district. To estimate base flow in Warm Springs Creek and distinguish base flow from TID contributions, flow in WSC @ Arnies Drain was measured when there was no water in the Toston Canal. This was averaged over the period of record to provide seasonal base flow in Warm Springs Creek. Seasonal contributions from the two drains were estimated by measuring flow in each drain during site visits and averaging over the period of record. Unfortunately, there was no way to estimate base flow in Warm Springs Creek at EOL because there was never flow in WSC @ EOL without outside influences (Marsh Creek and irrigation return flow). In Table 1, DIVERSIONS indicates acre-feet of water diverted through the Toston Canal and INFLOWS B4 EOL indicates acre-feet of water contributed by tributaries (Spring Creek Canal, Willow Swamp Canal and Muddy Lane Ditch), direct return flow (Arnies Drain and Hossfelds Drain) and base flow in Warm Springs Creek.

Table 1. Seasonal flow and minimum/maximum cfs for each station in the project and contributions from diversions and tributaries.

Station	Total (Acre feet)	Min cfs	Max cfs
Main Canal @ WSC	2475.9	0.9	18.5
WSC @ Arnies Drain	2872.7	0.0	17.3
Spring Creek Canal	771.0	n/a	n/a
Hossfelds Xing	3105.2	1.8	20.7
WSC B4 WS	2289.5	0.0	20.8
WSC after WS	2365.7	0.0	23.8
Muddy Lane Ditch	168.2	n/a	n/a
WSC @ WS	3521.2	0.1	32.8
WSC @ EOL	3884.5	3.0	33.1
Oil Road Xing	4455.2	0.4	38.2
Tunnel	12617.5* 16606.2**	0.00* 0.00**	92.0* 109.8**
Willow Swamp B4 July	142.4	0.0	3.1
wscafterws - wscb4	76.2		
Willow Swamp Canal	218.6		
Arnies drain	21.6		
Hossfelds drain	89.4		
Base flow of WSC	158.6		
DIVERSIONS	12617.5		
INFLOWS B4 WSC @ EOL	1427.3		
Upper Canal July – Oct	5057.0	0.0	55.8
Lower Canal July – Oct	1868.0	0.0	36.3

*Reported by MSU, **TID pumping record (Arnie Kohlberg)

Figure 2 is a schematic of monitoring stations along the Toston Canal and Warm Springs Creek (WSC). Seasonal flow (Acft) and seasonal sediment load (tons) are reported for each location with the exception of Willow Swamp Canal. Sediment loads were not reported for this area due to problems with backwater and monitoring station locations. Note: Main Canal @ WSC is where the Toston Canal discharges into WSC, which is coming in from the southwest.

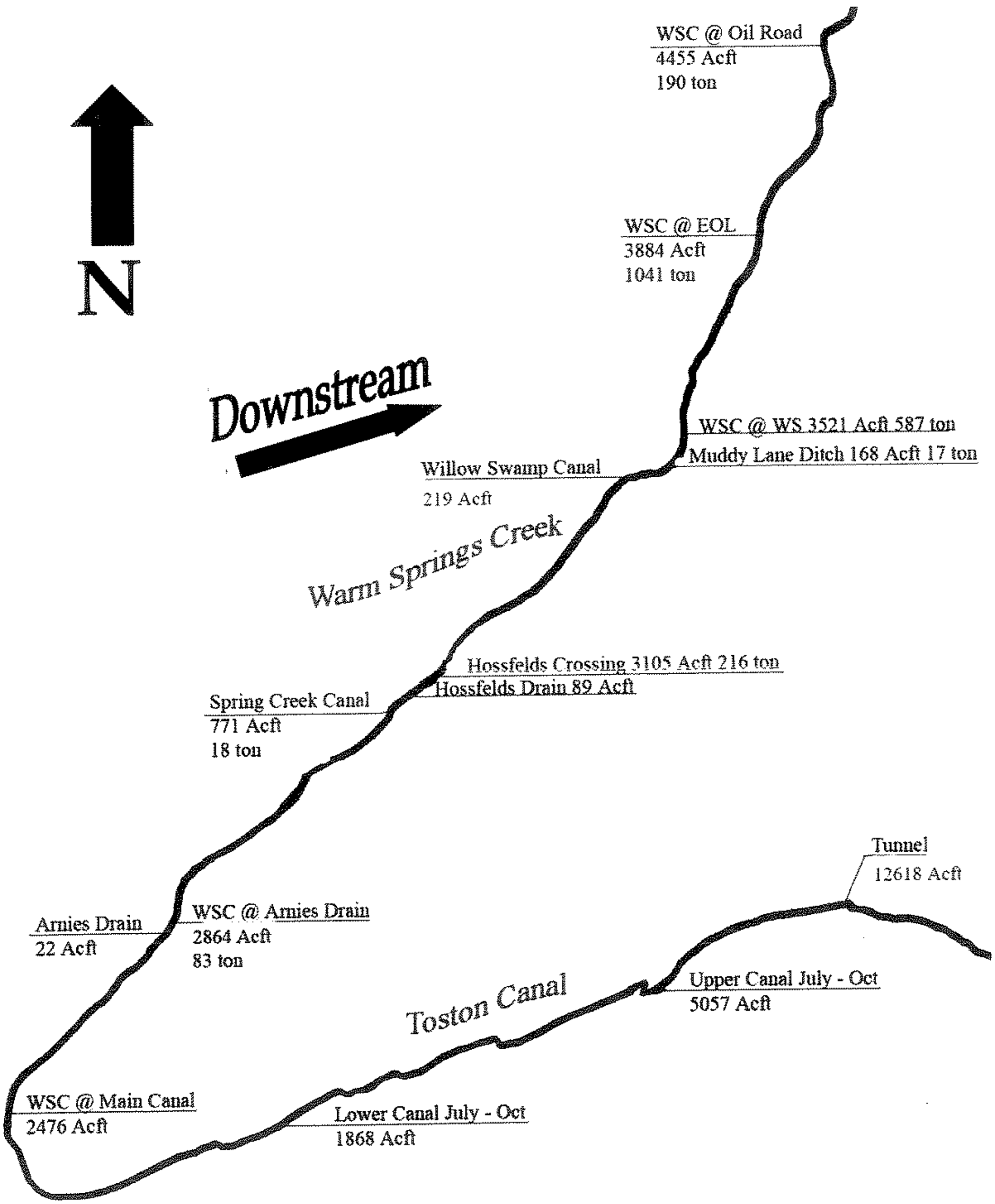


Figure 2. Schematic of monitoring station locations along the Toston Canal and Warm Springs Creek in 2005. Included are values for measured seasonal cumulative flow (Acft), and seasonal cumulative sediment load (tons).

Figures 3 through 11 are hydrographs of selected gauging stations comparing average daily flows (cfs) between stations for the 2005 season.

Figure 3 compares flow for the Tunnel and Main Canal @ WSC stations (Fig 3). The difference in flow between the tunnel and the end of the canal provides an indication of how much water is used in the upper portion of the TID. Based on our data, it appears that the majority of water pumped into the Toston Canal is being diverted from the canal before it enters WSC at the Main Canal @ WSC Station. It should be noted that the TID operates the Toston Canal to spill approximately 6 cfs of water into Warm Springs Creek for delivery to a district water user.

