9/16/2010

Thief River Watershed Sediment Investigation Final Report

Revision 2 | Corey Hanson

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September 16, 2010

Funded by a $96,500 Clean Water Partnership Phase I grant that was awarded to the Red Lake Watershed District by the Minnesota Pollution Control Agency

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This report and many others are available on the Red Lake Watershed District website:
www.redlakewatershed.org

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Introduction

The Thief River Watershed Sediment Investigation was initiated because of growing concern about water quality issues in the Thief River Watershed and a lack of detailed information on their severity or causes. The study provided an opportunity to diagnose the impact of hydrologic modification as well as other anthropogenic and natural factors influencing water quality in the Thief River watershed. The study was conceived for the purpose of intensively examining the Thief River watershed to learn more about the extent of water quality problems and to investigate the sources of those problems. The study provides us with intensive flow and water quality data from throughout the watershed that is both real (continuous and discrete monitoring) and simulated (SWAT model). This data can be used for assessment, future TMDL development, and examine the transport of pollutants through the watershed. Project ideas, both specific and general, are another product of this effort.

The watershed is heavily managed with more than 30 impoundments and many miles of channelized streams and man-made ditches. Some of the impoundments were built to address flooding concerns but most are operated primarily for wildlife habitat management. Because it is home to Agassiz National Wildlife Refuge and Thief Wildlife Management Area, the area is productive and important for waterfowl, shorebirds, and migrating birds. The watershed also features productive farmland that is important to the local economy. The Thief River flows to the Red Lake River, which is a drinking water source for the cities of Thief River (just downstream of the confluence), East Grand Forks, and Grand Forks.

Project planning was coordinated with the United States Fish and Wildlife Service (Agassiz national Wildlife Refuge), United States Geological Survey (Grand Forks Field Office), and the Marshall County Water Planner. Work on the project began in February 2007 and ended in August 2010. Monitoring was conducted from 2007 through 2009.

The investigation used sampling, continuous water quality monitoring, continuous stage monitoring, field reconnaissance, stakeholder involvement, and water quality modeling to accomplish its goals. The project's partners were a large part of its success, whether they were helping with the CWP project directly or if they were conducting their own study.

Regular sampling and flow monitoring was conducted at 11 sites throughout the watershed to verify the impairments. Sites were chosen to represent pour points, to bracket impoundments, and to bracket major ditch confluences. Continuous water quality data was collected at 6 sites for this project. Flow and sediment monitoring will be conducted in order to develop sediment budgets (SWAT and/or FLUX modeling) for the impoundments. Water quality results were loaded in the Soil and Water Assessment Tool (SWAT) to model contributions from various sources, estimate pollutant loads and evaluate pollutant reduction strategies. Data from discrete measurements was entered into the EPA STORET database and a comprehensive final report was written, published by the RLWD, and made available on the RLWD website (www.redlakewatershed.org). Continuous water quality monitoring data was prepped and sent to the MPCA for entry into the State's HYDSTRA continuous monitoring database.

One quantifiable goal of the study was the quantity of data collected. Monthly water quality samples were collected at the monitoring sites included in this study. There were 11 monitoring site that were used for the CWP portion of the study. There were 5 additional monitoring sites within Agassiz NWR as part of a complementary study that collected intensive data within the refuge. Continuous water quality monitoring for turbidity, dissolved oxygen, pH, temperature, and water level was conducted at 6 of the CWP sites. Five sites were originally planned, but a cooperative arrangement with the USGS allowed for the monitoring of an additional site on Ditch 200. Continuous stage monitoring was conducted at all of the sites by one agency or another. Over the three-year span data collection phase of the study, a minimum of 20 samples were collected at each CWP monitoring site. Monitoring results will be used in the next MPCA statewide water quality assessment.

The data provides for a more reliable and representative assessment than what has been possible in the past. It will either confirm or disprove the existence of impairments on many river and ditch reaches in the watershed. Data was also used to identify any new impairments. It will also help identify sources of sediment in the watershed. This study and corresponding studies will give us a better understanding of the timing of water and sediment movement through this complex watershed. This grant funded project allowed us to collect the continuous monitoring data needed to understand this timing. The large amount of data that was collected for this study can continue to be used to answer questions about the watershed even after the deadline for this report. When data from the USGS/USFWS Agassiz National Wildlife Refuge Water Quality Study becomes available, the amount of data available for analysis will be doubled.

There were a bunch of questions to which we hoped to find an answer through this project. Some were answered. For others, the answers will come from reviewing the data that was collected during all of the studies that are taking place in the Thief River watershed.

- Contribution of stream bank erosion
- How does Agassiz NWR water management affect water quality?
- Are there better ways to coordinate impoundment water releases?
- Are there management conflicts?
- What are the contributions from ditch systems?

Turbidity measurements will be compared to the current MPCA standard of 25 NTU. The turbidity levels in the Thief River will need to stay under this standard in at least 90% of the measurements collected in the most recent 10 years of monitoring in order to officially be considered to be fully supporting of aquatic life.

Dissolved oxygen readings will be compared to the MPCA state standard of 5 mg/L. The water quality in the Thief River will need to meet this standard in 90% of the measurements collected in the most recent 10 years of monitoring in order to officially be considered to be fully supporting of aquatic life.

Un-ionized ammonia is the toxic form of ammonia. The percentage of the total ammonia sample that is in the toxic un-ionized form is based on pH and temperature. The State has set the standard for this parameter at 0.04 for the classes of waterbodies that are found in the Thief River watershed. The water quality in the Thief River will need to meet this standard in 90% of the measurements collected in the most recent 10 years of monitoring in order to officially be considered to be fully supporting of aquatic life.

E. coli sample results from the most recent 10 years are grouped by calendar month. This encompasses all of the E. coli sampling done within the watershed. A geometric mean is calculated for each calendar month and compared to the standard of 126 Org/100ml. At Least five samples from each month are needed in order to complete a reliable and representative assessment of how safe the water is for aquatic recreation.

The MPCA approved a six-month extension for the Thief River Watershed Sediment Investigation. The project work plan was put together with a pre-planned one-year extension, so the project will be completed six months sooner than expected.

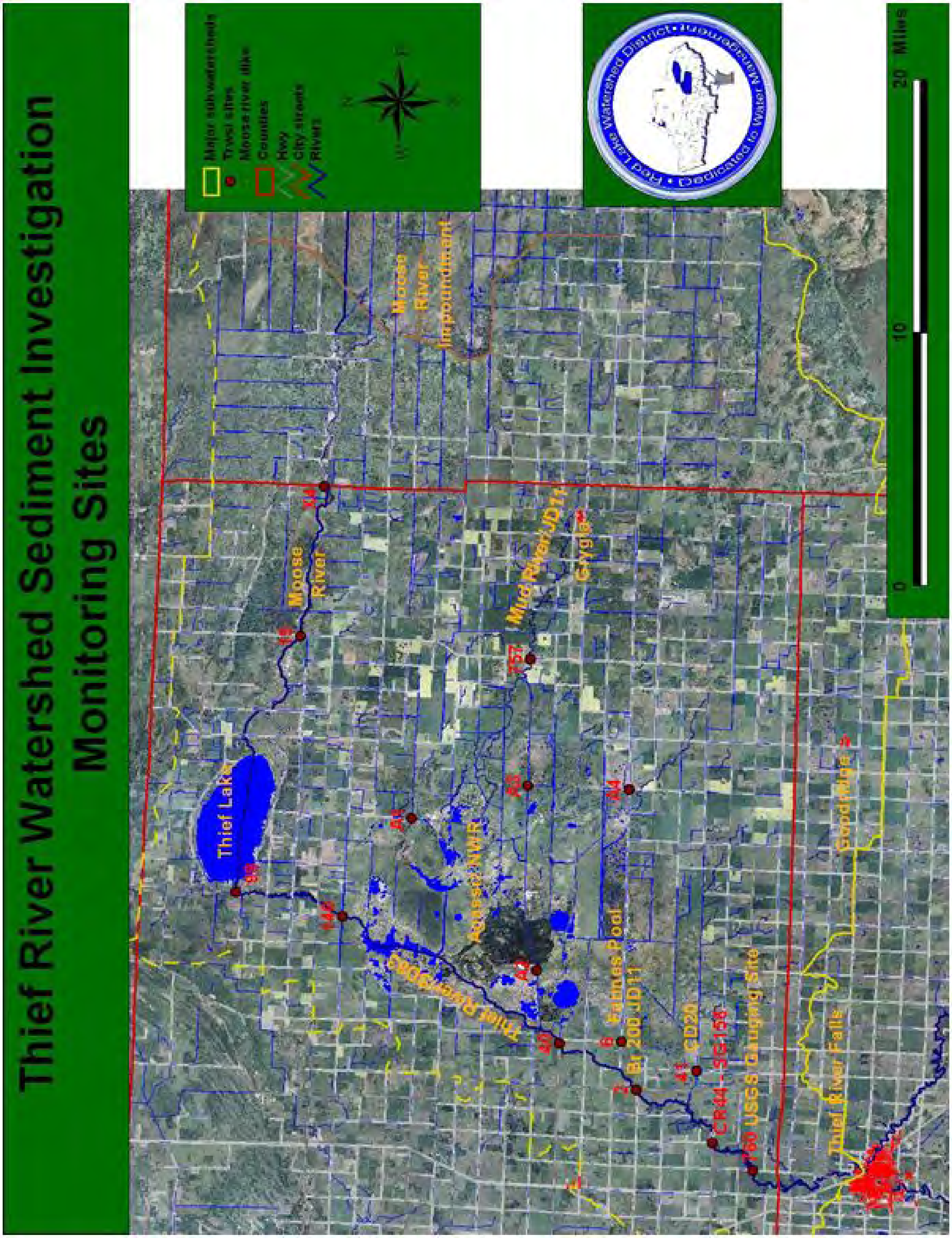


Figure 1. Thief River Watershed Sediment Investigation Monitoring Sites

Executive Summary

Prior to 2007, monthly/bi-monthly condition monitoring results indicated that there were water quality problems within the Thief River watershed, but didn't tell us much about how bad the problems actually were, or what was causing them. The Thief River Watershed Sediment Investigation (TRWSI) was an opportunity to diagnose the impact of hydrologic modification as well as other anthropogenic and natural factors influencing water quality in the Thief River watershed. It was funded by a Clean Water Partnership (CWP) grant that was awarded to the Red Lake Watershed District (RLWD) by the Minnesota Pollution Control Agency (MPCA). Intensive water quality monitoring and the development of a Soil and Water Assessment Tool (SWAT) model were used to more accurately assess conditions throughout the watershed. The watershed is heavily managed with more than 30 impoundments and many miles of channelized streams and man-made ditches. Some of the impoundments were built to address flooding concerns but most are operated primarily for wildlife habitat management. Because it is home to Agassiz National Wildlife Refuge and Thief Wildlife Management Area, the area is productive and important for waterfowl, shorebirds, and migrating birds. The watershed also features productive and important farmland. The Thief River flows to the Red Lake River, which is a drinking water source for the cities of Thief River (just downstream of the confluence), East Grand Forks, and Grand Forks. It most directly affects the Thief River Falls Reservoir and water supply. The Minnesota Department of Health has developed source water plans for Thief River Falls and East Grand Forks.

The project used sampling, continuous water quality monitoring, continuous stage monitoring, and water quality modeling to accomplish its goals. The project's partners were a large part of its success, whether they were helping with the CWP project directly or if they were conducting their own "piggyback" study.

This study involved investigative water quality monitoring at more than 11 sites throughout the watershed to verify the impairments. Flow and sediment monitoring was conducted in order to develop sediment budgets (FLUX modeling) for the impoundments. Water quality results were loaded in the Soil and Water Assessment Tool (SWAT) to model contributions from various sources, estimate pollutant loads and evaluate pollutant reduction strategies. Data was entered into the EPA STORET and the State of Minnesota's HYDSTRA continuous monitoring database. Specific and general project ideas for the improvement of water quality were identified. Sediment budgets from the SWAT modeling results give us an idea of how much sediment is being deposited in the impoundments. Sources pollutants (suspected and confirmed) of in the water shed were identified. Ideas for water quality improvement projects are also described in the final report.

Another goal of this project was the creation of a TMDL work plan. The MPCA has allocated money for the completion of a watershed-based TMDL and watershed assessment project. A work plan was developed as part of this project and it was submitted to the MPCA in January of 2010. The work done during this CWP project was one of the factors that helped increase the Thief River's priority for this funding. A comprehensive final report was written, published by the RLWD, and made available on the RLWD website (www.redlakewatershed.org).

Work Plan Review

I. Water quality monitoring
    a. Sampling
    b. Field measurements
    c. Equipment purchases
        i. HOBO Water Level Loggers
        ii. Eureka Manta logging multi-parameter sondes
II. Flow monitoring
    a. Flow measurements
    b. Sites
III. Data and information collection/analysis
IV. Development of a sediment budget
V. Water quality modeling
    a. SWAT
VI. Data analysis and assessment
    a. Review/assess the outcomes of the study
    b. Assess results
VII. Make recommendations
VIII. Report
    a. Write and review report
    b. Publish report
    c. Develop impaired water study work plan(s)

Acknowledgements

In addition to increasing the amount of attention paid to water quality in the Thief River Watershed, the TRWSI project also enhanced the amount of cooperation amongst local agencies for the purpose of studying water quality. The United States Fish and Wildlife Service (USFWS) was able to leverage money for a parallel water quality study that focused on inflows and outflows within the refuge. The USFWS partnered with the United States Geological Survey for much of the water quality and flow monitoring within the Refuge. A lot of the water quality sampling in the northern part of the watershed was accomplished through a subcontract with the Marshall County Water Planner, Jan Kaspari.

- Molly MacGregor, MPCA Basin Coordinator, for organizing initial meetings.
- Jan Kaspari, Marshall County water Planner, for her assistance with the monitoring effort.
- Lisa Newton, Marshall-Beltrami County SWCD, for helping Jan with sampling
- Rochelle Nustad, United States Geologic Survey
- Gregg Knutson, United States Fish and Wildlife Service

- Margaret Anderson, United States Fis h and Wildlife Service
- Northwest Regional Sustainable Development Partnership (provided funds for the purchase of a water quality monitoring sonde).
- Minnesota Department of Natural Resources (purchased a Eureka Manta sonde)
- Kristin Fritz, USFWS intern
- Kelly Kerfeld, USFWS intern
- Jim Courneya, MPCA Project Manager
- Dave Friedl, DNR
- All the people who attended the stakeholders' meetings
- Joel Huener, DNR, Thief Lake WMA, for providing a history of flow from the Thief Lake Dam.
- Stephanie Johnson and Houston Engineering, for the SWAT Model Development
- Nick Olson and Jim Blix of the RLWD, for collecting water level measurements

Background Information

The Thief River watershed covers 1090 square miles in northwest Minnesota. The Thief River is split into two major reaches. It begins at the outlet of Thief Lake and flows to Agassiz National Wildlife Refuge, where the river channel enters and supplies water to Agassiz Pool. The original channel parallels the western edge of the pool. Water is discharged from the pool via a radial gate/screw gate outlet and reenters the Thief River via Ditch 11. There also is a new structure that allows water to bypass the main area of the pool somewhat. It allows water that enters the pool from the north and flows along the inside of the dike to exit the pool at the southern extent of the western side of the dike and reenter the old channel of the Thief River. After leaving the Agassiz NWR area, the Thief River continues south to Thief River Falls, where it joins with the Red Lake River.

The main tributaries of the Thief River are the Moose River, Mud River, and a series of major ditch systems. The Moose River begins at the outlet of the Moose River Impoundment in the northeastern part of the watershed and flows west along the northern edge of the watershed to Thief Lake. Thief Lake is a shallow lake basin that was dredged for agriculture in the early 1900s, but was restored with the installation of a dam in the 1930s. It is the 15th largest lake in Minnesota.

The Mud River begins on the eastern edge of the watershed and flows west, through the town of Grygla, and eventually into Agassiz National Wildlife Refuge. Upstream of the town of Grygla, it resembles a ditch. Downstream of Grygla, it closely resembles a natural stream, despite the presence of a spoil bank along the north bank of the river.

Portions of the Moose River, Mud River, and Thief River have been channelized for the purpose of improving drainage for agriculture. These dredged reaches have been classified as public drainage systems. The Moose River upstream of Thief Lake and a several-mile reach of the Thief River downstream of Thief Lake are also known as the main branch of Judicial Ditch 21. The Mud River is also known as the main branch of JD 11. State Ditch 83 is a dredged reach of the Thief River that begins on the western edge of Agassiz NWR and ends downstream of the CR44 crossing, northeast of Thief River Falls. Other significant legal ditch systems that flow to the Thief River and its tributaries include:

- Branch A, JD21
- Marshall County Ditch 28
- Branch 1, JD 11
- Branch 200, JD11
- Marshall County Ditch 20
- Judicial Ditch 23
- Judicial Ditch 30

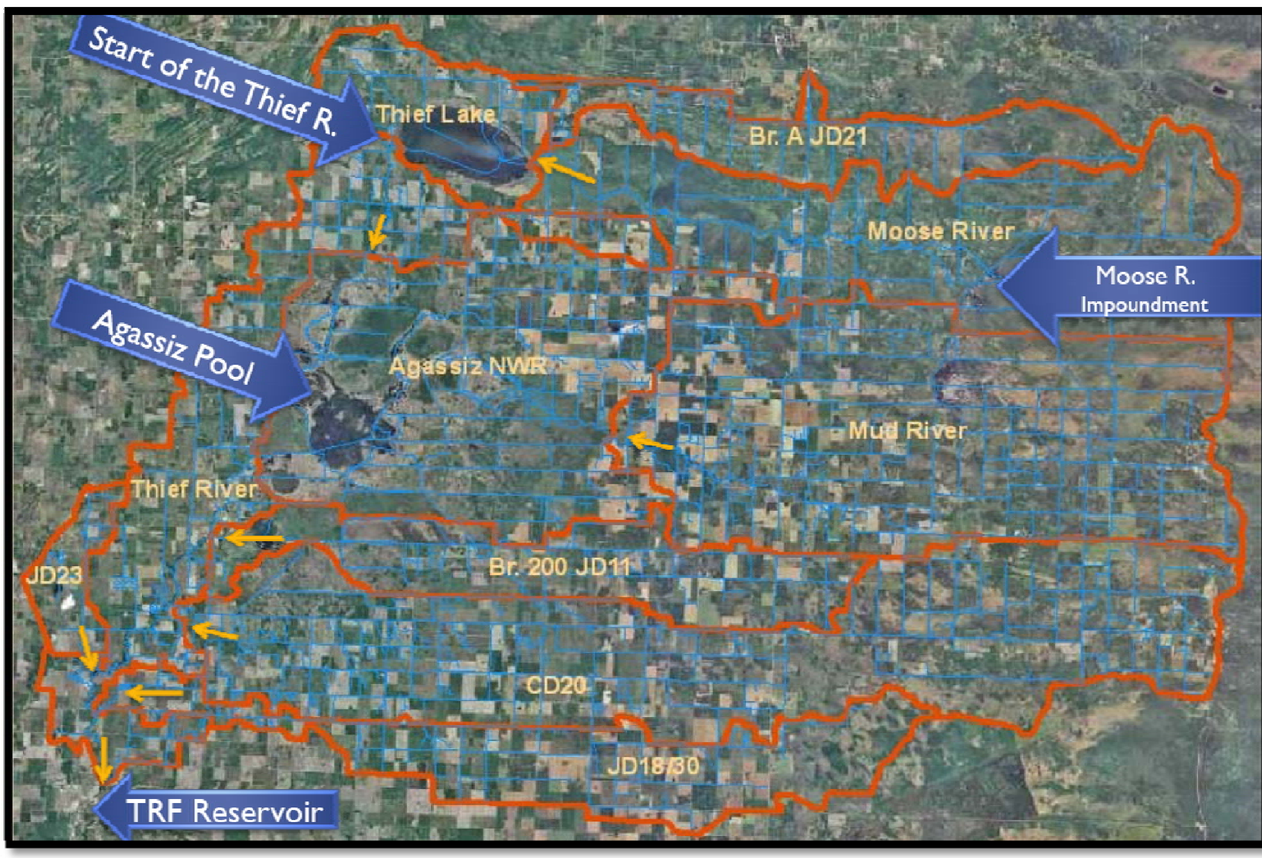


Figure 2. Some of the significant features of the Thief River watershed

The Thief River watershed is heavily managed with more than 30 impoundments and many miles of channelized streams and man-made ditches. Some of the impoundments were built to address flooding concerns but most are operated primarily for wildlife habitat management. The drainage-related hydrologic modification made farming possible within this area. Headlines in a 1909 edition of the Minneapolis Journal proclaim “Net-Work of Ditches and Laterals Reclaims Vast Area in Thief River Valley” (sic) and “THIEF RIVER BOTTOMS TO BECOME A GARDEN.”

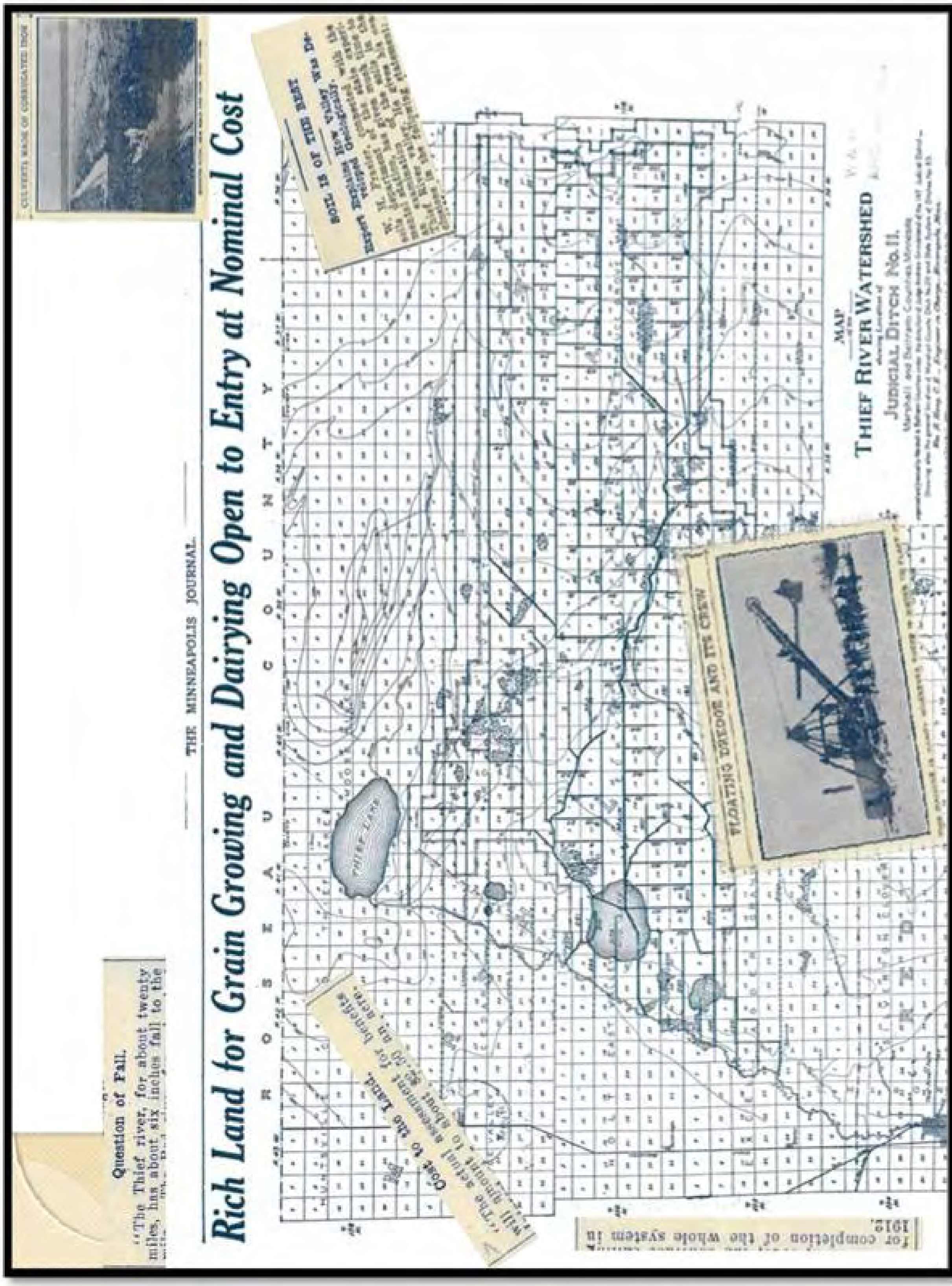


Figure 3. History of hydrologic modification

The Thief River lies within the Northern Minnesota Wetlands and Red River Valley ecoregions.

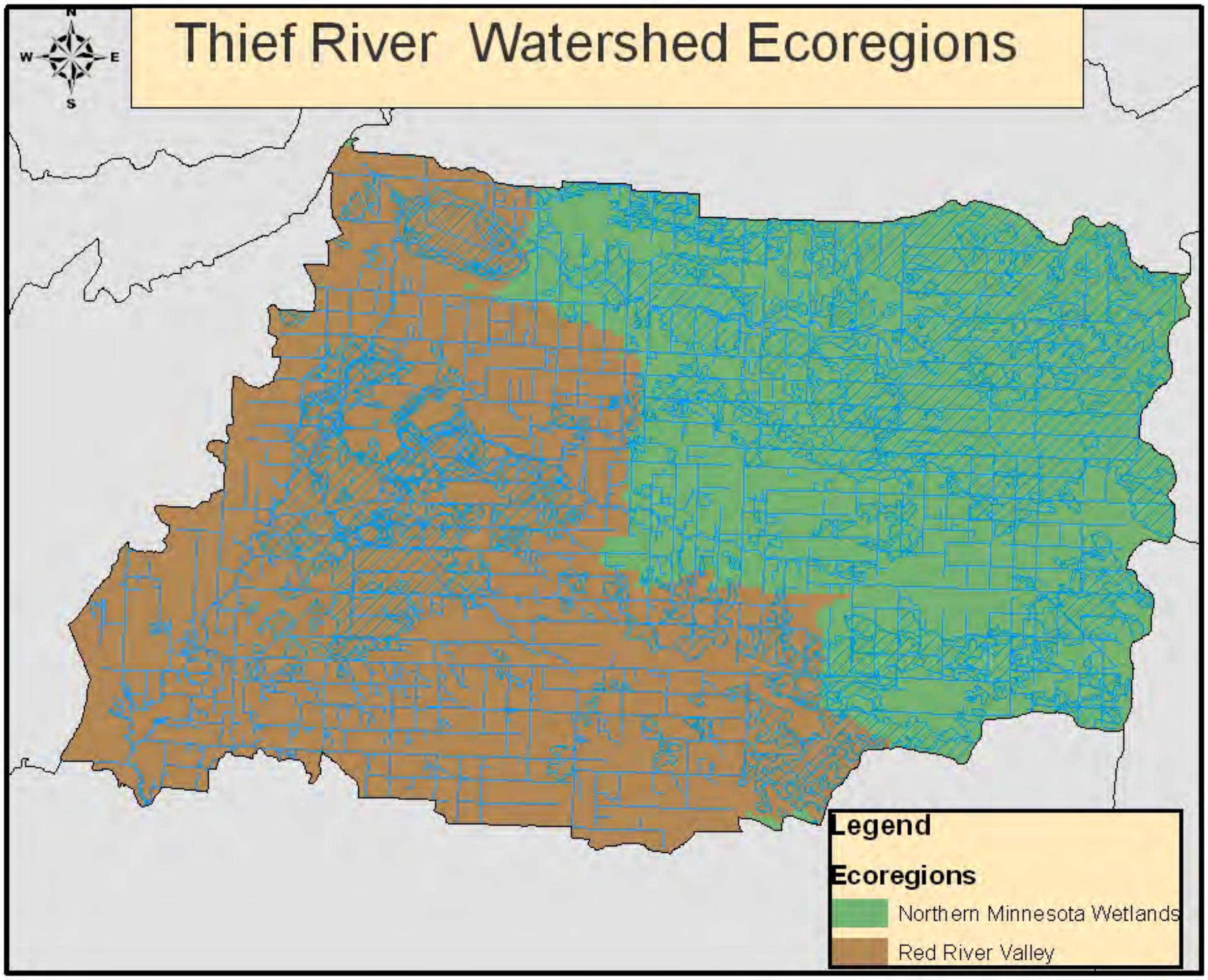
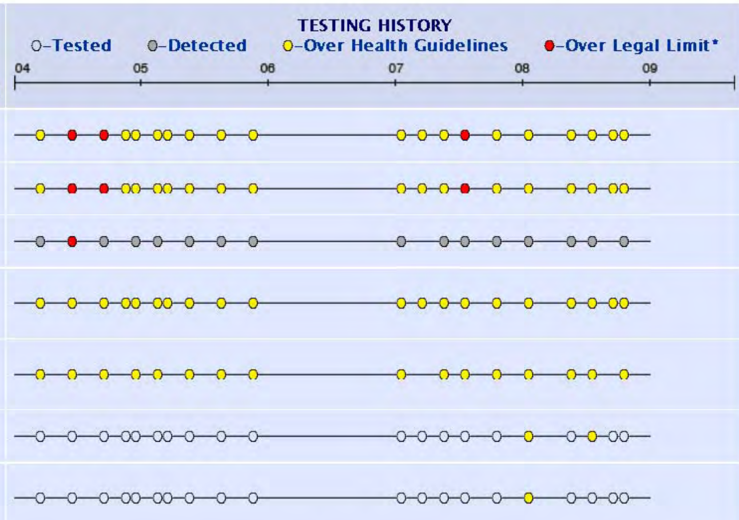


Figure 4. Thief River Watershed Ecoregions

The Thief River flows to the Red Lake River, which is a drinking water source for the cities of Thief River (just downstream of the confluence), East Grand Forks, and Grand Forks. It most directly affects the Thief River Falls Reservoir and water supply. The Minnesota Department of Health has developed source water plans for Thief River Falls and East Grand Forks. Spring runoff and storm event runoff brings high concentrations of sediment and organic matter down the Thief River and into the Thief River Falls Reservoir. This necessitates an increased level of water treatment for the city that causes the water to take on an offensive chlorine taste (like pool water). Increased organic contaminants necessitate a higher level of treatment that, in turn, creates higher concentrations of disinfection byproducts. One of the most worrisome categories is that of trihalomethanes. They are formed when chlorine or chloramine react with organic matter found in source water. They are genotoxic (DNA damaging) and carcinogenic. They have been linked to increased risk of birth defects, bladder cancer, liver problems, kidney problems, and central nervous system problems.

Contaminant	Average/ Maximum Result	Health Limit Exceeded	Legal Limit Exceeded
Chloroform	43 ppb 118 ppb	Yes 5.7 ppb	Yes 80 ppb
Total trihalomethanes (TTHMs)	46.88 ppb 121.7 ppb	Yes 9.8 ppb	Yes 80 ppb
Monochloroacetic acid	13.83 ppb 74.9 ppb	Yes 70 ppb	Yes 60 ppb
Bromodichloromethane	3.26 ppb 6.3 ppb	Yes MCLG: 0 ppb	No 80 ppb
Dichloroacetic acid	19.44 ppb 53 ppb	Yes MCLG: 0 ppb	No 60 ppb
Dibromochloromethane	0.2 ppb 3.2 ppb	Yes 0.4 ppb	No 80 ppb
Bromoform	0.43 ppb 8.5 ppb	Yes MCLG: 0 ppb	No 80 ppb



NOTE: Each dot in the above graph represents one month.
* Water utilities are noted as exceeding the legal limit if any test is above the maximum contaminant level (MCL). Most MCLs are based on annual averages so exceeding the MCL for one test does not necessarily indicate that the system is out of compliance.

Figure 5. City of Thief River Falls drinking water contaminants that are exceeding health guidelines. From the Environmental Working Group website.

- Link to the Thief River Falls Source Water Assessment:
  - http://mdh-agua.health.state.mn.us/swa/surfwaterFile/1570003.pdf
- Link to the East Grand Forks Source Water Assessment:
  - http://mdh-agua.health.state.mn.us/swa/surfwaterFile/1600004.pdf

Most of the soils in the Thief River watershed are poorly drained. Along the western edge of the watershed, there is a beach ridge from Glacial Lake Agassiz. This area has sandier, well-drained soils.

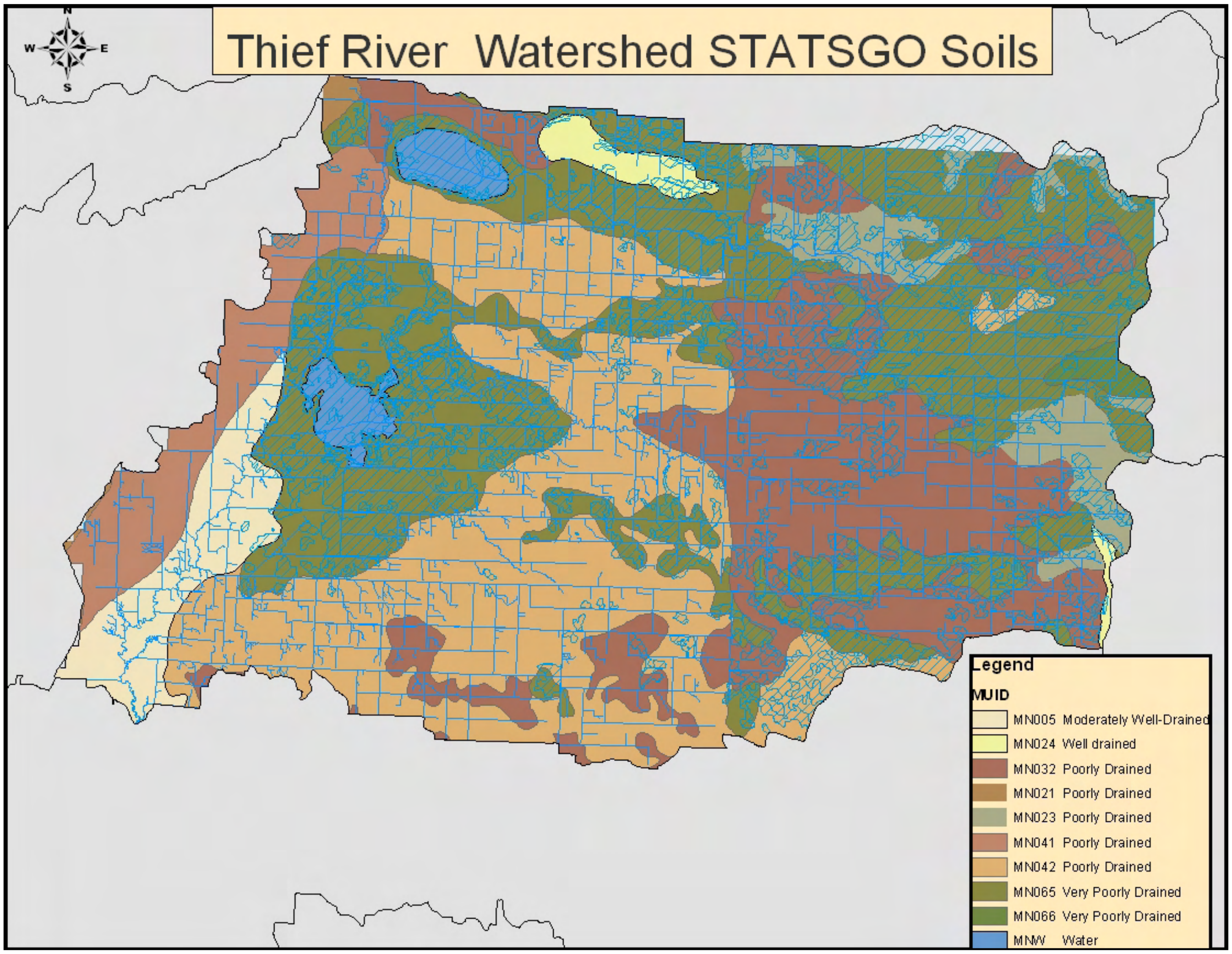


Figure 6. Thief River Watershed soil drainage properties

The Thief River has, particularly during runoff events, visibly poorer water quality than the Red Lake River. The Thief River has gotten most of the attention when discussing water quality in the Thief River Falls reservoir as it pertains to the City of Thief River Falls' water supply and sedimentation within the reservoir.

Figure 7. Sediment plumes from the Thief River at its confluence with the Red Lake River in Thief River Falls

Discharges from the larger pools have been shown, at times, to negatively influence water quality for the system (Red Lake Watershed District monitoring data). On the other hand, research conducted by Houston Engineering and the Pennington SWCD indicates that two-thirds of the sediment flowing into the Refuge's main pool is deposited there. A study by the NRCS found that 63% of the sediment yielded to streams in the Thief River Watershed comes from streambank and ditch bank erosion. The current long-term monitoring effort, although sufficient for identifying general problem areas, is insufficient (only 4 samples/year/site) to identify the causes of problems. More specific questions about the movement of sediment into and out of impoundments, contributions from agricultural ditches, current monitoring efforts (adequacy), channel erosion, and other issues have made this intensive study necessary.

This project has developed from discussion about water quality problems in the Thief River that have been found by the RLWD and Marshall County Water Plan water quality monitoring programs. The monitoring that had been done prior to the study included:

- Twenty years of quarterly monitoring by the RLWD
- Three years of monthly monitoring by the Marshall County Water Plan
- Investigative water quality monitoring by the RLWD
- Monitoring done by the Grygla River Watch team.

This discussion initially took place at Marshall County Water Plan meetings. Steps to address soil erosion, sedimentation, and other water quality issues were incorporated into the Marshall County Water Plan. The issues identified in this planning process were:

1. Streambank failure/ditch bank slumping in the watershed
2. Sediment in ditches/streams
3. Water quality impairments
4. Flooding – upstream? Downstream?
5. Drinking water at Thief River
6. Sediment in Thief River Reservoir.

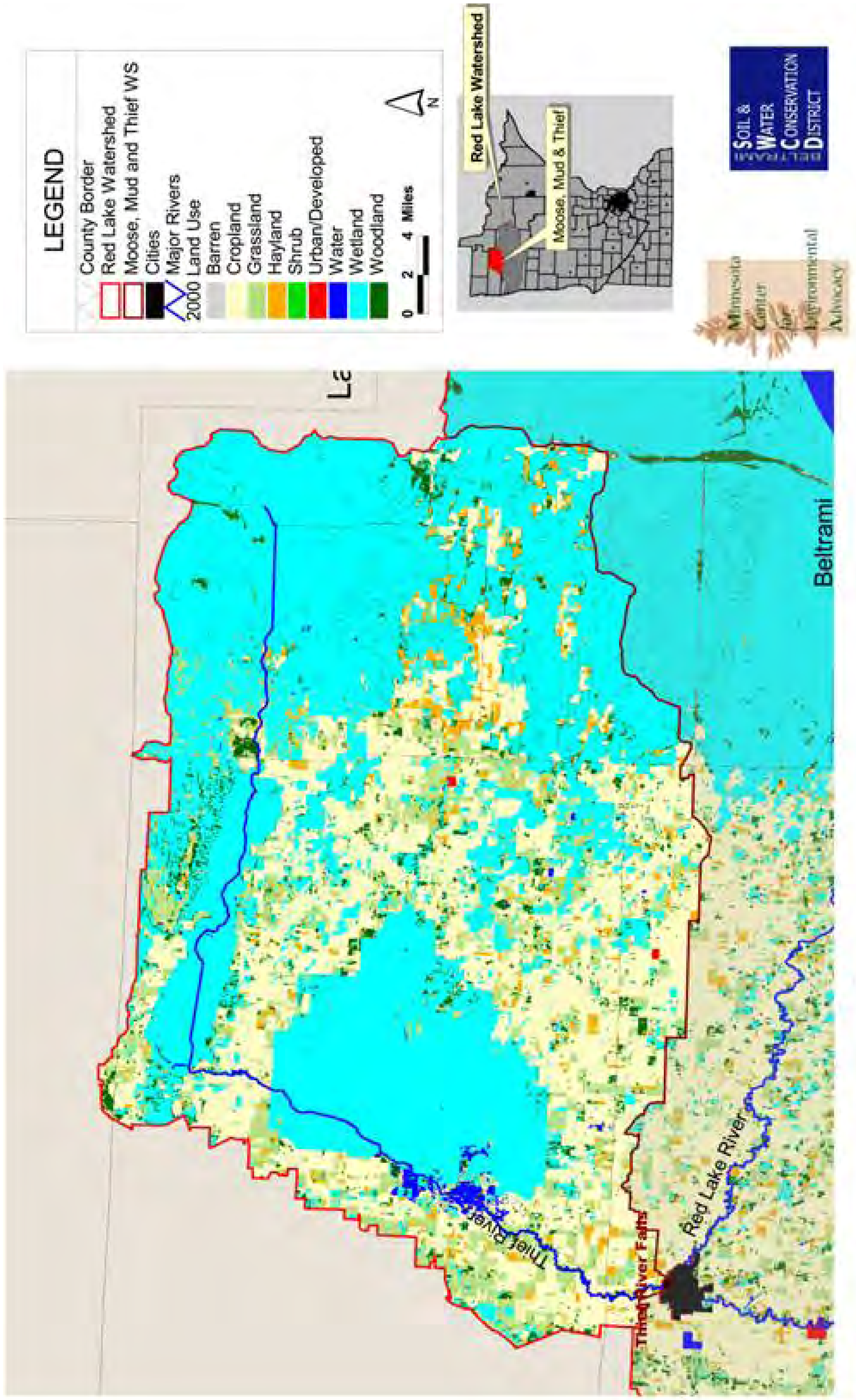


Figure 8. Thief River Subwatershed Existing Resources- 2000 Land Use Land Cover

The Thief River can be split into 71 minor subwatersheds. This is too fine of a scale for the scope of the monitoring planned for this project. Intermittent streams and ditches should be grouped into larger subwatersheds. There are some ditch systems that can flow throughout most of the open-water season. These can be treated as separate assessment reaches. The Thief River watershed/flow network can be split into twelve main reaches, or subwatersheds, that have perennial/near-perennial flow:

1. Thief Lake
2. Moose River
3. Branch A of Judicial Ditch 21
4. Marshall County Ditch 28
5. Thief River from Thief Lake to Agassiz National Wildlife Refuge
6. Agassiz National Wildlife Refuge
7. Mud River
8. Branch 200 of Judicial Ditch 11
9. Marshall County Ditch 20
10. Thief River from Agassiz national wildlife Refuge to the Red Lake River
11. Judicial Ditch 23
12. Judicial Ditch 30/Judicial Ditch 18 drainage system.

Monitoring sites were chosen for the purposes of assessment at "pour points" and the bracketing of major watershed features. Thief Lake and Agassiz NWR were bracketed to monitor water quality coming into the reservoirs and water quality flowing out of the reservoirs. Two significant ditches were chosen for characterization of inputs from ditch systems in the watershed. Branch 200 of Judicial Ditch 11 and Marshall County Ditch 20 were monitored and their confluences with the Thief River were bracketed. The Moose River was monitored further upstream than what would be ideal because of the ponded state of the river at Highway 89 near Thief Lake. Flow rating curve development is hindered by backwater, so the main Moose Rive monitoring site for this study was chosen at the Highway 54 crossing. That site was far enough upstream to avoid the backwater effect. The Mud River was monitored at the Highway 89 crossing, shortly before it enters Agassiz NWR.