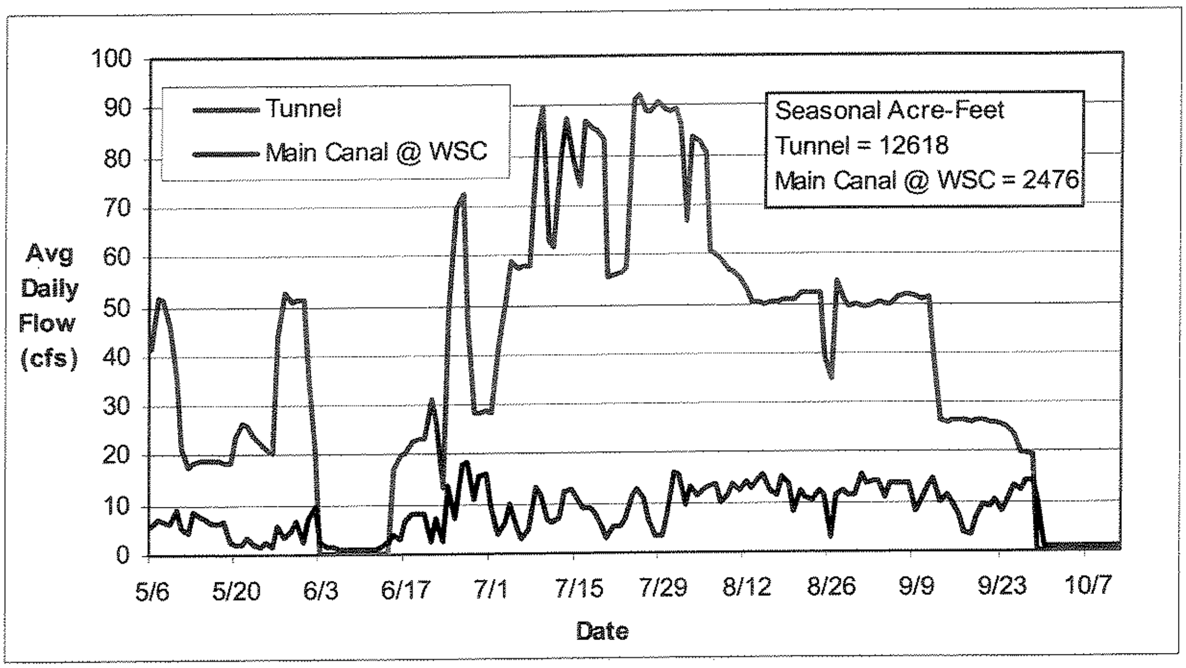


Figure 3. Average daily flows (cfs) at the Tunnel and Main Canal @ WSC stations for the period May 6 - October 12, 2005.

Figure 4 compares flow for the Tunnel and WSC @ EOL stations and illustrates the difference between water pumped into the canal and water flowing out of the TID (Fig. 4). A comparison of Figures 3 and 4 shows the WSC @ EOL and Main Canal @ WSC stations tracking closely while the tunnel has consistently higher flows. There are three tributaries (Spring Creek Canal, Willow Swamp Canal, and Muddy Lane Ditch) and two field drains (Arnies and Hossfelds) between the end of the canal and WSC @ EOL which contribute to flow in WSC at the end of the district.

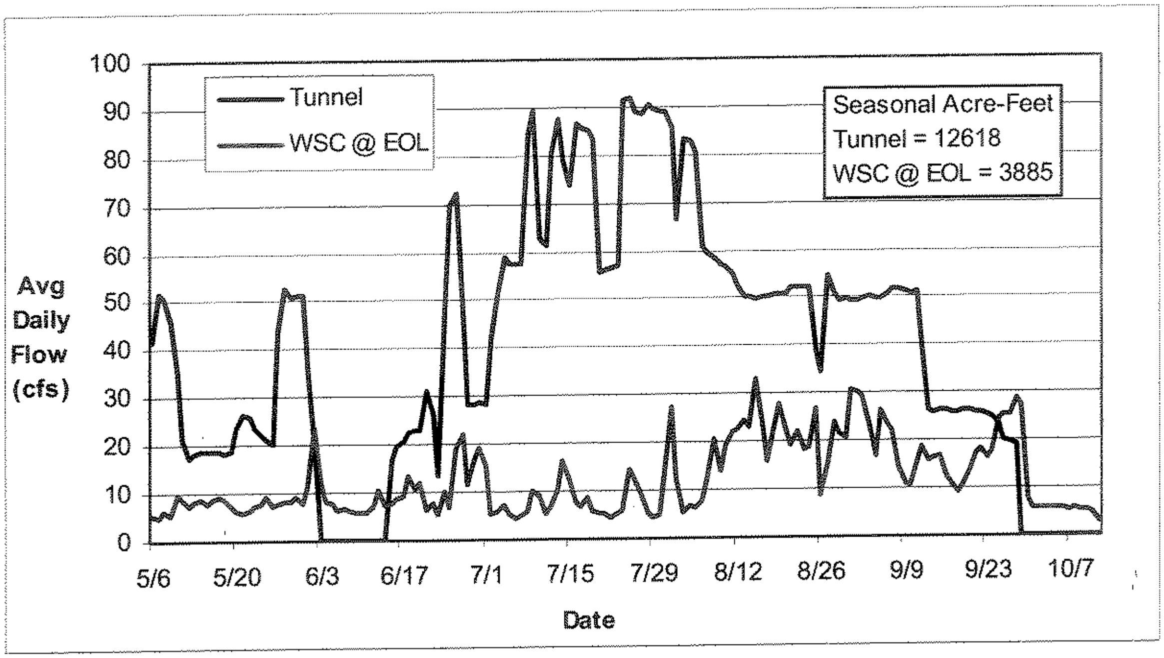


Figure 4. Average daily flows (cfs) at the Tunnel and WSC @ EOL stations for the period May 6 - October 12, 2005

Figure 5 compares flow for the WSC @ EOL and Oil Road Xing stations and illustrates water loss/gain between the end of the TID and the Oil Road Xing (Fig. 5). Based on our data, flow at WSC @ EOL correlates with flow at the Oil Road Xing. Early in the season, flow at Oil Road Xing exceeds flow at WSC @ EOL; during the later half of the season, flow at WSC @ EOL exceeds flow at Oil Road Xing. However, irrigation return flow and Marsh Creek, a tributary to the Missouri River, feed into WSC between WSC @ EOL and Oil Road Xing and are likely causes for this increase in flow during the later part of the season. Marsh Creek is a very braided, meandering stream, one fork of which enters WSC between WSC @ EOL and Oil Road Xing. Because this creek is used for spawning, regulations mandate that flow be maintained in Marsh Creek. Flow into Willow Swamp Canal or Marsh Creek is controlled by a headgate west of the district.

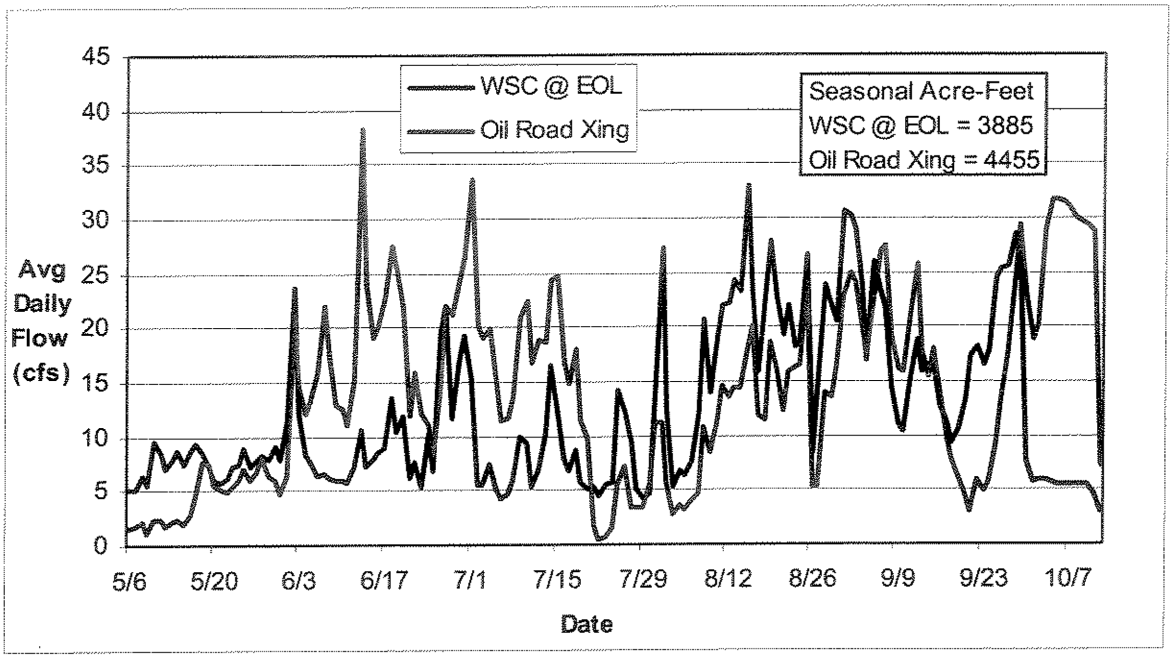


Figure 5. Average daily flows (cfs) for WSC @ EOL and Oil Road Xing stations for the period May 6 - October 12, 2005.

Figure 6 is a graph showing gains/losses in flow from WSC @ EOL to Oil Road Xing (Fig. 6). There appears to be a loss of water between WSC @ EOL and Oil Road Xing late May through late July, the first week of September and in October. This is likely due to pumping and diversions below WSC @ EOL. In May, late July through early September and from late September to the end of the irrigation season there seems to be a gain in water between WSC @ EOL and Oil Road Xing.

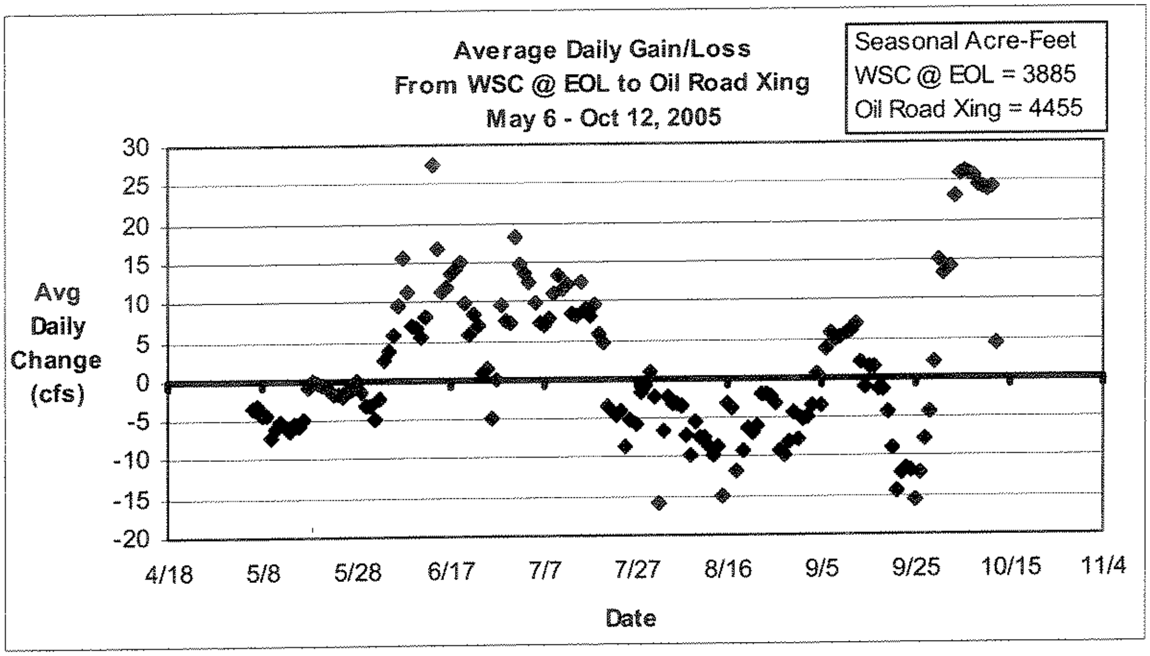


Figure 6. Average daily gain or loss (cfs) from WSC @ EOL to Oil Road Xing for the period May 6 - October 12, 2005. In situations where WSC @ EOL – Oil Road Xing Flow = negative, flow increases from WSC @ EOL to Oil Road Xing. In situations where WSC @ EOL – Oil Road Xing Flow = positive, flow decreases from WSC @ EOL to Oil Road Xing, likely due to diversions and pumping below WSC @ EOL.

Figure 7 compares flow at the Main Canal @ WSC to flow in WSC @ Arnies drain and illustrates the amount of water passing through the weir at the end of the canal and into WSC (Fig. 7). Flow at WSC @ Arnies drain closely tracks flow at the Main Canal @ WSC but at Arnies drain flow is, in general, slightly greater. This is likely due to irrigation return flow from a field drain (Arnies drain).

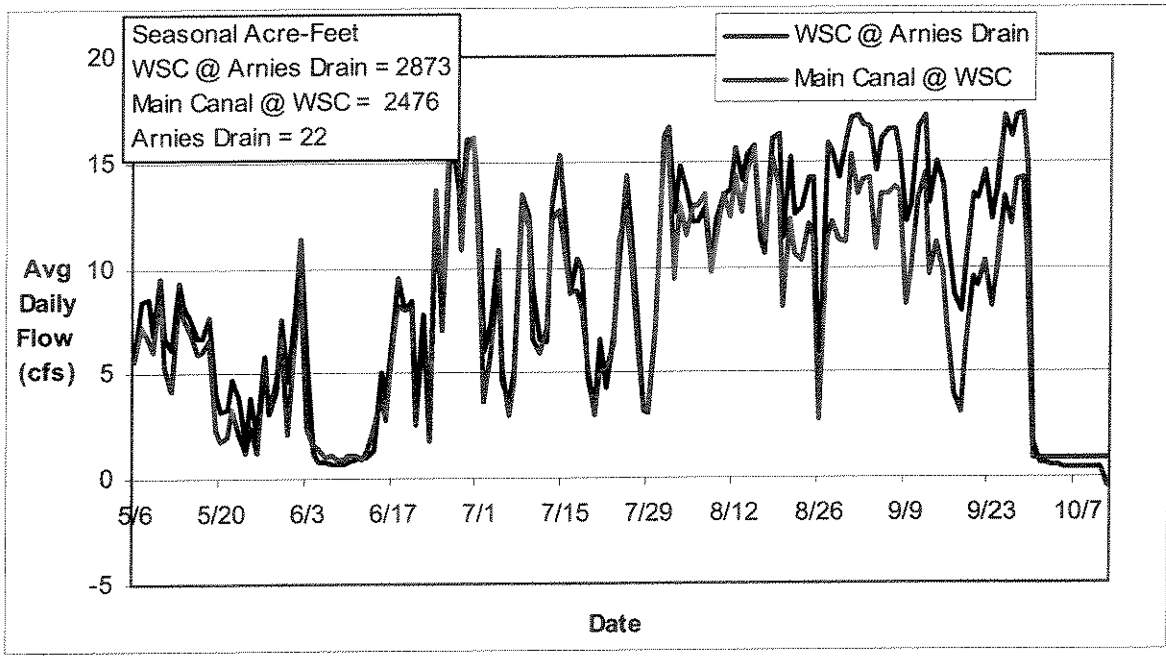


Figure 7. Average daily flows (cfs) for WSC @ Arnies Drain and the Main Canal @ WSC stations for the period May 6 - October 12, 2005.

Figure 8 compares average daily flow at Hossfelds Crossing (which is below the confluence with Spring Creek Canal) and WSC @ Arnies drain. This graph illustrates the influence of Spring Creek Canal and Hossfelds drain on WSC (Fig. 8). Data suggest flow patterns are fairly similar at these two stations but WSC at Hossfelds Crossing is augmented by Spring Creek Canal and Hossfelds drain. Hossfelds drain flowed relatively constant during the irrigation season, discharging an estimated 89.35 acre feet of water. Flow coming from Spring Creek Canal was estimated due to non-fluctuating flows at this station.