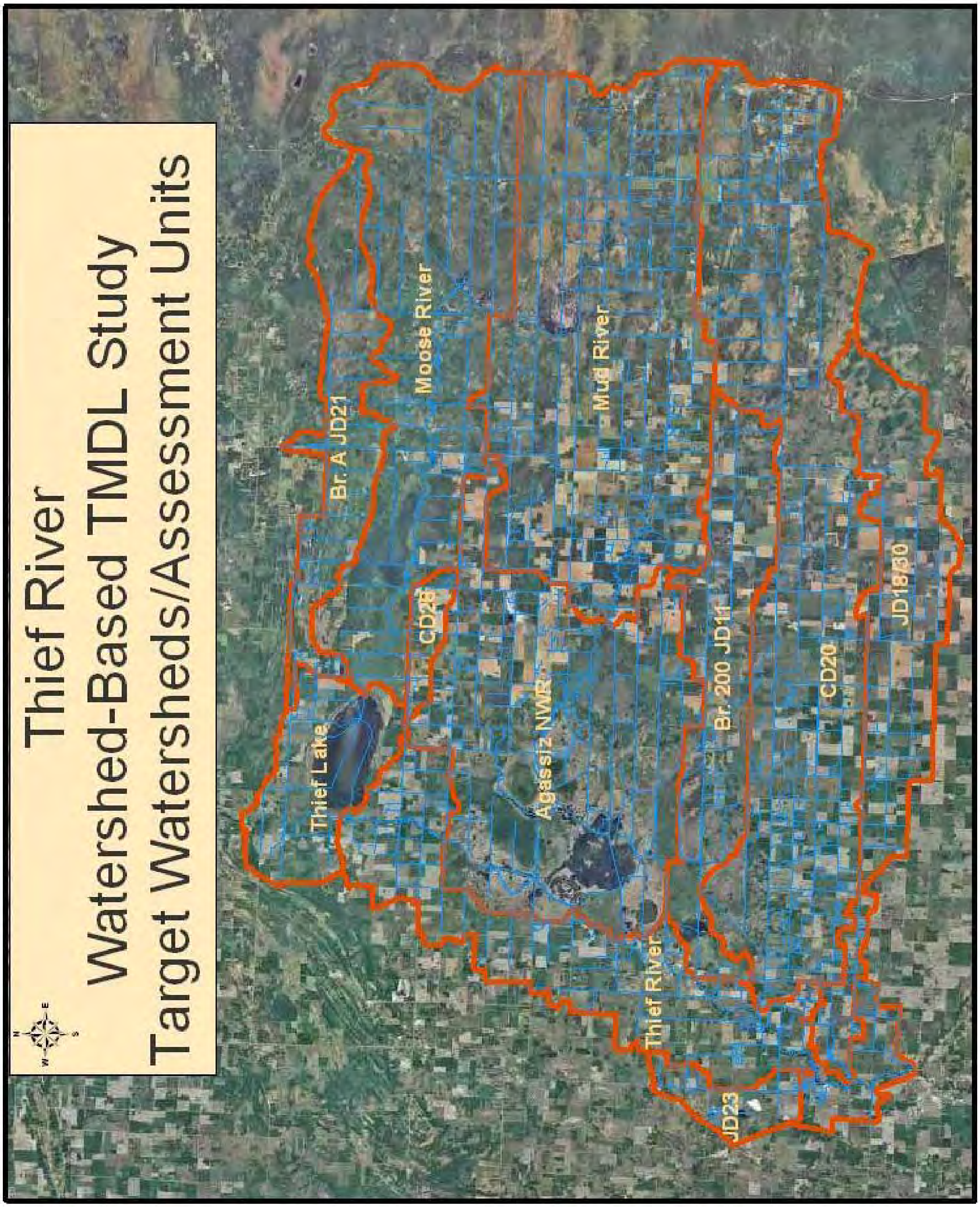


Figure 9. Sub-basins target as assessment units for the watershed-based TMDL study

Equipment Purchases

The RLWD purchased five Eureka Manta multi-parameter sondes for deployment at strategic locations for this study. These sondes provided a continuous (one reading every 15 or 30 minutes, depending on the site's data needs) water quality readings. They were equipped with sensors that measured dissolved oxygen (optical), turbidity, temperature, pH, specific conductivity, and water level. Onset HOBO water level loggers were purchased for the other six sites. After experiencing reliability issues with the Eureka Manta water level sensors, additional HOBO water level loggers were purchased and installed alongside the Mantas. Other monitoring equipment and supplies, such as batteries and calibration standards, were also needed for the completion of the project.

Equipment Calibration and Maintenance

Each Eureka Manta multi-parameter sonde was deployed in two-week periods throughout the open-water monitoring season. After each deployment period, the Mantas were retrieved from the field and brought to the RLWD lab for cleaning and maintenance. While the sonde and its sensors are deployed, they experience a drift in accuracy due to fouling and a drift in accuracy due to electronic calibration drift. Side-by-side readings in a bucket of stream water are taken before and after each step of the cleaning and calibration process with the deployed sonde and a portable sonde. The portable sonde acts as a "control" and the difference in the deployed sondes readings, relative to the change in the "control" sonde's readings from before to after each step is used as the "drift."

Throughout the project, the RLWD, USGS, and USFWS staff worked together to refine the methods used for the continuous monitoring effort. Our methods are closely based upon standard operating procedures developed by the USGS and British Columbia Ministry of Environment. We worked around equipment problems, glitches, and quirks. USFWS seasonal employees and interns did a lot of the work for the Agassiz National Wildlife Refuge Water Quality Study's continuous monitoring. Because of the nearly-annual changeover in seasonal staff, an outline of procedures outline was created for the cleaning and calibration process:

A. Calibrate sondes once every two weeks.
B. Remove half of the sondes at a time. Removing just a few Mantas, downloading data, cleaning, calibration, and replacing the Mantas will be a full day's work. The sooner the sondes are returned to deployment, the smaller the gap in data collection. *However, it is important not to take shortcuts in the cleaning and calibration process.*
C. Instructions for Manta removal
    1. Collect a full set of field measurements prior to removing the deployed Manta.

The Mantas take measurements once every 15-30 minutes. If the time is near a quarter-hour or half-hour mark (depending on the site), leave the deployed Manta in place for a few minutes for it to collect one last set of measurements. These paired sets of deployed and portable Manta readings can be useful when working the record.

2. Grab a storage cup and remove the Manta from the deployment tube.
3. When removing sonde, avoid cleaning of the sensors and put a very minimal amount (about a teaspoon) of water in the calibration cup before transporting the sonde back to the RLWD office. It just needs enough moisture to keep things moist. The sensors will be cleaned back at the lab and we want to see how the readings change before and after cleaning.
4. Replace the probe guard with the storage cup
5. Unhook the Manta from the suspension cable
6. It is ok to remove the grime and dirt on the body of the sonde before putting it into your vehicle. Make sure to rinse off the top of the sonde around the switch.
7. Back at the vehicle; use a paper towel to wipe moisture and dirt away from the switch. Turn the switch off.
8. In the field data sheet, make notes for this site visit. Record the fact that the sonde was removed, the sonde ID, and the time that it was removed.

Manta 2 Off

D. Calibration at the RLWD lab:

1. Make sure that the bubbler is running in a bucket of clean water (normally next to the far wall of the lab in the nook between the counter and the cabinet).
2. Make sure you have collected a fresh bucket of stream water. We have been using an orange water cooler that is kept under the sink when not in use. The Boy Scout Park by the 3rd Street crossing of the Red Lake River in Thief River Falls has docks and is a convenient and safe place to collect some water from the river.
3. Perform a calibration check on the portable Manta. Calibrate if needed.
4. Place the portable Manta in the bucket of stream water and turn it on. You will probably want to connect the Amphibian hand pad to a charger to conserve battery power.
5. To begin working on a deployed Manta, first remove the plug/switch. Check the connection where plug goes into Eureka. If the plug or the socket is dirty, wipe it clean with a Kim-wipe. Check o-rings on the plug to make sure they are in good shape. Wash the plug with a toothbrush and mild soap if needed. If necessary, replace the o-rings and apply some silicon grease. Be mindful that excess grease can collect contaminants.
6. Connect the deployed Manta to the computer using the communication cable.

An external power adapter is used to solve computer-to-sonde connection problems caused by power surges or power loss through a serial cable extension.

7. Open the Multiprobe Manager (or Manta 2 manager) program on the computer.
    i. The LED light inside the Manta will start flashing green at a 1-sec interval. If it starts flashing green and goes back to flashing amber, there is something wrong with the connection. There is a serial-to-serial extension that makes it easier to bring the Manta across the room to the sink. It works with most of the Mantas, but there are a few Mantas between the RLWD and ANWR that don't like to connect when the extension is used (LED light will alternate between green and amber as it keeps trying to connect and failing). These Mantas will connect if the serial extension cable isn't used.
8. Allow the program to complete the download of data before doing anything with the sonde.
    i. If the download freezes, close and restart the software.
    ii. Try to avoid moving the cord while downloading—this can cause the data file to have erroneous data in it.
    iii. While it's downloading, you can work on other things. Fill a sink with soapy water. Start writing the log book entries.
9. When the download is finished, save the data in the default folder with a filename that includes:
    i. Name the file "site_YYYYMMDD". For example: A1_20091130.
    ii. Do not put spaces in the file name)
10. Record the file name and sonde serial number on calibration log sheet.
11. After downloading, check the data file—does it have data in it for the dates you had the sonde deployed? Do the data values from the last reading look reasonable compared to the field readings you just took?
12. Click the save button again and make sure the file does in fact exist in the folder.
    i. This may seem redundant, but it has prevented lost data several times.
13. Save the file to a flash drive as a backup.
14. After the data double-check, click the delete data button to clear the Manta's memory (or it will take twice as long to download the next time it is hooked up to the computer).
15. Remove the storage cup and attach the probe guard.
16. Put the sonde in the bucket of stream water next to the portable Manta and give both sondes time to stabilize.
    i. Go to the real-time data screen. The Mantas are set up to take measurements once every couple of seconds when connected to the computer.
    ii. You can view a few time-series charts of the portable sonde's readings to see if it is stable or not.
    iii. pH will probably not completely stabilize as the chart of those readings resembles a zigzag line.
17. Record side-by-side readings in the Before Calibration columns for both sondes and each parameter (ODO, Temp, pH, Turbidity, Sp. Cond.).
18. Remove the deployed Manta and clean it thoroughly, yet gently, with soapy water.
19. Clean the storage cup thoroughly as well and use it to rinse the sonde several times with tap water to remove soap suds and any other loose pieces of crud that might be left in and around the probes.
    i. Put tap water in the cup, attach it to the sondes, and swish. Always swish, never shake.
20. Put the probe guard back on and put the Manta back in the bucket of stream water next to the portable Manta.

21. When both sondes have stabilized, record "After Cleaning/Pre-Calibration" readings in the appropriate columns for both sondes and all 5 parameters.
22. Calculate the differences between the deployed and portable sondes' readings and compare to the USGS Calibration Criteria table that is posted near the computer.
23. Perform each calibration that is needed according to the instructions on pages 15-26 of Appendix A in the Standard Operating Procedures for Water Quality Monitoring in the Red River Watershed.
    i. The tables needed for the dissolved oxygen calibration are posted inside the left cabinet door above the lab computer.
    ii. Keep track of calibration steps in the calibration log sheet.
    iii. If you receive a warning message during or after the pH calibration, this most likely means that the pH electrolyte will need to be changed. Make a note in the calibration log sheet that the pH electrolyte will need to be changed <u>prior</u> to the next calibration. Follow the instruction in the Eureka Manta manual or ask for assistance. The pH electrolyte solution should be changed once each month. Change pH electrolyte before doing a calibration.
    iv. Make sure sonde is recording DO in **mg/L** and Specific conductivity (SC) in **µS/cm**. Please make sure turbidity is being recorded in the column before depth.
    v. The turbidity
24. After calibrations, return the deployed Manta to the bucket of stream water once more to record post-calibration readings. These are only necessary for the parameters that were calibrated.
    i. At the end of the year, the pre/post cleaning and pre/post calibration readings will be used to calculate a "fouling error" and a "calibration drift error" that will be used to make corrections to each deployment's data set.
25. Make sure that the logging profile has been set to record readings once every 15 minutes.
26. Sync the time on the sonde with the time on the computer.
27. Remove the sonde from the water and disconnect it from the computer.
    i. Don't disconnect/reconnect a Manta while the Multiprobe Manager program is running.
    ii. Between Mantas, completely close out of the Multiprobe Manager program after finishing with a Manta and before starting the next one. Connect the Manta before opening the software program.
    iii. Connect Manta ► Open Program ► Close Program ► Disconnect Manta
28. Rinse the probes and replace the storage cup (with about a teaspoon of tap water inside it).
29. Replace batteries.
30. Make sure the plug/switch is clean and that there is silicon grease on the o-rings. Add some grease if you think it might be needed.
31. Make sure the switch is in the off position for now.

E. Redeploy sondes the same day.
    1. Take field readings when sonde is redeployed.
    2. **MAKE SURE THE PLUG IS TURNED TO "ON"**

Manta 2 On

BEFORE DEPLOYING IN THE STREAM.

  i. O = Off
  ii. | = On
  iii. The Manta 2 sondes are turned on and off by flipping the top plate over. You don't want to be able to see the silver magnet when you are deploying the Manta 2. If the magnet is facing out, that means that the probe is turned off and it won't log any data.

3. Connect the Manta securely to the cable.
4. Slowly lower the Manta into the deployment pipe.
5. Along with any notes from the field measurements,
   i. Note that the Manta was deployed,
   ii. Note the Sonde ID, and
   iii. Note the time of deployment.

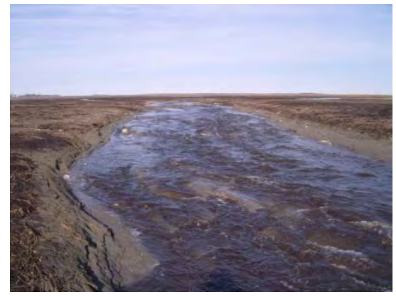
Documentation is extremely important! Please make sure Field Data Sheet and Calibration Log is completed each time an inspection or calibration is done. If something unusual is noticed, make note of it.

Water Quality Monitoring

Water quality monitoring for this project began in the spring of 2007 and ended at the onset of winter in late 2009. The monitoring effort included monthly sampling by the Marshall County Water Planner and the RLWD and the deployment of Eureka Manta multi-probe sondes. Here are some of the highlights:

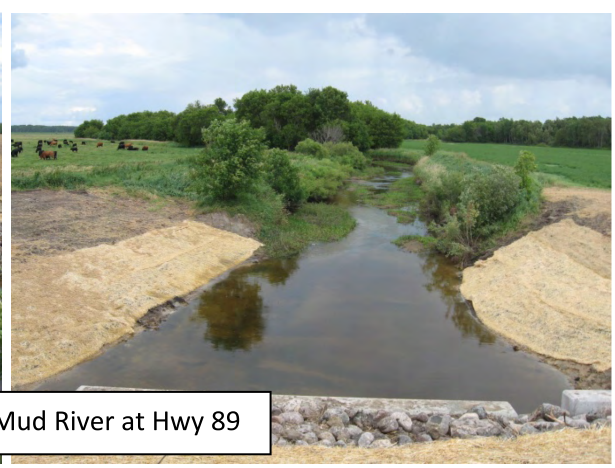
- High E. coli concentrations were found in the Thief River between Agassiz NWR and Thief River Falls throughout the study.
- Northern pike were often spotted in CD20.
- White suckers and freshwater drums were common sights.
- Heavy spring runoff into and within a newly improved and unvegetated ditch along the east side of CSAH 54 brought a sustained plume of sediment into the Moose River at the upstream end of the southern CSAH 54 culvert.
- Eureka Midge dissolved oxygen loggers and In-Situ TROLL 9500 multi-probe sondes were used to collect late-summer dissolved oxygen data from the Moose River in 2009.
- In 2009, the outlet structure of Farmes Pool, which outlets into Ditch 200, needed repair. The pool was drawn down to allow for the work to be done. Water was bypassed through a channel cut through the gravel road. This created a spike in flow and turbidity downstream. The increased flow during the drawdown also brought fish upstream. When flow went back down to normal, many of these fish were trapped in the ditch. Northern pike, many freshwater drum, and some walleyes were spotted in the ditch.
- The United States Fish and Wildlife Service was able to secure a large amount of funding throughout the course of this project, including 2010, to conduct a similar study that focuses more closely on water quality at the inlets and outlets of their pool systems. The contracted with the United States Geological Survey for their monitoring. RLWD, USFWS, and USGS staff worked together to plan the monitoring efforts and methods at sites surrounding Agassiz NWR.

- In the late fall of 2009, the USFWS opened the radial gates outlet of Agassiz Pool for an extended draw-down period. The turbidity was very high in the Thief River downstream of there for an extended period of time. The USGS also continued to collect samples during the continued drawdown of Agassiz Pool. There was extensive gully formation, sloughing, and erosion within the pool along the old drainage ditch that runs down the pool's center. A thick layer of organic sediment was deposited on deposition areas downstream.



- On April 4th of 2008, RLWD staff discovered a green discharge from a ditch near the CR7 (Agassiz Headquarters Road) crossing of the Thief River (SD83). This discharge also had a strong odor. The turbidity of this water was very high (99 NTU). There wasn't supposed to be any discharge from Parkers Pool into this ditch at the time, so this may have been water that was sitting somewhere along the ditch over the winter.

- The bridges over the Mud River and Moose River along Hwy 89 were replaced with box culverts in mid-summer, 2009. So, the monitoring at these sites was interrupted for the months of June and July of that year. For the long run, however, the box culverts that replaced the bridges provide much safer monitoring sites. Monitoring staff are able to park and work out of the path of traffic on Highway 89.



New Culverts for the Mud River at Hwy 89

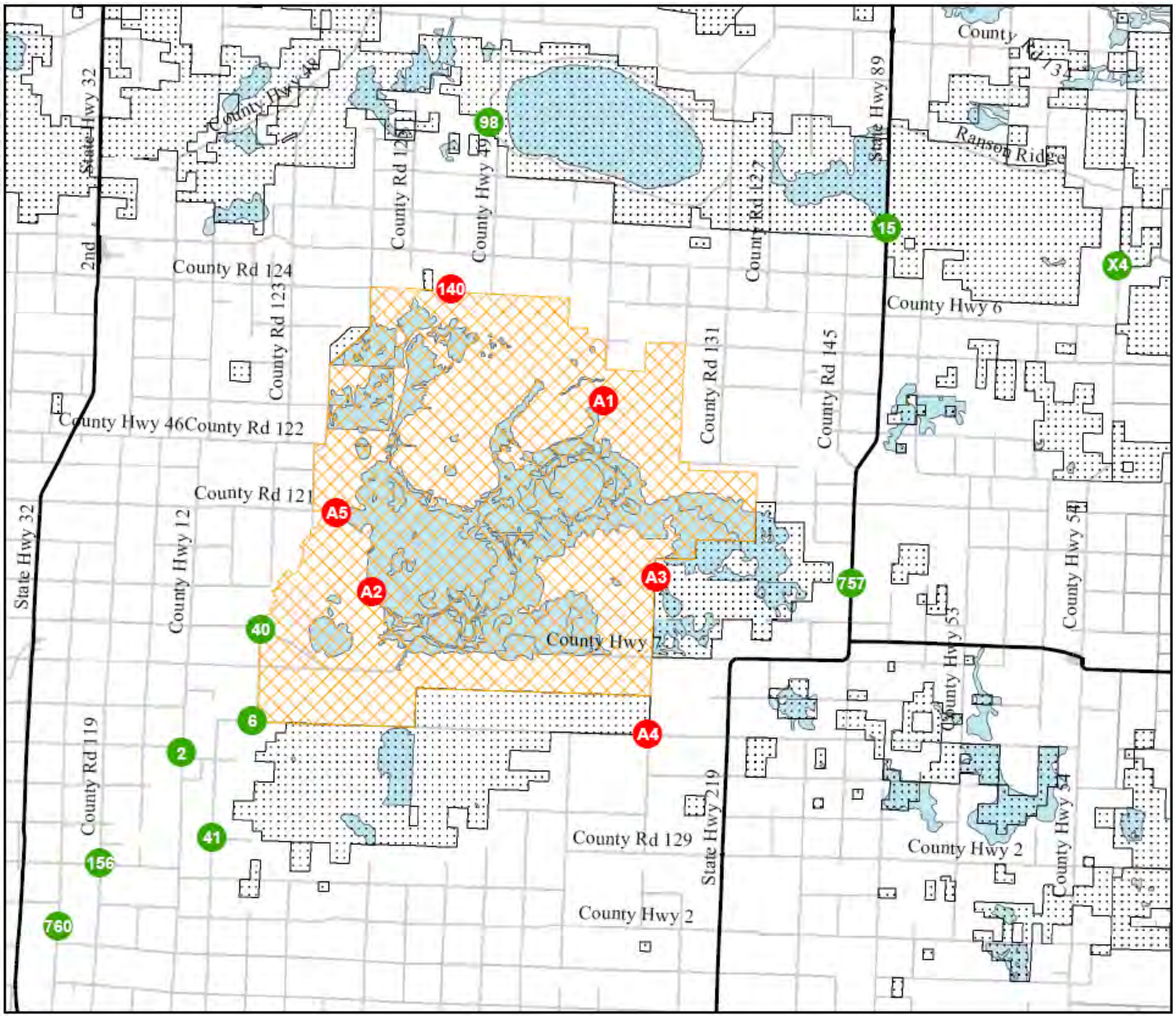


Figure 10. Thief River watershed and Agassiz National Wildlife Refuge monitoring site locations

Parameters

- Original study parameters
  - Total phosphorus, total suspended solids, ammonia nitrogen, E. coli.
- USGS sampling parameters
  - Total phosphorus, orthophosphorus, ammonia nitrogen, total Kjeldahl nitrogen, dissolved nitrite, dissolved nitrates & nitrites

The USGS is collecting both suspended sediment concentration and total suspended solids samples at each of their site visits. These are basically two different ways to measure the same thing. A total suspended solids sample is taken at one point within the water column. There is an assumption that the concentration at the sampling point is representative of the average concentration across the entire cross-section of the water column. The suspended sediment concentration uses a vertically-integrated sampling method that collects water from different rates of flow. The rate at which water is drawn into the sampling bottle changes with velocity. The dual sampling is being done to determine the correlation between the two types of samples. The TSS samples collected by the USGS were analyzed by the RLWD using the services of RMB Environmental Laboratories. The two types of samples will be compared when USGS data becomes available.

Data Inventory and STORET submittals

Data collected for this project was entered into the RLWD water quality database and submitted it to the MPCA for STORET entry each year near the end of October or in early November. Data reviews were conducted each year by comparing digital data records with original field sheets and lab reports prior to final submittal to STORET.

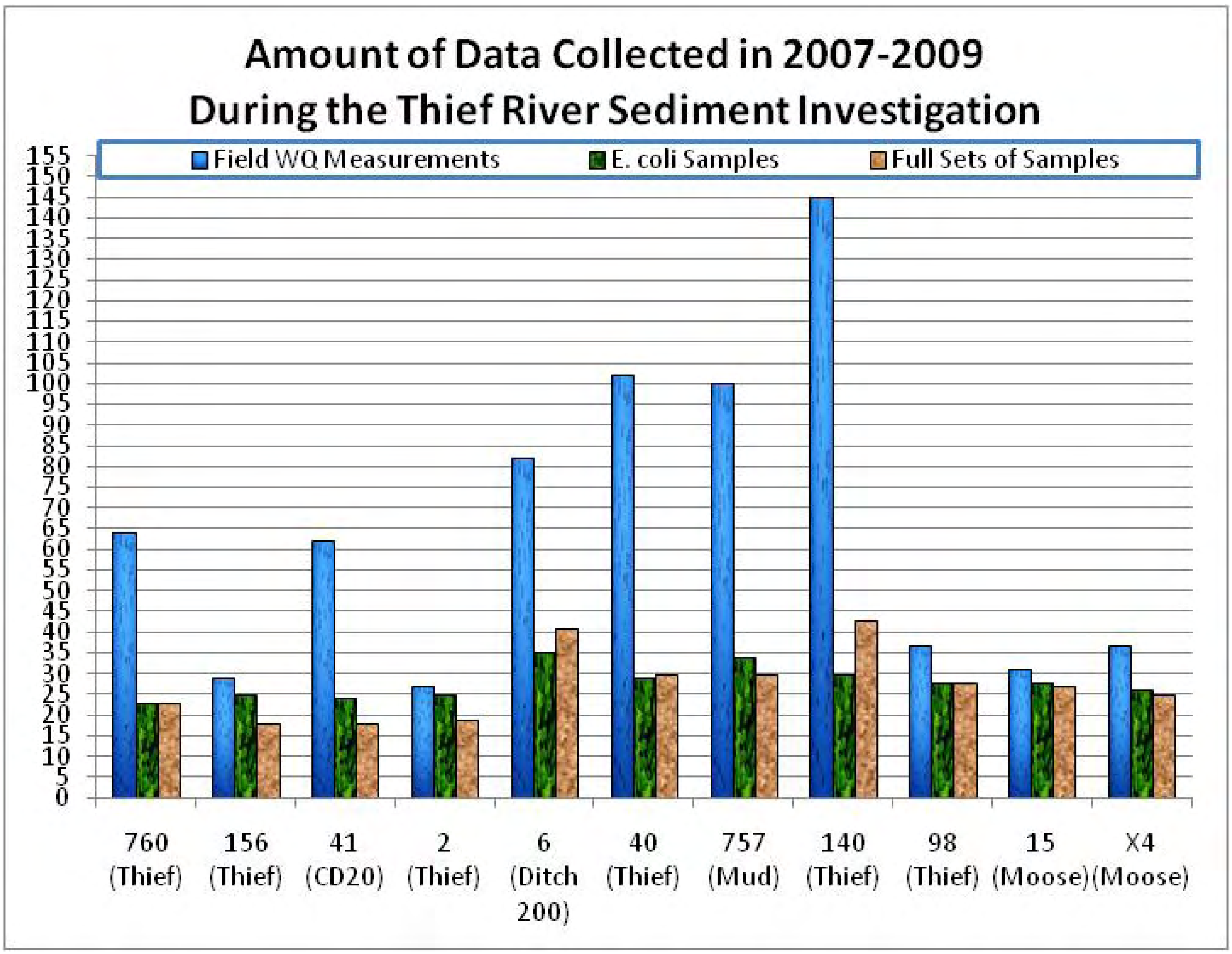


Figure 11. Amount of discrete water quality data that was collected by the RLWD

In 2007, 268 sets of measurements collected by USFWS staff, 104 sets of measurements collected by the RLWD, and 42 sets of measurements collected by the Marshall County Water Planner were submitted to STORET. 2008 Data was entered and submitted to STORET. Around 433 sets of measurements were submitted from monitoring completed by the RLWD, Marshall County Water Planner, and USFWS. In

2009, 387 sets of sample results and/or sets of field measurements were sent to STORET from the RLWD along with 55 sets of measurements and sample results from the Marshall County Water Planner.

Continuous water quality data was compiled, prepared, and submitted to the MPCA so that it can be stored in the State's HYDSTRA database. The MPCA will be able to access this data for their Statewide water quality assessments.

Continuous Monitoring

Continuous water level, turbidity, optical dissolved oxygen, pH, conductivity, and temperature data has been collected from 5 sites monitored by the RLWD and the Marshall County Water Planner, as well as 6 sites monitored by the USFWS for three consecutive years. Continuous stage data has been collected at 4 other sites monitored by the RLWD and Marshall County. Field measurements of turbidity, dissolved oxygen, pH, temperature, conductivity, and stage were collected during site visits (whether sampling or retrieving equipment). The sondes collected data at 15 (for the USGS) or 30 (for the RLWD) minute intervals, dependent upon where they were deployed. In 2007, the RLWD completed construction and moved into a new office building. This new building included a laboratory that could be used for calibrating, cleaning, and storing water quality equipment.

This project pioneered the use of continuous water quality monitoring in the area. Some continuous monitoring had been done by the RLWD prior to this study, but the methods were refined and the amount of expertise was increased significantly. RLWD, USGS, and USFWS staff worked together to plan monitoring efforts, schedules, and methods. Laboratory protocols for cleaning and calibration of equipment were established so that calibration and fouling drift corrections could be calculated and applied. The RLWD purchased Aquarius software in 2009 that is used for compiling data, adjusting it using calibration and fouling drift values, and trimming outlier readings.

While there is undoubtedly room for improvement, a successful method of sonde deployment evolved during this study. Six inch PVC pipes are attached at an angle to two fence posts within the stream. The PVC pipes are perforated at the lower end to allow water to flow through past the sensors while still providing some protection. The sonde is tethered to an I-Bolt located near the top of the pipe. This works better than tethering it directly to the cap. Sonde removal is easier when the cap is always removable in case the sonde happens to get partially frozen in the pipe at the end of the monitoring season. Warm water can then be used to loosen the ice inside the pipe if necessary. The angled installation works better than a vertical installation because it is less obtrusive to flow and doesn’t contribute to debris jams. These deployments could be improved by extending the length of the pipe up the streambank to allow for retrieval and installation at higher flows.

High flows were an obstacle to the process of sonde maintenance and deployment. The continuous monitoring effort wasn’t as complete in 2009 as it had been in other years. The high flows prevented access to deployment tubes. Bridge replacement at the Mud River continuous monitoring site meant equipment needed to be removed from that site for the months of June and July of 2009. During high flows, extra spot measurements of stage and water quality were collected at the Thief River Study monitoring sites.

Some additional HOBO water level loggers were purchased to get a better record of water levels than what the Eureka Mantas provide.

In January 2008, Eureka Manta continuous water quality monitoring equipment that had problems (mostly the pH and depth probes) were shipped to Eureka Environmental Engineering for repair.

In 2009, Manta water quality loggers couldn't be installed in the Thief River until water levels went down far enough to allow access to deployment pipes in July.

Continuous water quality monitoring was being done for three concurrent studies in 2007-2009. The monitoring equipment used up a lot of batteries. To ease our consciences about this generation of battery waste, the RLWD began collecting the batteries for recycling. The RLWD uses the Big Green Box battery recycling service.

During the study, Mantas were deployed at the following sites:

- Thief River at Stream gauge 140
    - Managed by the USGS and USFWS
- Thief River at Stream Gauge 40.
    - Managed by the RLWD
- Thief River at USGS Gauge 05076000
    - Managed by the RLWD
- CD20 at Stream Gauge 41
    - Managed by the RLWD
- Mud River at USGS Gauging Site 05075700
    - Managed by the RLWD
- A1 – Branch 1 of JD 11 inflow to Agassiz NWR
    - Managed by the USGS and USFWS
- A2 – JD11 at the Agassiz Pool radial gates outlet
    - Managed by the USGS and USFWS
- A3 – JD11 above Agassiz Pool
    - Managed by the USGS and USFWS
- A4 – Branch 200 of JD 11 upstream of Farmes Pool at the eastern edge of Elm Lake WMA
    - Managed by the USGS and USFWS
- A5 – New, northwest outlet of Agassiz Pool
    - Managed by the USGS and USFWS


Figure 12. A2 Eureka Manta Multi-parameter sonde and HOBO Water Level Logger pipes.


Figure 13. A5 outlet (new Thief River/SD83 outlet structure).

Water Quality Sampling

Water quality samples were collected at all the study's monitoring sites. Samples were mostly collected on a monthly interval. Some additional samples were collected in 2009 with the goal of meeting the MPCA's minimum data requirements for water quality assessment. Jan Kaspari, the Marshall County Water Planner and Lisa Newton from the Marshall-Beltrami SWCD worked together to collect samples at the northern sites under a sub-contract agreement with the RLWD. Corey Hanson, the Red Lake Watershed District Water Quality Coordinator, collected samples at the southern sites. The data will be used to assess water quality at the sites, create a TSS/turbidity relationship, calibrate the SWAT model, and more.

Investigative Sampling

A new impairment for E. coli was discovered in the Mud River at Hwy 89 west of the town of Grygla. Several potential sources of E. coli were identified between Hwy 54 (in Grygla) and Hwy 89. The town of Grygla's wastewater lagoons, if discharging, would discharge to the Mud River. There also are some livestock operations along the river. A longitudinal survey of E. coli concentrations was collected along the Mud River between Highway 89 and Highway 54 on June 4th, August 4th, and August 20th in 2009. These dates represented different flow levels. At the Hwy 89 monitoring site, the flow was 36.7 CFS on June 4th, 18.4 CFS on August 4th, and 59 CFS on August 20th. The August 20th sampling followed a recent rainstorm and had relatively high flow for that time of the year.

In the August samples, the E. coli concentrations were high on the east (upstream) side of Grygla, so that indicates that there are more potential sources upstream that should be investigated. E. coli concentrations were high throughout the sampled reach during high flows. The increases and decreases during the higher flows (August 20th) are all less than the average relative percent difference between duplicate E. coli samples, so it is hard to confirm sources based on that data.

The August 4th samples paint a clearer picture. There are two livestock operations in which cattle appear to be accessing the river. The operation downstream of CR53 apparently has had more of an effect on the stability of the river than the E. coli concentrations. Concentrations decreased from the upstream side to the downstream side of this reach in each set of samples. The livestock operation located downstream of 380th Ave NE, however, has freshly trampled areas where livestock are accessing the stream and there is a small drainage channel that carries runoff from the farm to the river. The section that includes this farm saw a very significant upstream-to-downstream increase in E. coli concentrations in the August 4th samples.

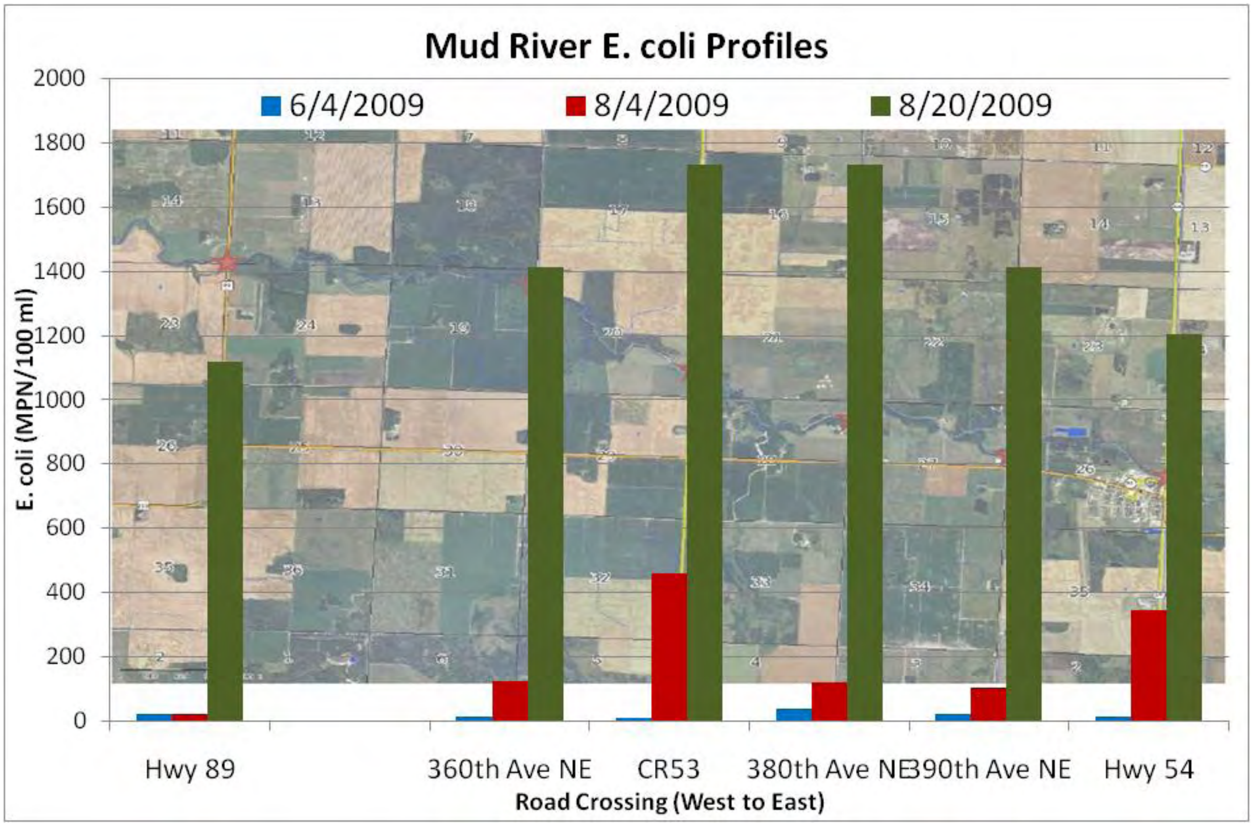


Figure 14. Longitudinal E. coli sampling results from the Mud River

Flow Monitoring

One of the goals of this project was the collection of flow records at the monitoring sites. Water level loggers were installed during the open-water months to collect this data on 30 minute intervals. Flow rating curves were developed by physically measuring flow and stage at various points throughout the range of flows seen at a site.

Multiple flow measurements were made at each monitoring site for the purpose of establishing flow rating curves. Most measurements were done with a wading rod, magnetic-head flow meters, and an AquaCalc 5000 computer. A bridge crane was used at some of the sites that had high water.

After analyzing Eureka Manta water level data in March 2009 and discussion at the March 3rd, 2009 coordination meeting, it was decided that it would be necessary to purchase Onset HOBO water level loggers (more reliable than the Manta's probe) for water level logging at stream gauges 757, 41, and 40. In the spring of 2009, water levels remained too high to access installation pipes at the two sites on the main channel of the Thief River. Frequent field measurements were collected to compensate for this circumstance.

The high flows in early 2009 and 2010 provided opportunities to get some additional flow measurements to establish the upper ends of flow rating curves for the sites.

The following subsections show the flow records collected at each site.

Thief River at Hillyer Bridge

A USGS gauging station is installed near the Thief River at the 140th Ave NE crossing of the Thief River. This bridge is referred to as the "Hillyer Bridge", has the USGS gauge number 05076000, is referred to as site number 760 by the RLWD, and has the STORET code of S002-079 for water quality monitoring. Quarter-hour data was downloaded from the USGS website regularly throughout the project in case there was a need to compare flow and water quality on a small time scale. Daily and monthly mean flows were also downloaded from the USGS website for this stream gauging station (http://waterdata.usgs.gov/nwis/uv?05076000). The flow record from this station was used for calibration of the SWAT model.

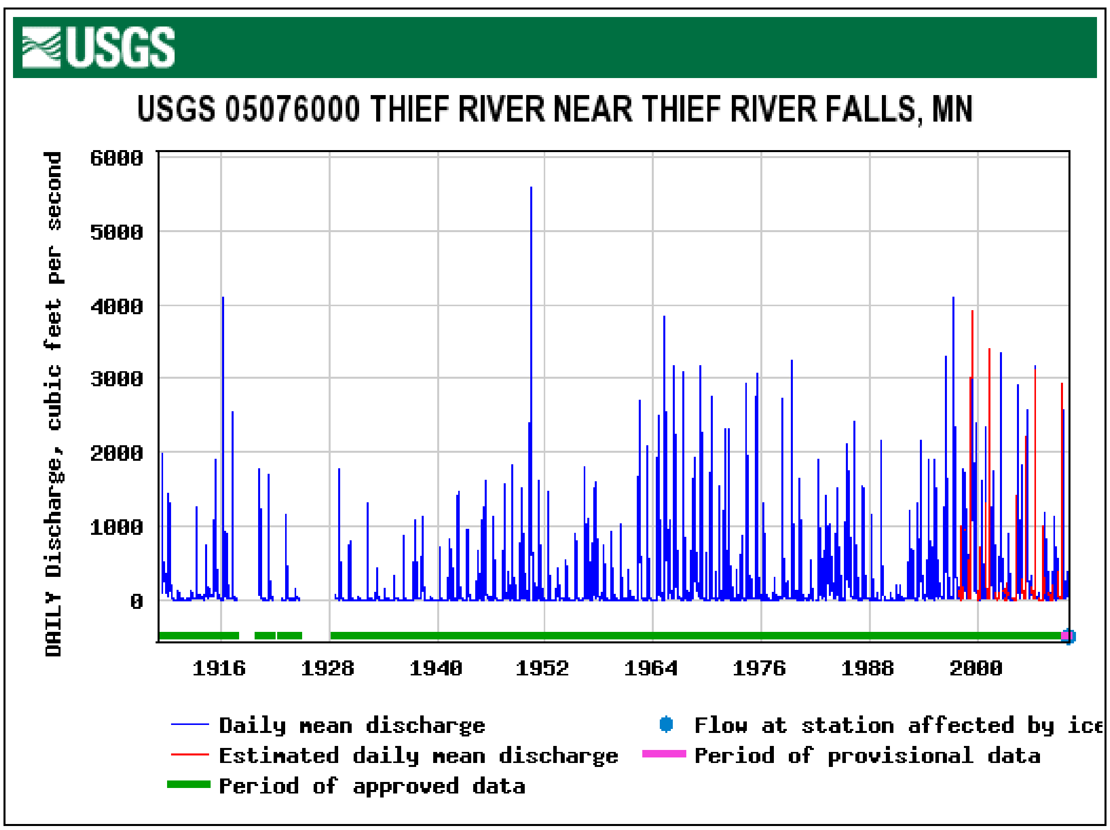


Figure 15. Historical flow record at the Thief River USGS gauge

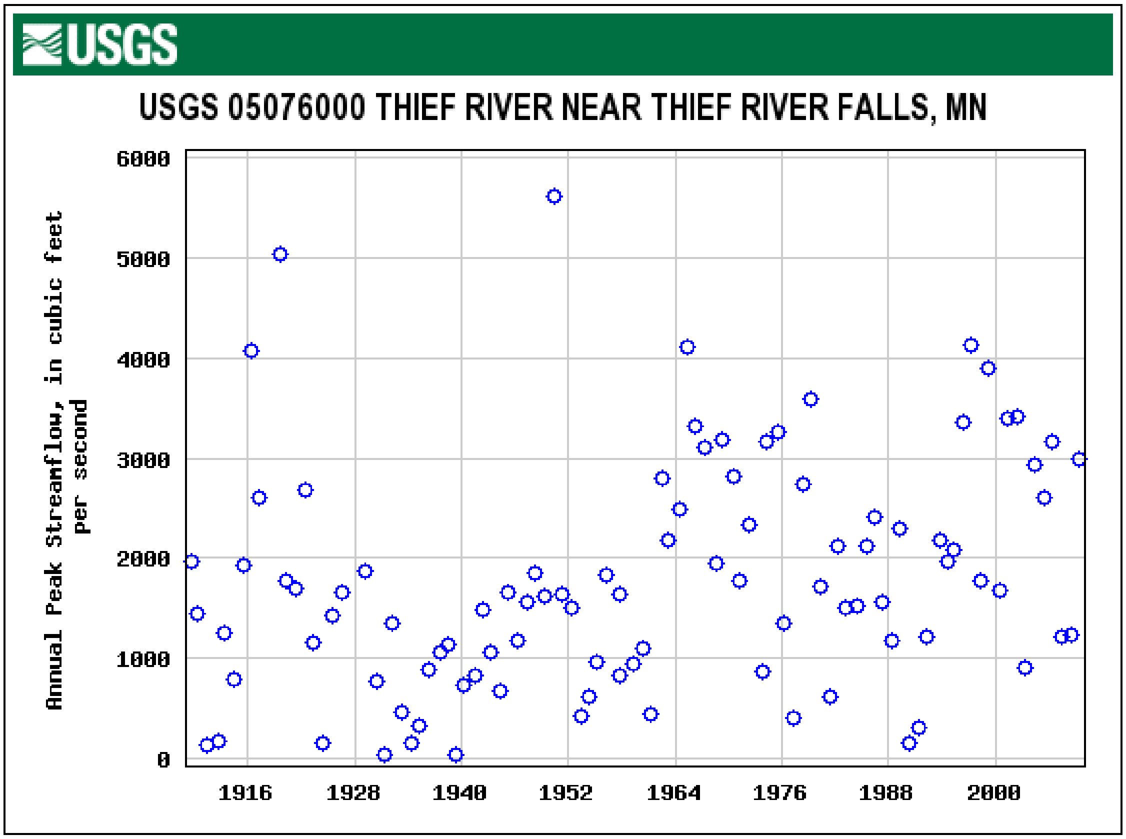


Figure 16. Historical record of peak flows on the Thief River

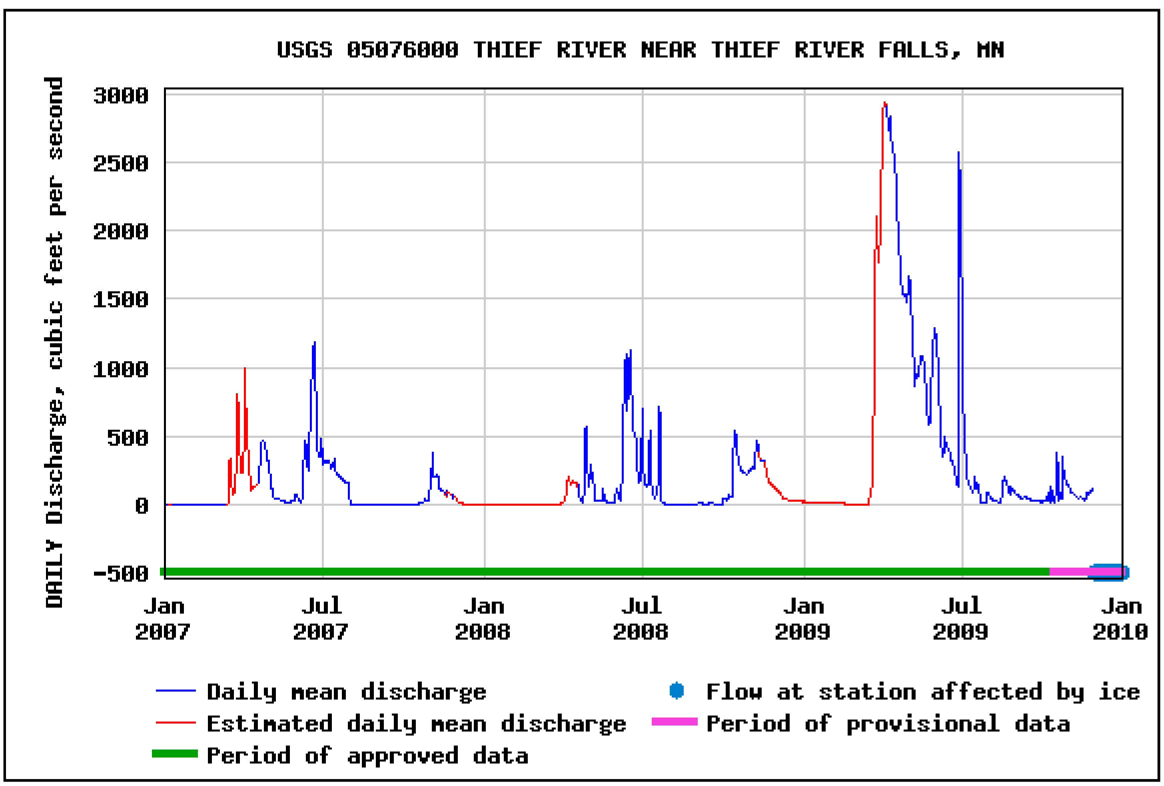


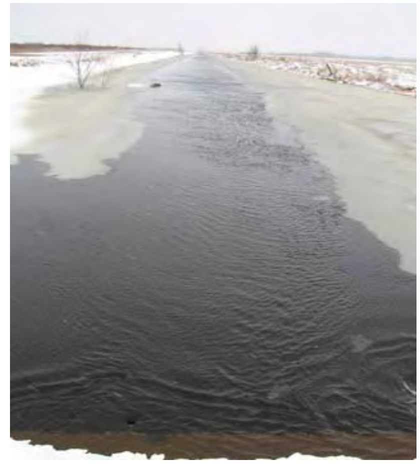
Figure 17. 2007 through 2009 Discharge at USGS 05076000

Table 1. Monthly mean flow summary table.