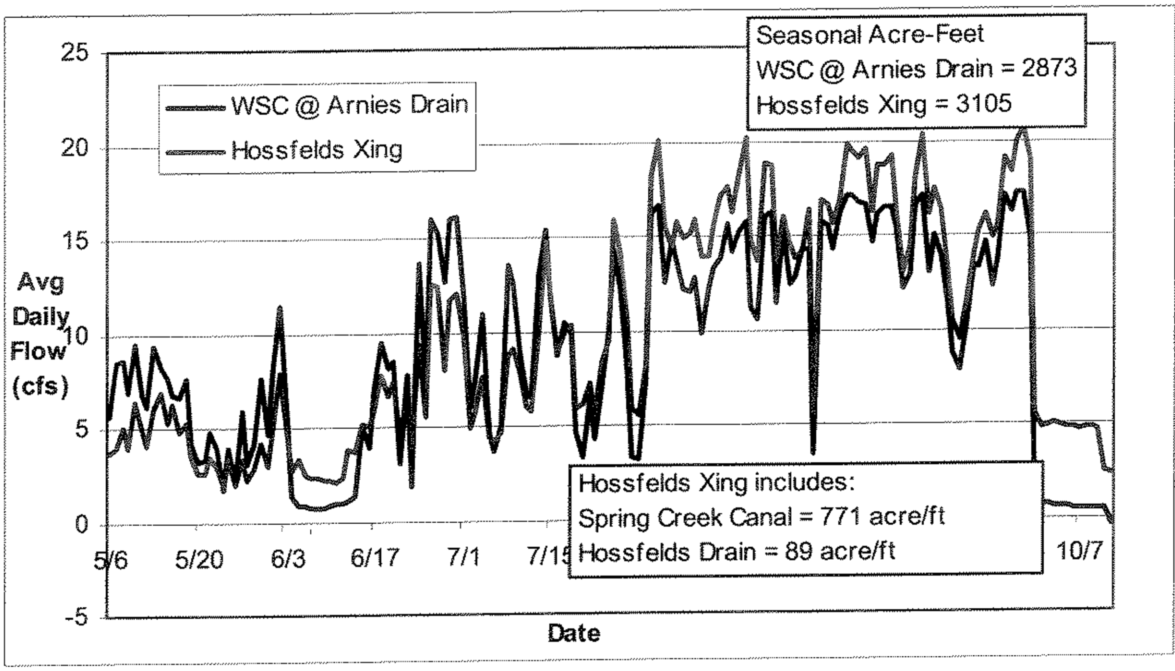


Figure 8. Average daily flows (cfs) for WSC @ Arnies Drain and Hossfelds Crossing stations for the period May 6 - October 12, 2005.

Figure 9 compares WSC before and after the confluence with Willow Swamp Canal and gives a rough estimate of how much water is being added by Willow Swamp Canal (Fig. 9). WSC after WS is consistently higher than WSC B4 WS. This is to be expected as these stations were installed to measure inflow from Willow Swamp Canal. The difference between WSC after WS and WSC @ WS is likely influenced by the diversion back into Willow Swamp Canal east of WSC.

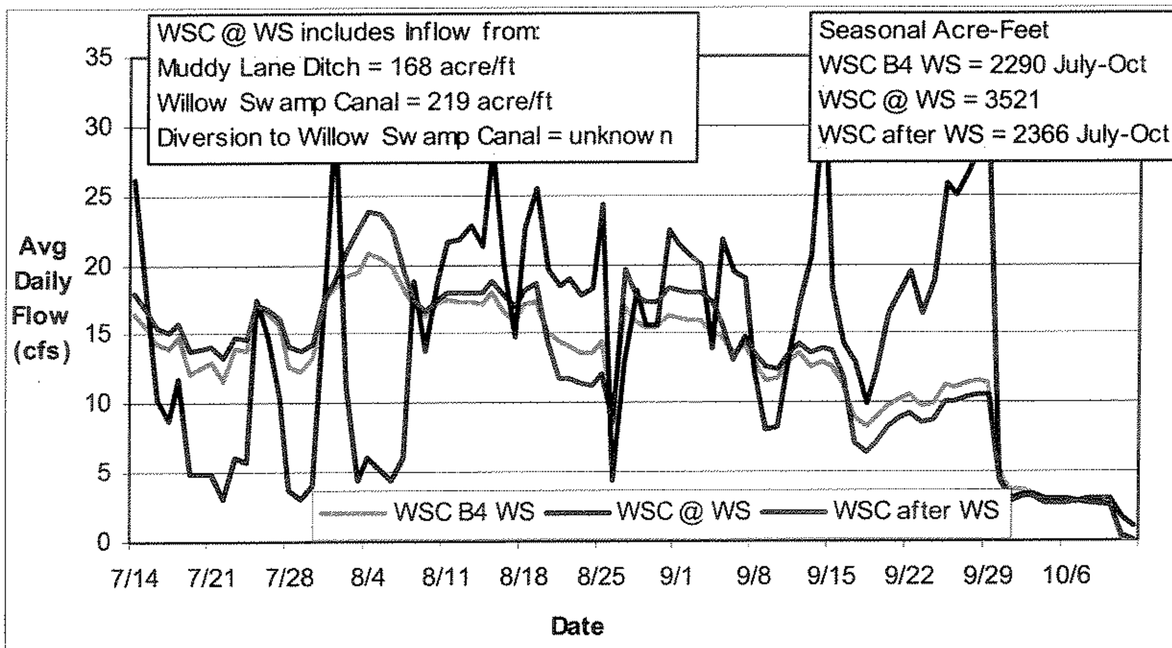


Figure 9. Average daily flows (cfs) in Warm Springs Creek before the confluence with Willow Swamp Canal (WSC B4 WS), after the Willow Swamp Canal confluence (WSC after WS), and after the Willow Swamp Canal diversion (WSC @ WS) for the period July 14 - October 12, 2005.

Figure 10 compares average daily flows between WSC @ Arnies drain and WSC @ EOL (Fig. 10). This figure illustrates water being picked up by WSC as it moves through the district. Flow in WSC @ EOL is generally greater than at Arnies drain. Inflow from drains, Spring Creek Canal, Muddy Lane Ditch and Willow Swamp Canal will increase flows at WSC @ EOL while diversions for Willow Swamp Canal and flood irrigation in the lower sections of the district will decrease flows at WSC @ EOL. As can be seen in Figure 10, contributions from return flow to flow in WSC@ EOL become increasingly more significant as the irrigation season progresses.

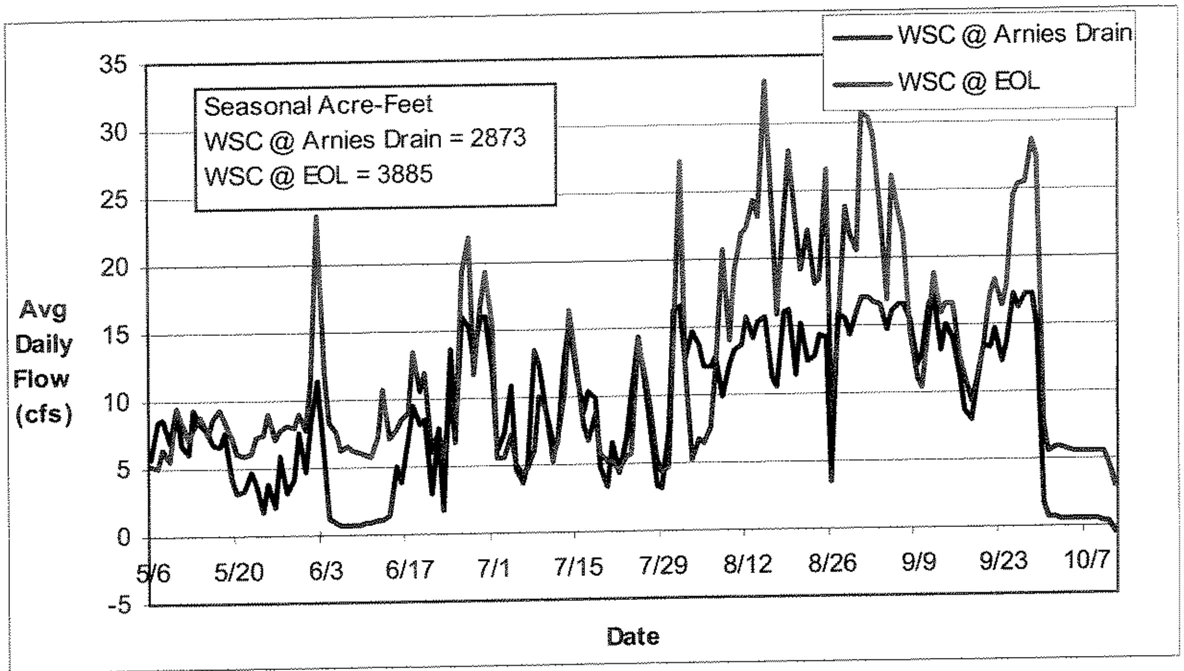


Figure 10. Average daily flows (cfs) for WSC @ Arnies Drain and WSC @ EOL stations for the period May 6 - October 12, 2005