USGS Gauge 05076000 Thief River North of Thief River Falls		Month						
		April	May	June	July	August	September	October
40 Years of Individual Monthly Mean Flows (cfs)	1970	655.4	784.5	1375.0	404.5	2.7	3.9	98.9
	1971	408.8	125.6	34.7	12.1	1.1	8.7	469.1
	1972	1141.0	473.5	86.3	10.5	5.1	2.4	61.8
	1973	26.4	32.6	11.2	0.8	4.9	177.8	407.3
	1974	1340.0	1642.0	623.6	45.6	132.5	61.6	36.7
	1975	1131.0	1291.0	331.4	2103.0	71.8	103.0	110.7
	1976	556.4	37.8	50.1	2.3	4.6	1.4	1.2
	1977	28.2	34.0	8.9	1.7	0.0	8.9	18.3
	1978	1646.0	624.1	151.8	92.8	43.7	69.5	160.5
	1979	1231.1	1788.4	655.7	129.7	12.7	11.3	91.5
	1980	617.2	63.4	0.0	0.0	0.0	14.0	4.2
	1981	7.8	6.1	83.2	105.4	3.4	14.6	
	1982	930.8	829.8	165.8	185.6	149.3	8.9	369.2
	1983	655.6	358.2	443.9	576.6	195.6	187.8	296.3
	1984	537.1	211.2	468.8	243.1	46.9	8.7	75.7
	1985	750.4	748.9	1002.6	1136.5	841.7	943.0	636.6
	1986	1366.8	1248.4	248.5	28.4	9.7	122.3	3.5
	1987	112.9	325.7	69.8	109.3	52.3	5.5	2.8
	1988	244.9	18.9	31.6	0.4	0.1	13.0	1.3
	1989	726.9	227.9	161.0	85.0	10.4	0.1	0.0
	1990	14.5	1.8	11.9	2.8	0.0	0.0	0.0
	1991	10.2	21.7	4.0	21.2	1.0	6.1	4.0
	1992	636.6	412.0	57.8	61.0	33.7	389.6	161.1
	1993	639.7	89.8	171.0	710.7	1011.6	1012.3	232.8
	1994	90.4	94.0	77.9	913.8	136.8	239.9	151.4
	1995	656.2	372.3	66.4	148.1	102.8	82.4	104.2
	1996	1070.2	2114.2	1176.3	690.4	360.2	31.2	68.0
	1997	1924.0	1979.0	774.3	921.4	111.0	8.9	82.9
	1998	201.9	560.2	688.9	899.5	199.0	97.1	390.5
	1999	2750.0	1893.2	1235.0	487.9	376.0	1619.1	471.4
	2000	239.5	115.5	457.4	285.4	52.1	28.9	41.8
	2001	1605.2	900.4	644.2	380.2	1129.6	235.0	77.6
	2002	50.7	167.5	2237.9	1907.7	617.8	237.8	89.1
	2003	118.4	122.9	150.8	68.9	15.3	1.4	4.7
	2004	683.4	1351.5	1525.9	421.2	68.5	555.0	688.2
	2005	1318.5	751.8	1662.4	1309.7	91.5	53.8	140.9
	2006	2166.3	1073.4	35.5	6.7	4.2	7.5	0.4
	2007	336.1	43.8	449.6	236.2	1.6	0.5	16.8
	2008	151.0	63.4	493.4	146.1	1.9	6.7	216.4
	2009	2254.7	1052.5	696.3	192.1	77.8	40.4	116.9
Summary Statistics (cfs/sq.mi.)	Maximum	2750.00	2114.19	2237.93	2103.00	1129.65	1619.10	688.19
	Average	775.80	601.32	465.52	377.11	149.53	160.50	151.39
	Median	647.55	365.24	209.75	147.10	45.28	21.75	89.06
	25th Percentile	189.20	83.22	64.26	26.61	4.00	7.29	10.74
	10th Percentile	28.02	31.51	11.82	2.25	0.89	1.38	1.24
	Minimum	7.75	1.83	0.03	0.00	0.00	0.00	0.00

Site number 6 on Ditch 200

Stream Gauge 6 on Branch 200 of Ditch 11 on 3/31/09



Stage records at this site were collected using an Onset HOBO water level logger installed in a pool at the downstream side of the crossing. The level logger was deployed via suspension in an angled PVC pipe. This site was selected to minimize the effect of backwater from the Thief River during flooding. There still were some times in which there was a backwater effect at the site. Flows are normally highest in the late spring and early summer as the pools are being drawn down to their summer levels. Throughout most of the summer and fall, flow is minimal through this ditch but doesn't completely stop.

With the spring flood of 2009 came very high flows in ditch 200. The water level was at a higher elevation than the top of the culvert. Water was roiling down the ditch until water levels in the Thief River rose enough to create a backwater effect that slowed the velocity of the flow within Ditch 200 dramatically, even though the stage remained high.

Table 2. Yearly flow statistics at stream gauge 6 on Ditch 200.

	Flow Stats @SG6		
Row Labels	Average of Flow	Max of Flow	Min of Flow
2007	21.7	101.1	0.0
2008	7.3	89.2	0.0
2009	18.7	353.0	-0.1
Grand Total	**15.4**	**353.0**	**-0.1**

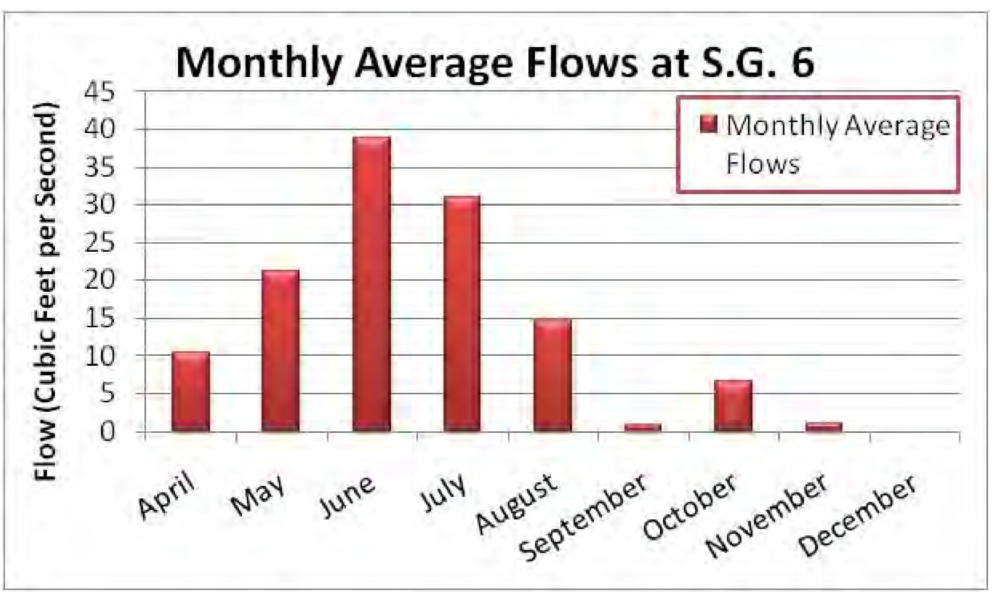


Figure 18. Monthly average flows at stream gauge 6 on Ditch 200.

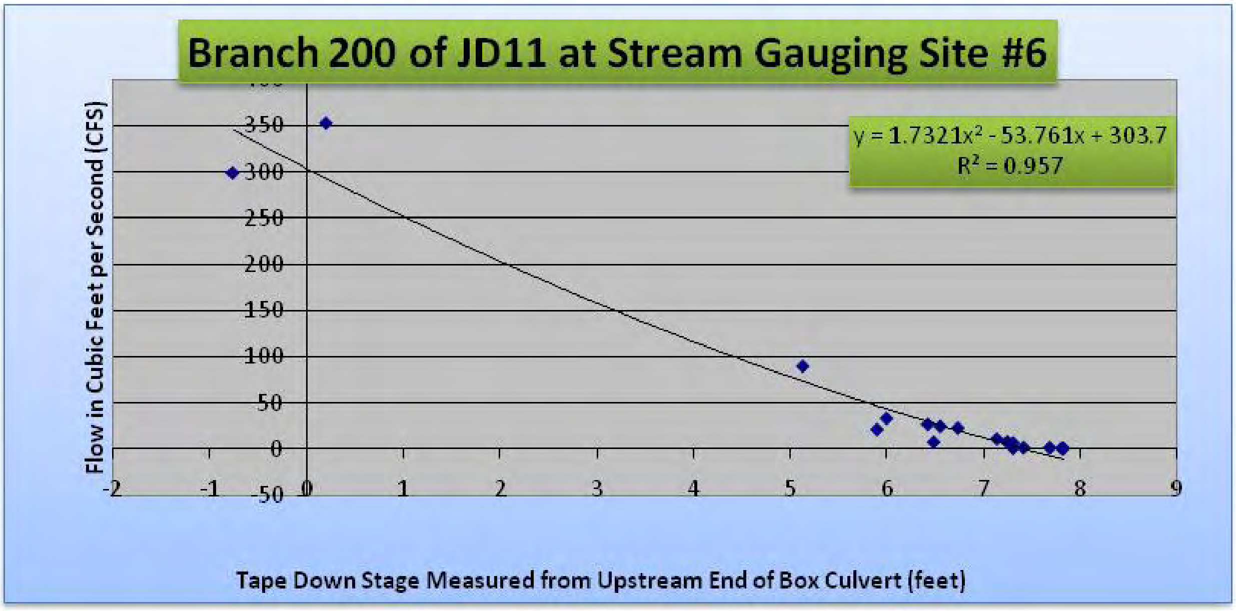


Figure 19. Flow rating curve for stream gauge number 6

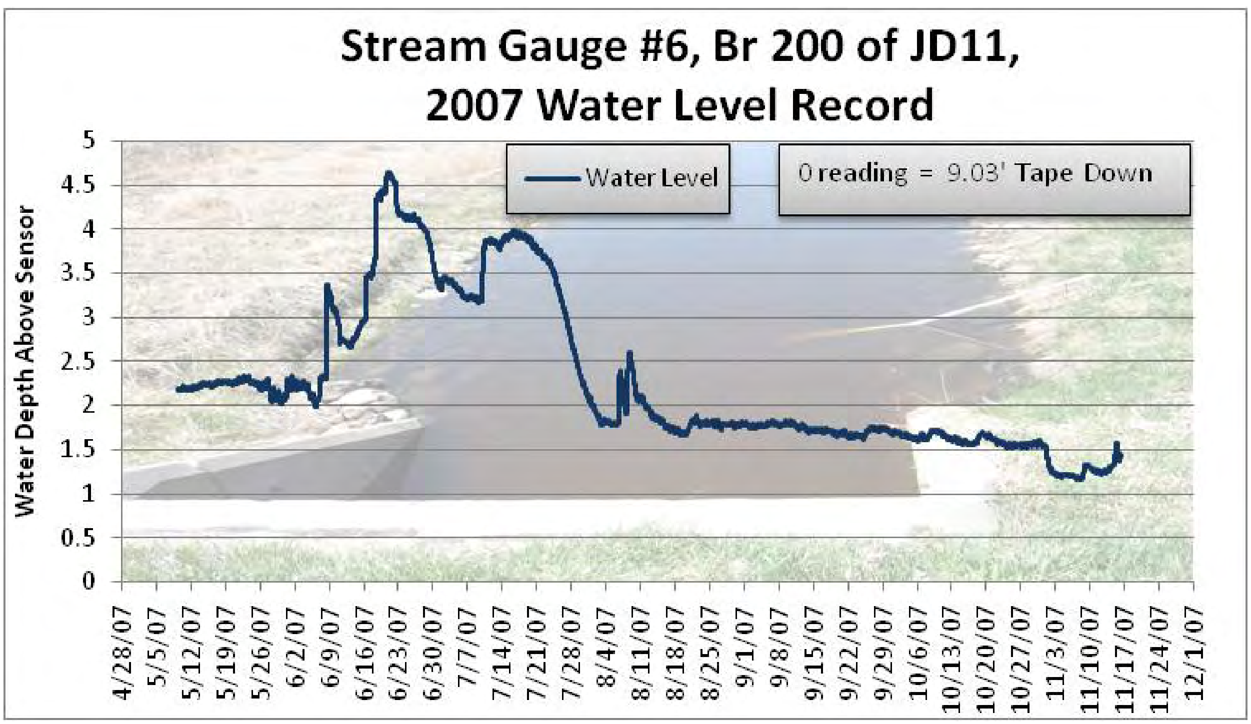


Figure 20. 2007 stage record at stream gauge 6

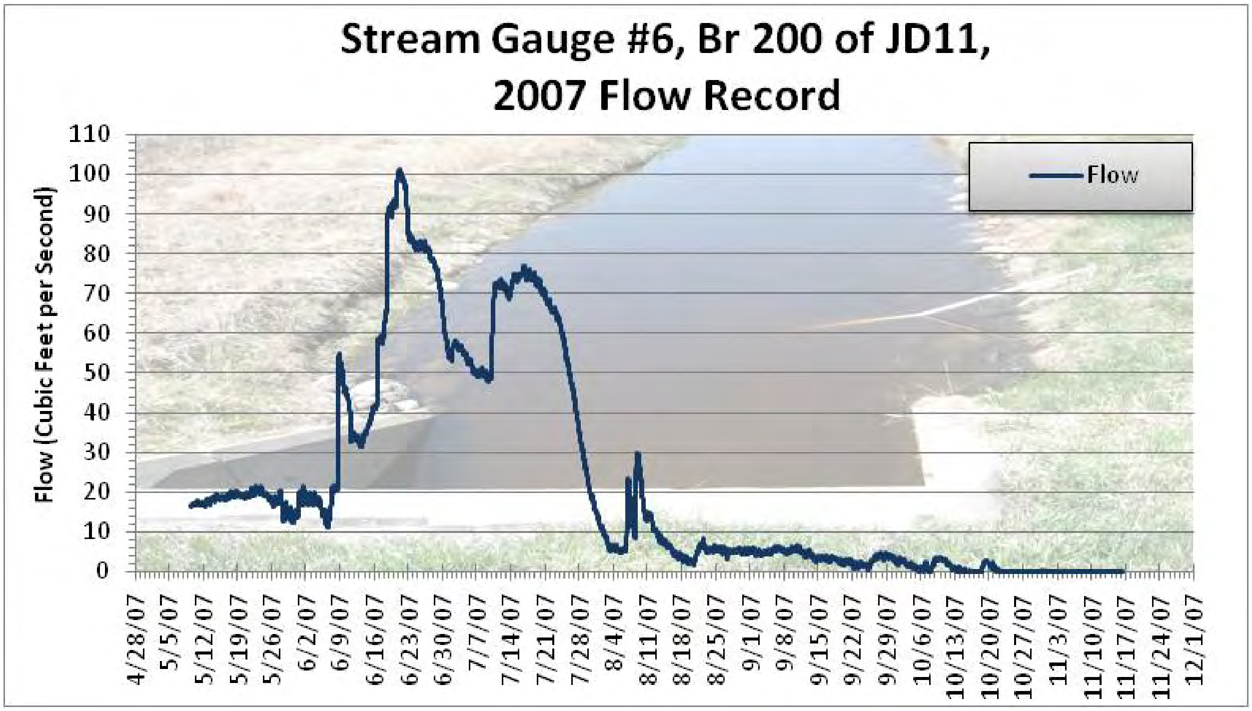


Figure 21. 2007 flow record at stream gauge 6

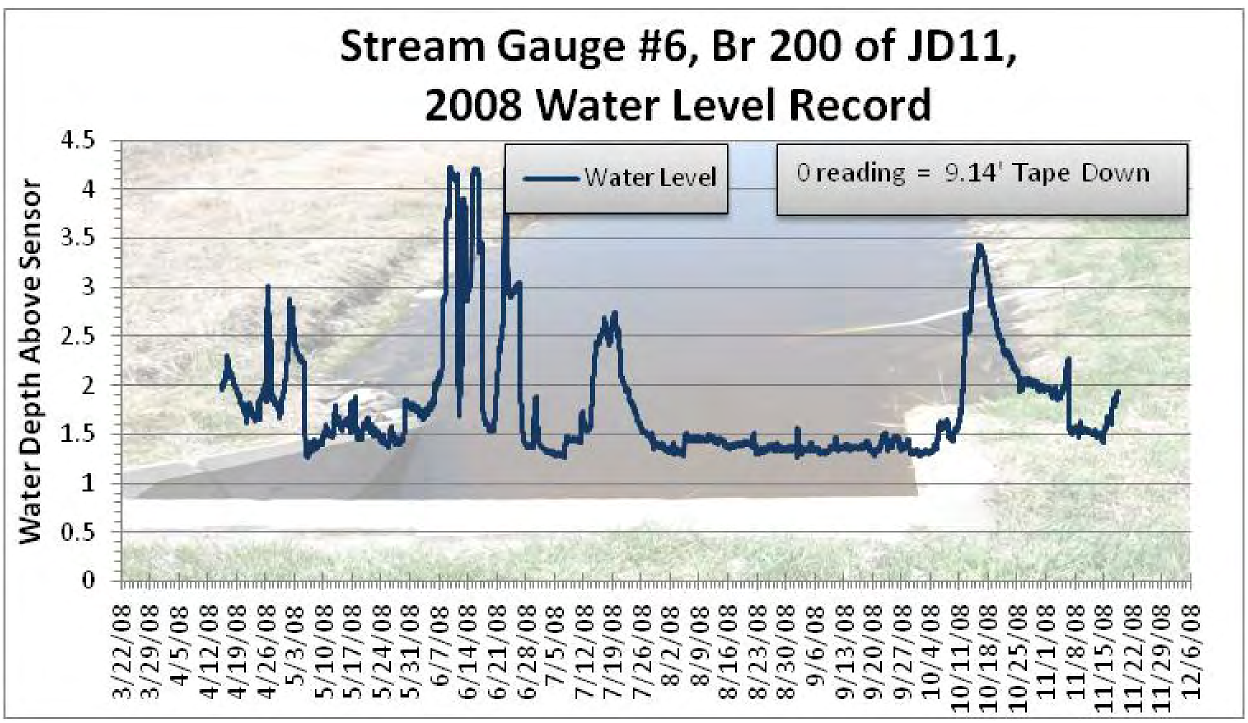


Figure 22. 2008 stage record at stream gauge 6

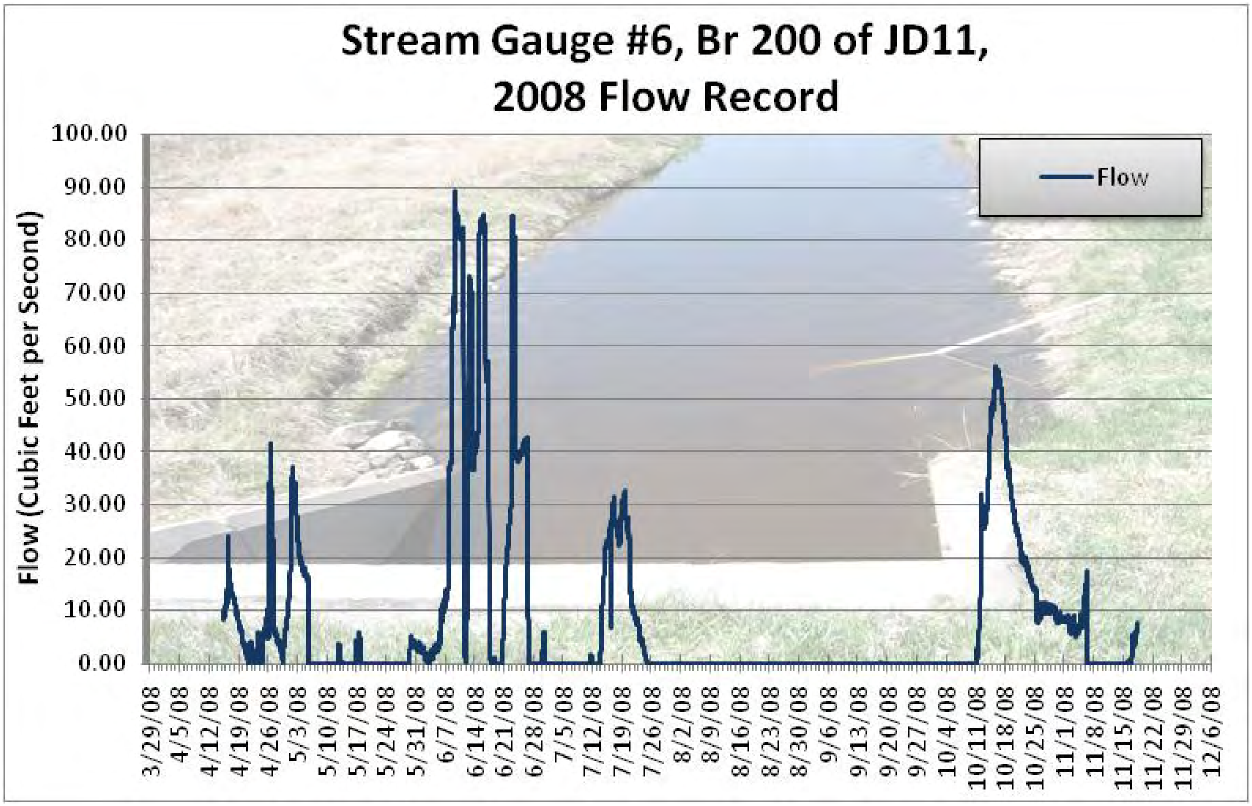


Figure 23. 2008 flow record at stream gauge 6

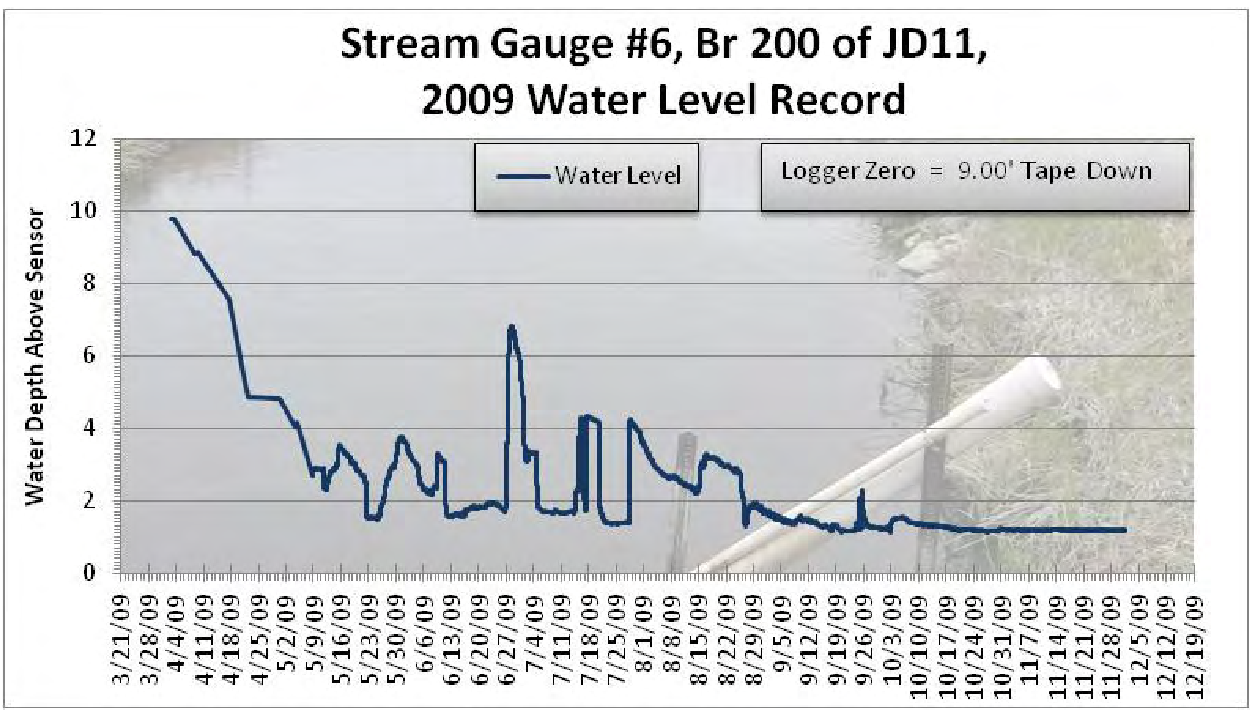


Figure 24. 2009 stage record at stream gauge 6

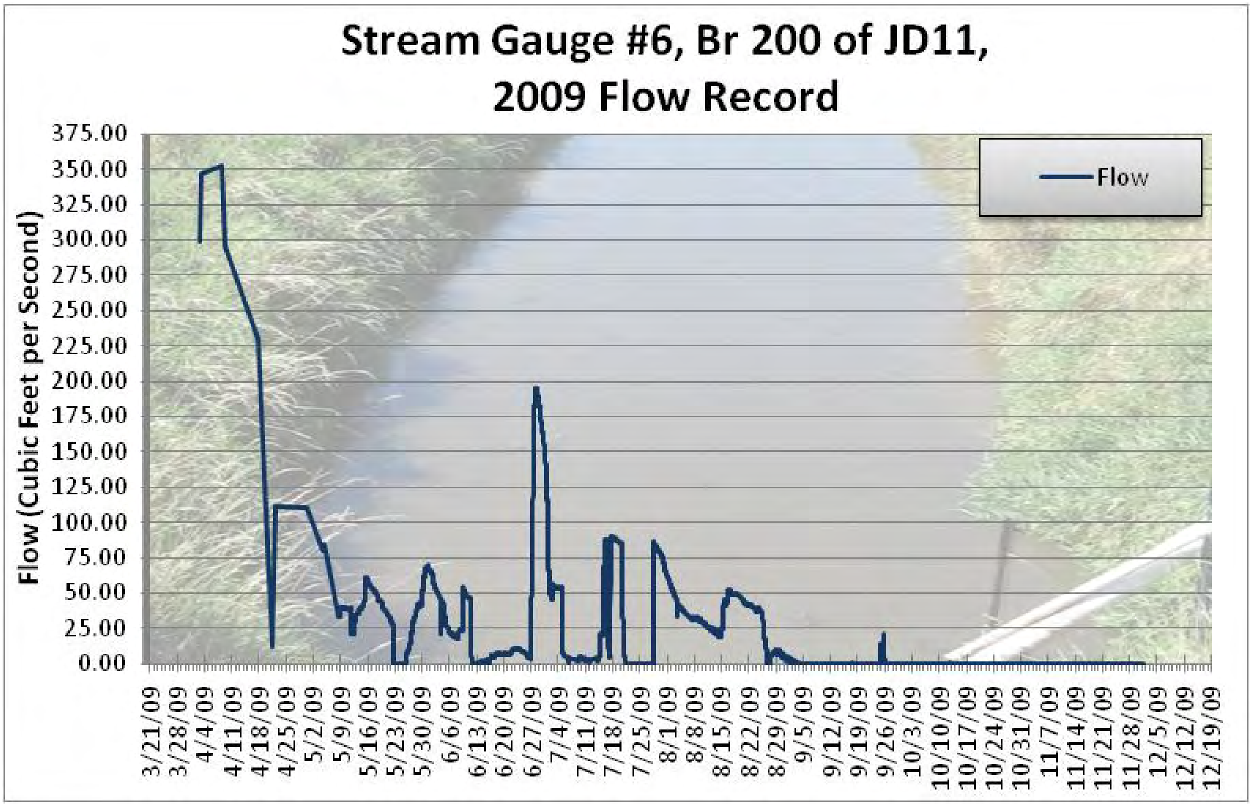


Figure 25. 2009 flow record at stream gauge 6

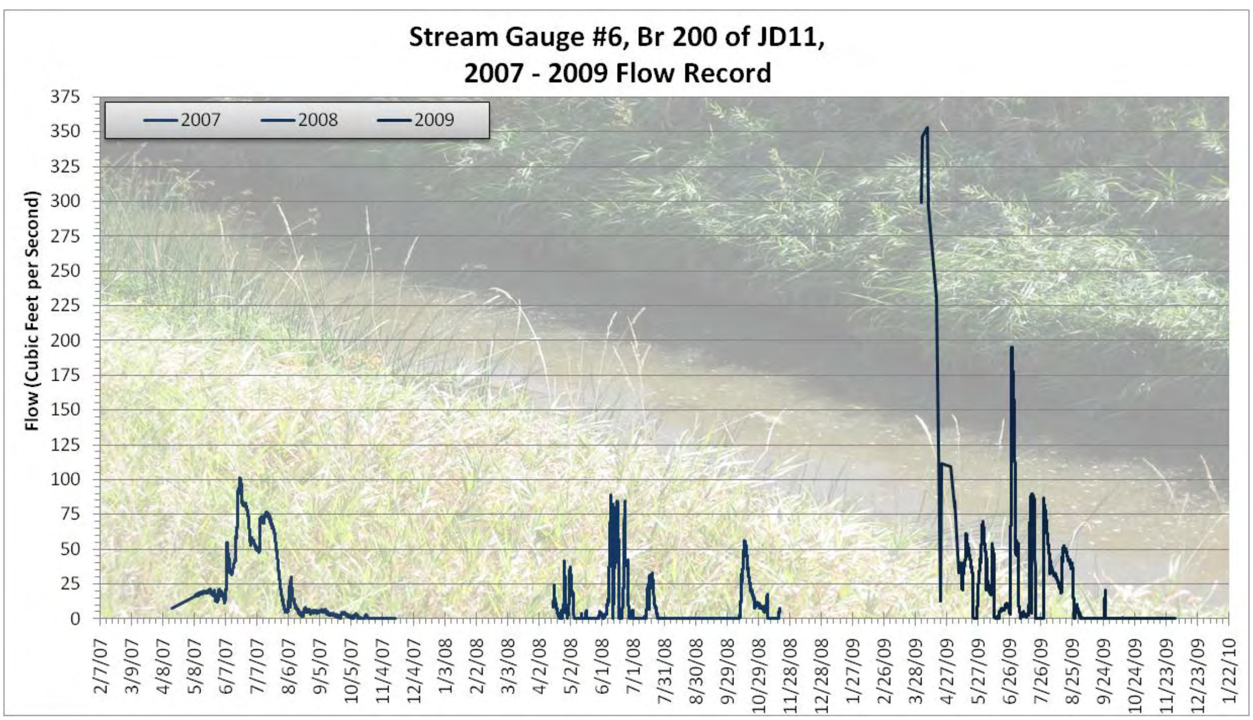


Figure 26. 2007 through 2009 combined flow record at S.G. 6.

RLWD Stream Gauge Number 2 on the Thief River

This monitoring site on the Thief River is referred to as site #2. This number comes from the RLWD's stream gauge numbering system. This site is the CSAH 12 (referred to locally as the Rangeline Road) crossing of the Thief River. The site's STORET code is S004-052. Water levels are measured by measuring down from the upstream reference point (RP), located near the center of the bridge, with a tape or survey rod. Flows were measured both by wading and by using a bridge crane.

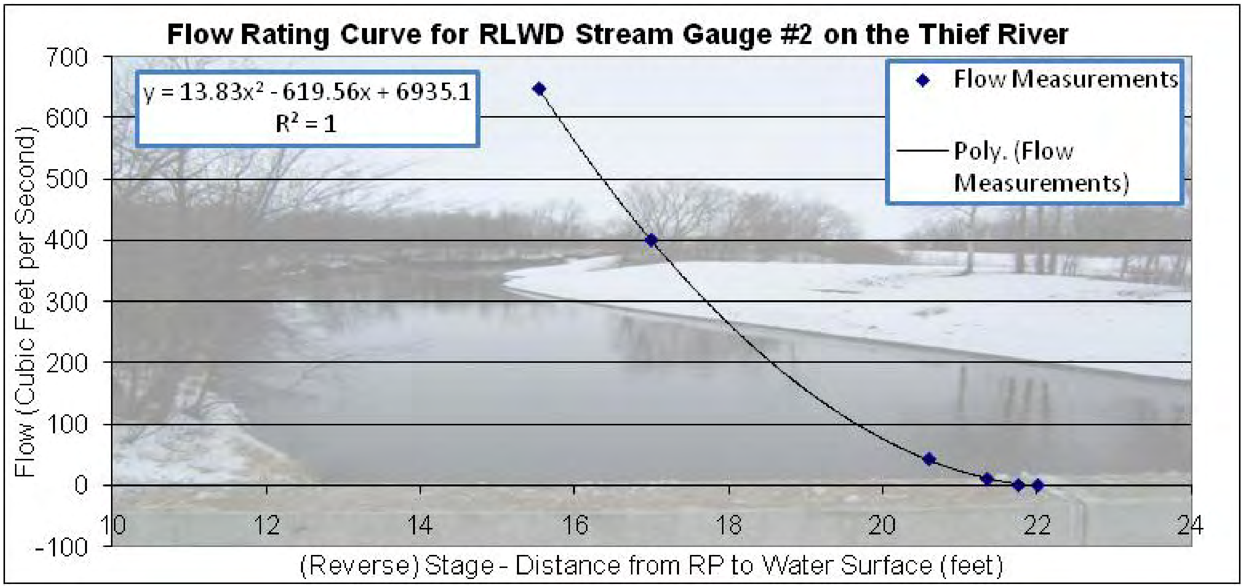


Figure 27. Flow rating curve for stream gauge 2 on the Thief River

There is a large difference between the minimum, maximum and average flows at this site.

Table 3. Statistics from continuous monitoring at S.G. 2.

	Average of Flow	Max of Flow	Min of Flow
2007	136.3	1027.7	16.3
2008	114.0	946.1	1.2
2009	122.4	2784.6	10.8
Grand Total	**123.4**	**2784.6**	**1.2**

Water levels in this part of the river drop off considerably in late summer and early fall. Water is very shallow across riffles. The increase in average flows in the late fall is typically due to discharge from wildlife pools and impoundments as they are lowered to winter levels.

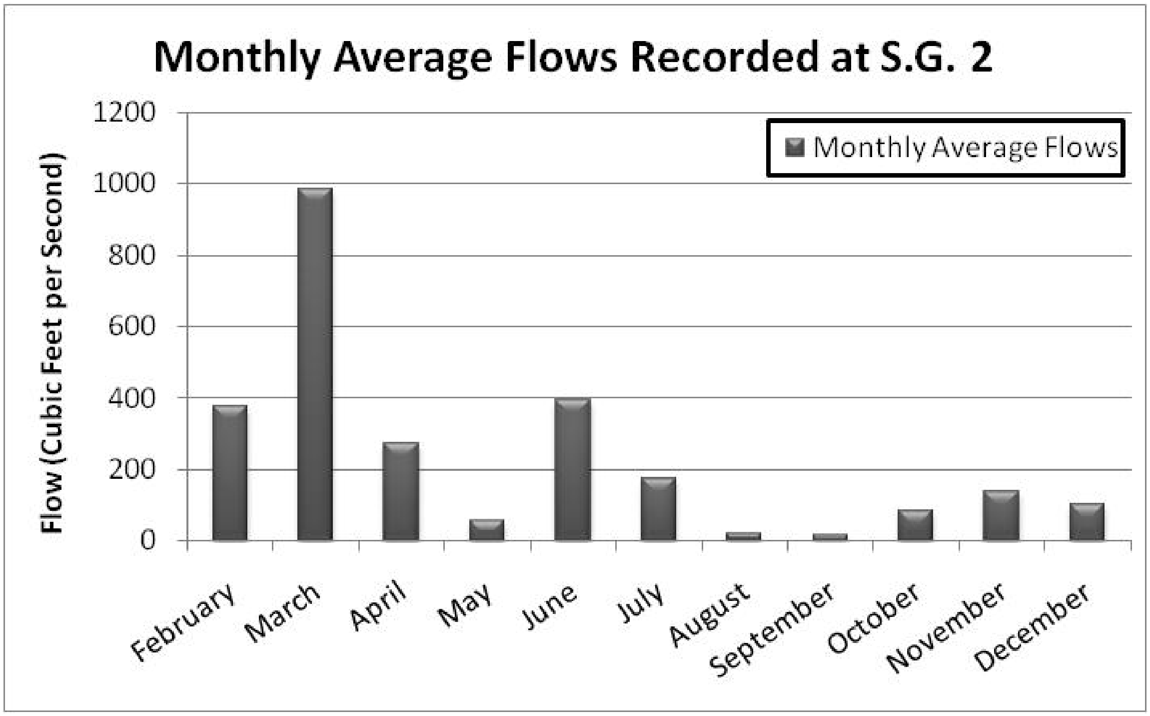


Figure 28. Monthly average recorded flows at stream gauge 2 on the Thief River

The 2009 flows in the Thief River at the "Rangeline Road" weren't the highest of record, but they were up there with some of the highest flows that have been recorded.

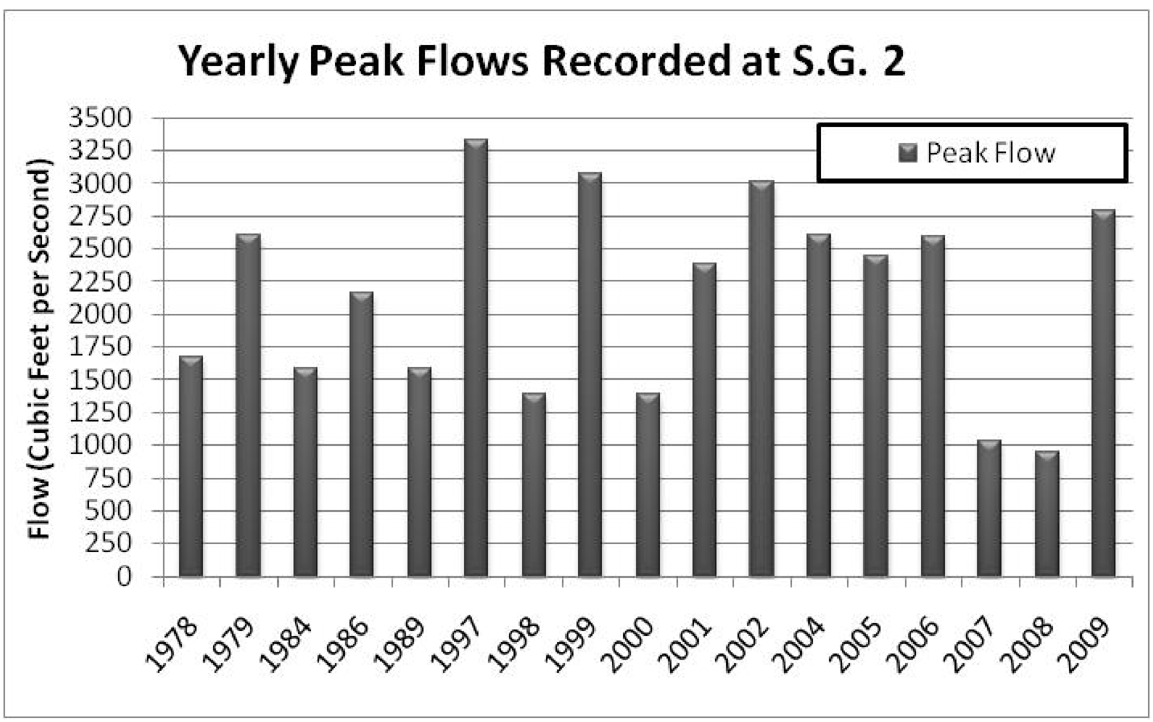


Figure 29. Yearly Peak Flows at S.G. 2

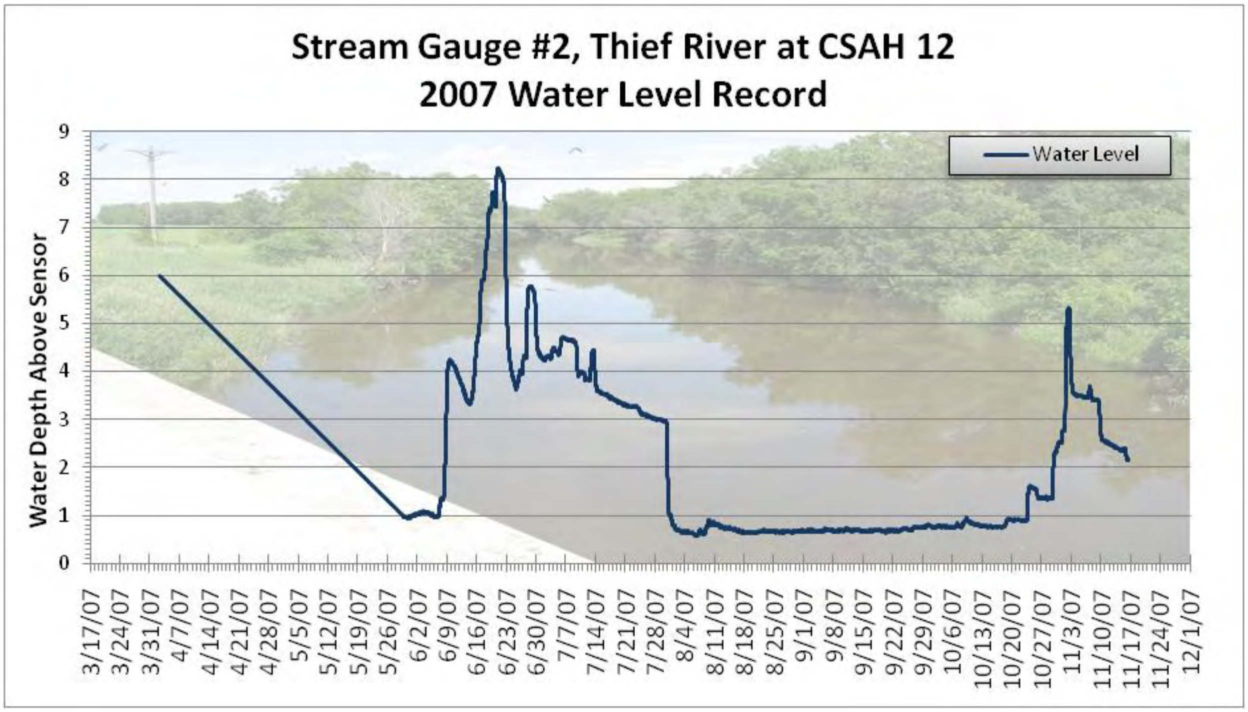


Figure 30. 2007 stage record at stream gauge 2

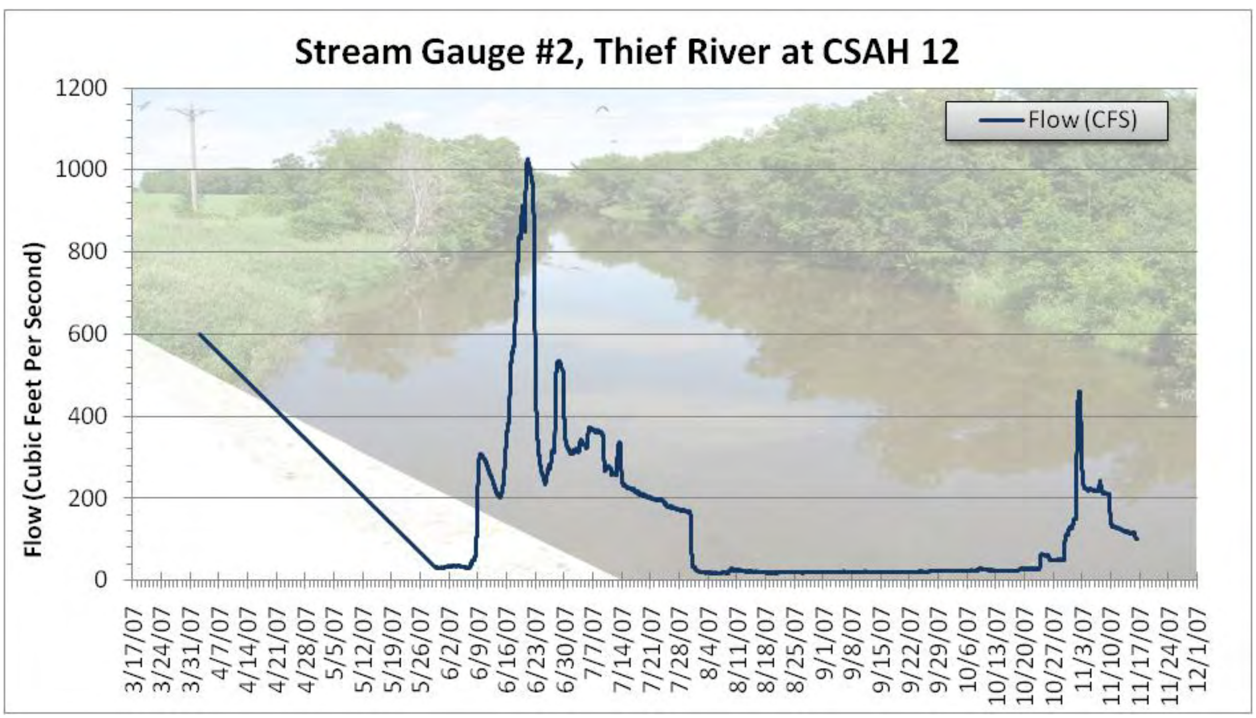


Figure 31. 2007 flow record at stream gauge 2

Flows and water levels are very flashy in the Thief River. Flow at this site mostly relies upon impoundment discharge and ditch flow. So, the baseflow in late summer is minimal.

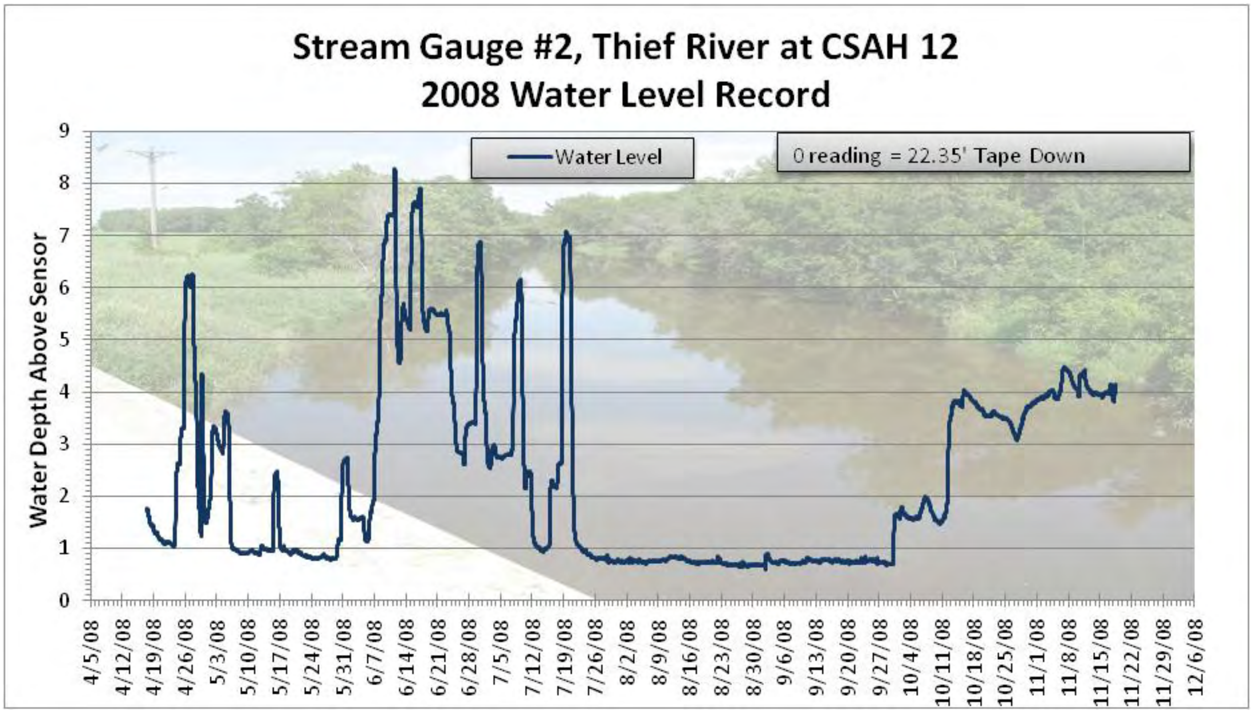


Figure 32. 2008 stage record at stream gauge 2

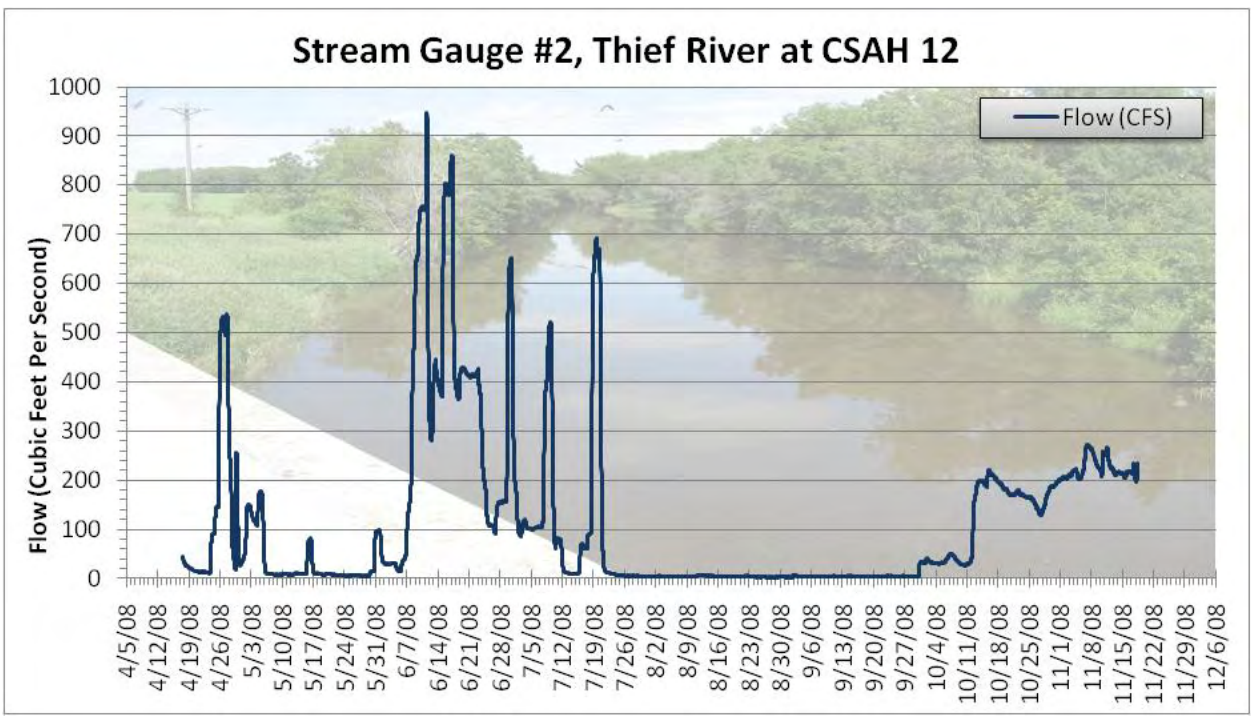


Figure 33. 2008 flow record at stream gauge 2

Very high flows in 2009 prevented the immediate installation of water level loggers, but frequent manual stage measurements were taken in order to piece together a flow record. You can see that there were two peaks to the flow in the spring. These represent the original pitch from the snowmelt and a second peak that comes from impoundment discharge.

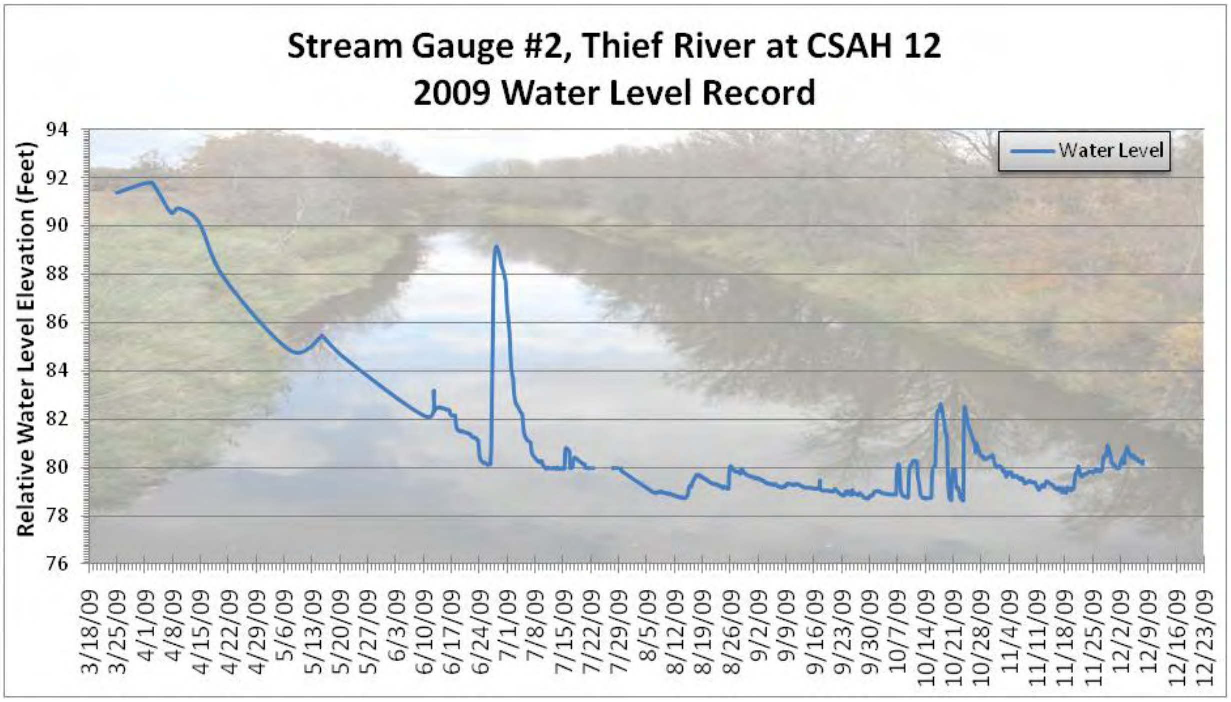


Figure 34. 2009 stage record at stream gauge 2.

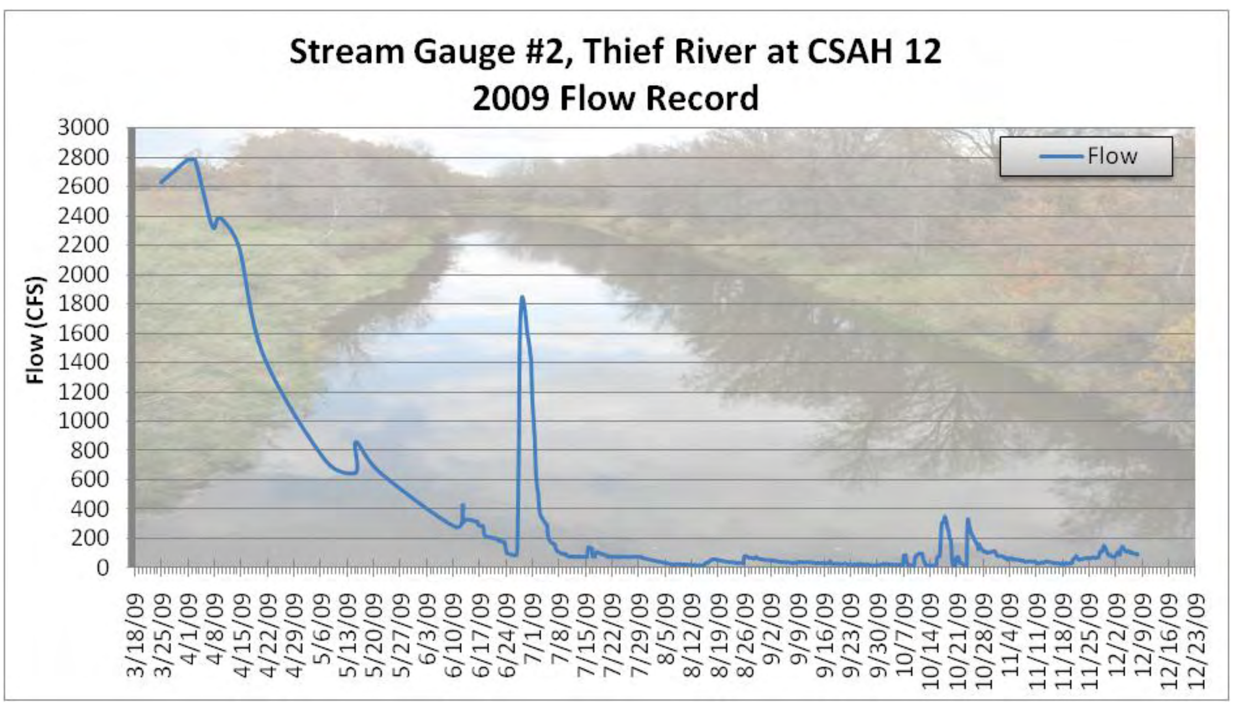


Figure 35. 2009 flow record at stream gauge 2.

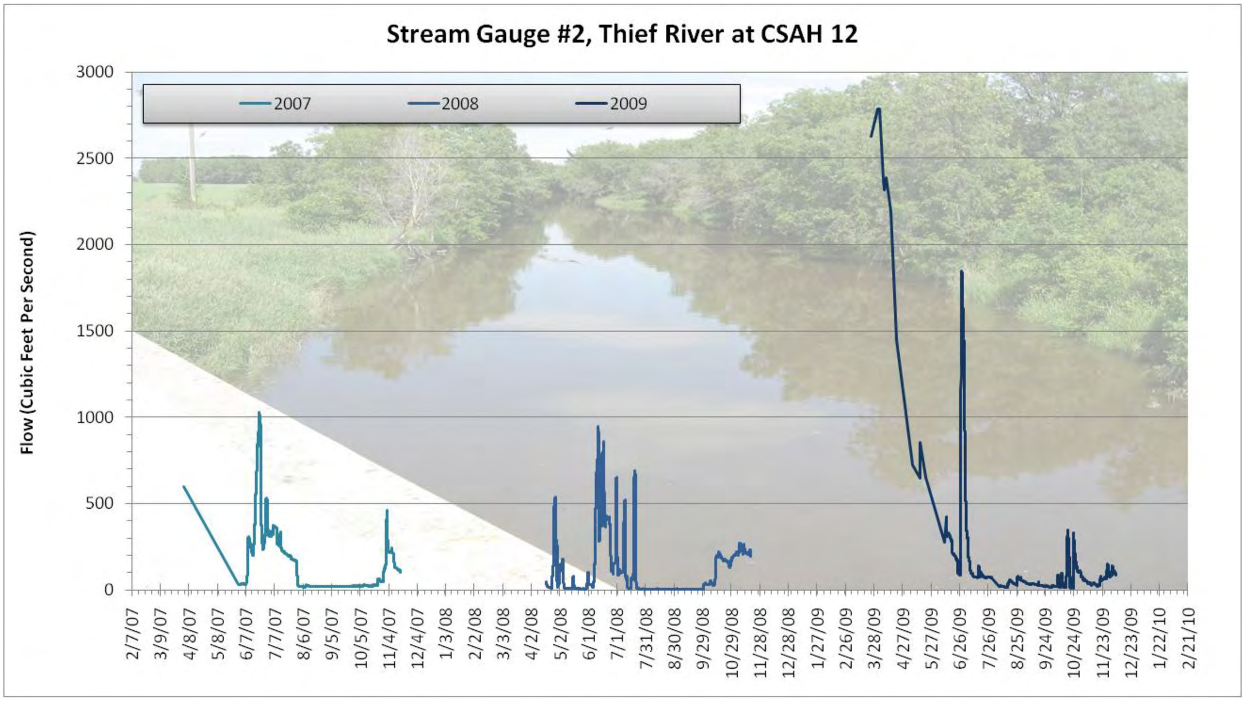


Figure 36. 2007 through 2009 combined flow record at stream gauge 2

Thief River at CR44

A new stream gauging station (number 156) was established at the Pennington County Road 44 crossing of the Thief River. The site was given the STORET code of S004-495 by the MPCA. The crossing is located approximately 6 miles north of the northeast edge of town. This site is close to the end of the dredged portion of the river. The water levels at this site are relatively deep and ponded. Riffles shortly downstream represent the end point of the dredging. Most flow measurements at the site were taken with a bridge crane. The Onset HOBO water level logger was deployed in a PVC pipe that was installed by the northwest bridge pillar.

High flow measurements made in the spring of 2010 helped improve the flow-rating curve over the 2009 version.

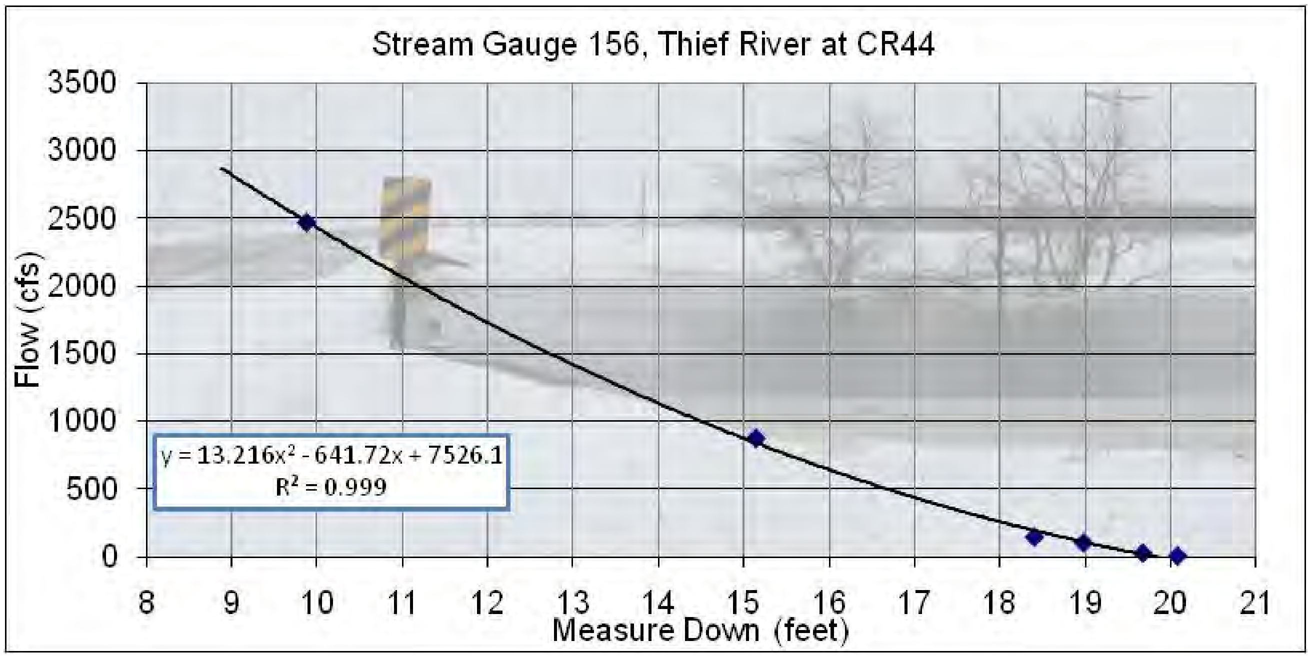


Figure 37. Flow rating curve at stream gauge 156

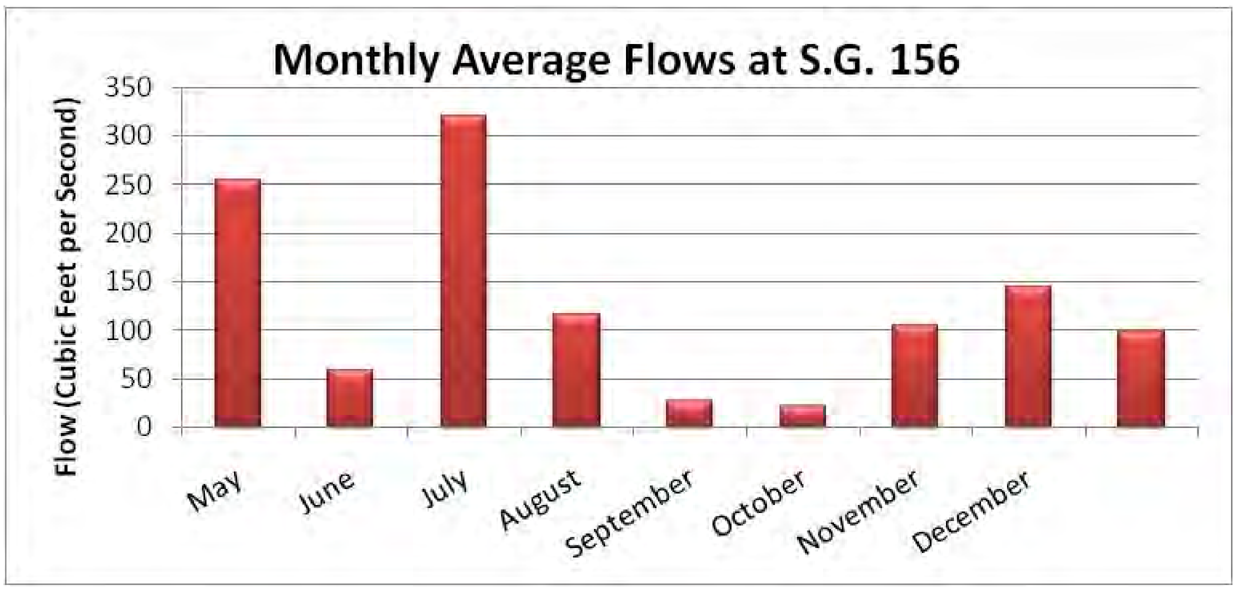


Figure 38. Monthly average flows at S.G. 156

Table 4. Flow statistics by year at S.G. 156

	Flow Stats @ 156			
	Average of Flow	Max of Flow	Min of Flow	# of Measurements
2007	248.4	1116.4	0.0	22426
2008	147.7	1029.5	0.0	10034
2009	74.2	4161.5	20.5	6923
Grand Total	**192.1087127**	**4161.455465**	**0**	**39383**

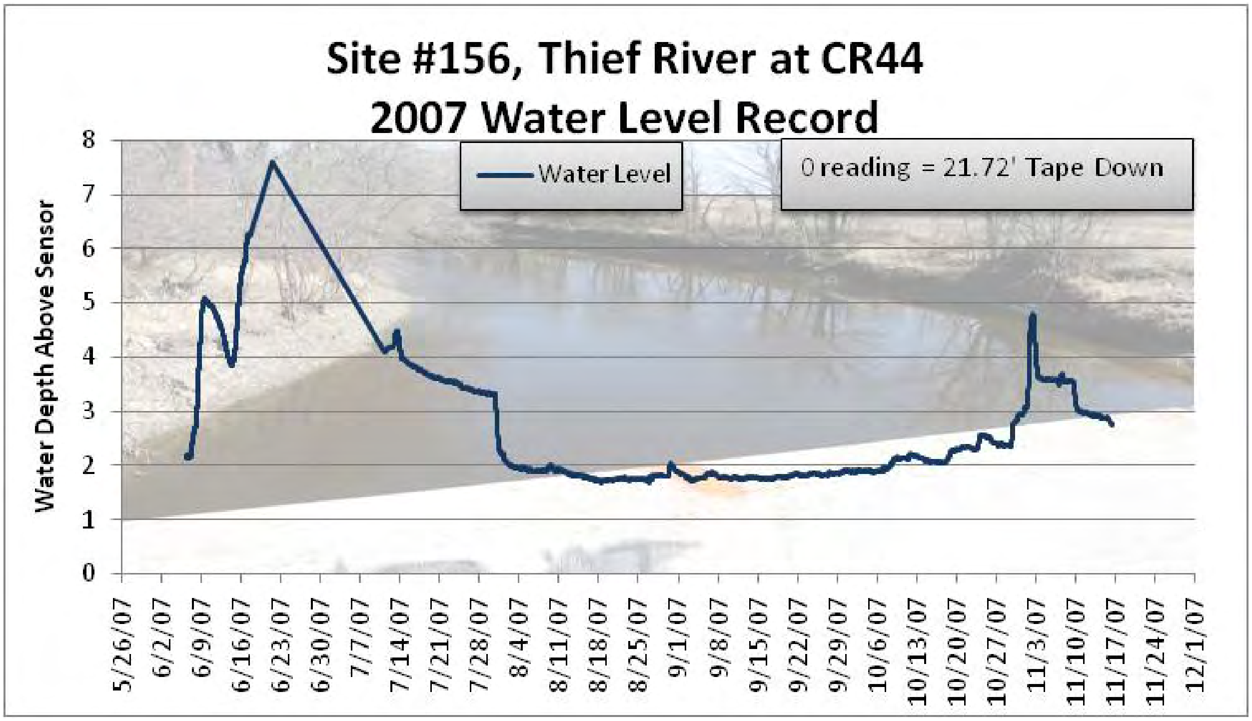


Figure 39. 2007 water level record at S.G. 156

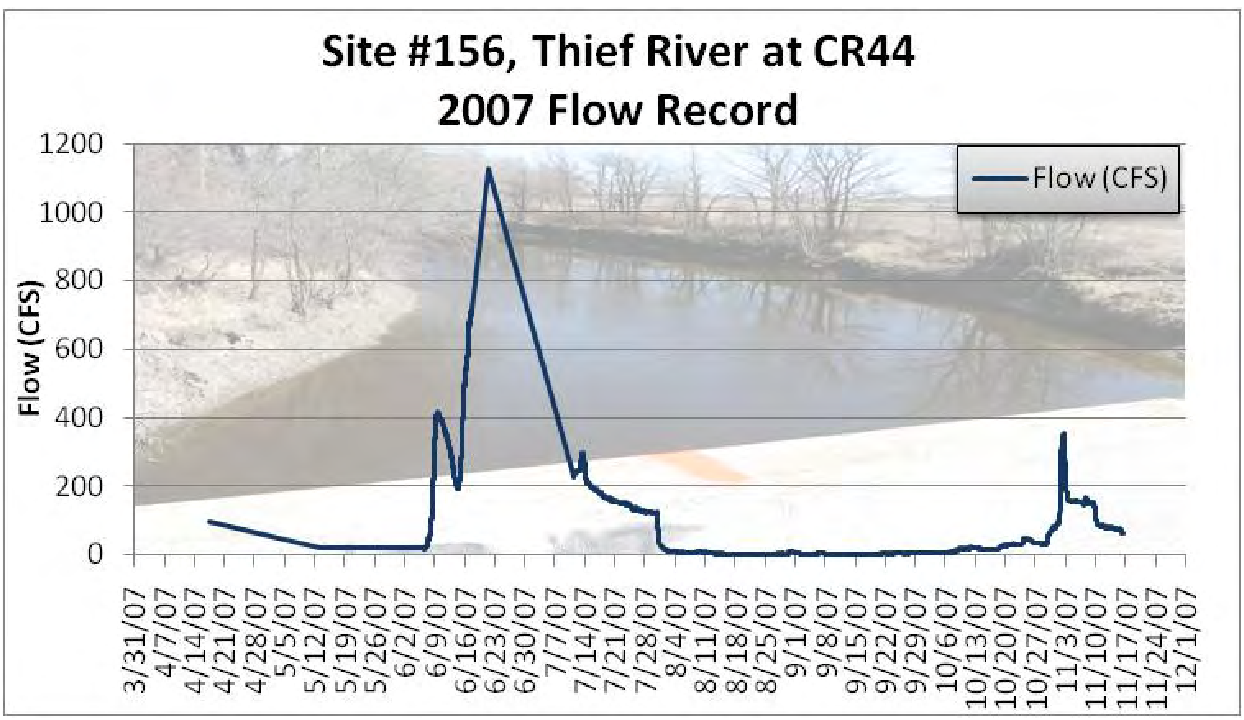


Figure 40. 2007 Flow record at S. G. 156

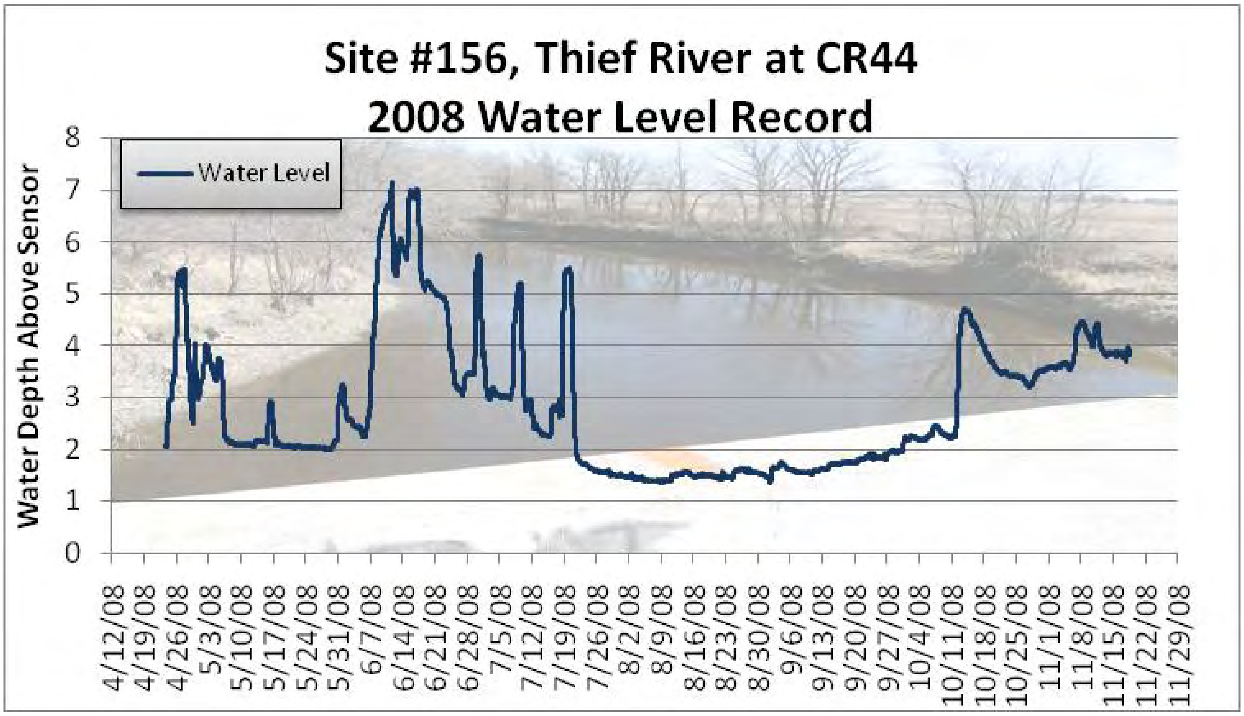


Figure 41. 2008 water level record at S.G. 156

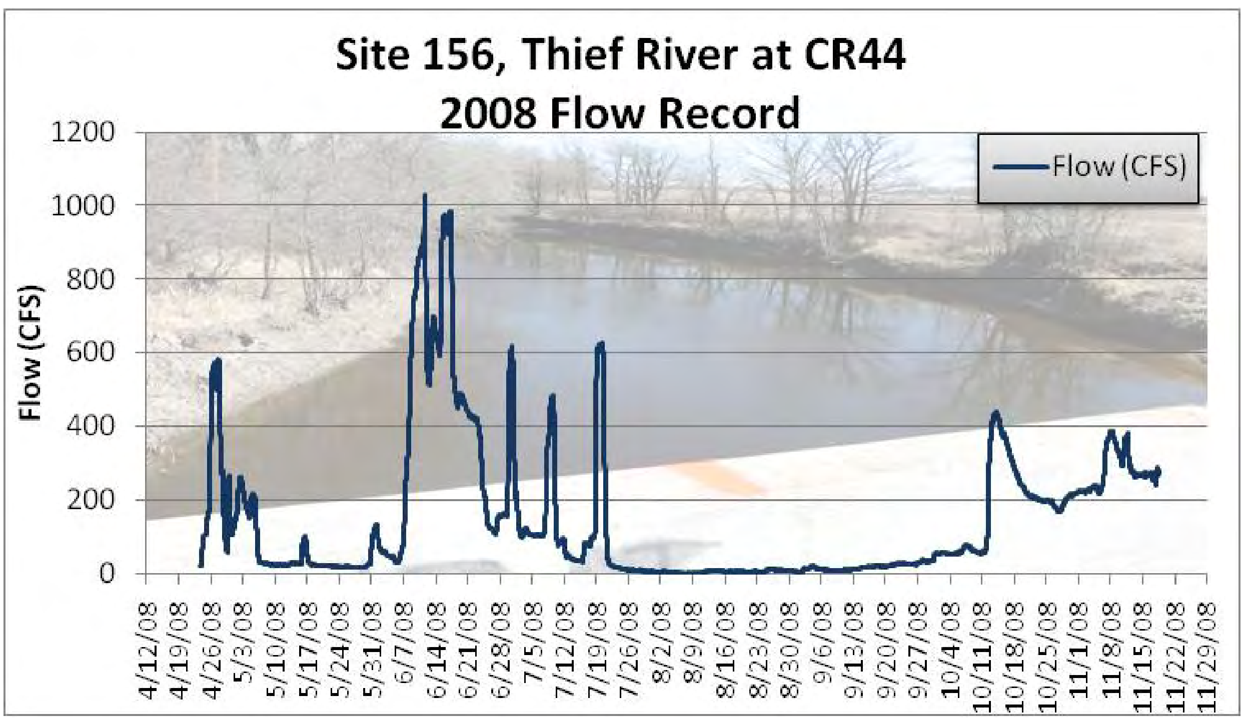


Figure 42. 2008 flow record at S.G. 156 on the Thief River

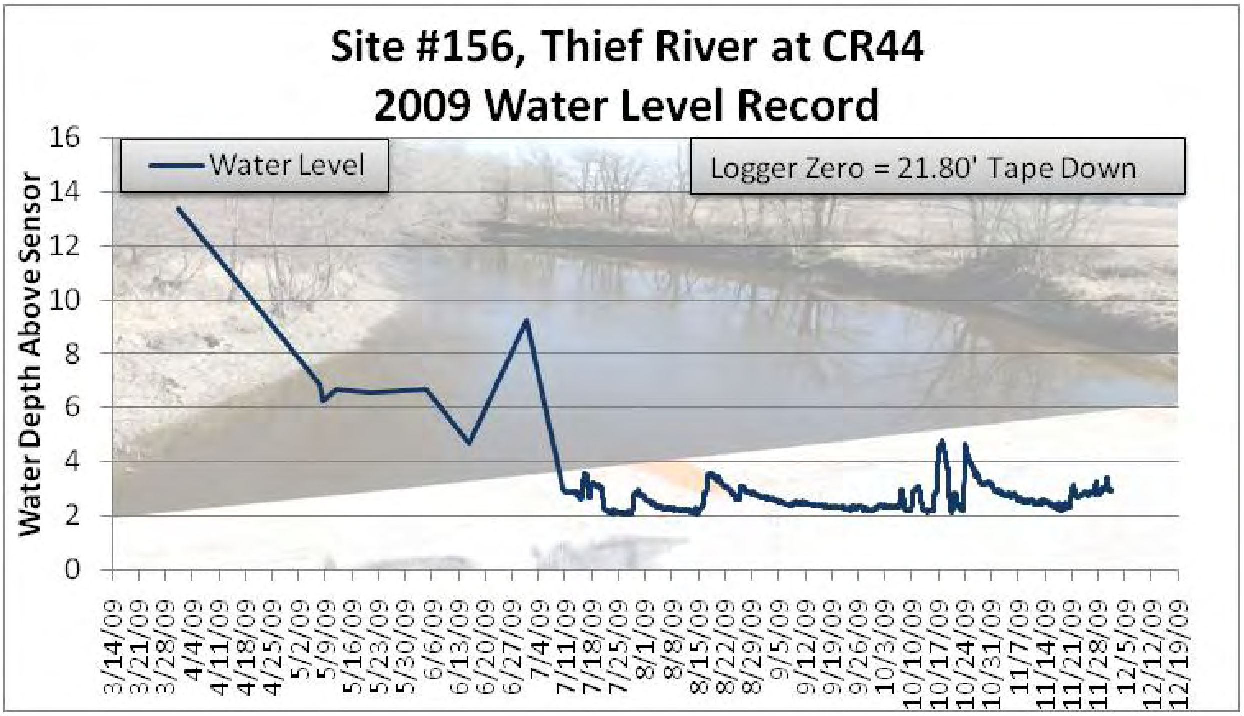


Figure 43. 2009 water level record at S.G. 156.

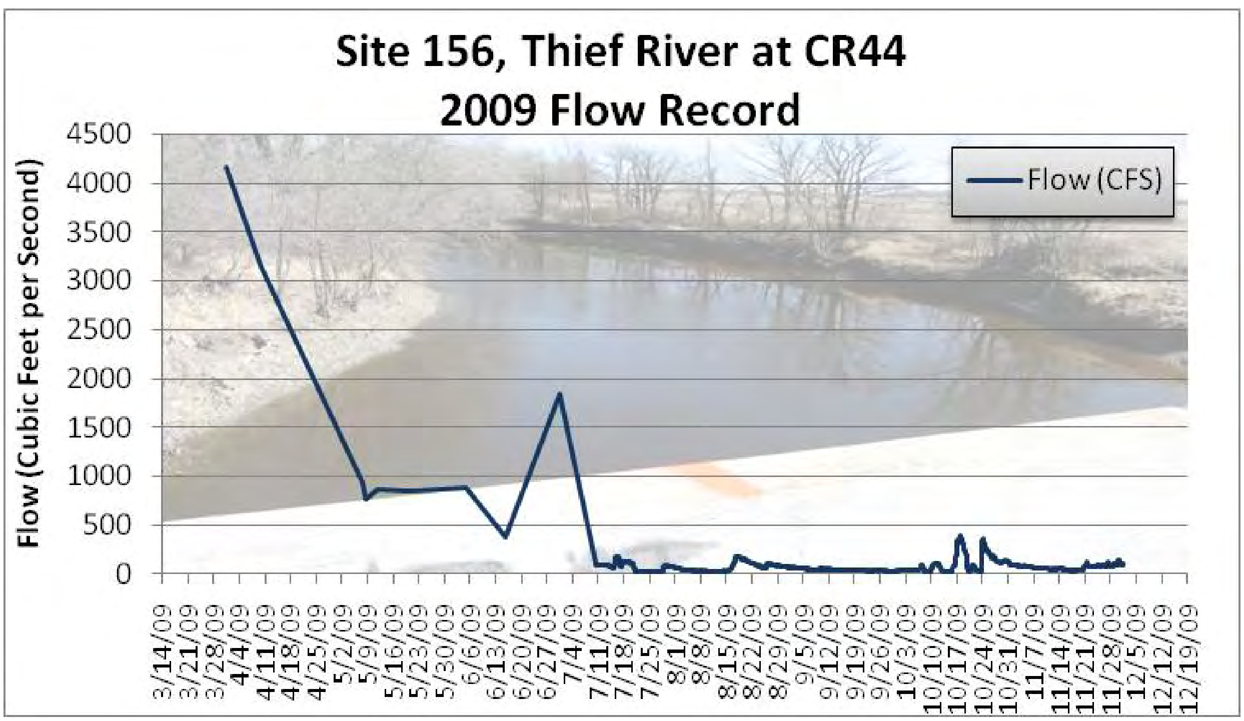


Figure 44. 2009 flow record at S.G. 156..

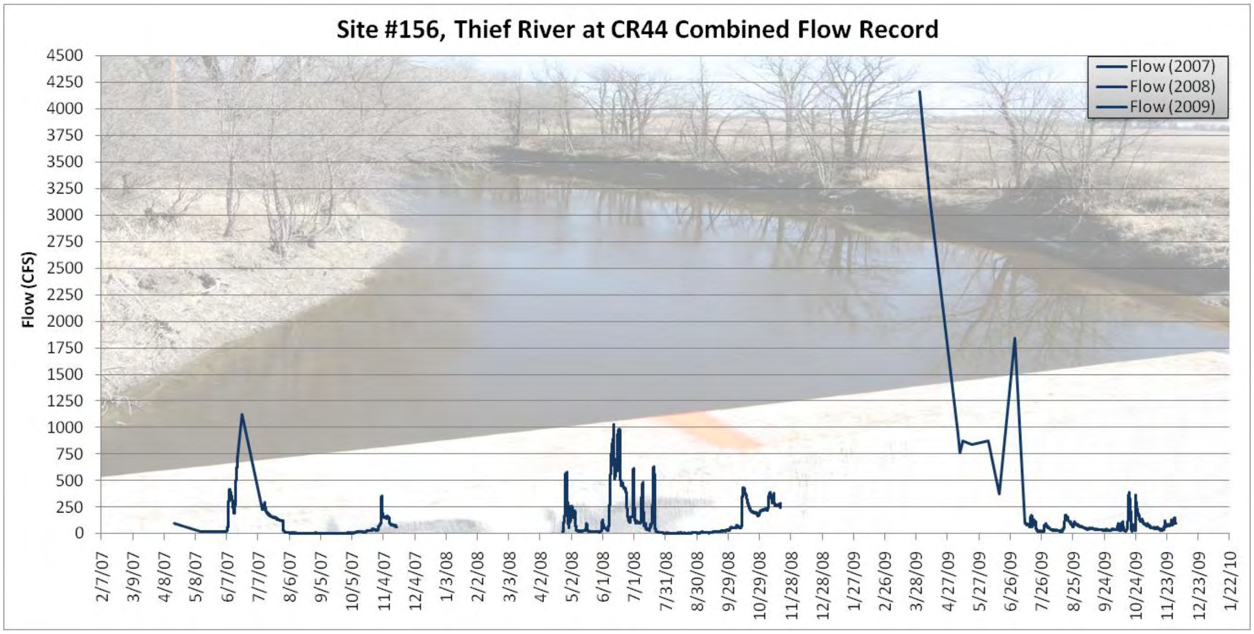


Figure 45. 2007 through 2009 combined flow record at S.G> 156 on the Thief River

County Ditch 20

During the flood of 1997, Marshall County Ditch 20 carried a more water than the Thief River. This is a very significant tributary of the Thief River. The ditch flows throughout most of the year.