Figure 11 compares average daily flow at the upper and lower canal stations within the main canal to flow from the tunnel and to flow at the end of the Main Canal @ WSC (Fig. 11). This graph illustrates a greater degree of fluctuation in flow at the lower canal station (0-35 cfs) than at the upper canal station. The lower station fluctuated between 0 and 35 cfs throughout the season while the upper station consistently decreased over the season. Our data suggest that flow at the end of the canal is more affected by the lower canal station while flow at the upper canal station tracks closely with discharge from the tunnel until late in the season. This discrepancy may be due to individual pump units along the upper section of the canal shutting down for the season.

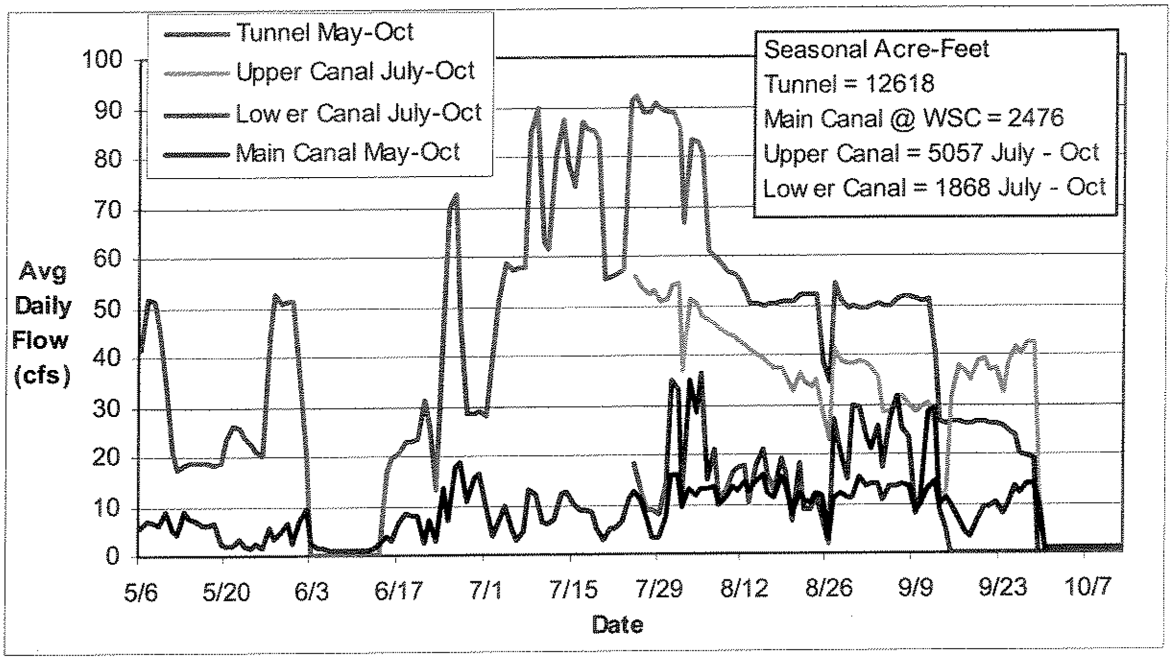


Figure 11. Average daily flows (cfs) at the Tunnel, Main Canal @ WSC stations for the period May 6 - October 12, 2005. Data for the Upper and Lower Canal stations is from July 14 through October 12, 2005.

Sediment Patterns

Sediment amounts (loads) were determined by combining daily flow data with sediment concentration as a function of flow. A sediment sample was collected each time a flow measurement was taken for the entire season and flow x sediment relationships were developed for all stations along Warm Springs Creek (Appendix B). Combining average daily flow velocities with sediment concentrations provided a mechanism for calculating sediment loads at each station as a function of time. Calculations made were for total sediment (tons) and sediment concentration (tons/acre-feet). Sediment loads reported in Table 2 are cumulative for the period May 6 to October 12, 2005.

Table 2 shows cumulative sediment (tons), seasonal acre feet of water and sediment concentrations (tons/acre ft) for each station along WSC (Table 2). It should be noted that Willow Swamp Canal only has values until July. The check dam just upstream of WSC @ WS influenced sediment X flow relationships at WSC @ WS, WSC B4 WS, WSC after WS, and Muddy Lane Ditch, so sediment concentrations may not be accurate and were not reported.

Table 2. Cumulative sediment (tons), seasonal acre-feet of water and average sediment concentrations (tons/acft) at each station along WSC from May 6 to Oct 12, 2005. Note: Willow Swamp Canal only has values to July due to problems in this area.

Station	Cumulative Sediment (Tons)	Seasonal Acre feet	Sediment (Tons/Acre ft)
WSC @ Arnies Drain	85.2	2872.7	0.0
Spring Creek Canal	17.8	771.0	0.0
Hossfelds Xing	214.5	3105.2	0.1
Muddy Lane Ditch	16.9	168.2	0.1
WSC @ WS	148.3	3521.2	0.0
WSC @ EOL	295.6	3884.5	0.1
Oil Road Xing	175.1	4455.2	0.0
Willow Swamp B4 July	4.1	142.4	0.0

Table 3 shows cumulative sediment (tons) for each station along WSC, and how much sediment was lost or gained between stations. From this table one can get an idea of reaches where sediment is being transporting and deposited in WSC. Sediment sourcing was not attempted for this season.

Table 3. Sediment gains/losses (tons) for each station on WSC.

Station	SED	GAIN	LOSS
	Tons		
Main Canal @ WSC	0.0		
WSC @ Arnies	85.2	85.2	
Hossfelds Xing	214.5	129.3	
WSC @ WS	148.3		-66.3
WSC @ EOL	295.6	147.3	
Oil Road Xing	175.1		-120.5

Figure 12 illustrates seasonal sediment loads for select monitoring stations along WSC and downstream of the TID (Oil Road Xing). Spring Creek Canal, Muddy Lane Ditch and Willow Swamp Canal were not included because sediment loads were estimated at those stations in 2005.