In choosing a monitoring site for this ditch, we wanted to be close to the confluence with the Thief River to quantify the contribution from CD20. Yet, we needed a site that wasn't influenced by backwater so we could create a reliable rating curve for the site. A site was chosen approximately 2 miles upstream of the confluence with the Thief River at the township road crossing that is 1 mile east of CSAH 12. The site has the RLWD stream gauge number 41 and the STORET code S004-494. It is the 180th Ave NE crossing of CD20. The first two years of water level monitoring were accomplished with sensors on the Eureka Manta multi-parameter sondes. The 2009 (and 2010 too) water level monitoring at this site is being collected with an Onset HOBO water level logger deployed in a PVC pipe on the downstream side of the bridge near the north ditch bank.

	Values			
Row Labels	Average of Flow	Max of Flow	Min of Flow	Count of Flow
2007	46.0	913.0	0.0	3730
2008	34.5	269.6	0.0	8291
2009	83.2	2528.1	0.6	10645
Grand Total	**59.3**	**2528.1**	**0.0**	**22666**

Figure 46. Yearly flow statistics at S.G. 41.

Average flows in CD20 don't have the late fall bump from pool discharge that the Thief River gets. The statistics for CD20 show a more "natural" flow pattern.

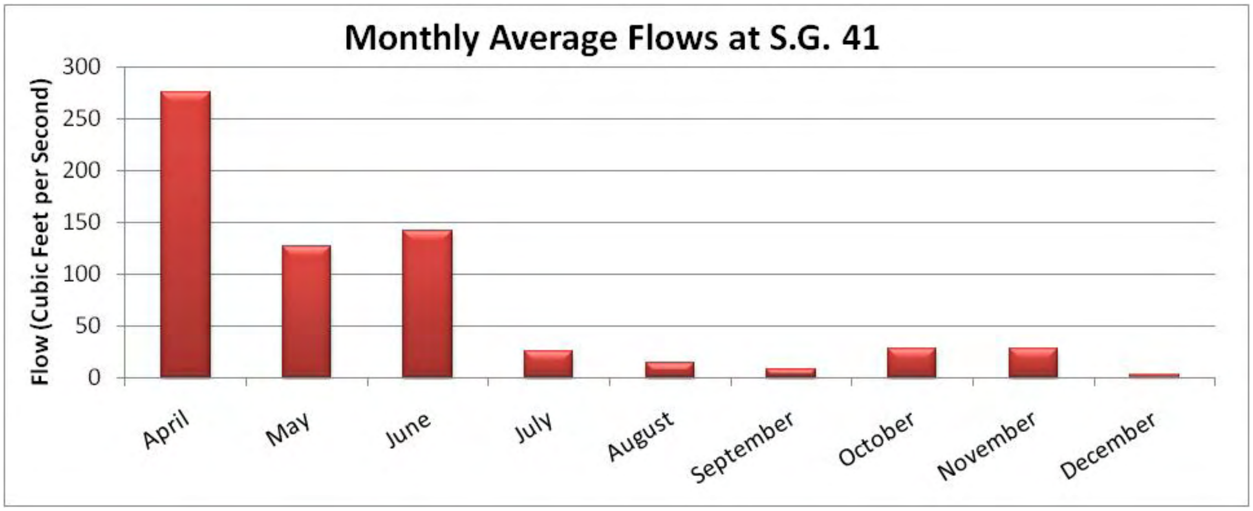


Figure 47. Monthly average flows at S.G. 41

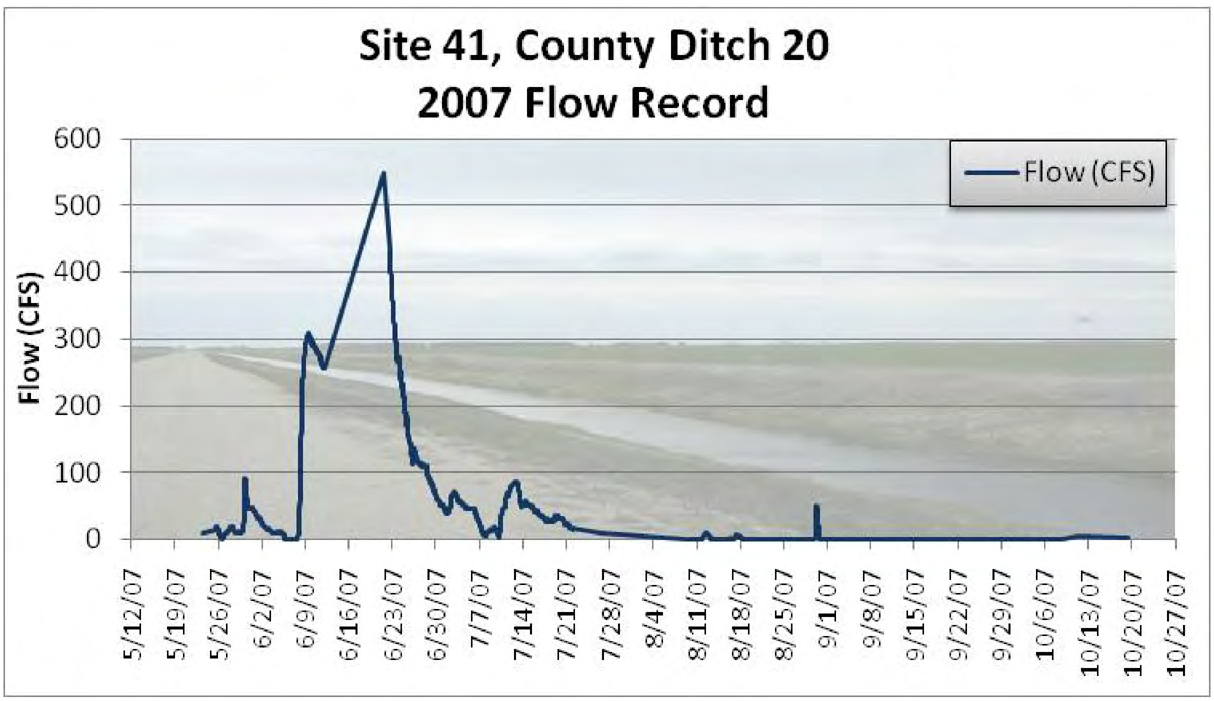


Figure 48. 2007 flow record at S.G. 41 on County Ditch 20

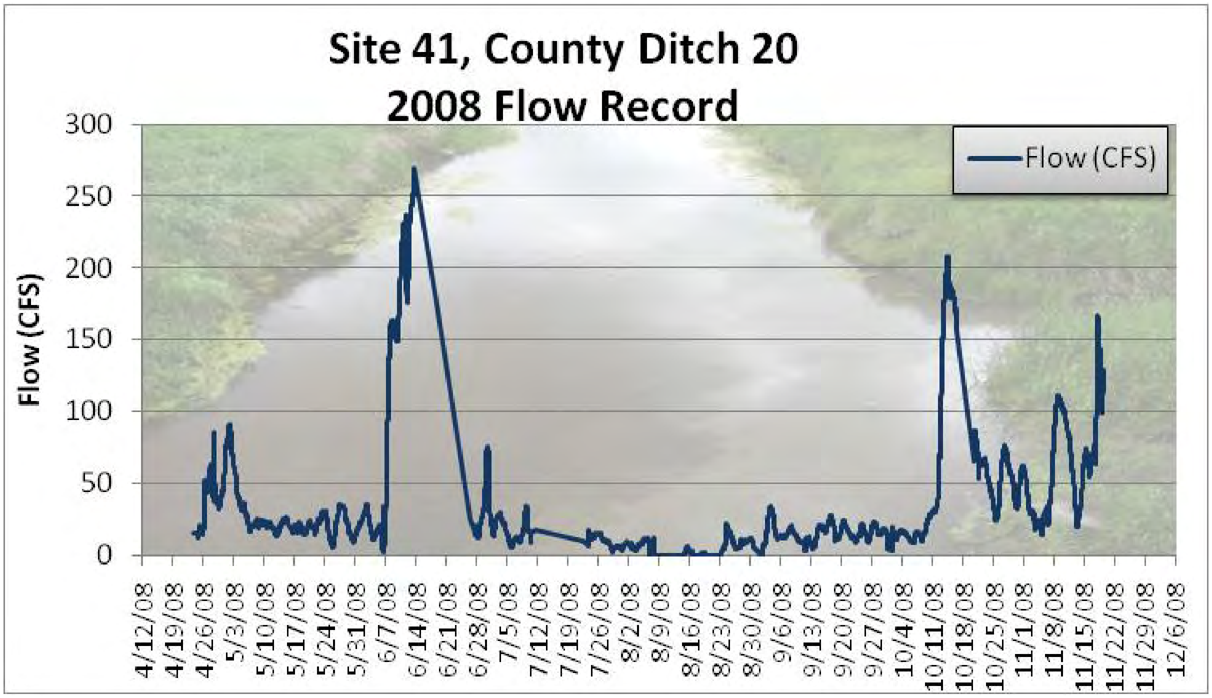


Figure 49. 2008 flow record at S.G. 41 on County Ditch 20.

Flows in CD 20 are less flashy than the Thief River. The flows can still increase quickly, but subside more gradually.

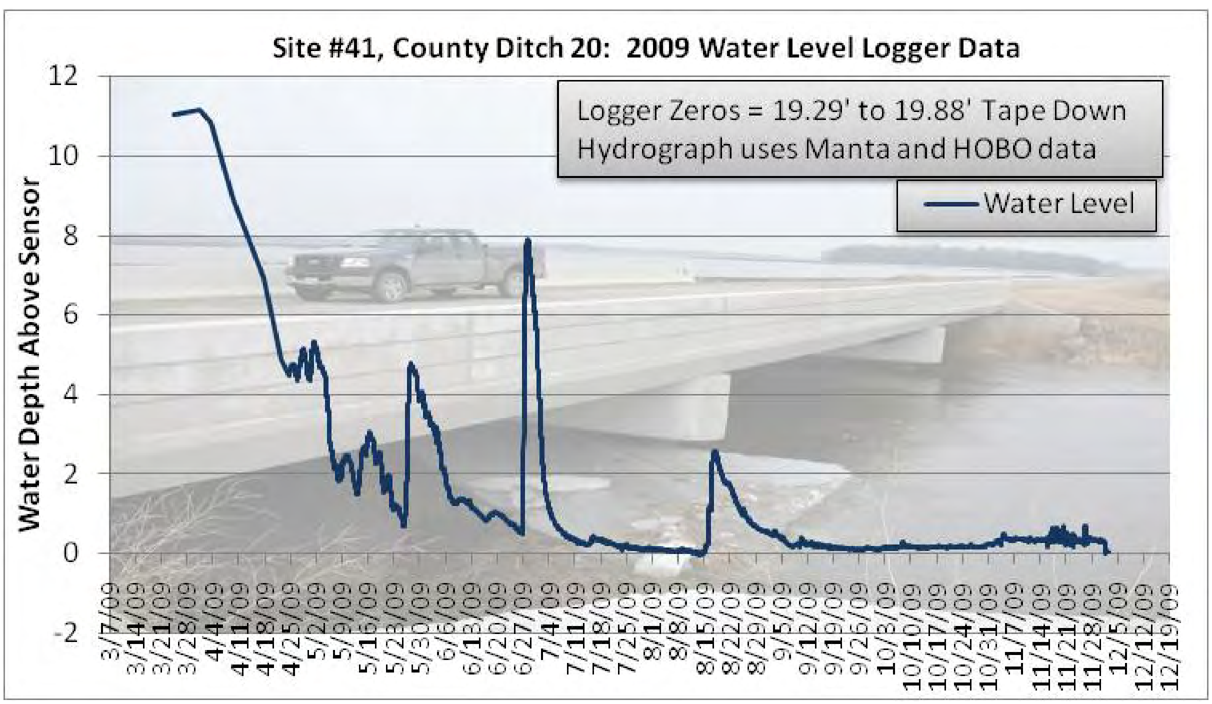


Figure 50. 2009 water level logger record at S.G. 41

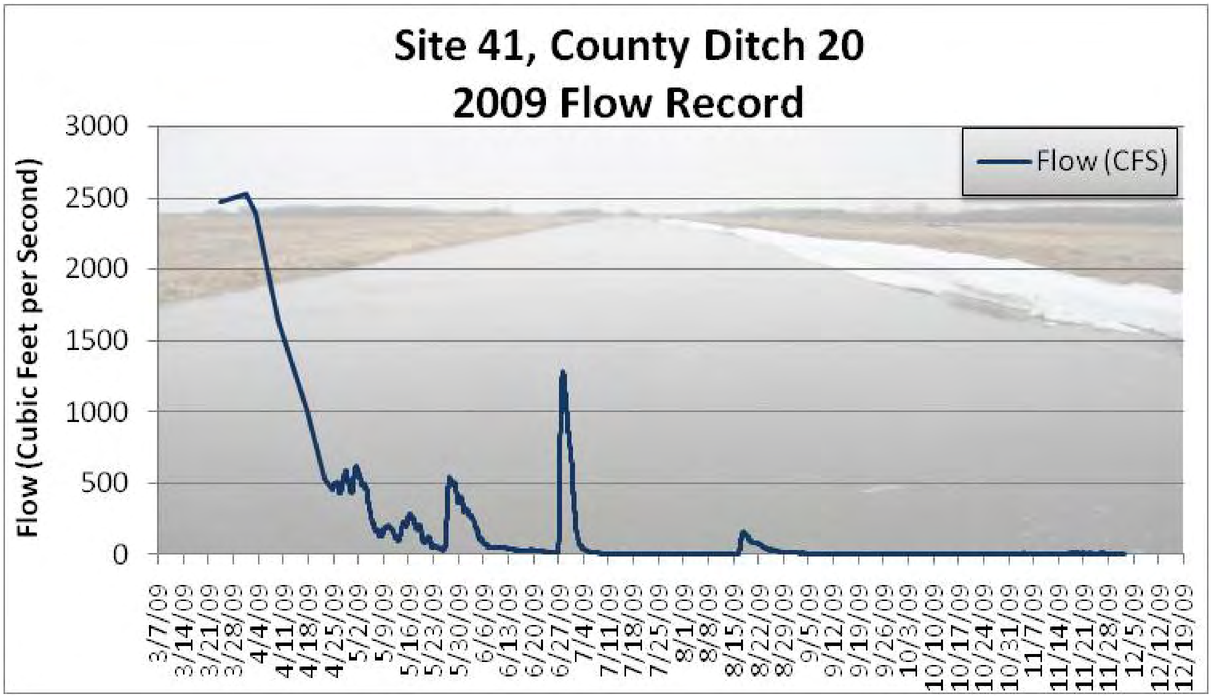


Figure 51. 2009 flow record at S.G. 41

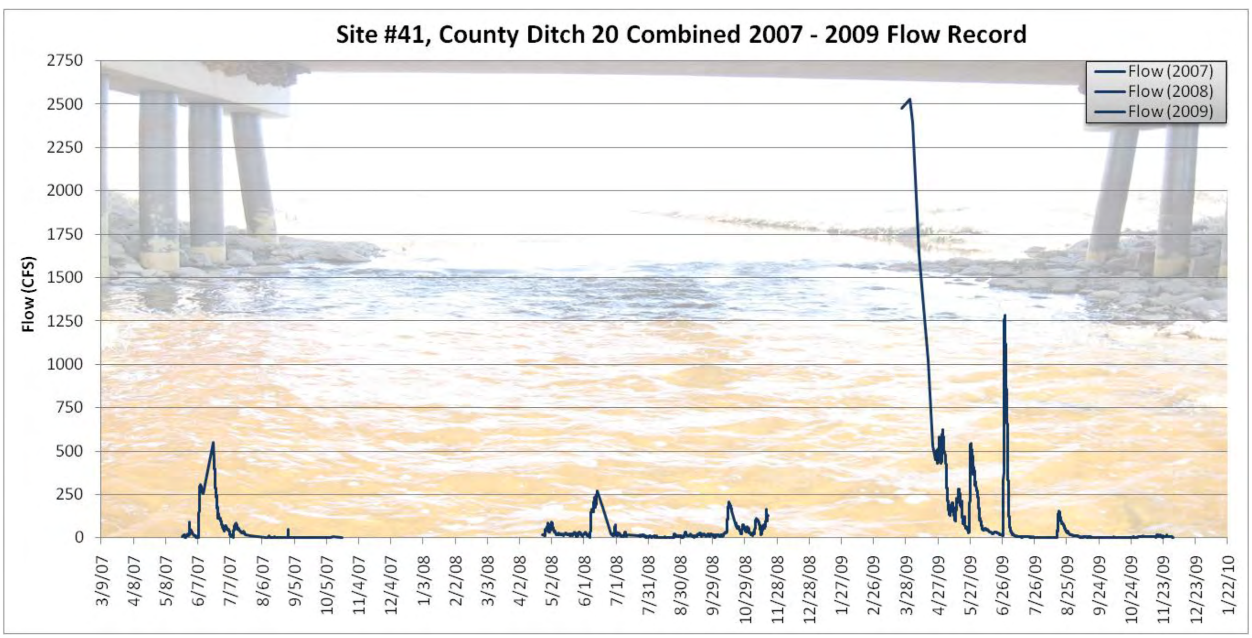


Figure 52. Combined 2007 - 2009 flow record at S.G. 41

Thief River at the County Road 7

High level of flow in the Thief River downstream of Agassiz NWR

Stream Gauge 40 at the CR7 Thief R. crossing on 3/31/09

Green water at CR7 Bridge on 3/18/09

The Thief River at Marshall County Road 7 (Agassiz NWR Headquarters Road) is referred to as stream gauge site # 40 by the RLWD. The official STORET code is S002-088. There is a staff gauge on the downstream side of the bridge. Water levels were collected with manual readings and a Eureka Manta multi-parameter sonde during the first part of the project. A HOBO water level logger was purchased and installed later on. Loggers are installed in pipes along the northeast wing wall of the bridge.

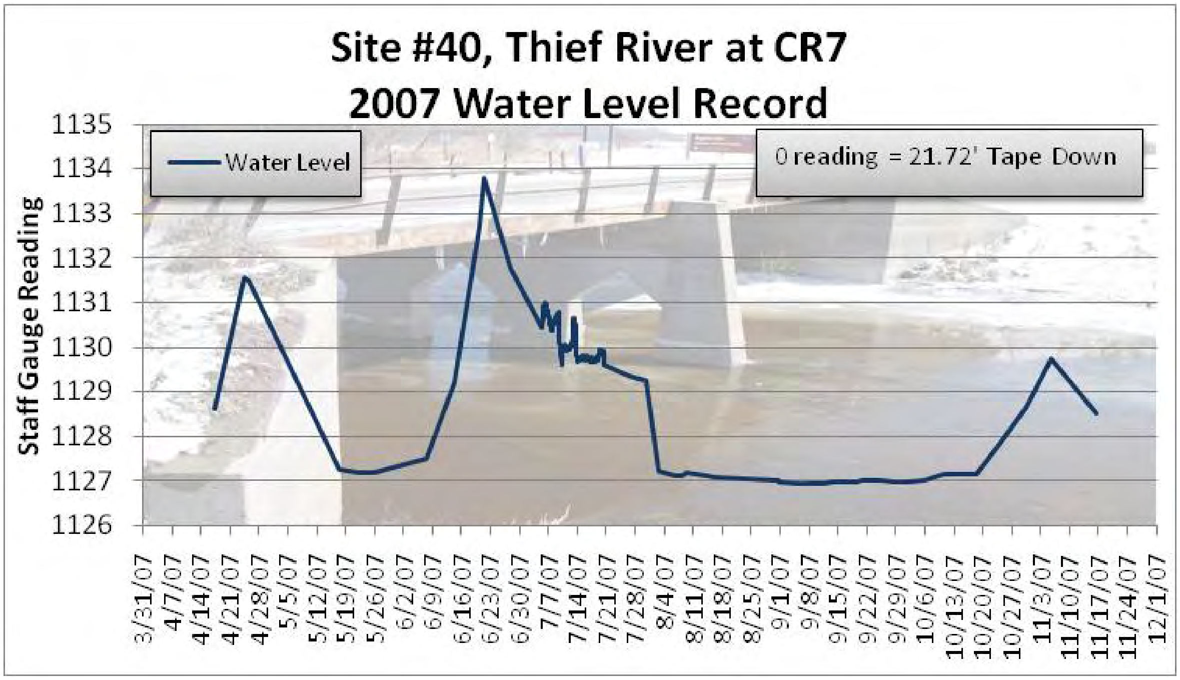


Figure 53. 2007 water level record at S.G. 40.

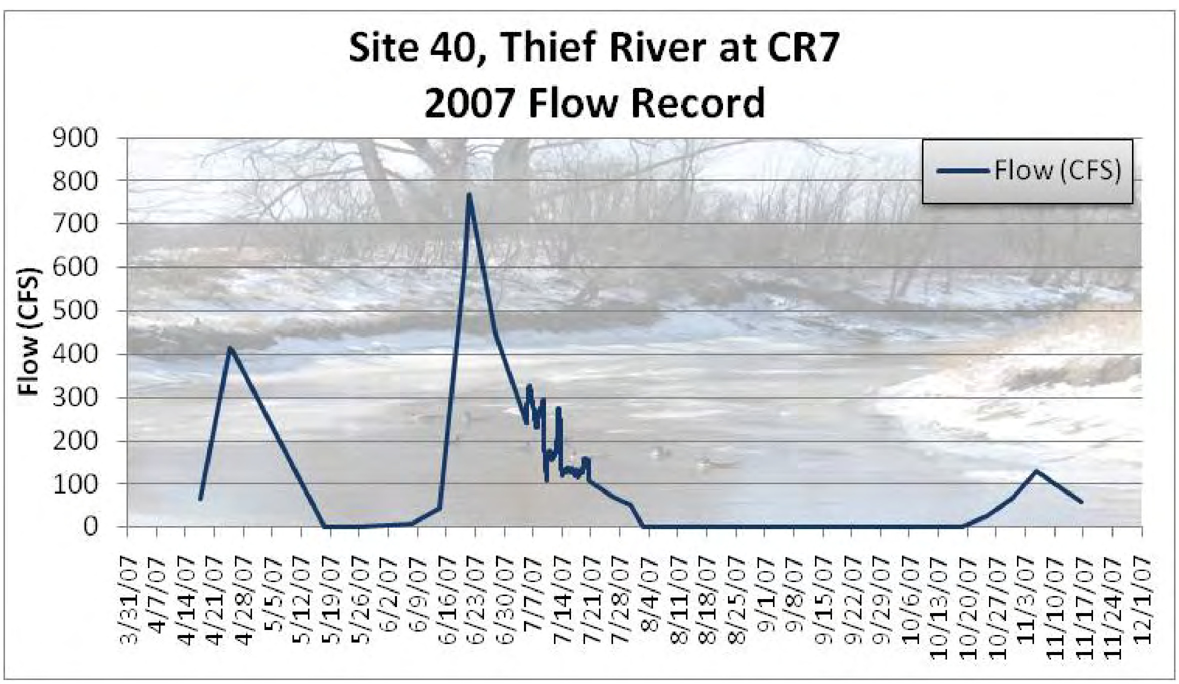


Figure 54. 2007 flow record at S.G. 40

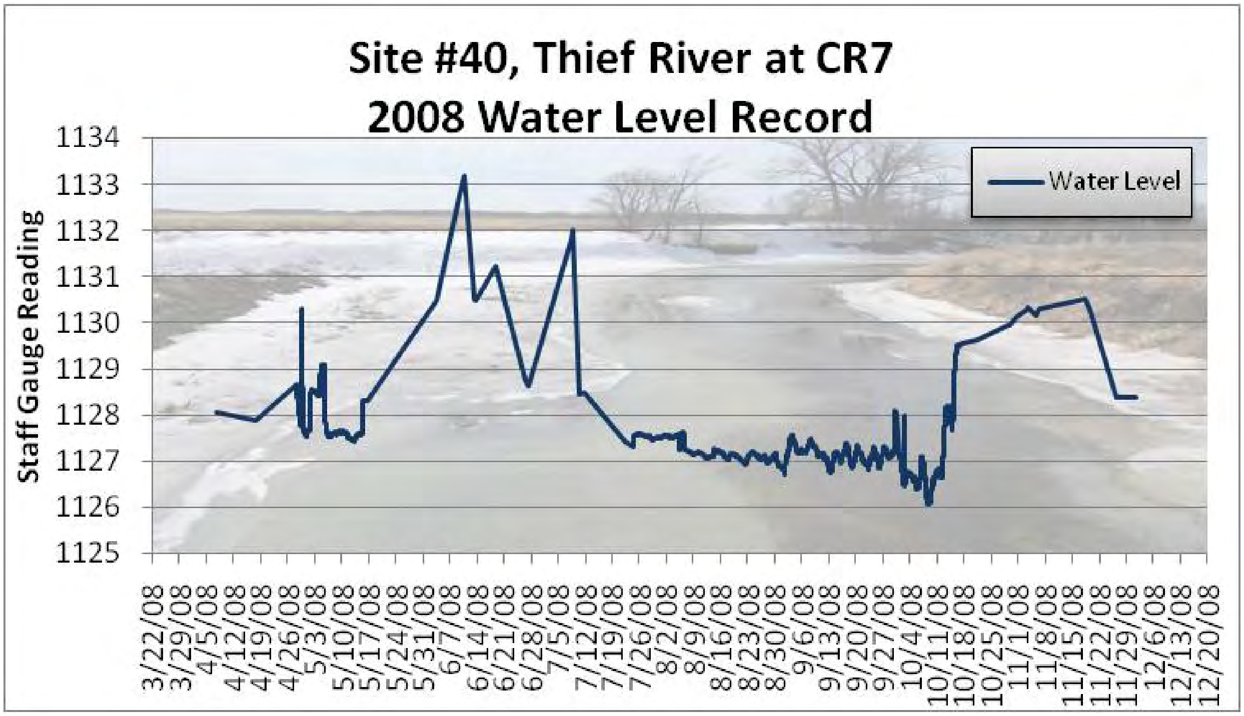


Figure 55. 2008 water level record at S.G. 40

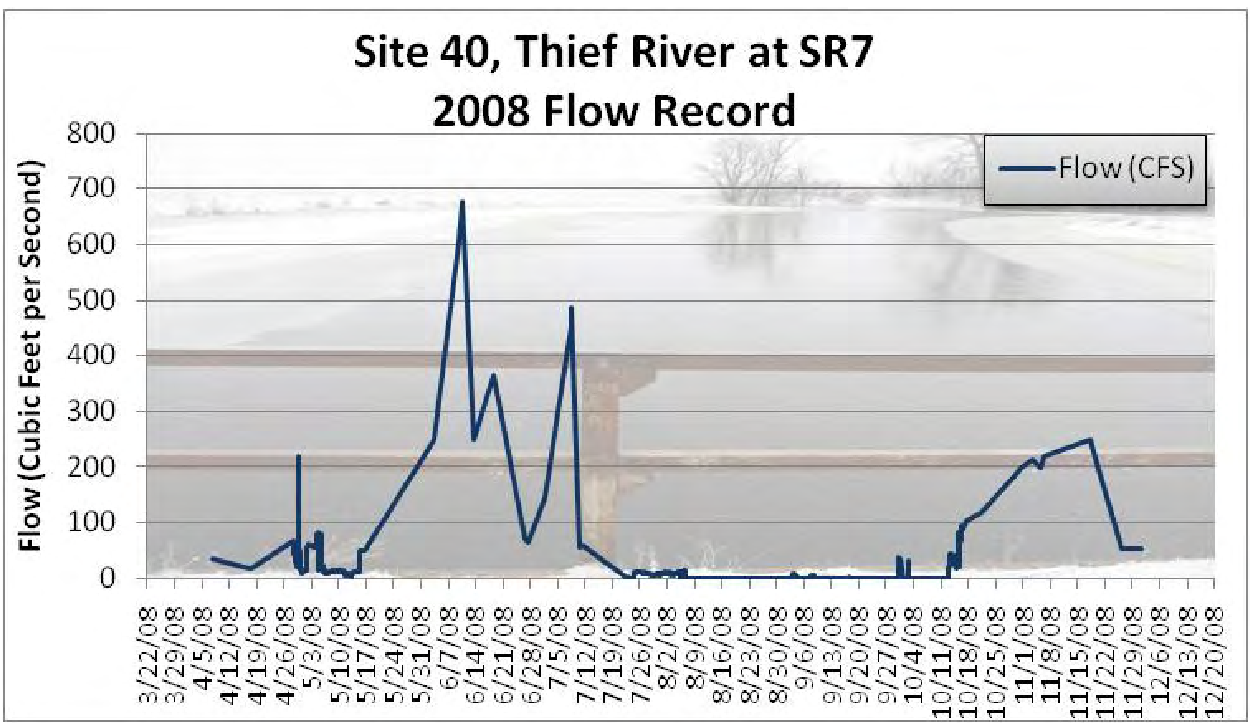


Figure 56. 2008 flow record at S.G. 40

In 2009, flows were too high to install the Onset HOBO water level logger until June. Frequent manual water level measurements were collected to compensate for that situation. Water level measurements (over all years) were collected by the RLWD, Marshall County Water Planner, and USFWS staff.

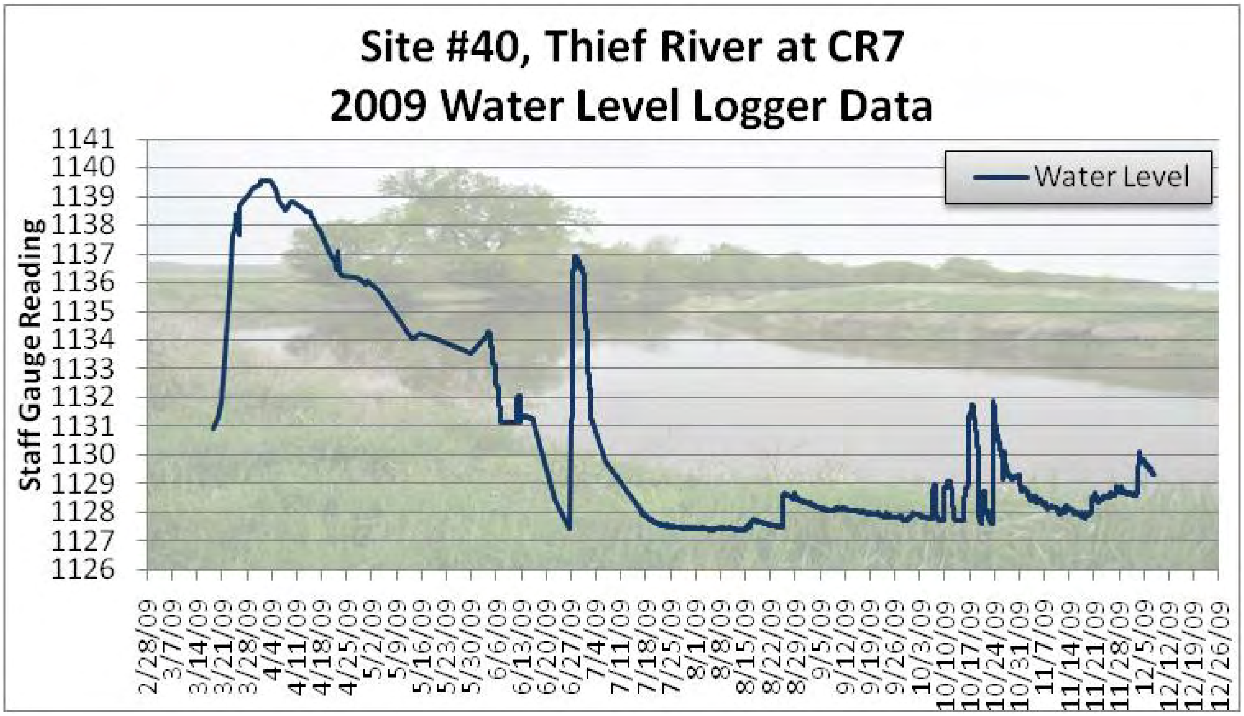


Figure 57. 2009 Water Level record at S.G. 40

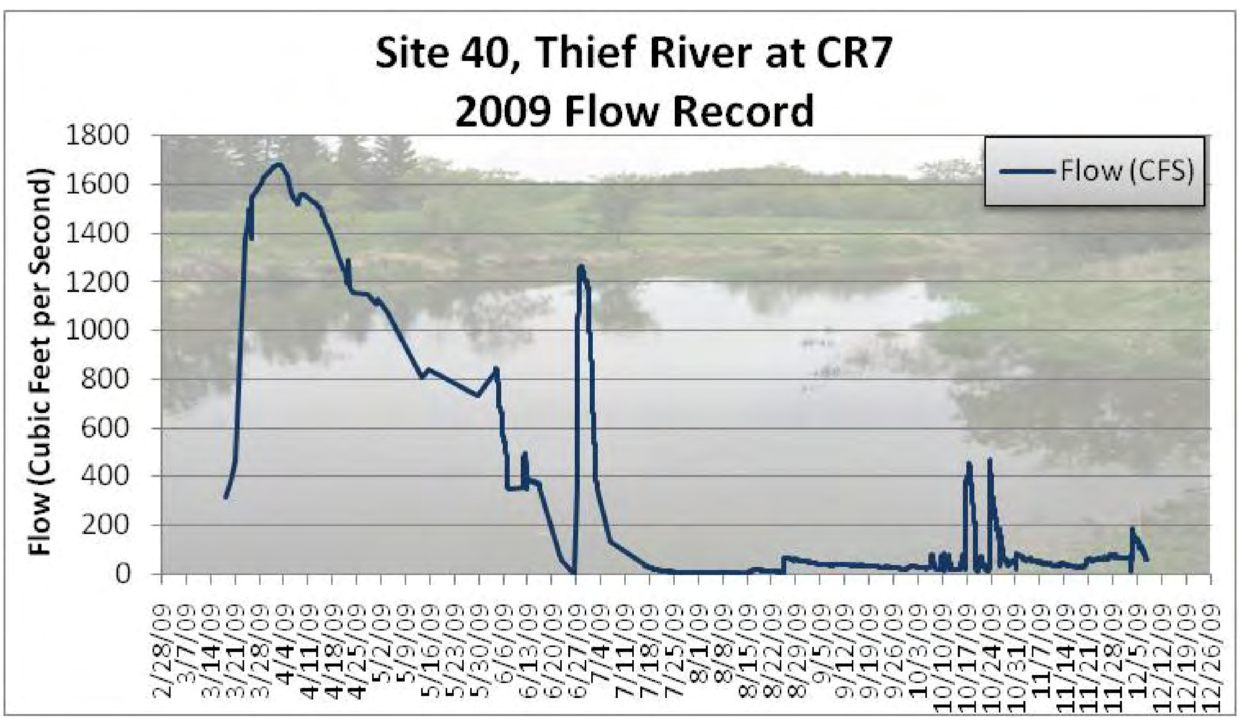


Figure 58. 2009 flow record at S.G. 40

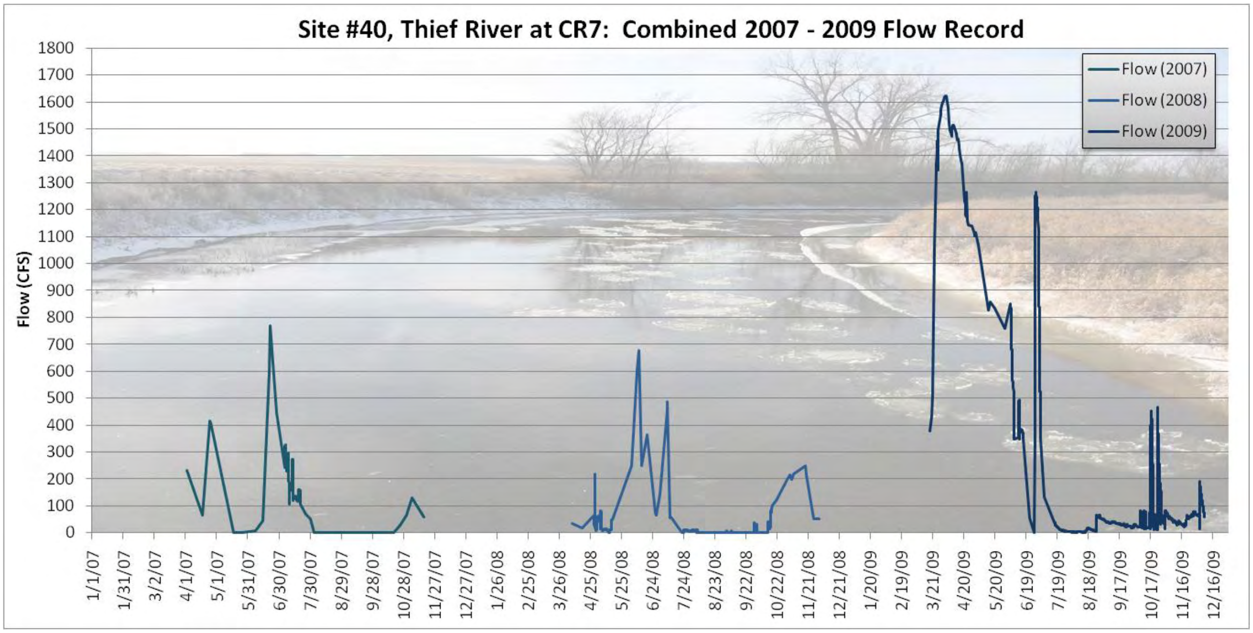


Figure 59. Combined 2007 - 2009 flow record at S.G. 40.

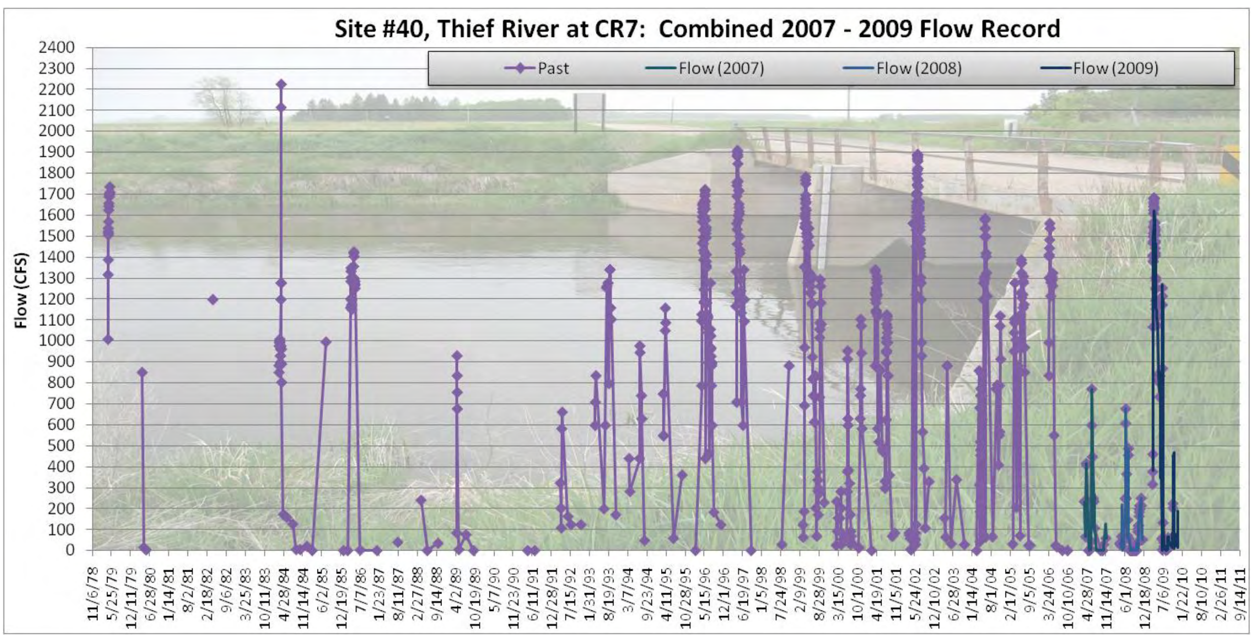


Figure 60. Complete flow record at S.G. 40

13,738 stage measurements have been collected at this site in the history of this gauging location as of the end of 2009. Most of the historical data was collected during high flows when people were most concerned about the water level at the site and the threat of flooding downstream. So, only the most recent three years of data truly come close to having a complete flow record at the site. 2009 is the best of these three thanks to diligent daily measurements made by Agassiz NWR and a switch from reliance on the Eureka Manta's level probe to the installation of a HOBO water level logger. Flow data and stage measurements came from a handful of different sources:

- Agassiz NWR monitoring by refuge staff for water management purposes
- Agassiz NWR monitoring by interns for the water quality study
- RLWD engineering technicians
- RLWD district monitoring program
- Continuous monitoring for this study
- Discrete measurements collected for this study
- Marshall County water planner
- Volunteer gauge reading done by local residents for the RLWD

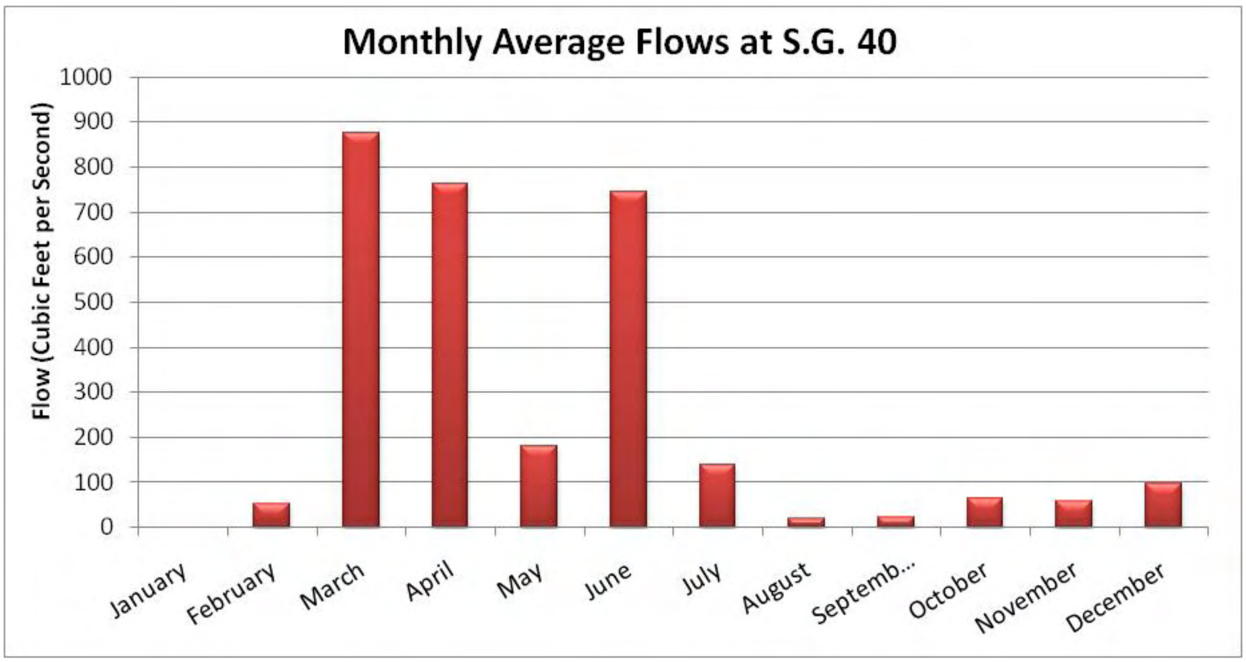


Figure 61. Monthly average flows at S.G. 40 based on all recorded stage measurements

Table 5. Yearly flow statistics at stream gauge 40

Flow Stats @ 40				
Row Labels	**Average of Flow**	**Max of Flow**	**Min of Flow**	**Number of Meas.**
1978	1145.0	1645.8	233.7	17
1979	1550.2	1734.2	1007.7	16
1980	289.2	849.7	3.0	3
1982	1197.2	1197.2	1197.2	1
1984	877.5	2223.9	5.0	29
1985	497.5	995.0	0.0	2
1986	1099.1	1424.7	0.0	29
1987	40.0	40.0	40.0	1
1988	91.7	240.0	0.0	3
1989	419.8	928.7	0.0	8
1991	0.0	0.0	0.0	2
1992	285.3	660.2	107.4	8
1993	902.1	1339.4	170.5	14
1994	561.9	976.1	48.0	8
1995	700.0	1156.1	58.2	9
1996	1241.4	1721.6	0.0	68
1997	1428.2	1908.0	0.0	39
1998	454.8	881.3	28.4	2
1999	1119.5	1781.6	63.3	69
2000	388.0	1102.4	13.2	31
2001	917.8	1339.4	0.0	53
2002	1270.3	1889.0	2.9	64
2003	340.0	881.3	28.5	7
2004	852.0	1584.2	0.0	49
2005	958.1	1386.8	24.4	30
2006	1058.2	1560.5	0.0	24
2007	182.0	770.8	0.0	754
2008	8.7	676.0	0.0	4720
2009	114.3	1622.9	0.0	7678
Grand Total	**120.0**	**2223.9**	**0.0**	**13738**

Thief River near the Thief Lake Outlet

Flow at the outlet of Thief Lake has been monitored by several agencies for more than 30 years. Minnesota Department of Natural Resources personnel manage the dam at the outlet of Thief Lake take regular (near daily) water stage levels and flow estimates. Staff from the Red Lake Watershed District and Marshall County have conducted water quality and stage monitoring at the CSAH 49 bridge that is 250 yards downstream of the Thief Lake dam. A HOBO water level logger was deployed at the bridge in 2007, 2008, and 2009. It collected measurements at a half-hour interval while it was deployed. Discrete flow measurements and estimates were used to “round out” each year by filling in the early spring high flows and the early winter (post-freeze) low flows when the water level logger was not deployed. The site was given the STORET code of S002-084 by the MPCA.

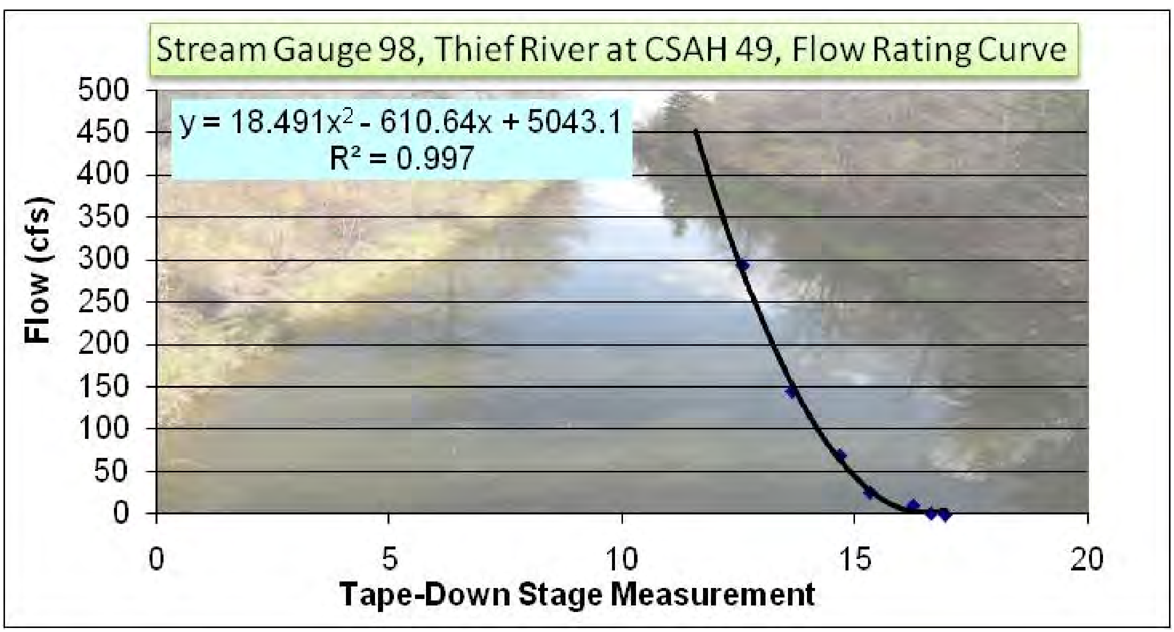


Figure 62. Flow rating curve for stream gauge 98.

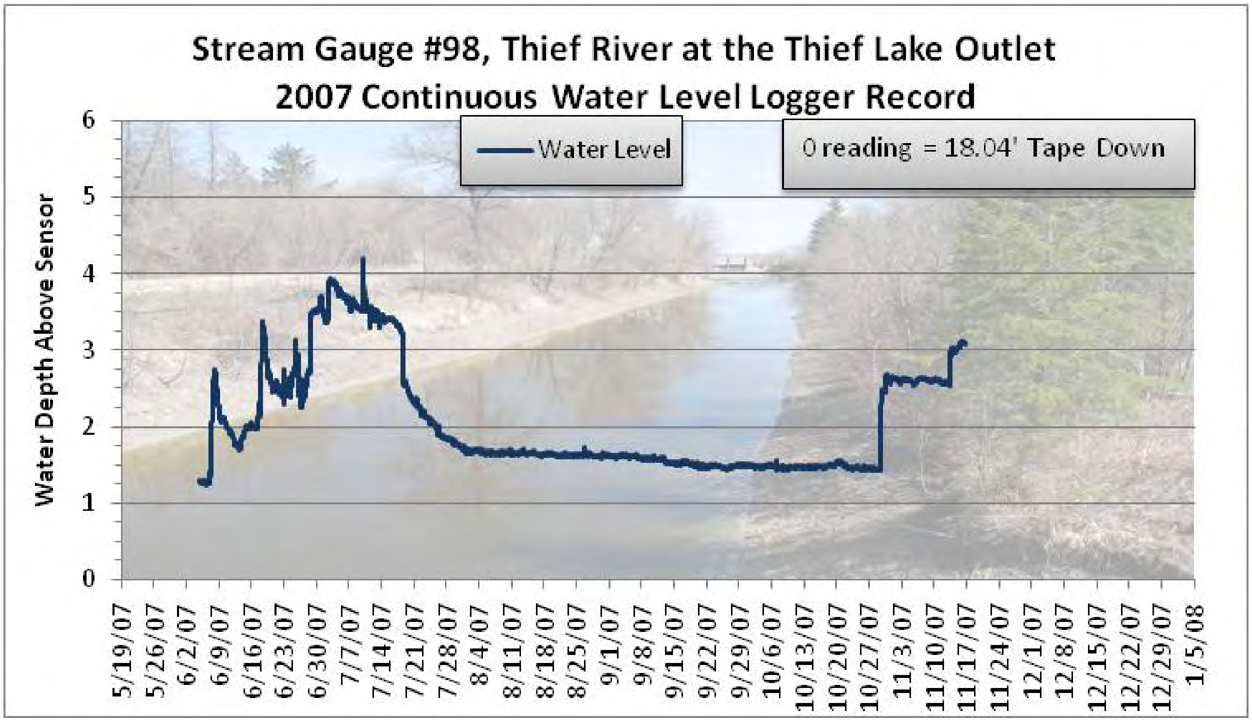


Figure 63. 2007 water level record at S.G. 98

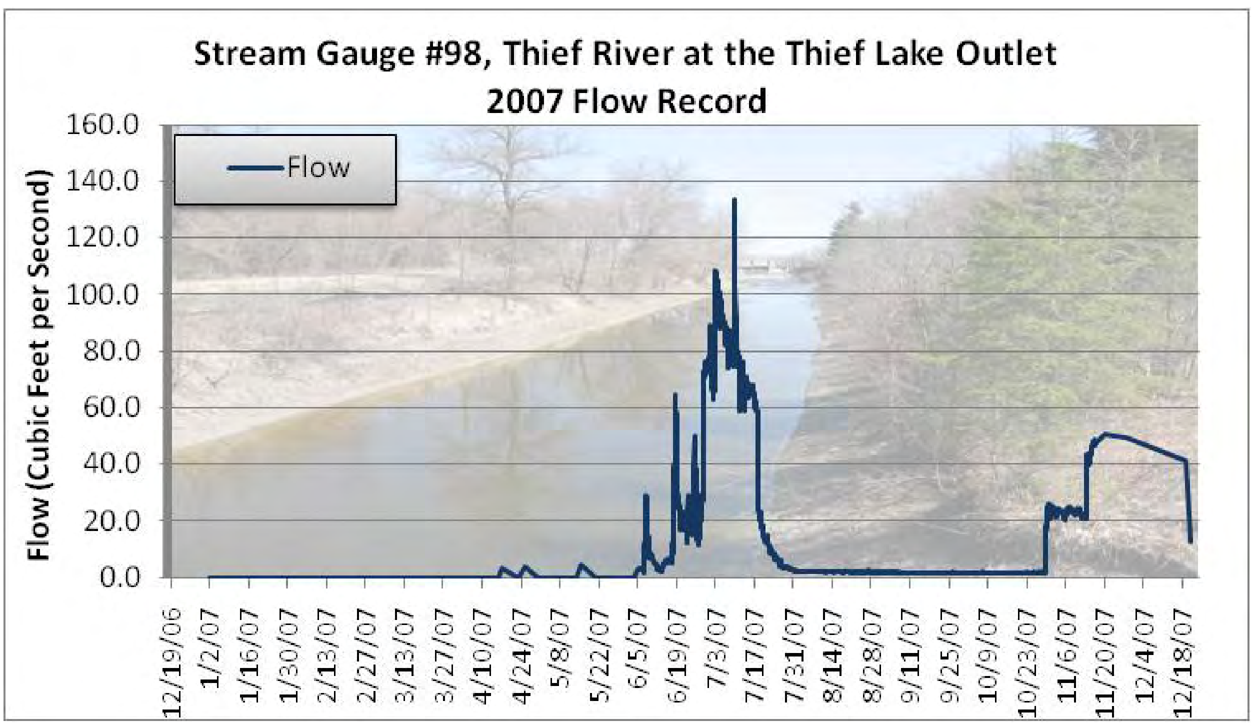


Figure 64. 2007 combined flow record at the Thief Lake Outlet

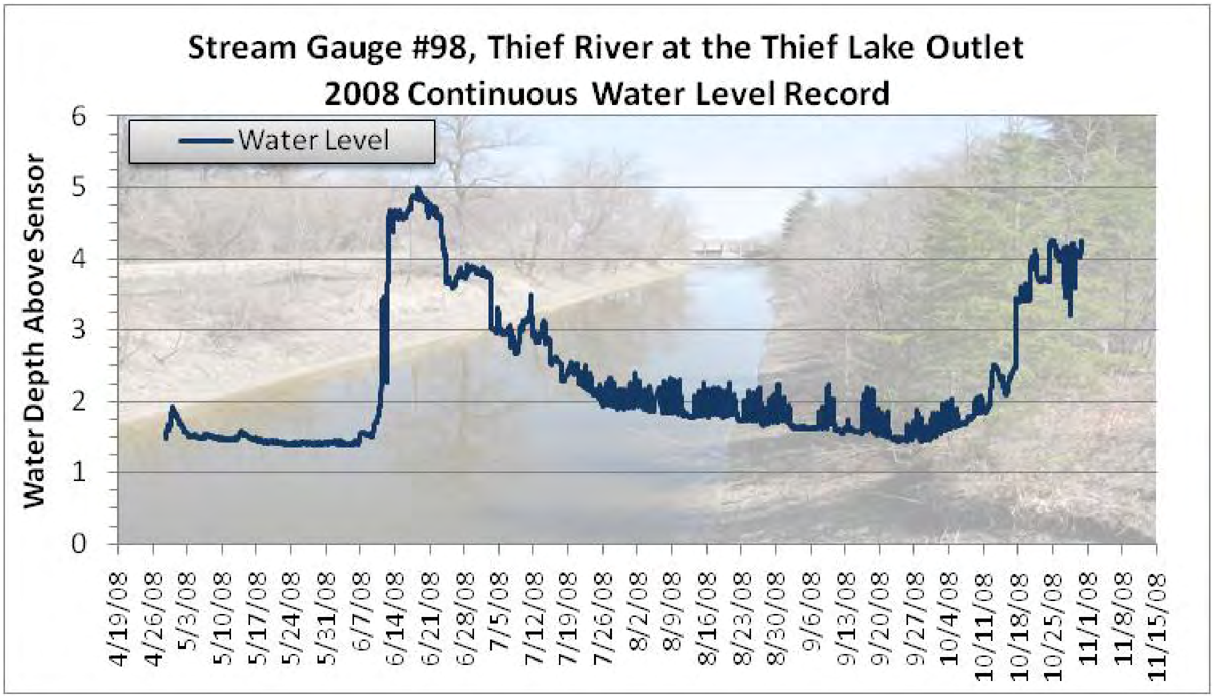


Figure 65. 2008 water level record at the Thief Lake outlet.

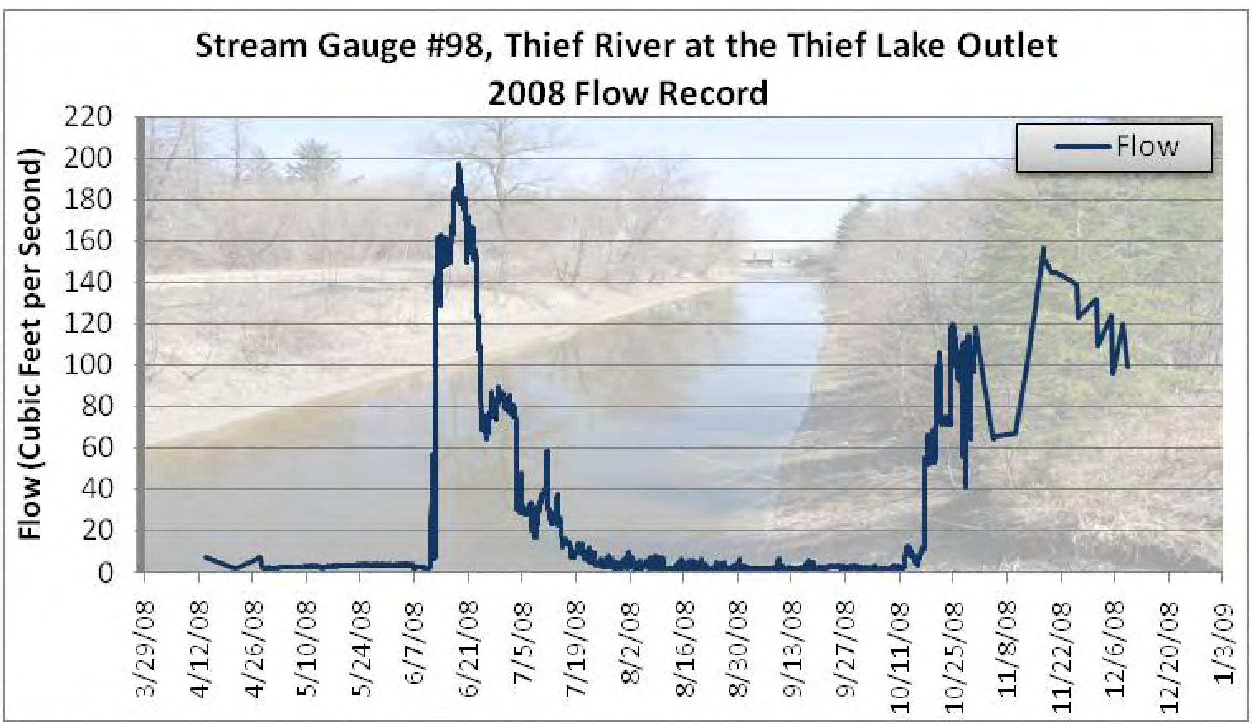


Figure 66. 2008 flow record at the Thief Lake outlet

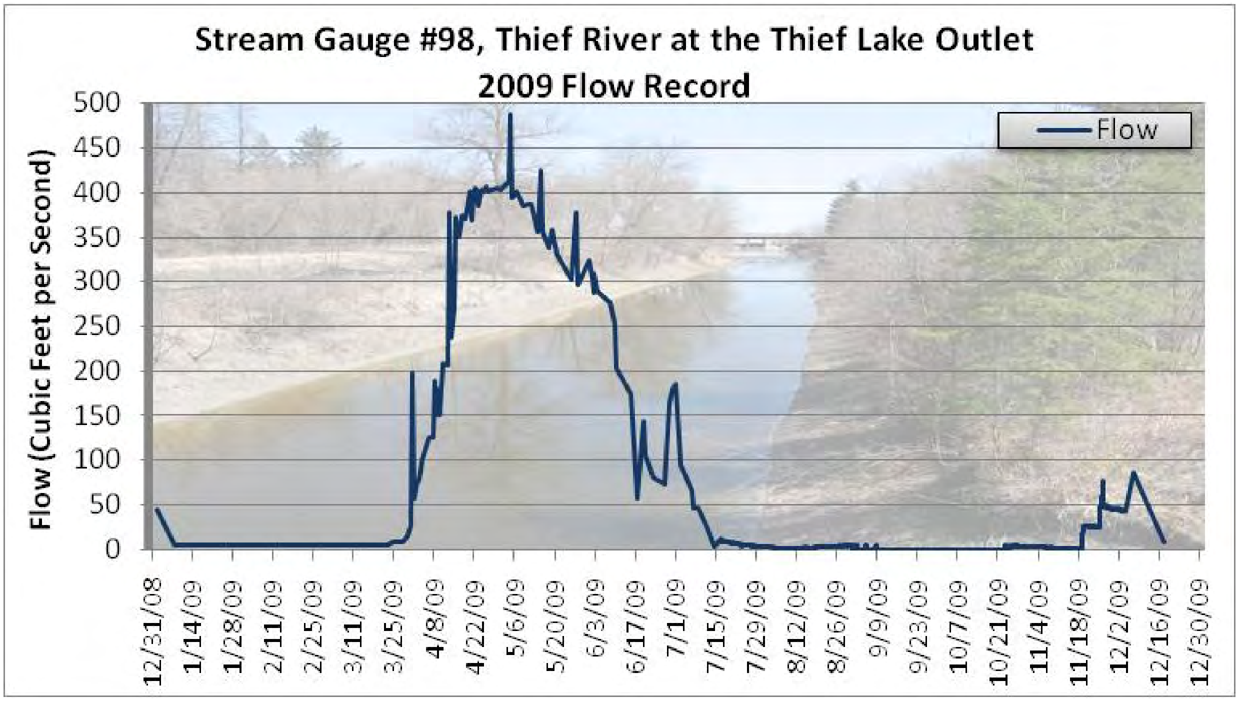


Figure 67. 2009 flow record at the Thief Lake outlet

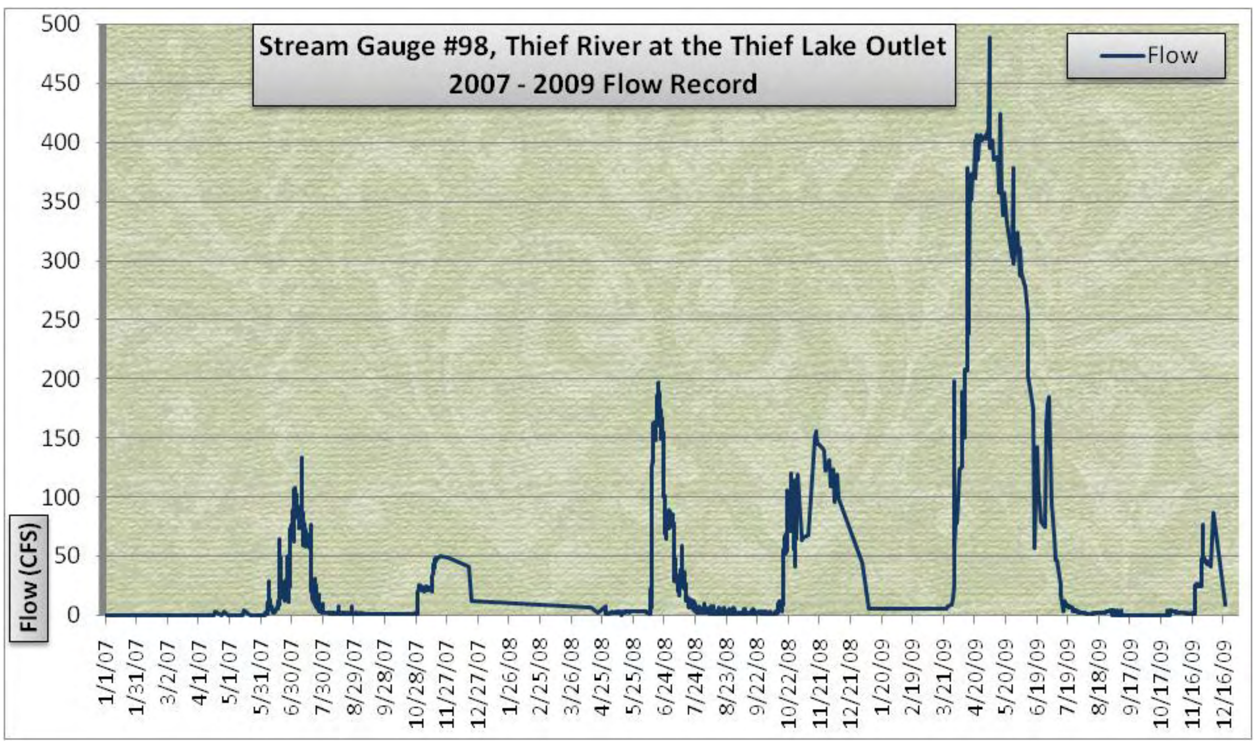


Figure 68. 2007 through 2009 combined flow record at the Thief Lake outlet

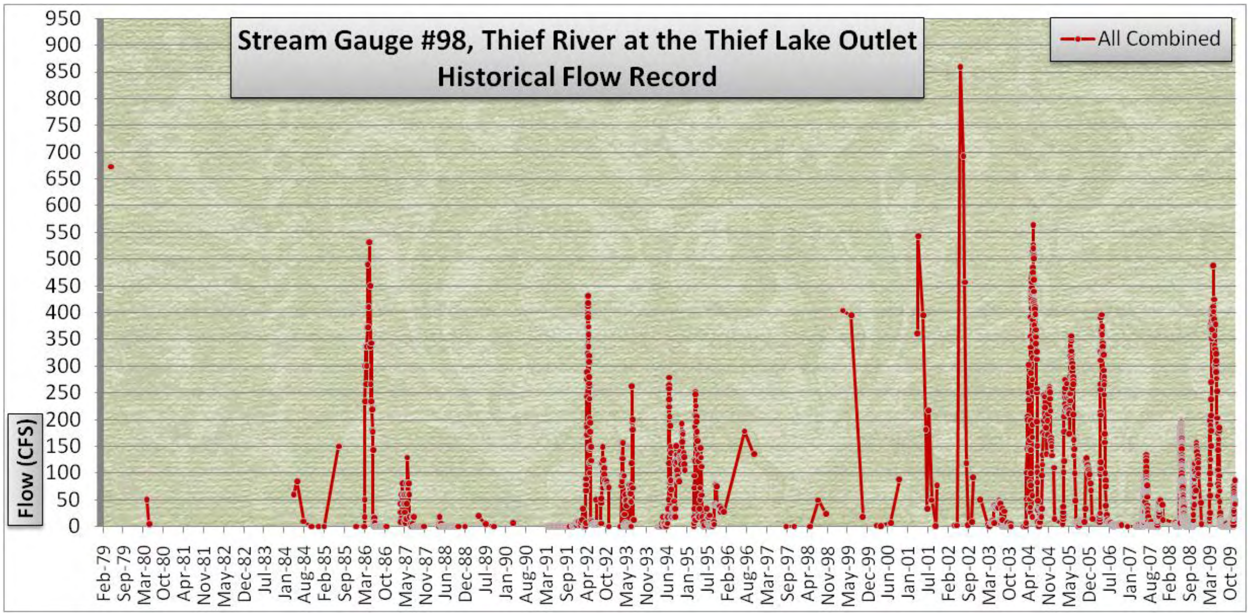


Figure 69. Historical flow record at the Thief Lake outlet.

The summer months have many observations of flow levels due to the water level logger that was installed. The early spring and early winter measurements are fewer in number and could be skewed toward the high side because people are generally more concerned with recording water levels during high flows than normal/low flows.

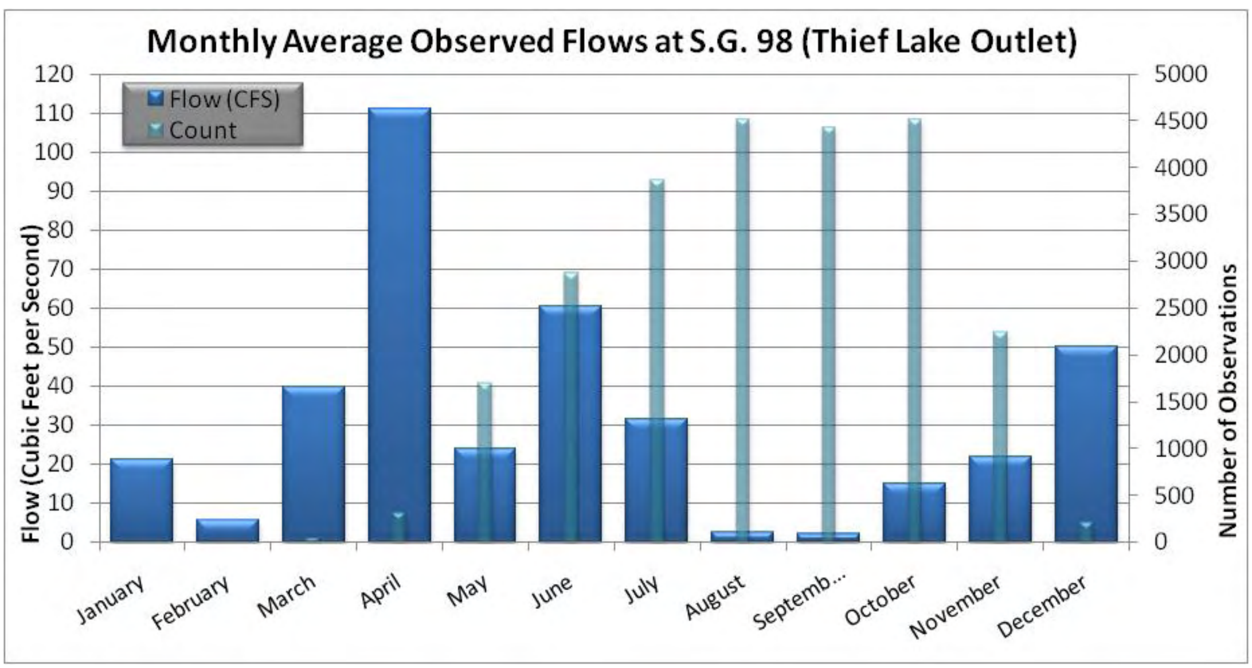


Figure 70. Monthly flow statistics at the Thief Lake Outlet

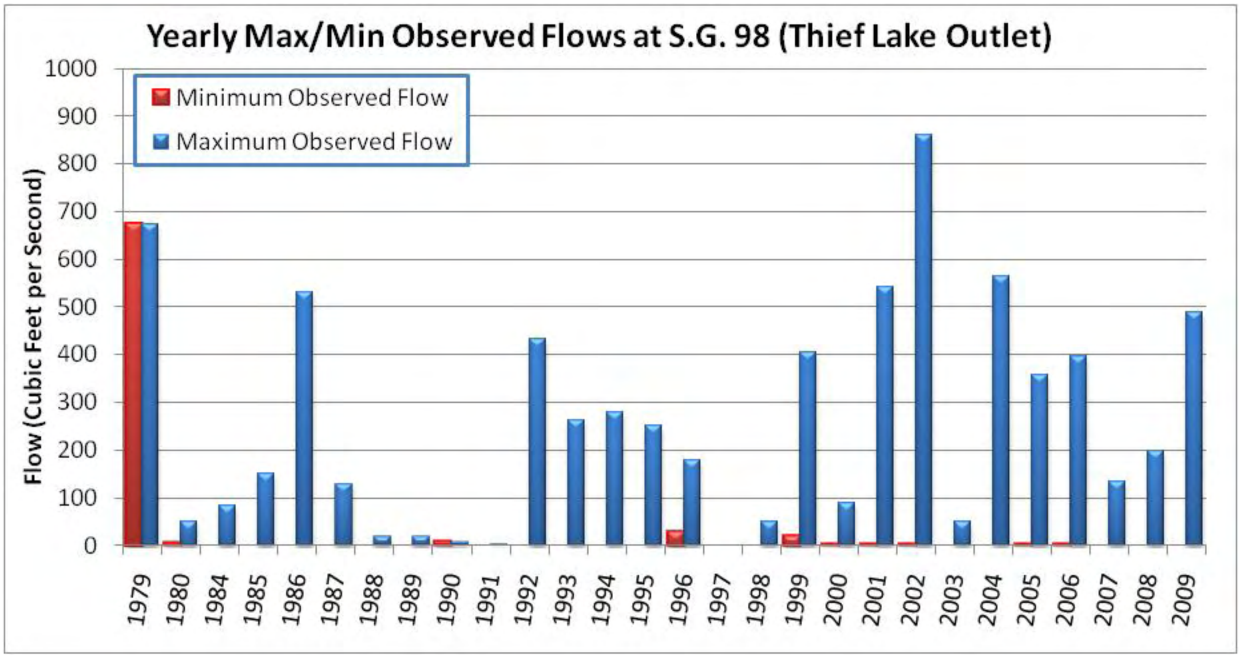


Figure 71. Yearly maximum and minimum flows at the Thief Lake outlet.

Flow at this site is characterized by a relatively gradual rise and fall to water levels in the spring, low flow throughout the summer, and an increase in flow at the end of the year. The end-of-the-year increases in flows occur annually as the Thief Lake water level is allowed to draw down to the targeted winter pool. At the same time that the DNR is trying to lower the water level in Thief Lake for the winter, the Moose River Impoundment, located at the opposite, upstream end of Moose River, is also drawing down to winter elevations.

Table 6. Yearly flow statistics for the Thief Lake outlet (for use in TMDL development).

Year	Max of Flow	Min of Flow	Count of Flow
1979	672.6	672.6	1
1980	50.0	5.0	2
1984	84.7	0.0	5
1985	150.0	0.0	2
1986	532.0	0.0	72
1987	129.0	0.0	59
1988	18.0	0.0	62
1989	20.0	0.0	3
1990	7.5	7.5	1
1991	3.0	0.0	62
1992	431.7	0.0	149
1993	263.0	0.0	73
1994	279.0	0.0	94
1995	251.0	0.0	82
1996	178.5	28.0	3
1997	0.0	0.0	2
1998	49.8	0.0	3
1999	403.6	18.8	3
2000	88.1	1.9	4
2001	543.3	1.9	9
2002	859.7	1.9	9
2003	50.9	0.0	66
2004	834.7	0.0	140
2005	356.7	1.7	98
2006	396.0	1.8	83
2007	133.7	0.0	7979
2008	284.7	0.0	8929
2009	488.7	0.0	6797
Grand Total	**859.7**	**0**	**24792**

Mud River at Highway 89

Mud River at Hwy 89 on 3/24/09

The Highway 89 crossing of the Mud River is a strategic point for measuring the stage of the river and the amount of flow headed toward Agassiz NWR from the east. This site was given the STORET code S002-078 by the MPCA. For many years, stage measurements were collected using a staff gauge on the downstream side of the bridge by measuring down from reference points. The upstream curb was used for tape downs by the RLWD water quality program. The downstream curb RP was used by the RLWD engineering staff. In recent years, a USGS RP (notched into the top of a steel guard rail post) was used more often in recent years because it provided a nice crisp edge at a more convenient height. In July of 2009, the bridge was replaced with box culverts. An RP was marked and surveyed at the top (outer lip, not the curb) of the upstream end of the center culvert. This construction disrupted the stage monitoring in the first half of 2009.

The USGS has installed a gauge to measure peak flow at this site. They also measure flow several times each year. A combination of USGS and RLWD flow measurements were used to create a flow rating curve for the site. The USGS measurements of high flows don't follow the curve well, so they're quality is questionable. The quality of the measurements is affected more by the difficulty of the measurement (flow spread out across a floodplain) than the skill of any of the people that are recording the measurements/estimates.

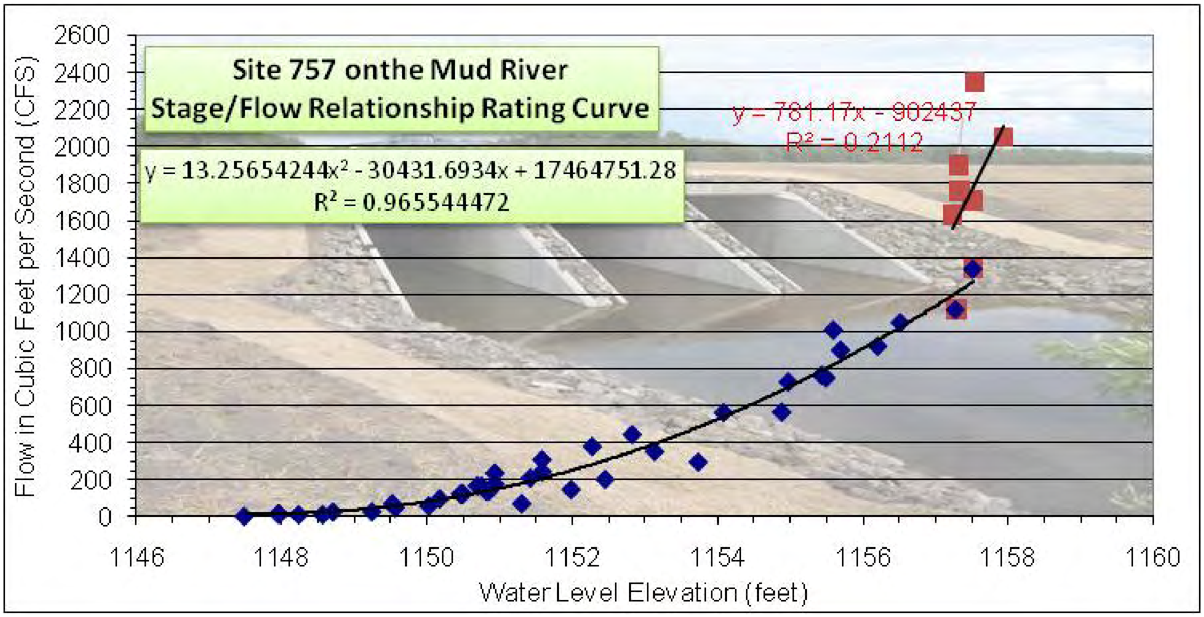


Figure 72. Flow rating curve at USGS station 05075700

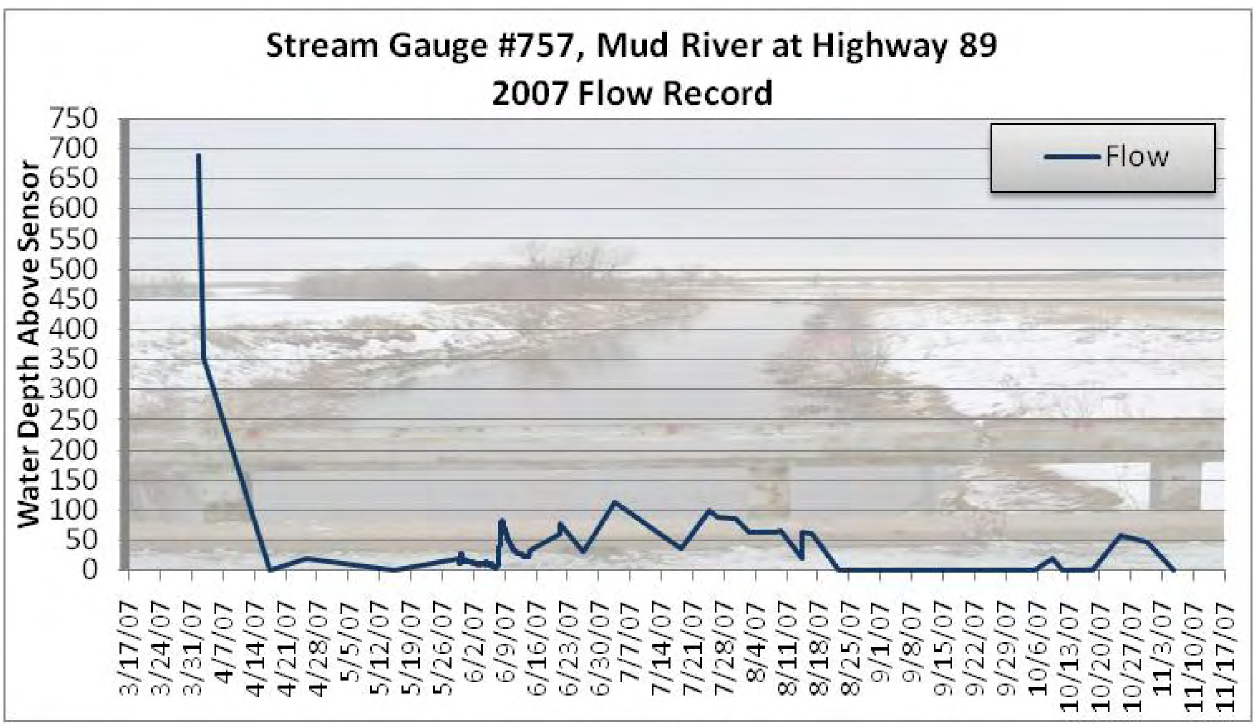


Figure 73. 2007 flow record at S.G. 757.

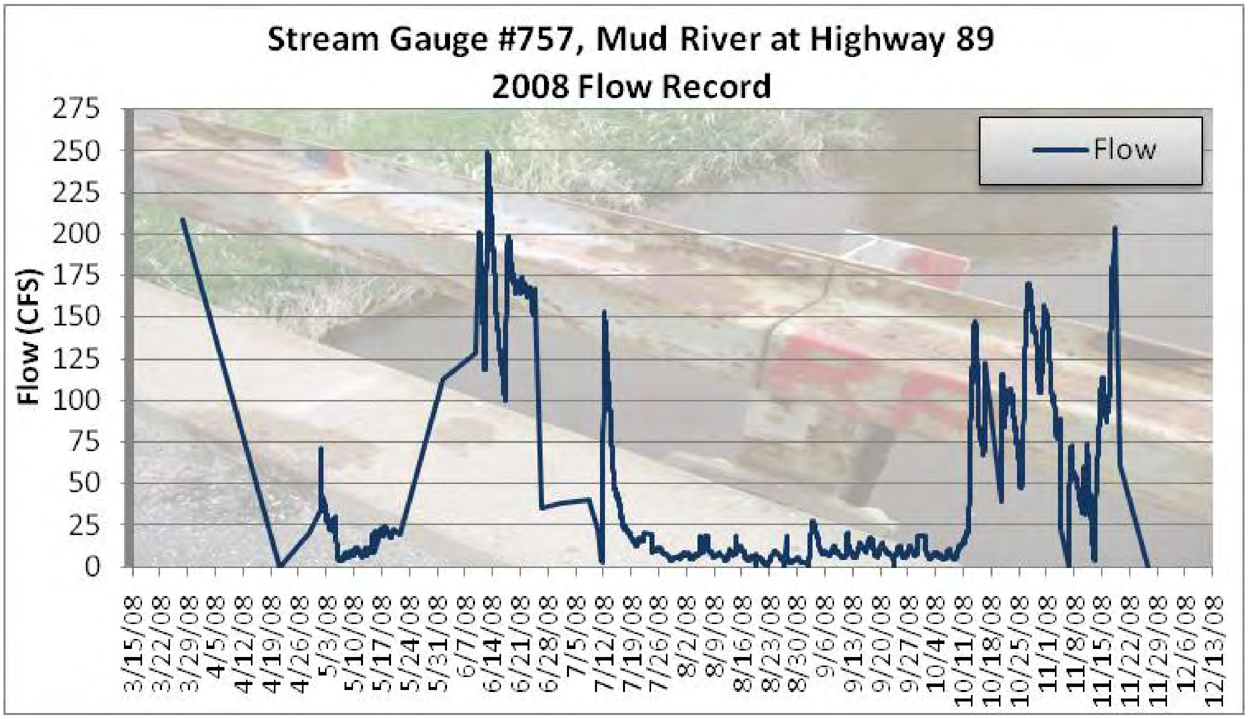


Figure 74. 2008 flow record at S.G. 757

The spring of 2009 was marked by major flooding in the area. The floodplain inundation was approximately ½ mile wide at Highway 89.