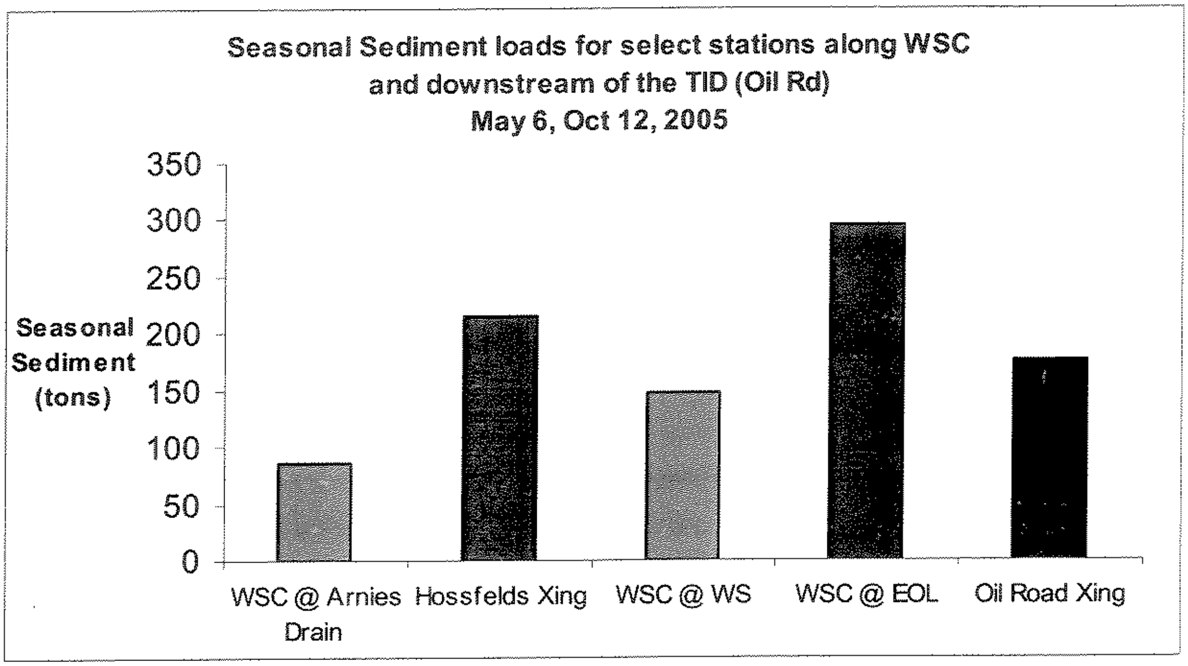


Figure 12. Seasonal sediment loads for select stations along WSC and downstream of the TID (Oil Road Xing) for the period May 6 - October 12, 2005.

Summary

The majority of water diverted from the Missouri River into the Toston Canal is diverted from the canal along the upper reaches of the district. Therefore, a significantly smaller quantity of the diverted water actually makes it into Warm Springs Creek via the Toston Canal under normal circumstances. However, WSC @ EOL had greater seasonal flow than Main Canal @ WSC. This is likely due to contributions to WSC from Spring Creek Canal, Willow Swamp Canal and return flow from the TID. Greater fluctuations of water levels occurred in the lower canal section (Lower Canal) while the upper section (Upper Canal) consistently tracked with what was transpiring at the head of the canal (Tunnel).

Table 4 provides stage and flow data collected by the TID and MSU at the tunnel station for the 2005 season (Table 4). TID pump record data was acquired by selecting four equally spaced stage values (ft/mm) and the correspondingly reported flows (Acft, converted to cfs) from the TID pump record sheet. BOR data was obtained by matching MSU stage data (ft/mm) to flow (cfs) from the BOR graph for the rated section at the tunnel station, and MSU measured data was collected during site visits.

Table 4. TID, BOR and MSU stage and flow data for the Tunnel station in 2005.

TID pump record data			BOR data (rated section)			MSU measured data	
TID slab reading		TID record	MSU slab reading		Calc'd	Trutrack	measured flow
feet	mm	cfs ▲	feet	mm ◆	cfs ■	mm	cfs ●
1.45	441.96	31.24	1.8	548.64	40.66	233.7	23.23
1.85	563.88	41.21	2.15	655.32	55.04	340.6	43.91
2.4	731.52	63.87	2.72	829.06	78.46	525	68.79
3.05	929.64	106.28	2.9	883.92	85.85	591.2	65.91

Figure 13 is a comparison of TID, BOR and MSU Trutrack and slab rating curves for the tunnel station (Figure 13). This graph is an illustration of data presented in Table 4 and reveals differences between flows (cfs) reported by the TID and flows calculated from BOR and MSU rating curves. Reported average daily cfs and seasonal acre-feet of water for the tunnel station were calculated using the equation generated by the MSU Trutrack rating curve (Fig 13) (green circles). Although a different zero datum stage applies to the MSU Trutrack rating curve, notice how well the MSU Trutrack rating curve corresponds with the BOR (pink squares) and MSU slab rating curves (orange diamonds). Similarly, the TID rating curve (blue triangles) appears to match the trend seen in the others with the exception that flows appear to be overestimated at low and high stage readings.

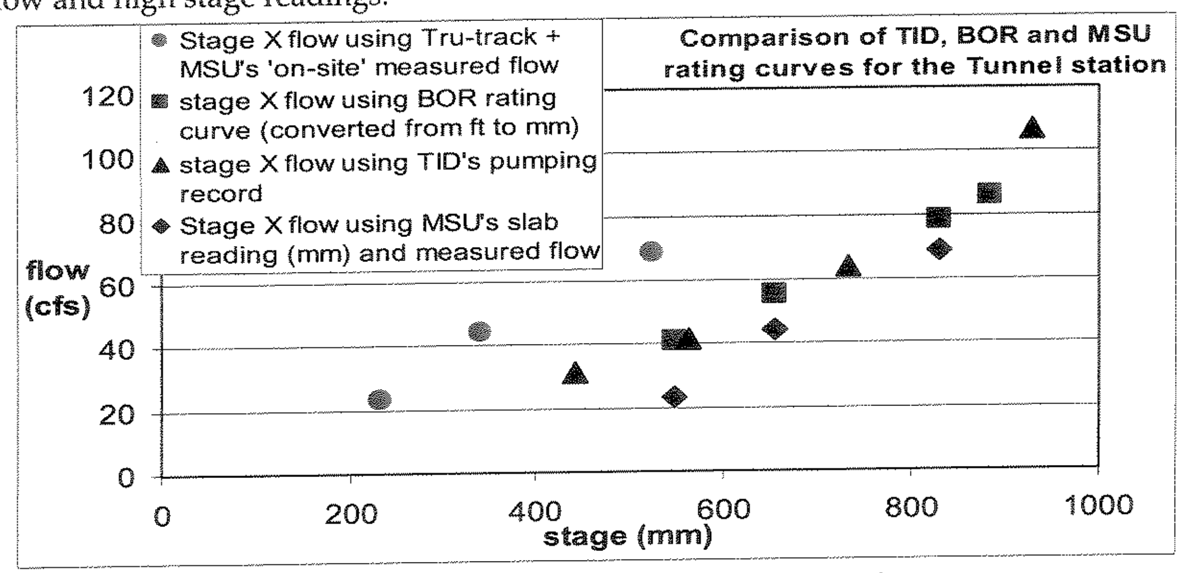


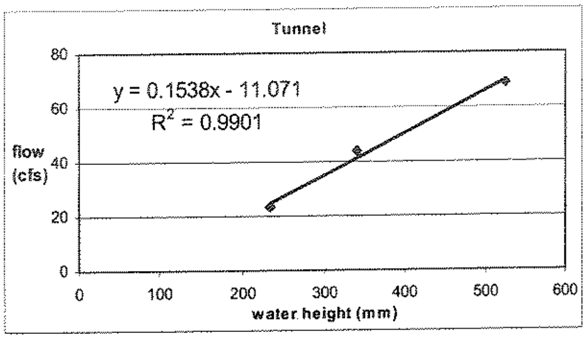
Figure 13. Comparison of TID, BOR and MSU rating curves for the Tunnel station.

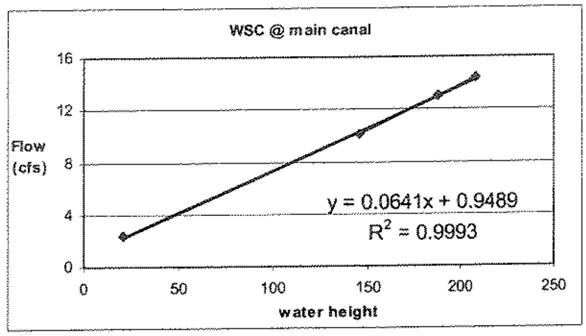
NOTE: MSU Trutrack rating curve = real-time Trutrack stage (mm) values vs. MSU's measured flows.
BOR rating curve = stage (slab reading) vs. flow (cfs) for the BOR rated section.
MSU slab rating curve = stage (slab reading) vs. MSU's measured flow.
TID rating curve = stage (slab reading) vs. reported flow from TID pump record.