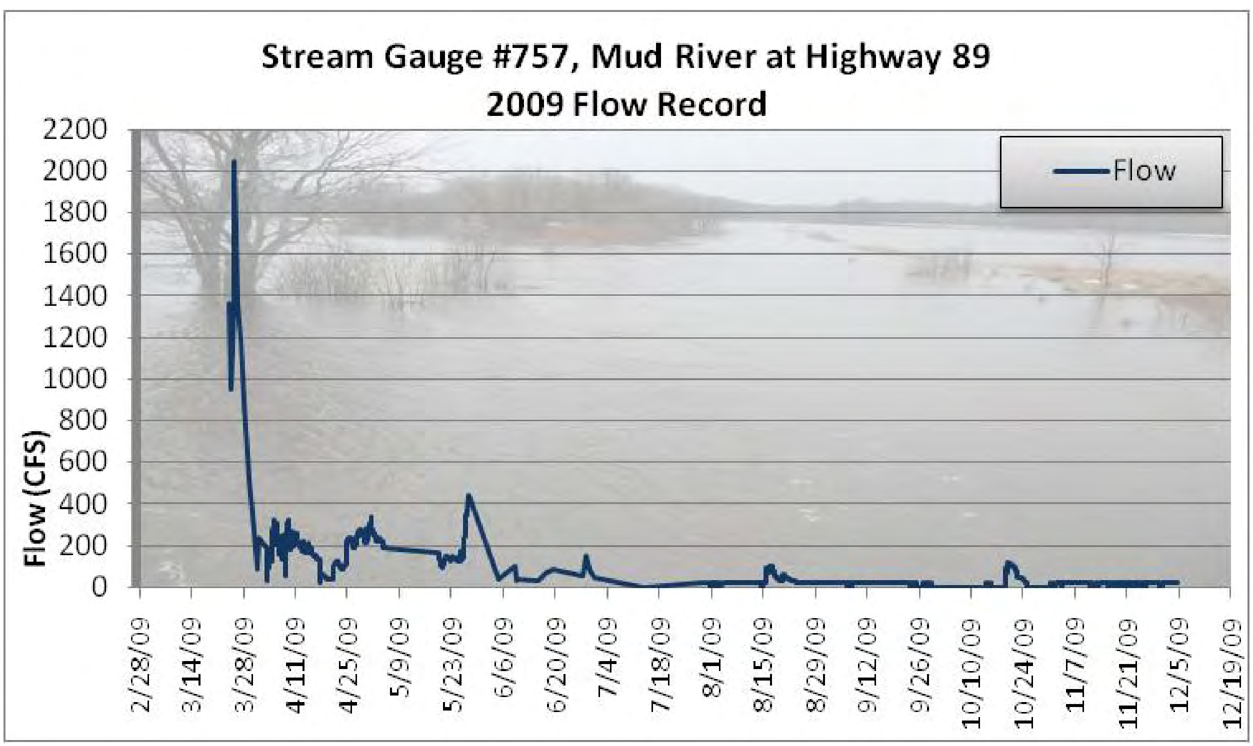


Figure 75. 2009 flow record at S.G. 757

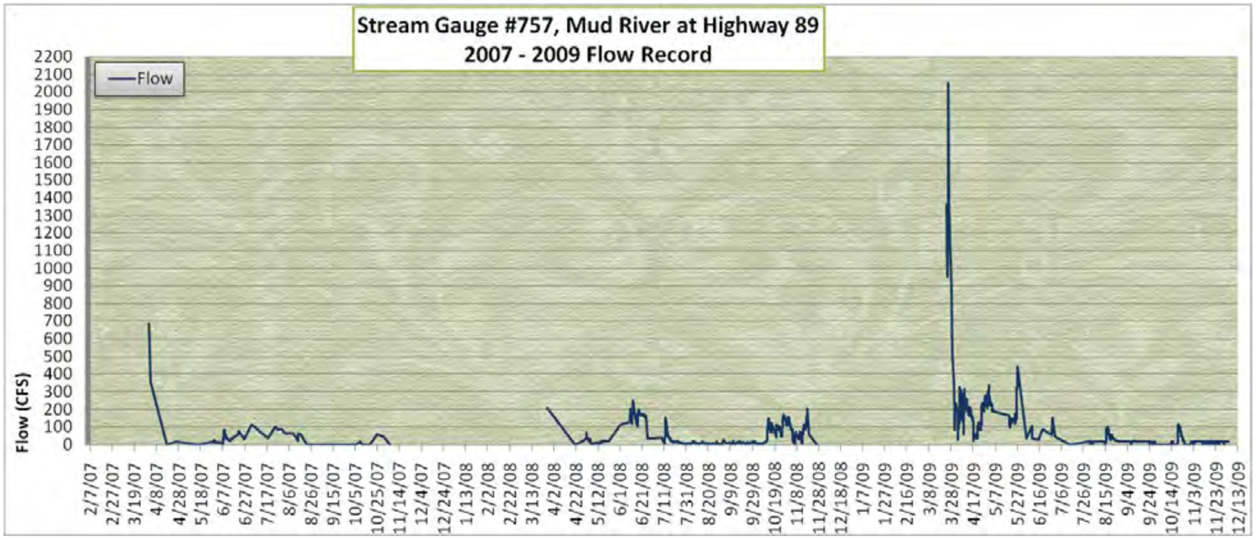


Figure 76. 2007 - 2009 flow record at S.G. 757

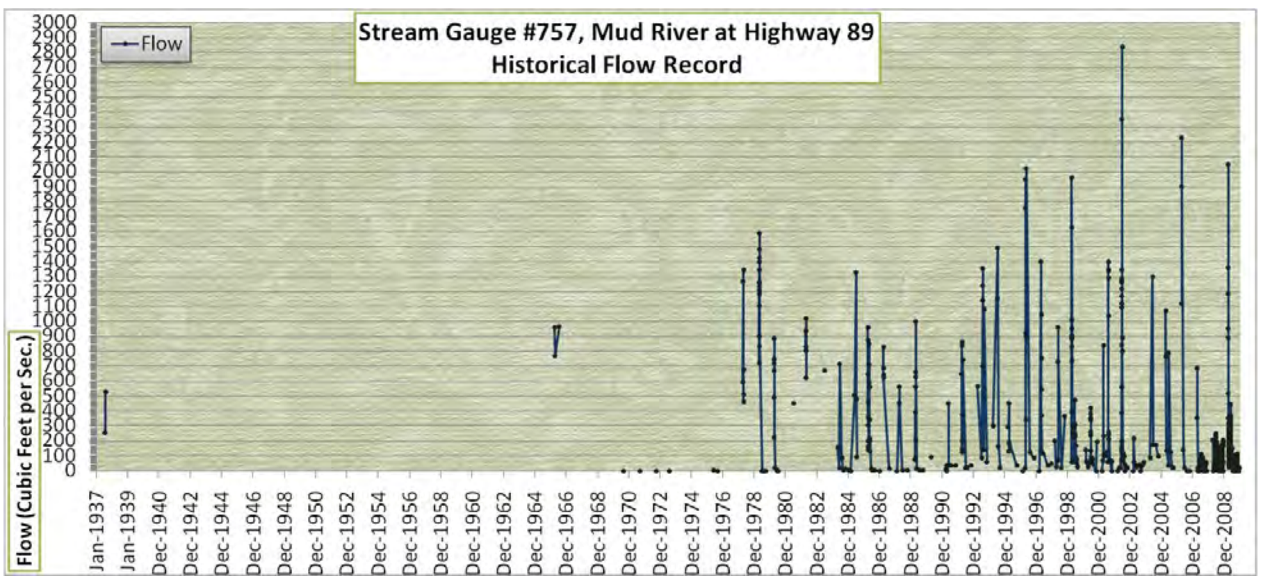


Figure 77. Historical flow record at USGS 05075700

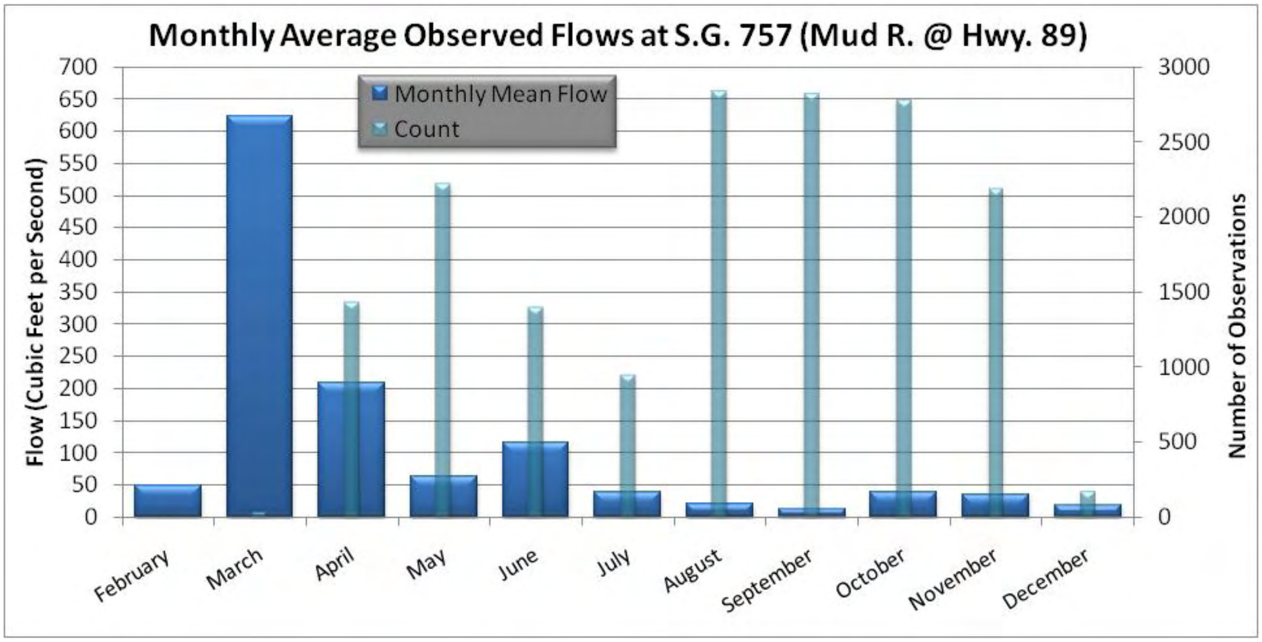


Figure 78. Monthly average flows at S.G. 757

The yearly minimum observed flows are a little higher prior to the start of the RLWD monitoring program in the early 1980's. This is probably because the site was used as a peak flow monitoring station by the USGS. People weren't concerned with measuring stage during low flows and there wasn't any other reason to visit the site.

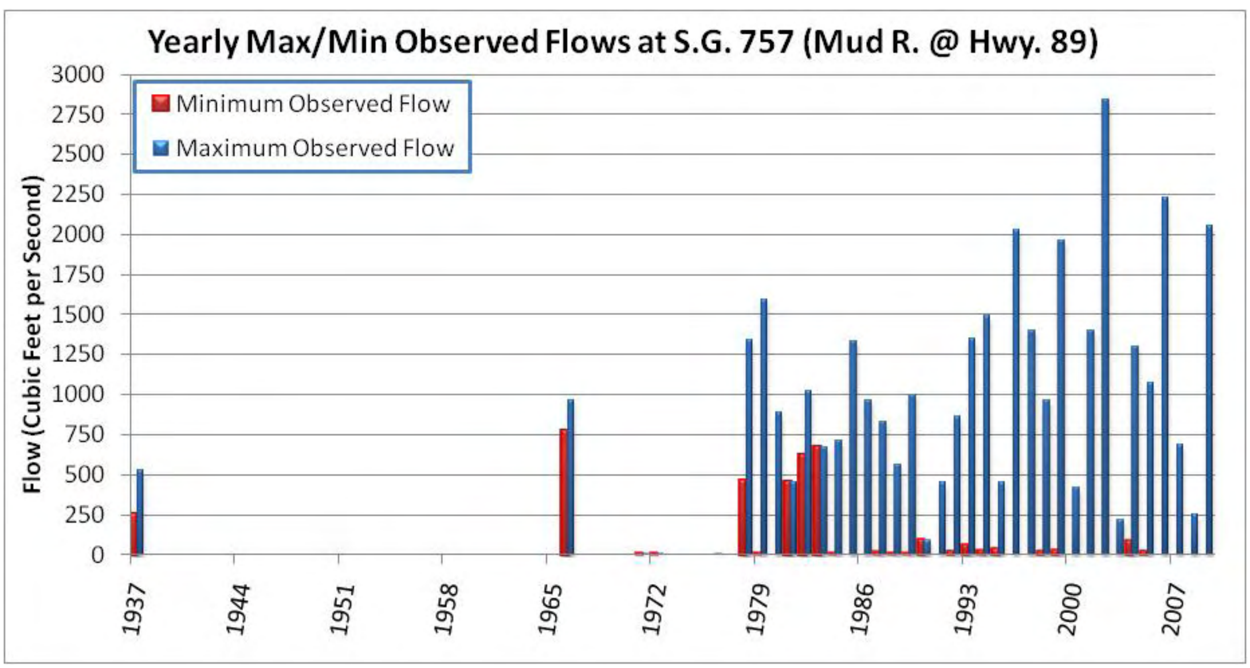


Figure 79. Historical peak flows at S.G. 757

Moose River at CSAH 54

The Marshall County Water Planner had done some sampling at the CSAH 54 crossing of the Moose River prior to this study. The Highway 89 crossing is closer to Thief Lake, but backwater from the lake makes rating curve development virtually impossible. It is impossible to estimate loads without a rating curve. So, the Moose River flow monitoring site for this project was moved to the CSAH 54 monitoring site. The site has been given several names over the years. It is stream gauge number 43 for the RLWD; the Marshall County Water Planner named it X4; and the MPCA gave it the S004-211 STORET code.

An Onset HOBO water level logger was installed on the south bank of the river on the upstream side of the crossing. Stage is measured in a couple of ways. There is a staff gauge on the downstream end of the center culvert that can be read during high flows (the center culvert is dry during low flows). During every site visit, a measure-down stage reading was taken at the painted RP on the upstream end of the south culvert. Flow was measured by the RLWD for the purpose of creating a flow-rating curve. This has been a high quality flow monitoring site. Most of the flow measurements lie very close to the curve, so flow can be accurately predicted from a stage reading.

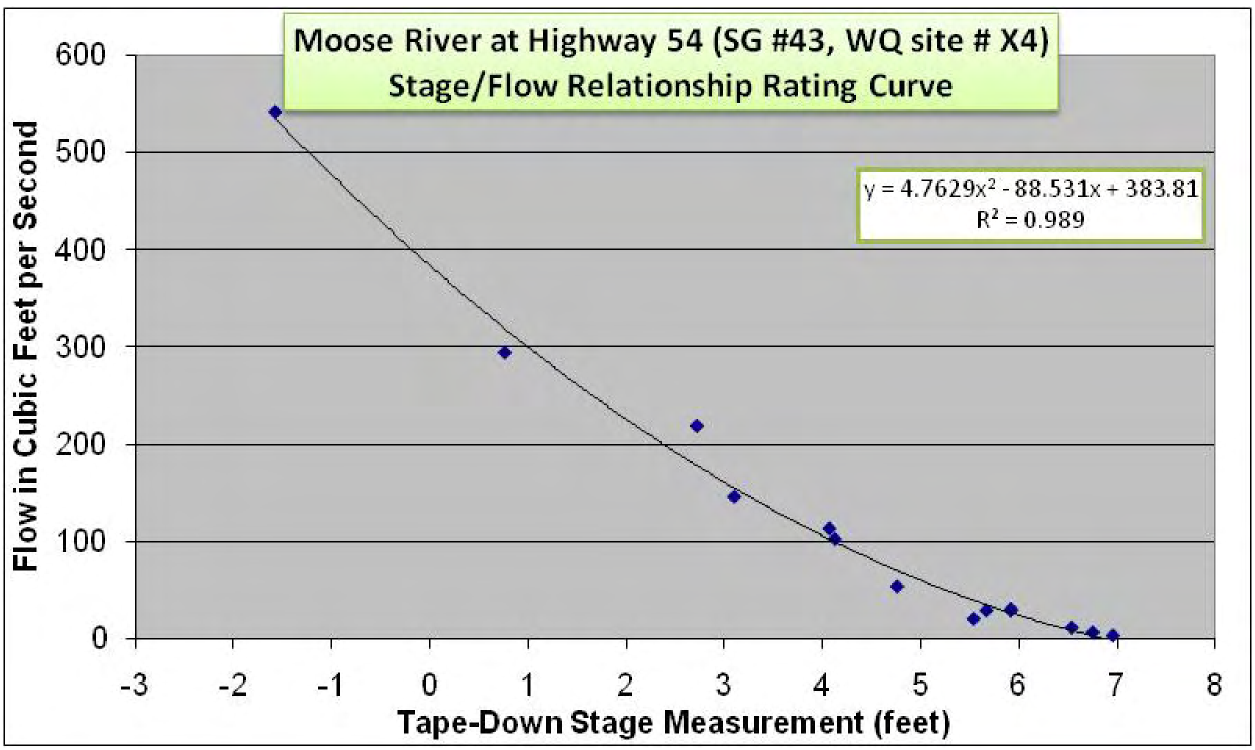


Figure 80. Flow rating curve for stream gauge #43 on the Moose River

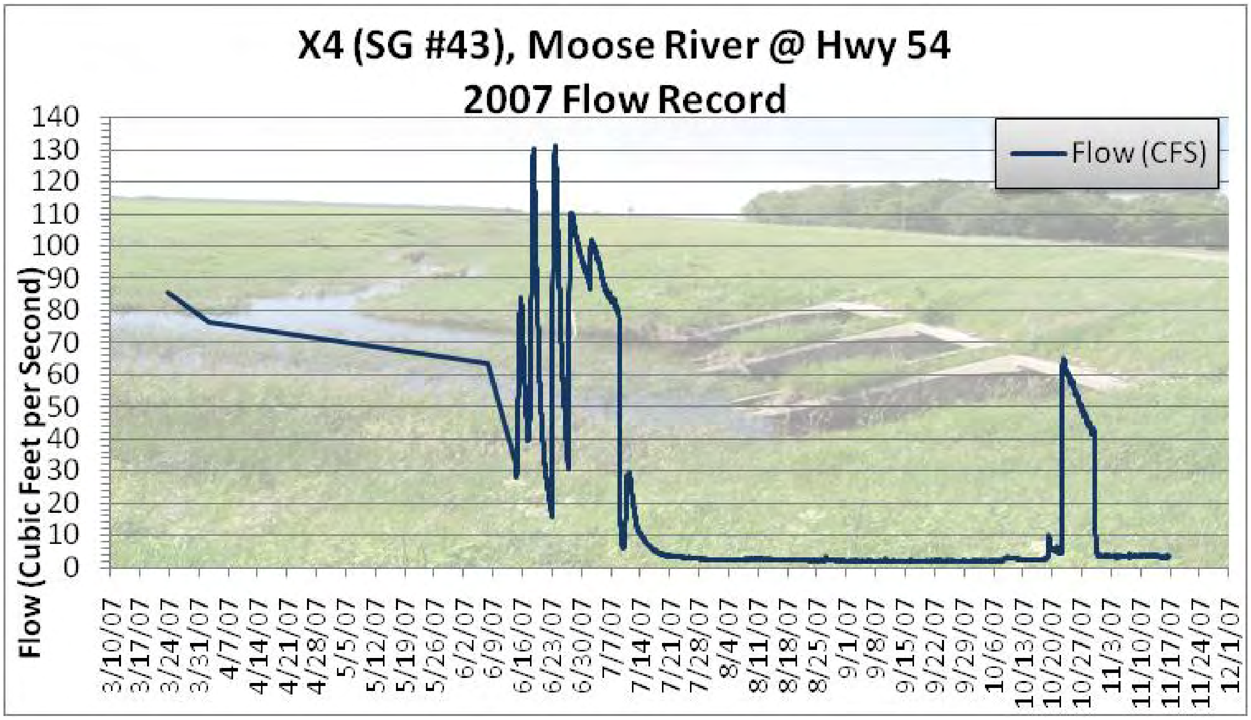


Figure 81. 2007 flow record for the Mud River at CSAH 54.

Flow at the site is influenced by rainfall events, snowmelt, and impoundment operation. This is another site in this watershed that experiences increases in flows in the late fall. That is when the Moose River Impoundment is being drawn down to its target winter pool level.

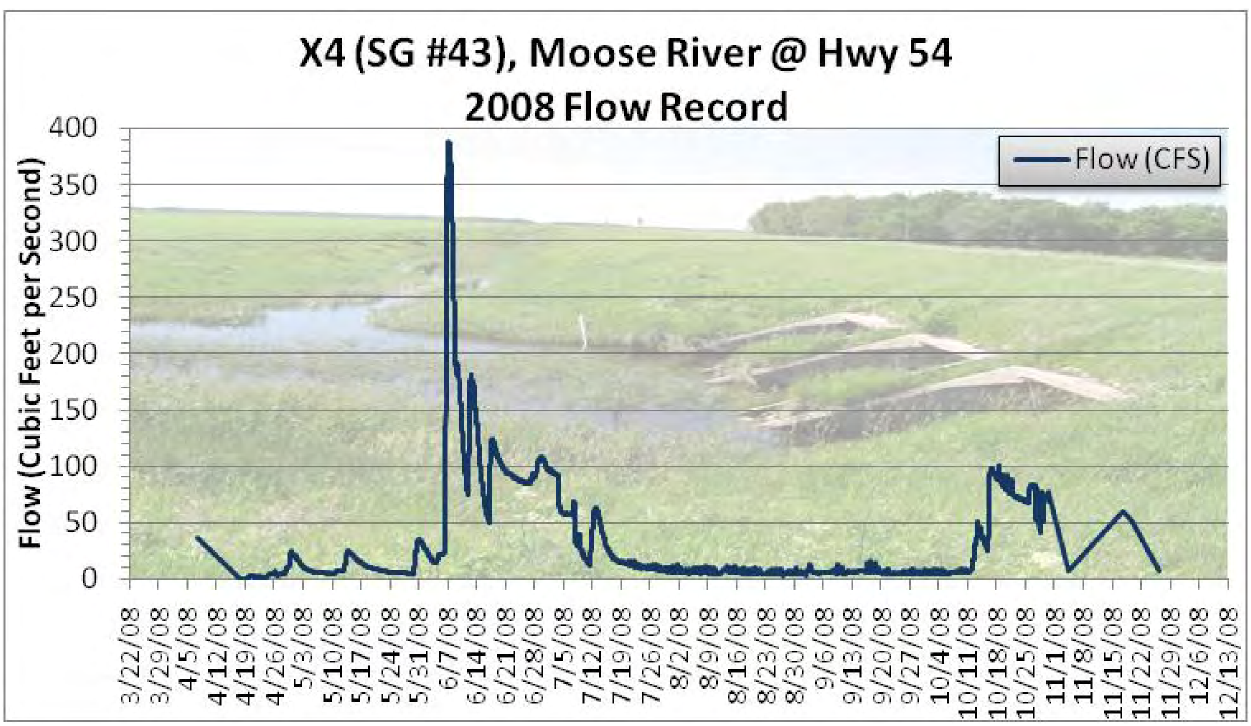


Figure 82. 2008 flow record for the Moose River at CSAH 54.

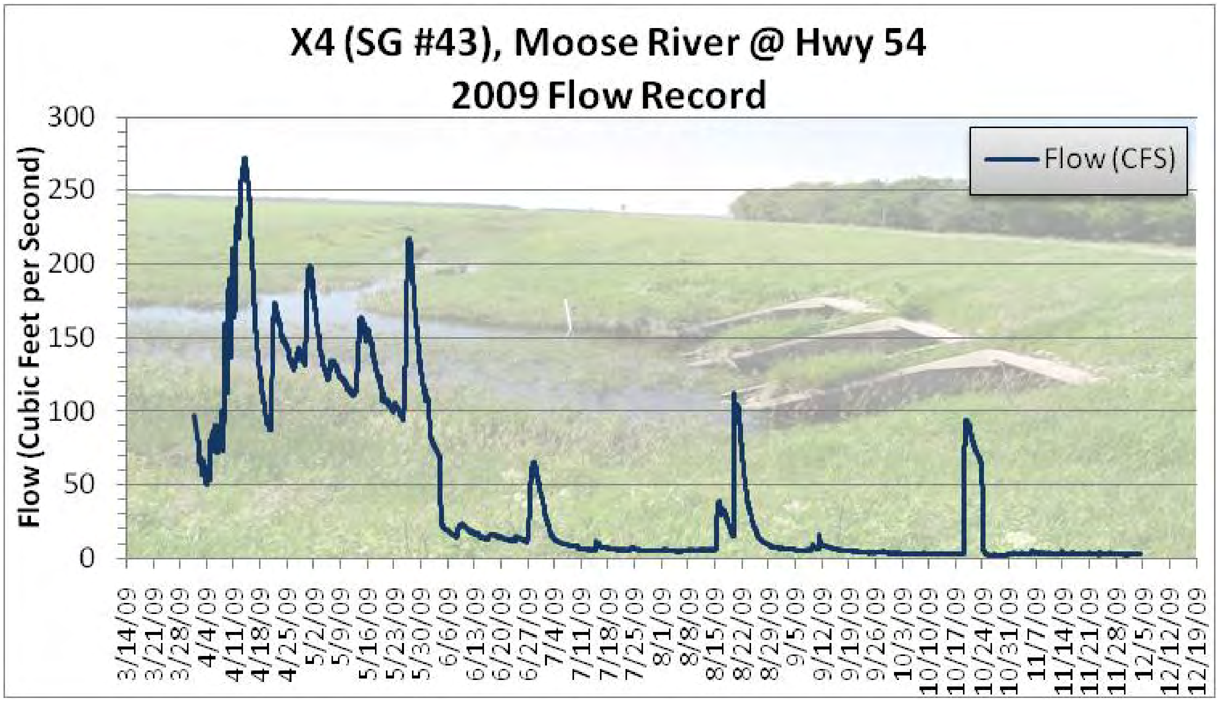


Figure 83. 2009 flow record for the Moose River at CSAH 54

Flow in the Moose River appears to have been relatively well mitigated by the impoundment upstream during the 2009 spring flood. 2009 flows didn't reach the level seen in 2008, whereas other places in the Thief River watershed had much higher flows in 2009 than they had in 2007 or 2008.

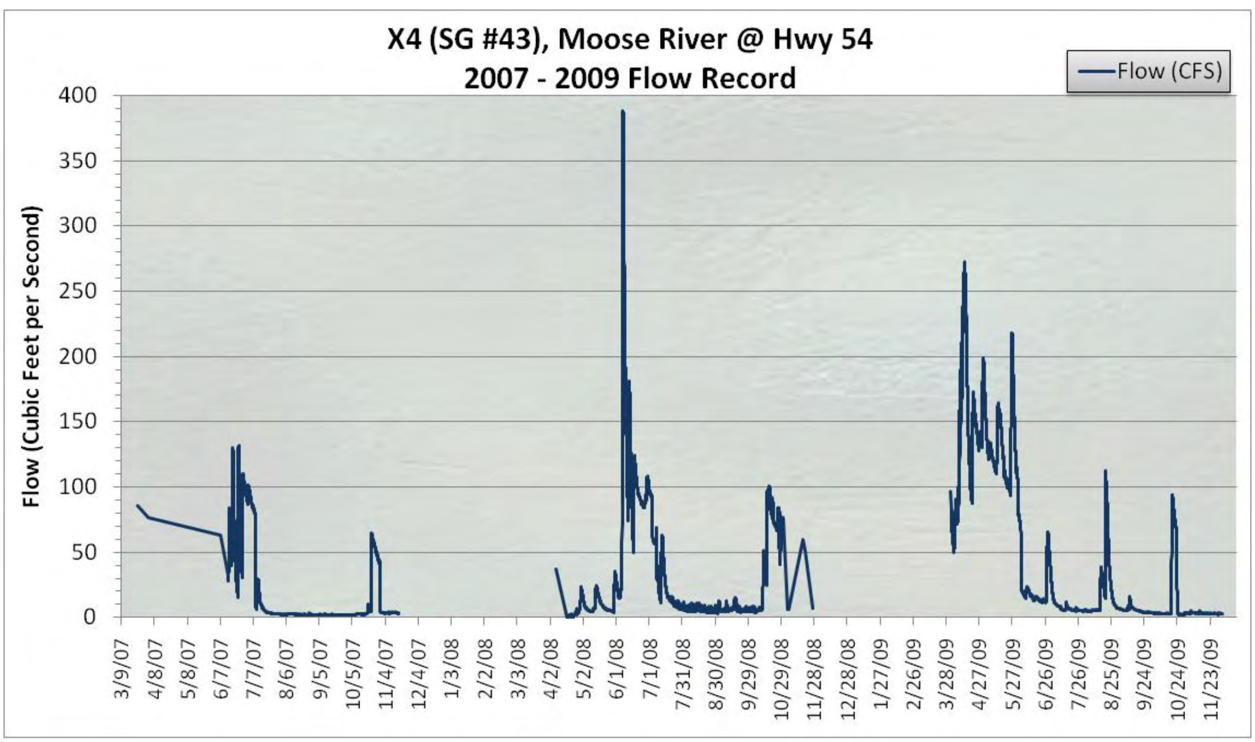


Figure 84. 2007-2009 flow record for the Moose River at CSAH 54

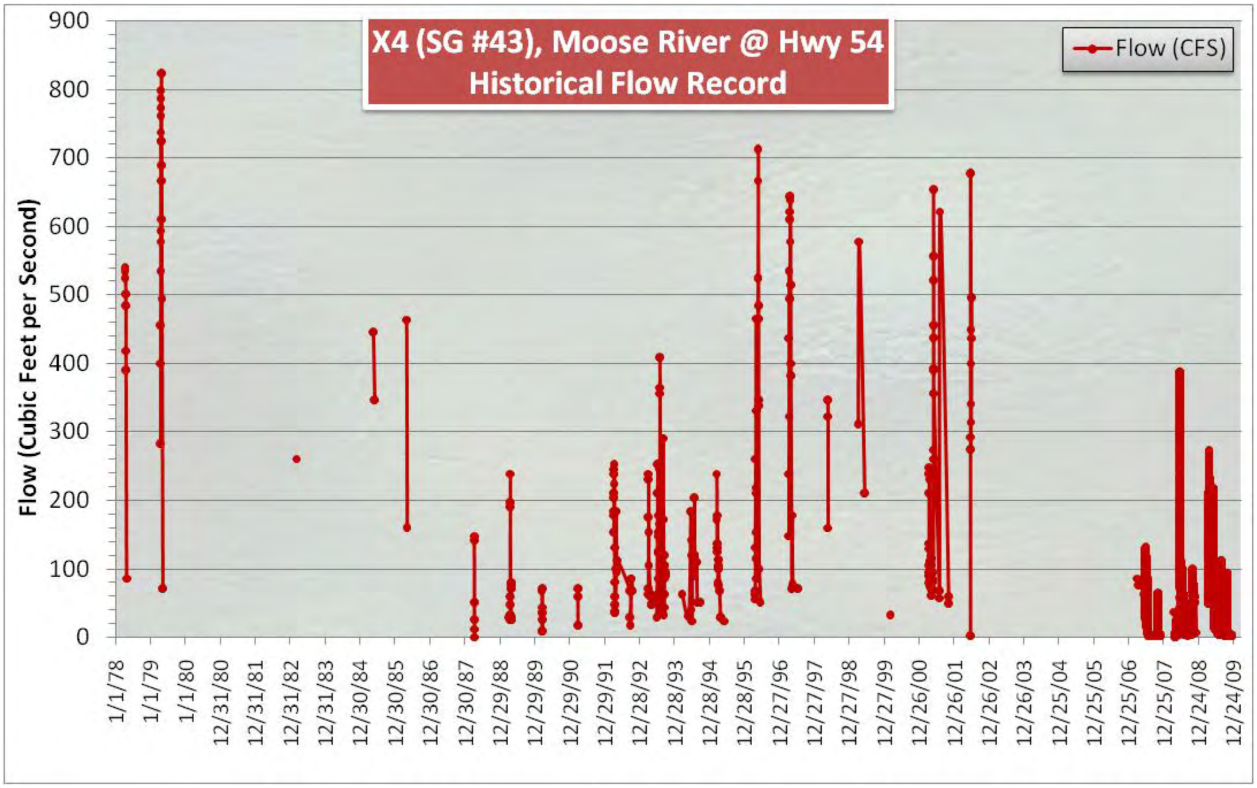


Figure 85. Historical flow record for the Moose River at CSAH 54

Notice the increase in flows in the month of October. This is mostly due to the yearly drawdown of the Moose River impoundment in addition to any October rainfall events that may have occurred.

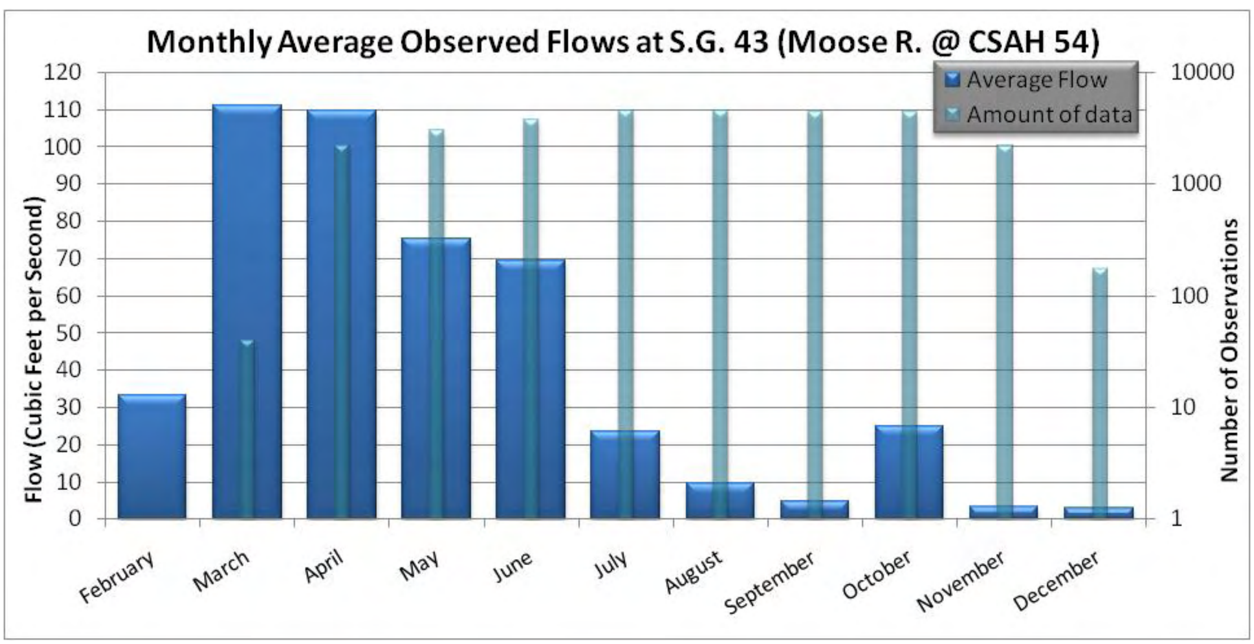


Figure 86. Monthly average flows at S.G. 43 on the Moose River.

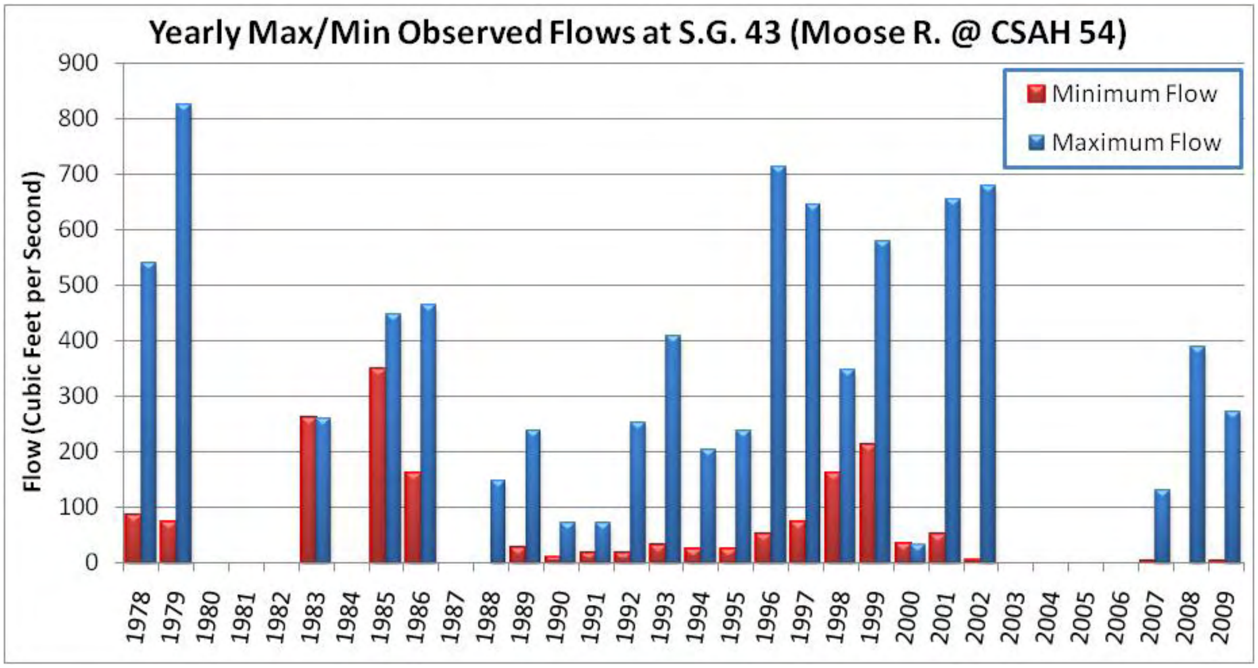


Figure 87. Peak flows in the Moose River at CSAH 54.

Data Analysis

Assessment of discrete water quality measurements and samples

The focus of the monitoring conducted for this study was not just on sediment, but also on collecting more intensive data for more accurate water quality assessments. Water quality assessments are based upon the standards and methods that have been developed by the State of Minnesota and described in the MPCA's *Guidance Manual for Assessing the Quality of Minnesota Surface waters for Determination of Impairment: 305 (b) Report and 303 (d) List*.

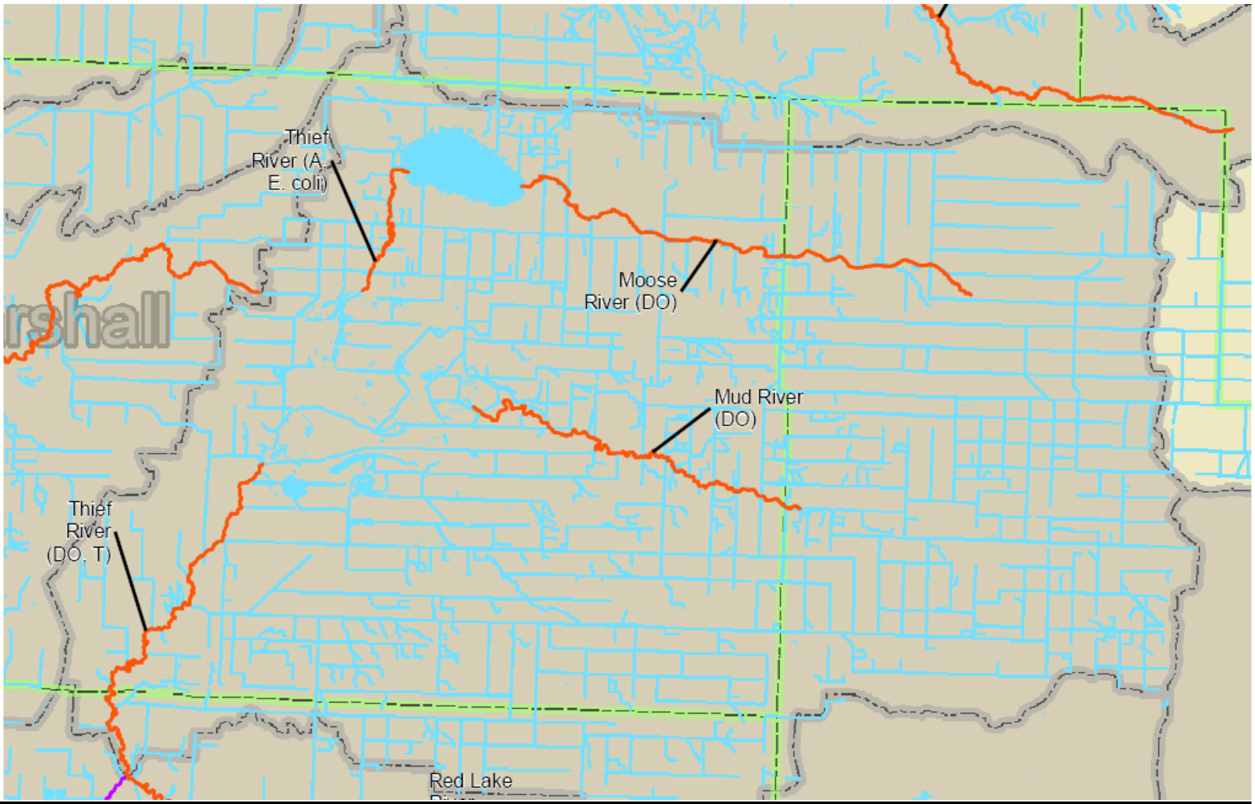


Figure 88. Current impairments in the Thief River Watershed that are on the 2010 303(d) List of Impaired Waters

- Low dissolved oxygen problems
  - The lower (western) part of Moose River.
    - Impairment at Highway 89
    - Monitoring sites near the upstream end show full support so far.
    - Flow slows down and becomes more stagnant near the downstream end of the reach.
  - Branch 200 of JD11 downstream of Farmes Pool
    - Most of the water in the ditch is coming from a large wetland where there is stagnant water and lots of consumption of dissolved oxygen.
    - Water in the ditch at the monitoring site becomes stagnant during the summer. Water is still moving through the ditch, but at a very low rate.
- pH
  - Moose River near Thief Lake
  - Thief River entering Agassiz NWR from the north
  - Thief River/SD83 downstream of Agassiz NWR
  - Mud River
- E. coli bacteria problems
  - Mud River
    - This is a newly discovered impairment
    - Feedlots are the primary suspected source of this problem.
  - Thief River from where it leaves Agassiz NWR, through CSAH 12, and then again at the USGS gauge site north of Thief River Falls.
  - Marshall County Ditch 20 (August)

- Additional E. coli samples will need to be collected at most of these sites to verify impairment. Investigative crossing-by-crossing sampling on the Mud River will hopefully reveal the extent of the impairment and narrow down the list of possible sources. This is still true after the 2009 monitoring season. The October 2010 revision of the State Guidelines for water quality assessment eliminates the use of fecal coliform data in aquatic recreation use assessments. This makes the available data set from assessing some of these sites a lot smaller.
- Monthly geometric mean E. coli concentrations are highest at either end of the Agassiz-NWR-to-Thief-River-Falls reach of the Thief River. This could be due to the proximity of the sites to sources. It could also be attributed to the additional years of data that are available at those two sites.

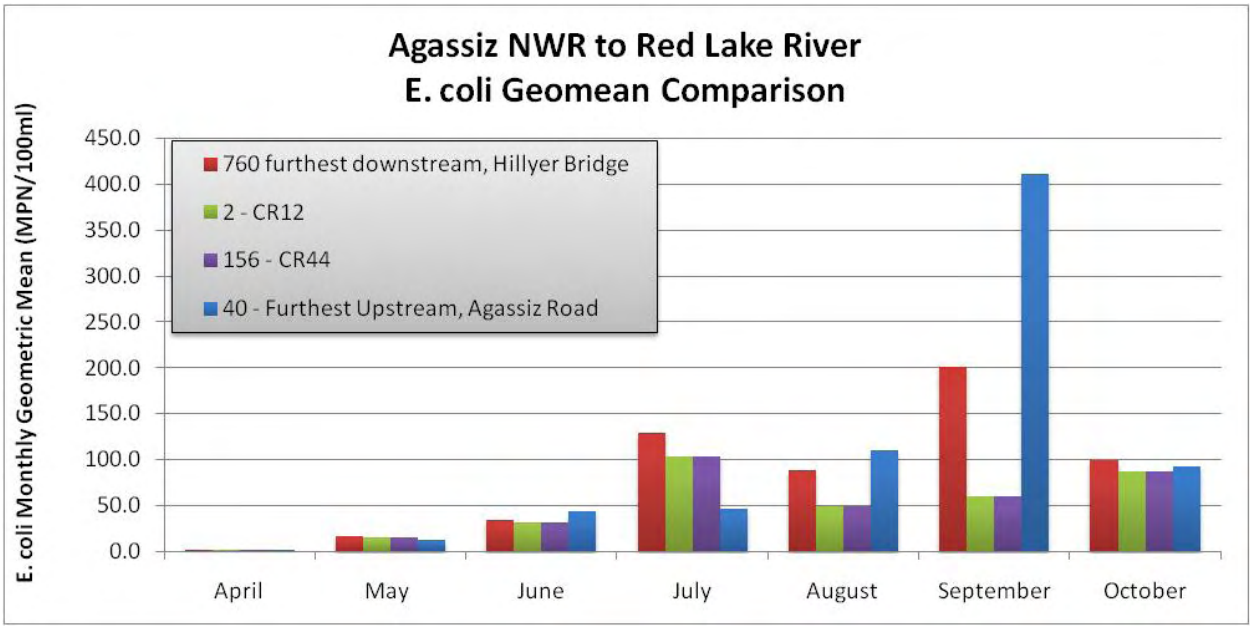


Figure 89. E. coli monthly geometric means along the lower Thief River.

- Turbidity problems
  - Thief River from Agassiz NWR to the Red Lake River.
- Un-ionized Ammonia?
  - Thief River from Thief Lake to Agassiz NWR
    - The concentration of the toxic, un-ionized ammonia is a percentage of the concentration of total ammonia calculated using pH and temperature values. There have only been two occurrences of high levels of this toxic form of ammonia recorded on this reach of the Thief River, ever. They occurred in July 2000 and April 2002.
  - Thief River downstream of Agassiz NWR (only once – not impaired).
  - Only three total instances in the whole watershed.
- Good News
  - The Thief River between Agassiz NWF and TRF appears to be meeting the dissolved oxygen standard (currently listed for low DO).
  - Ditches flowing into the Thief River meet turbidity standards.
  - CD20 meets the dissolved oxygen standard.

- The low dissolved oxygen problem on the Moose River doesn't appear to extend all the way upstream
- Lower Thief River has scenic stretches and supports a good fishery

Compilation of Continuous Water Quality Monitoring Data

Three years of data have been collected. Sondes were deployed for two weeks at a time. After each deployment period, sondes were brought to the RLWD lab for cleaning and calibration checks. The readings taken before and after cleaning and calibration are used to calculate the fouling drift and calibration drift that occur while the sonde is deployed in the river. USGS and RLWD staff then have to "work the record" for each deployment period by making adjustments to the data based on fouling and calibration drift values.

A software package was purchased that will allow for much more tidy and efficient handling of the thousands of data points that are collected at each site by the continuous water quality monitoring equipment. Aquarius software will allow me to pull raw data into the program, correct for fouling error, correct for calibration drift, examine time series graphs to check for outliers, export a corrected and compiled data file, and export a file listing all the changes that have been made to the data. I will be able to send a clean .csv file (along with the original files for archiving) to the State's HYDSTRA database that is being used for the storage of continuous water quality and flow data.