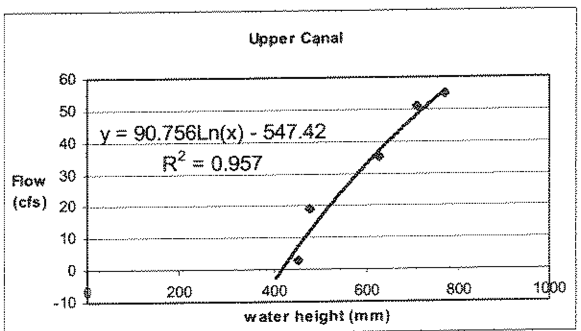
Recommendations for 2006

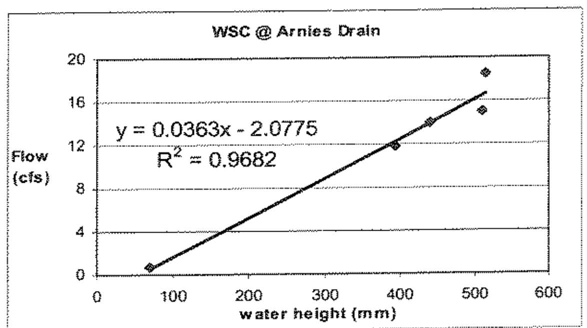
Determining base flow in WSC @ EOL and Oil Road Xing stations is critical for 2006. Irrigation west of WSC and other discrepancies between WSC @ Arnies drain and Hossfelds crossing substantiate the need for re-assessment of both stations in 2006. Due to non-fluctuating flow and backwater at the Spring Creek Canal Station, it will need to be re-evaluated and possibly moved. A check dam at the Willow Swamp Canal diversion influenced sediment and flow measurements during the 2005 season. Stations in this area (WSC B4 WS, Muddy Lane Ditch, WSC after WS and WSC @ WS) will need to be re-assessed and possibly relocated for the 2006 season to more accurately reflect conditions at these stations. It may also be beneficial to install a station on the diversion back into Willow Swamp Canal to more precisely calculate seasonal acre feet of water at stations in this area. It may be advantageous to measure non-irrigation and irrigation season sediment concentrations and flows to more accurately define contributions from the TID on a yearly basis. There was no attempt to source sediment this season, but this can be done in 2006 if warranted.

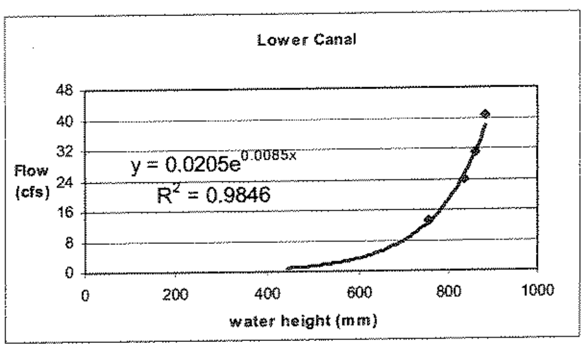
APPENDIX A. Flow (cfs) by Stage (mm) rating curves for each station in 2005.

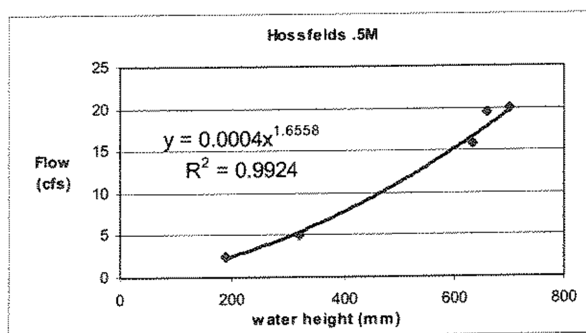




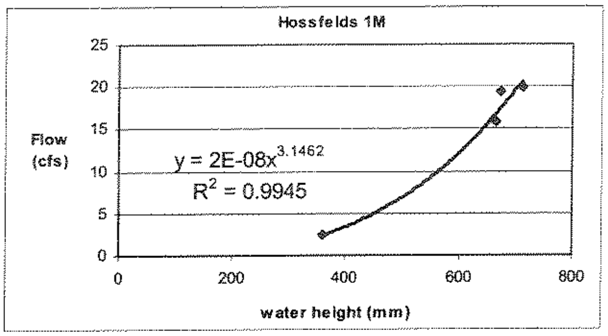


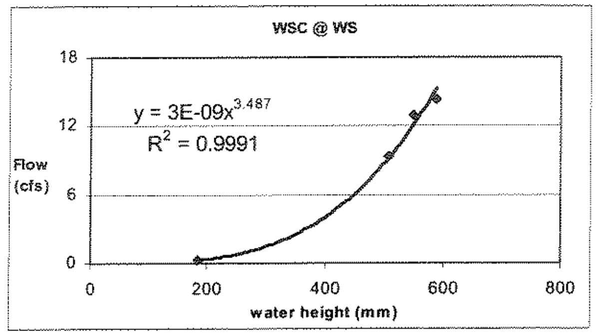


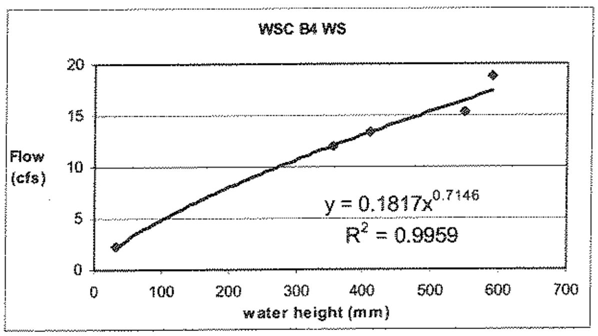


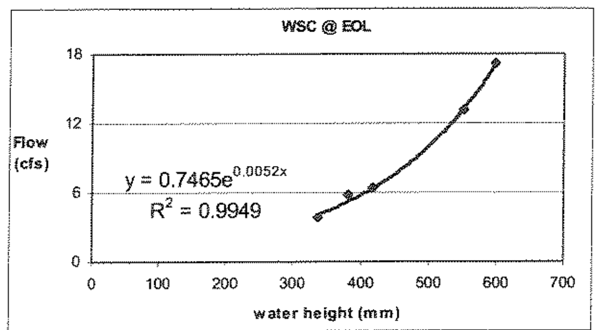


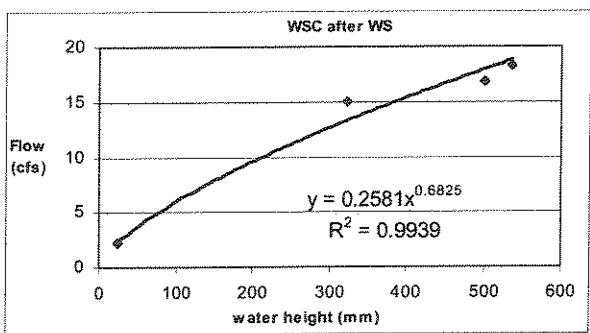
APPENDIX A (con't). Flow (cfs) by Stage (mm) rating curves for each station in 2005.

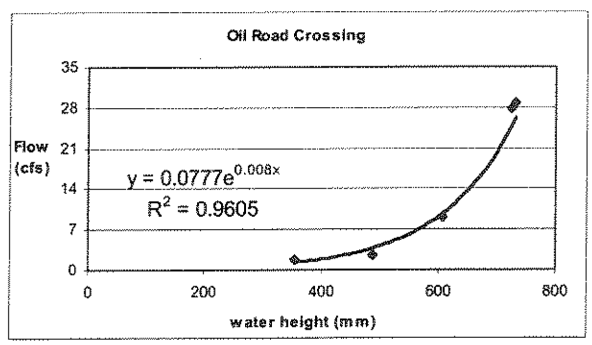




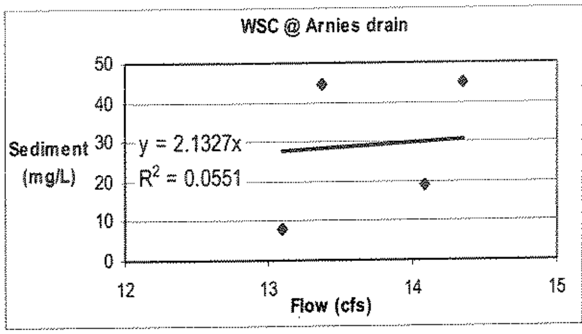


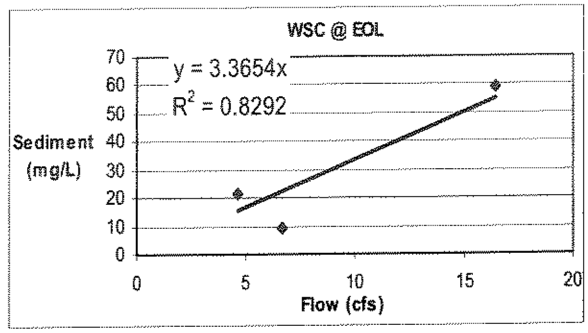


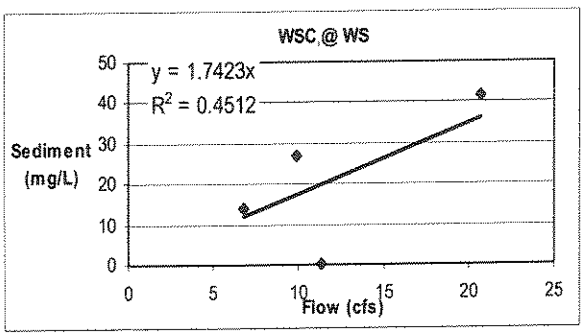


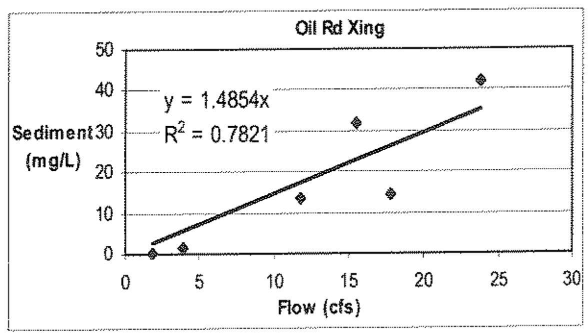


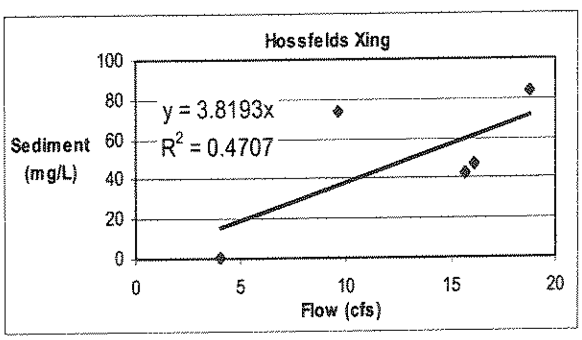
APPENDIX B. Flow (cfs) by Sediment (mg/L) relationships for sediment monitoring stations in 2005.



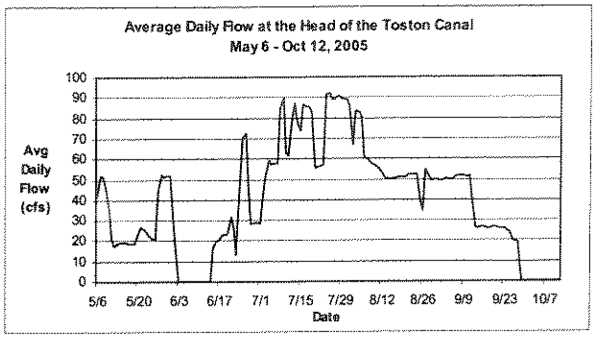


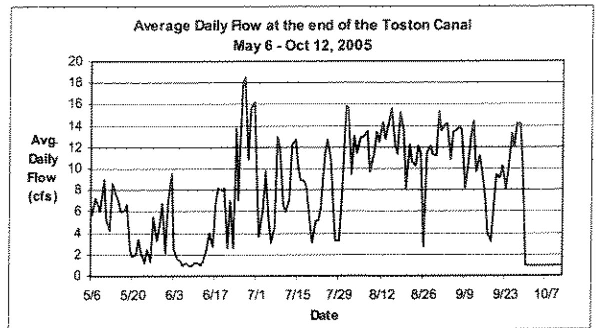


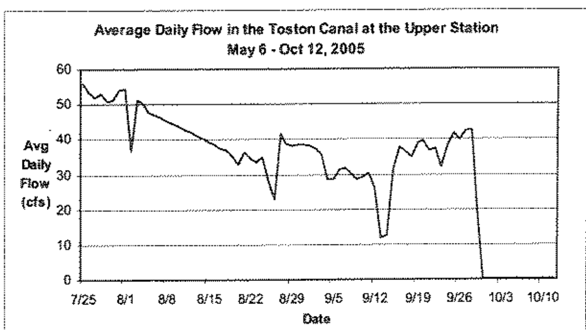


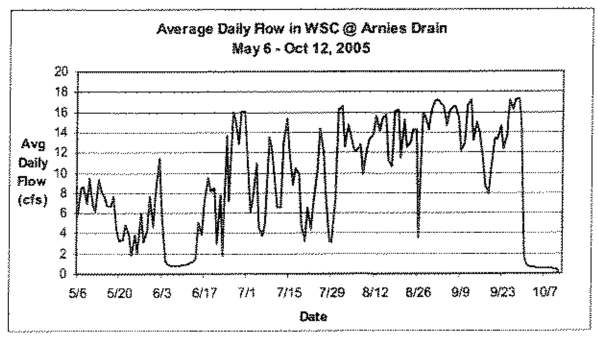


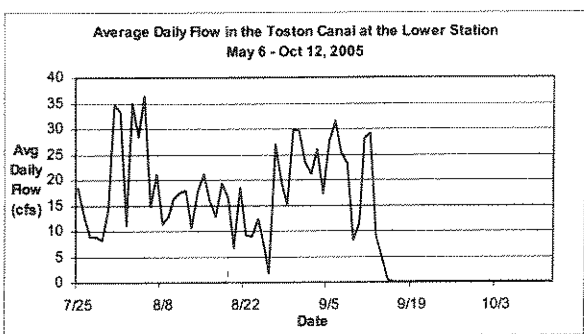
APPENDIX C. Average daily flow (cfs) for each station in the TID in 2005. Note: Average daily flows for Spring Creek Canal and Muddy Lane Ditch were averaged for the entire season so were not included in this appendix.

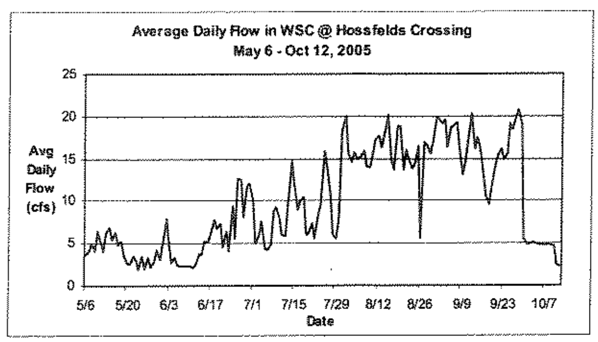












APPENDIX C (con't). Average daily flow (cfs) for each station in the TID in 2005. Note: Average daily flows for Spring Creek Canal and Muddy Lane Ditch were averaged for the entire season so were not included in this appendix.