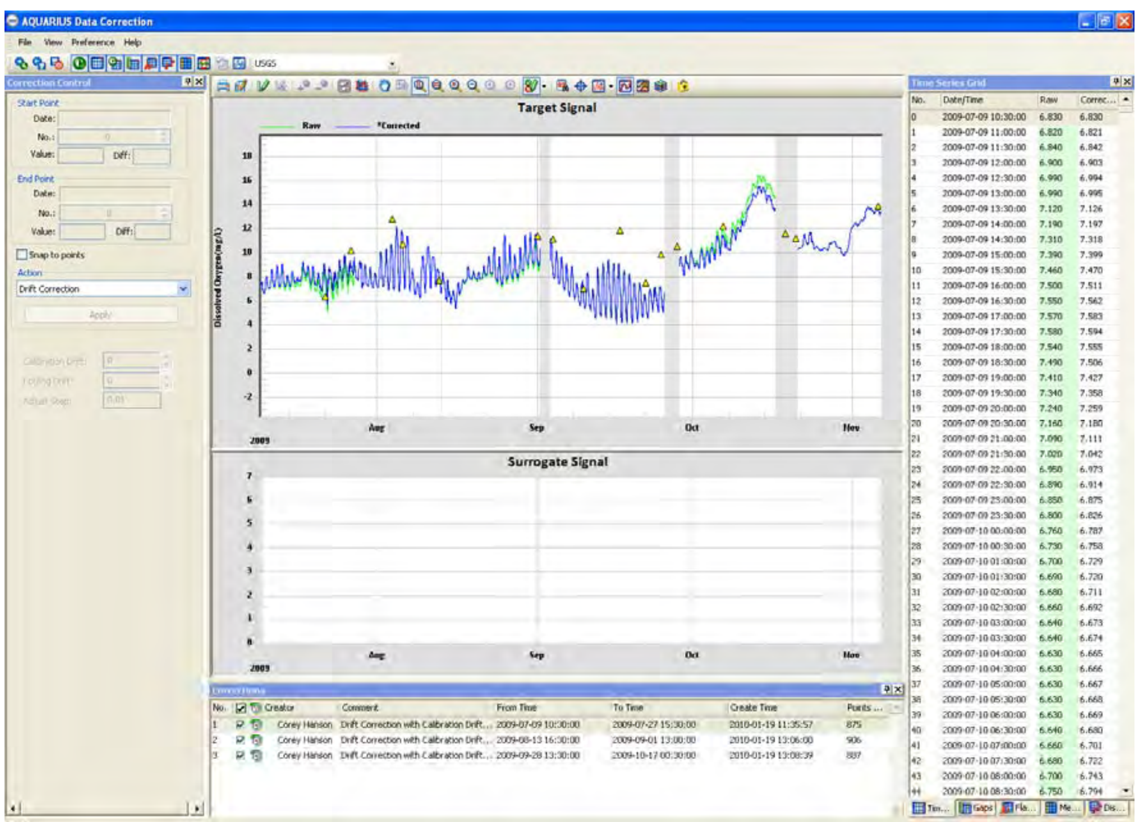


Figure 90. Aquarius Software screenshot

Thief River at Hillyer Bridge

The sonde at this site was deployed in a tube attached to a bridge pier and a fence post on the north bank of the river. This is a somewhat popular fishing spot, so it's probably a good thing that the end of the pipe isn't extended all the way up onto the shore. The location does prevent installation/retrieval during high flows though.

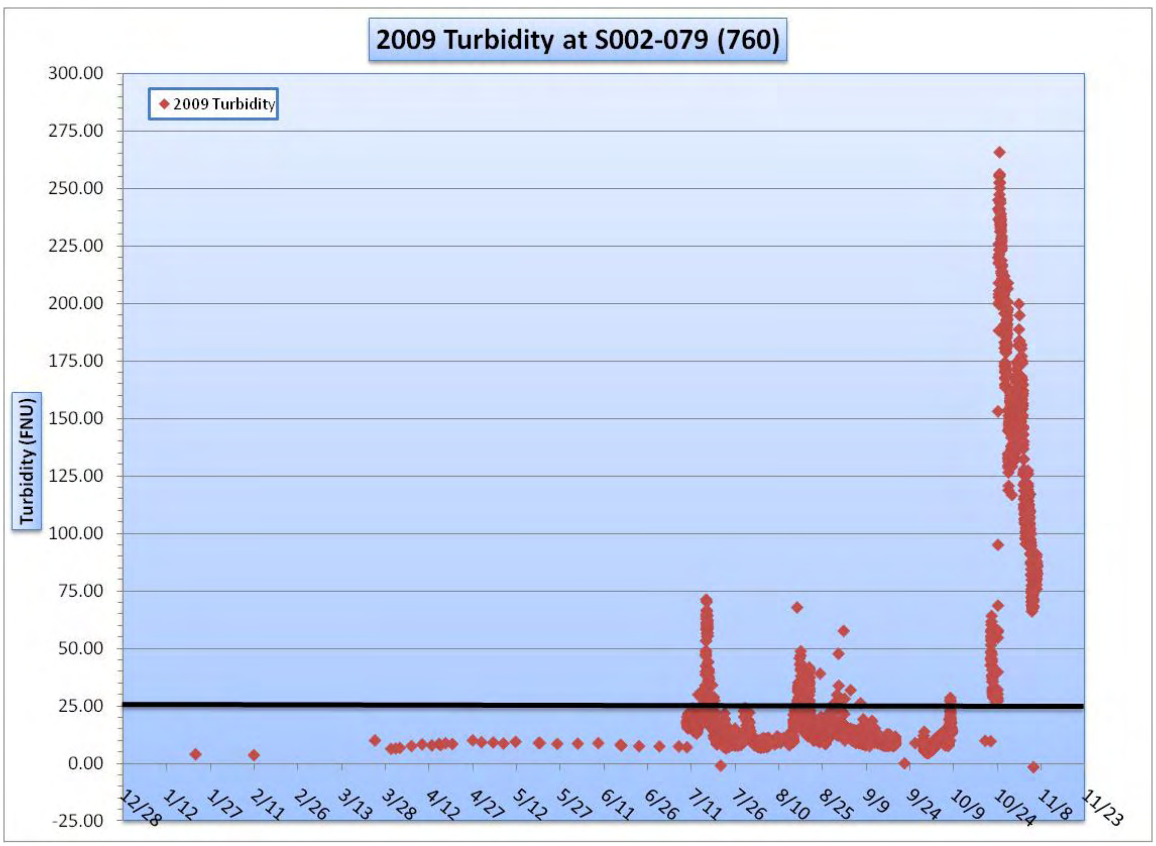


Figure 91. Full 2009 turbidity record at S002-079 (760)

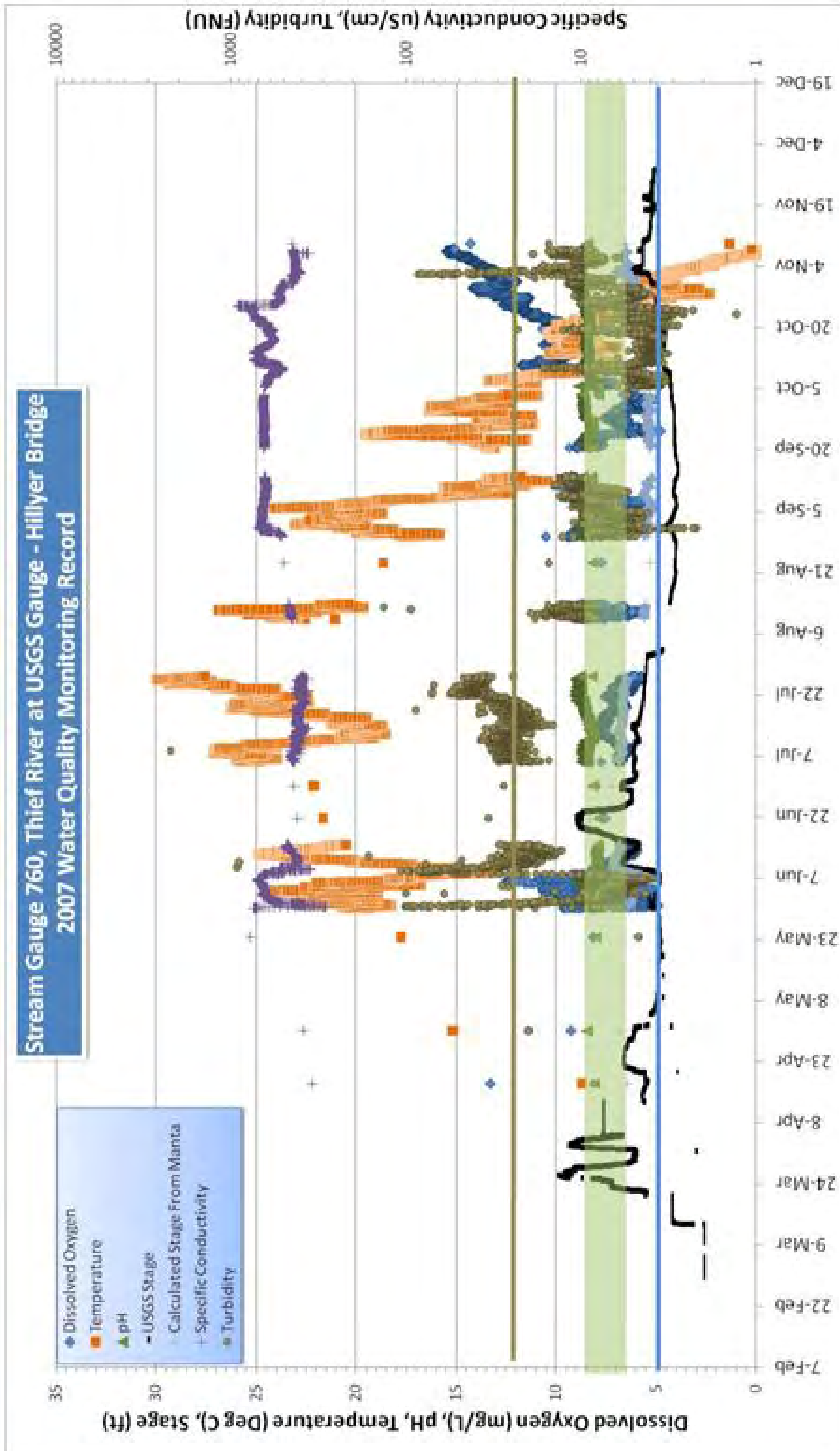


Figure 92. 2007 Continuous monitoring data at S002-079 (760)

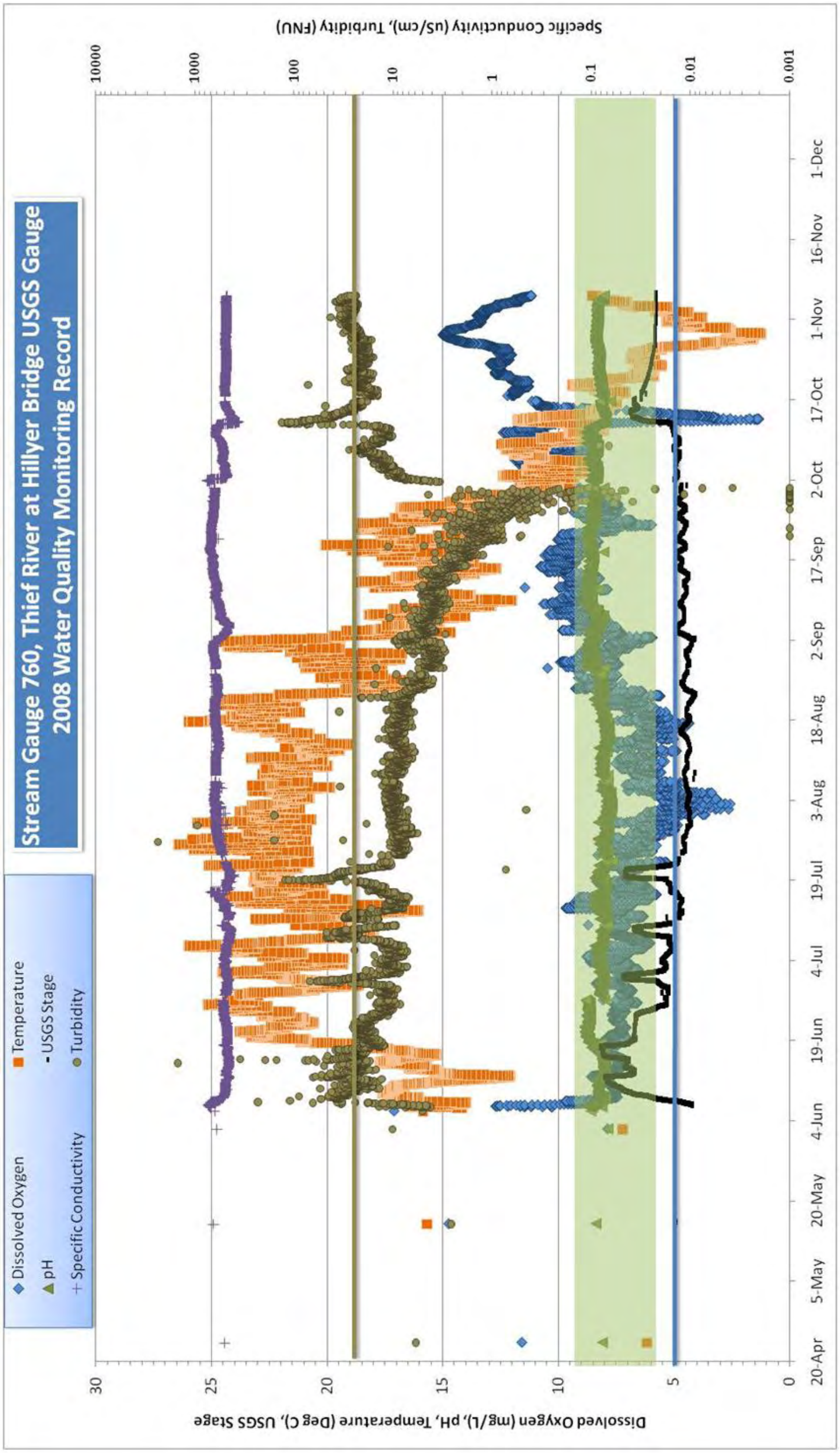


Figure 93. 2008 continuous water quality record at S002-079 (760)

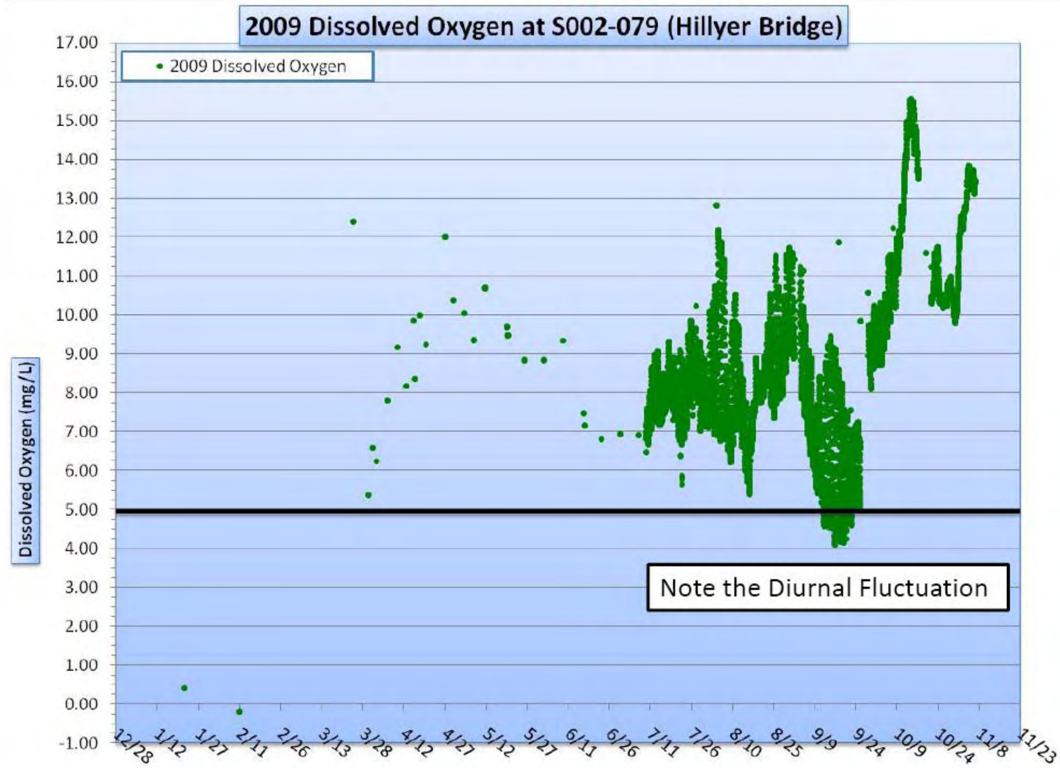


Figure 94. Full 2009 dissolved oxygen record

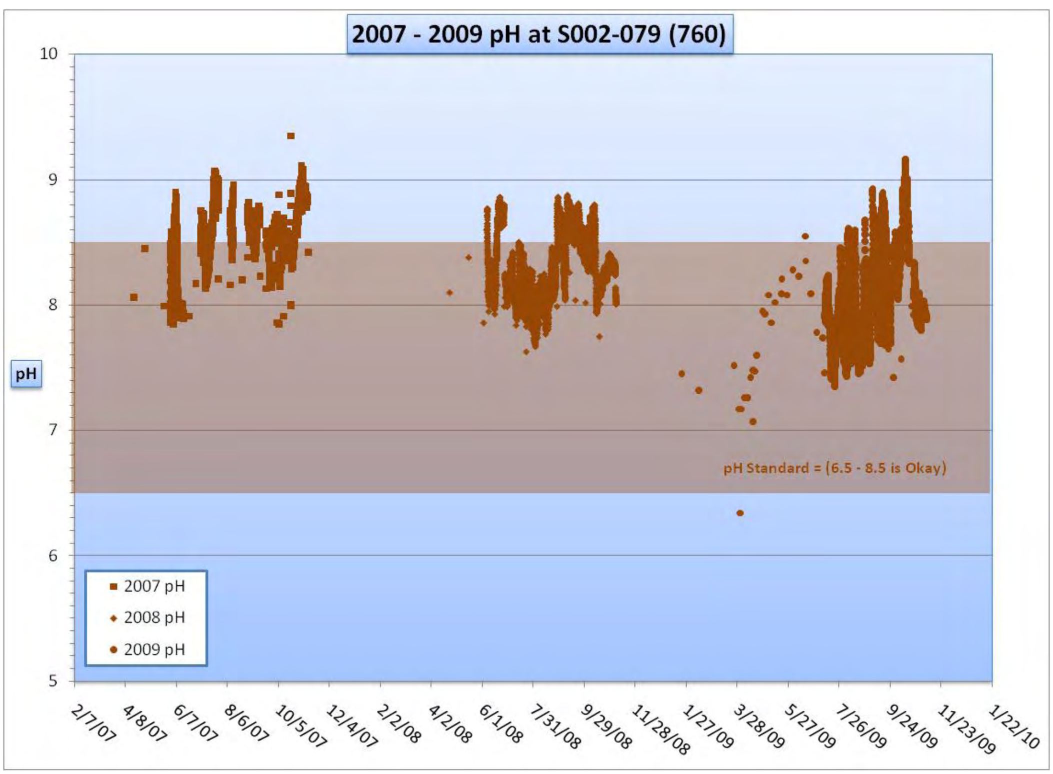


Figure 95. 2007 through 2009 pH record at S002-079 (760)

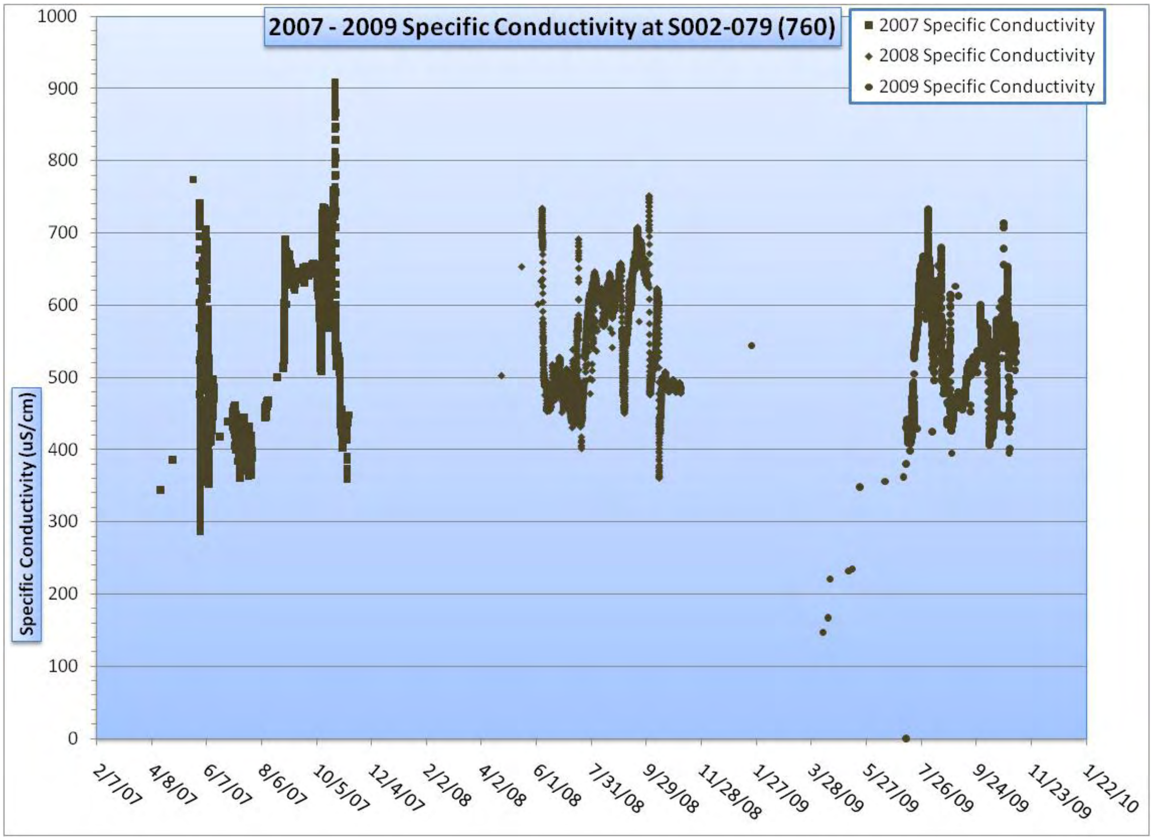


Figure 96. 2007 through 2009 specific conductivity in the Thief River at S002-079 (760)

Thief River at County Road 7

Continuous water quality monitoring at the Marshall County Road 7 crossing of the Thief River (a.k.a. S002-088, stream gauge 40, T2) was accomplished with the deployment of Eureka Manta multi-parameter sondes. The deployment pipe was installed along the northwest wing wall. The perforated end extends into the thalweg of the river. The Mantas were relied upon for the water level record for the first couple of years. They didn't do a satisfactory job, so an Onset HOBO Water Level Logger was purchased and installed at the site (as soon as we could access the deployment pipe) to collect a more accurate water level and flow record.

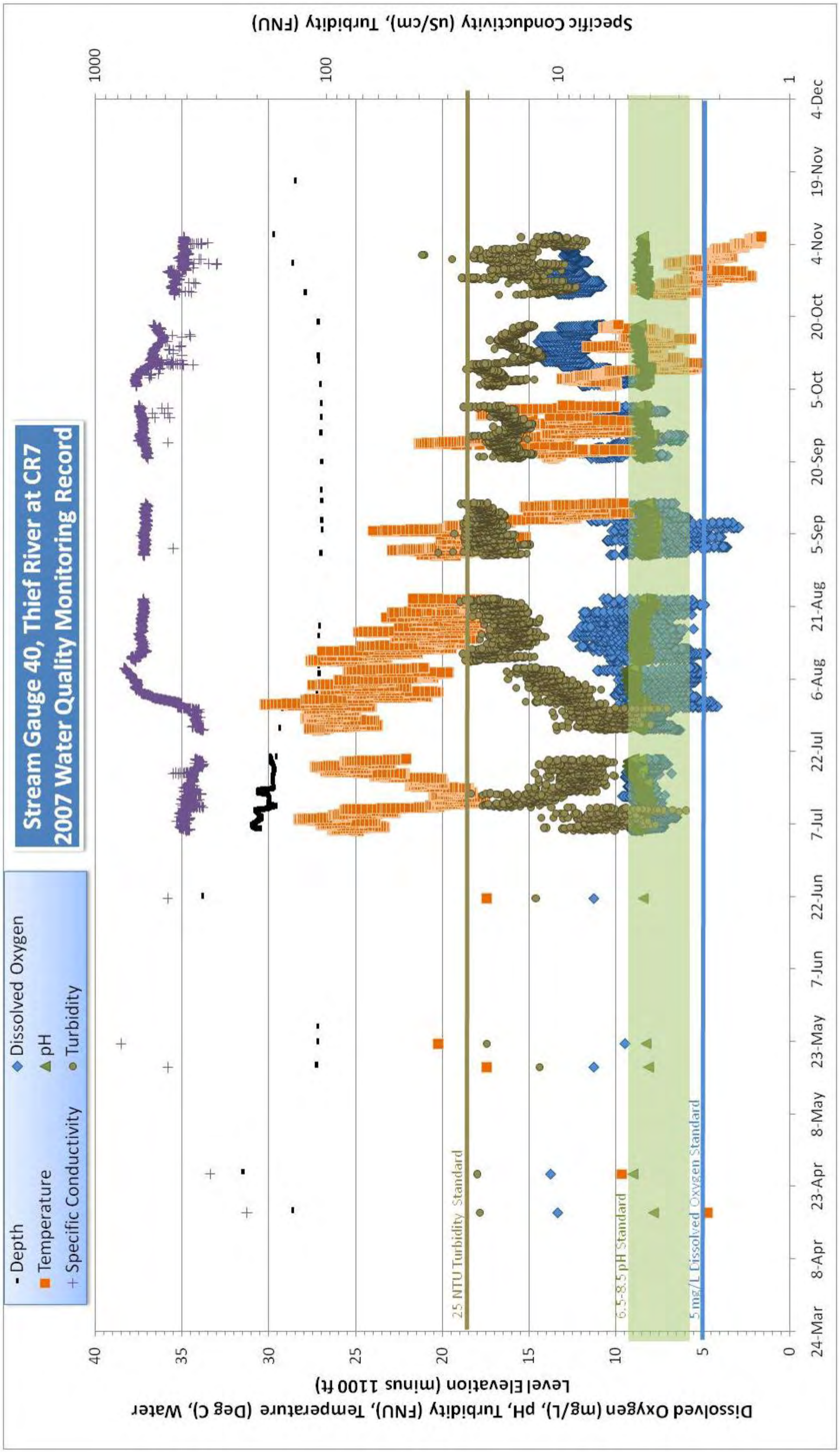


Figure 97. 2007 Continuous monitoring record at S002-088 (40)

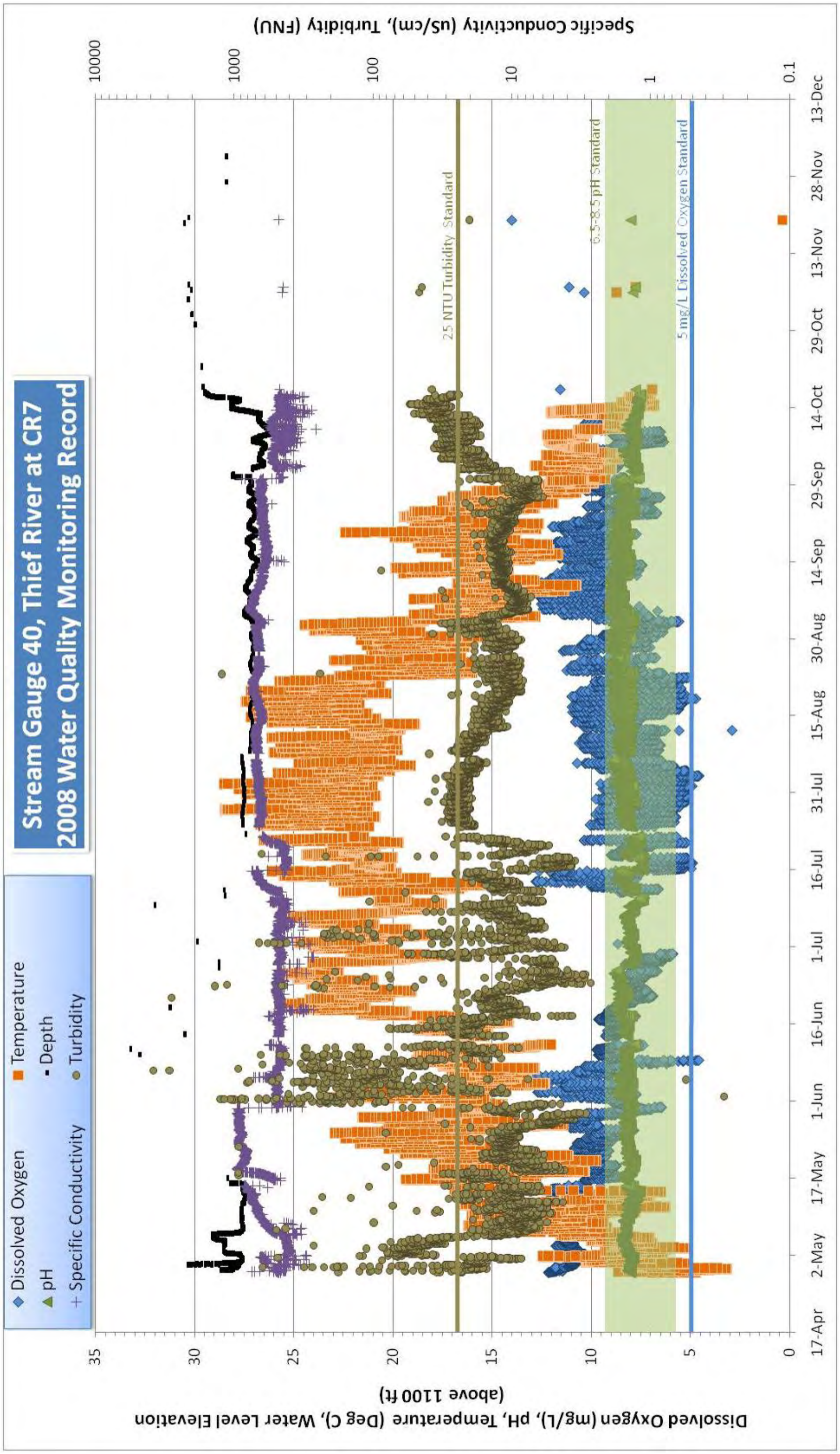


Figure 98. 2008 Continuous monitoring record at S002-088 (40)

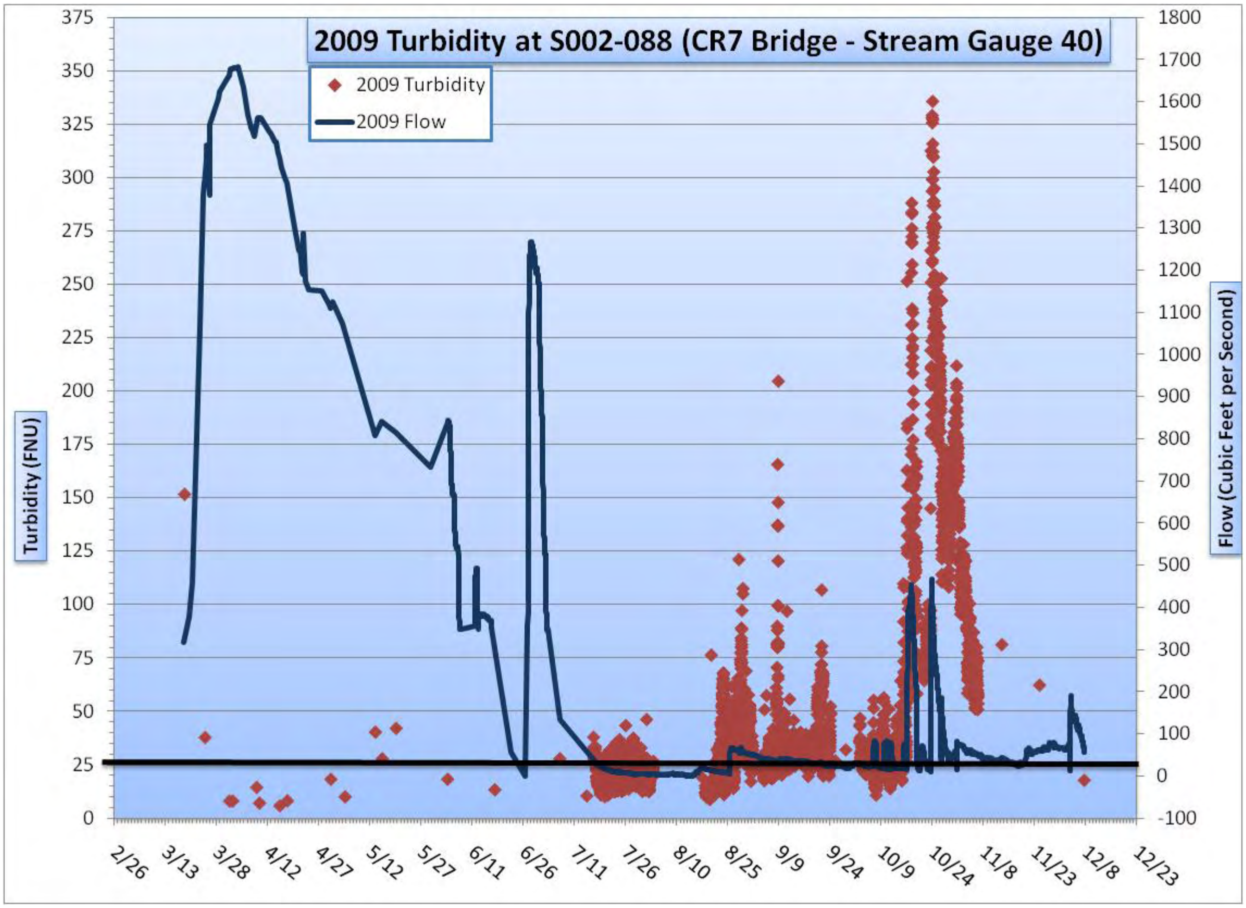


Figure 99. 2009 Turbidity at S002-088 (40)

The flow rate in early 2009 was very high, but the turbidity wasn't as high as what would be expected. The melt was very quick. Much of the ground still had frost, which helped hold soil in place. In the fall of 2009, the USFWS opened the radial gates at the outlet of Agassiz Pool in order to drain it down as completely as possible. As the water was drawn down, the loose peat soil and other sediment was washed downstream. An old ditch running though the center of the pool concentrated flow within the pool during the drawdown. Chunks of the loose sediment would collapse into the stream and get washed downstream. Gullies formed along both sides of this central ditch. As shown in the figure above, the turbidity levels were very high during the drawdown in October and November of 2009. Some of the highest turbidity levels ever measured in the Thief River were measured at the CR7 bridge in late 2009.

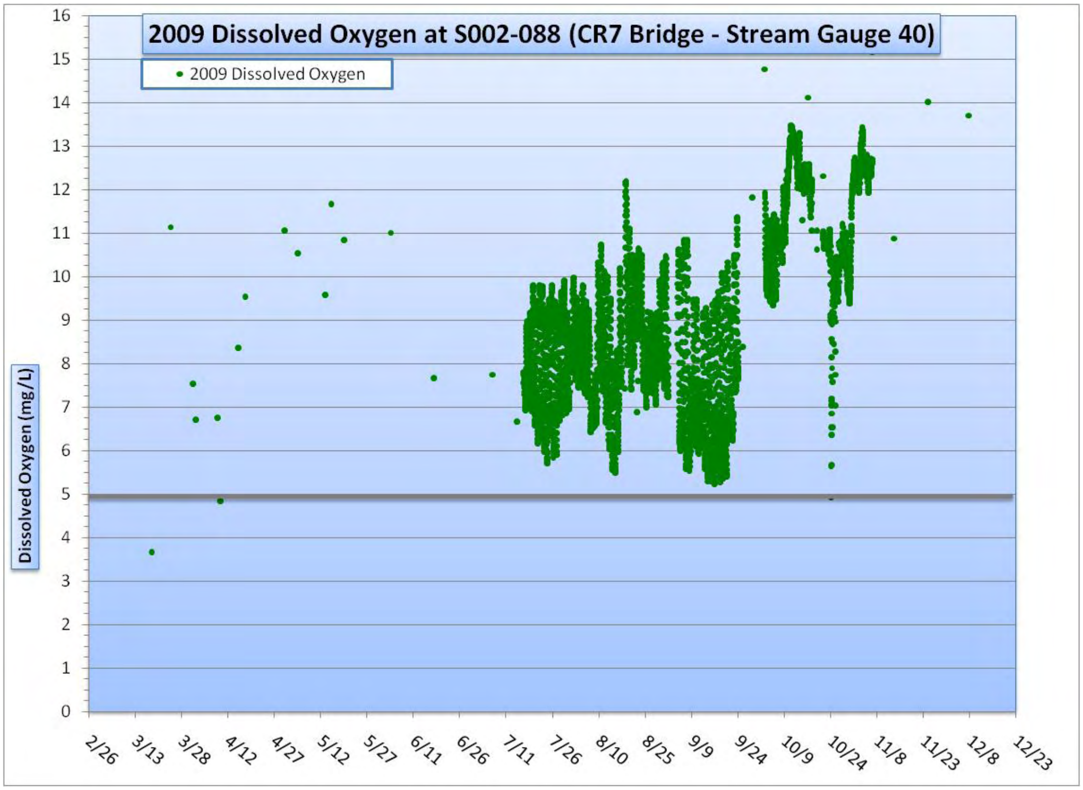


Figure 100. 2009 dissolved oxygen at S002-088 (40)

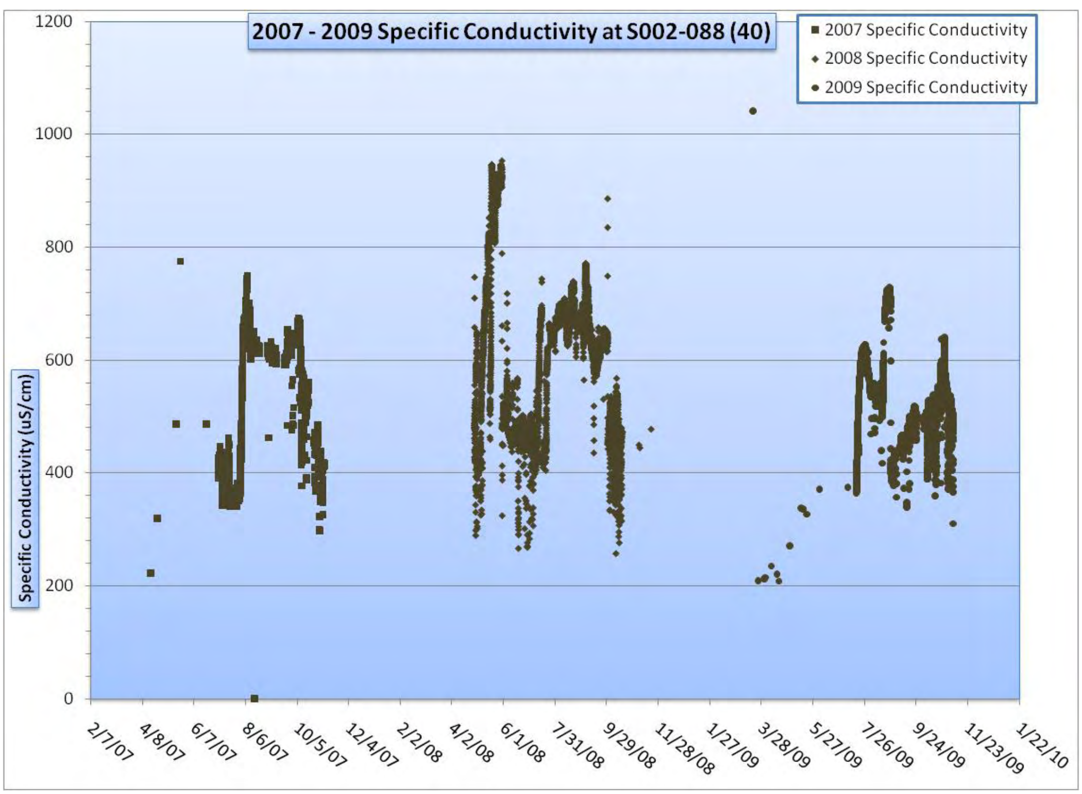


Figure 101. 2007 through 2009 specific conductivity at S002-088 (40)

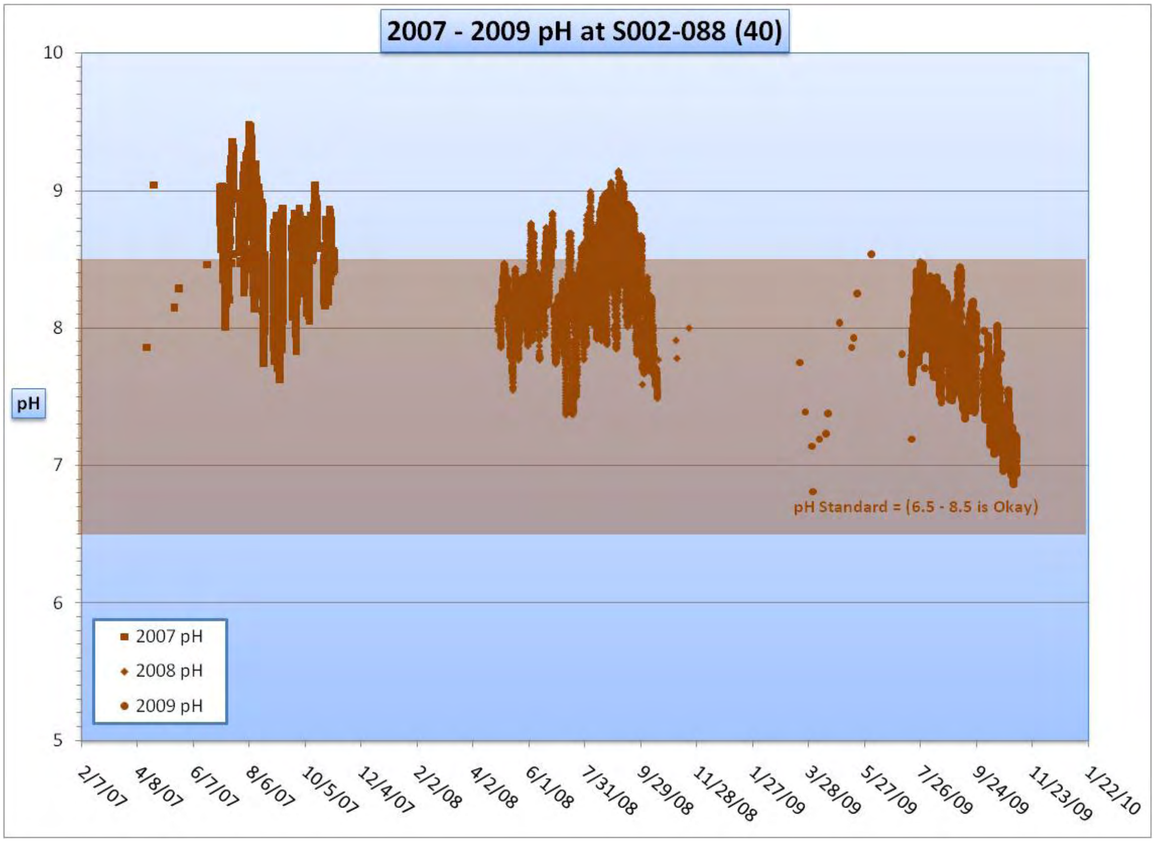


Figure 102. 2007 through 2009 pH at S002-088 (40)

County Ditch 20

Eureka Manta multi-parameter sondes were deployed in a PVC pipe under the northwest side of the bridge at the 180th Ave NE crossing. Although tea-stained, the water in CD20 is normally clear. The bottom of the ditch at this site is sand, gravel and cobble. There is a rock riffle underneath the bridge, just upstream of the Manta deployment pipe.

Some high turbidity levels were recorded in early 2007. These can be attributed to the county road ditch that enters CD20 on the southeast side of the bridge. The ditch runs along the east side of 180th Ave NE and was crudely cleaned out in late fall of 2006 or early spring of 2007. So, there was no vegetation in the ditch to prevent erosion. There was a significant plume of sediment entering CD20 during every runoff event until vegetation started to grow in the ditch. Headcutting also occurred along this ditch prior to establishment of vegetation for hundreds of yards to the south.

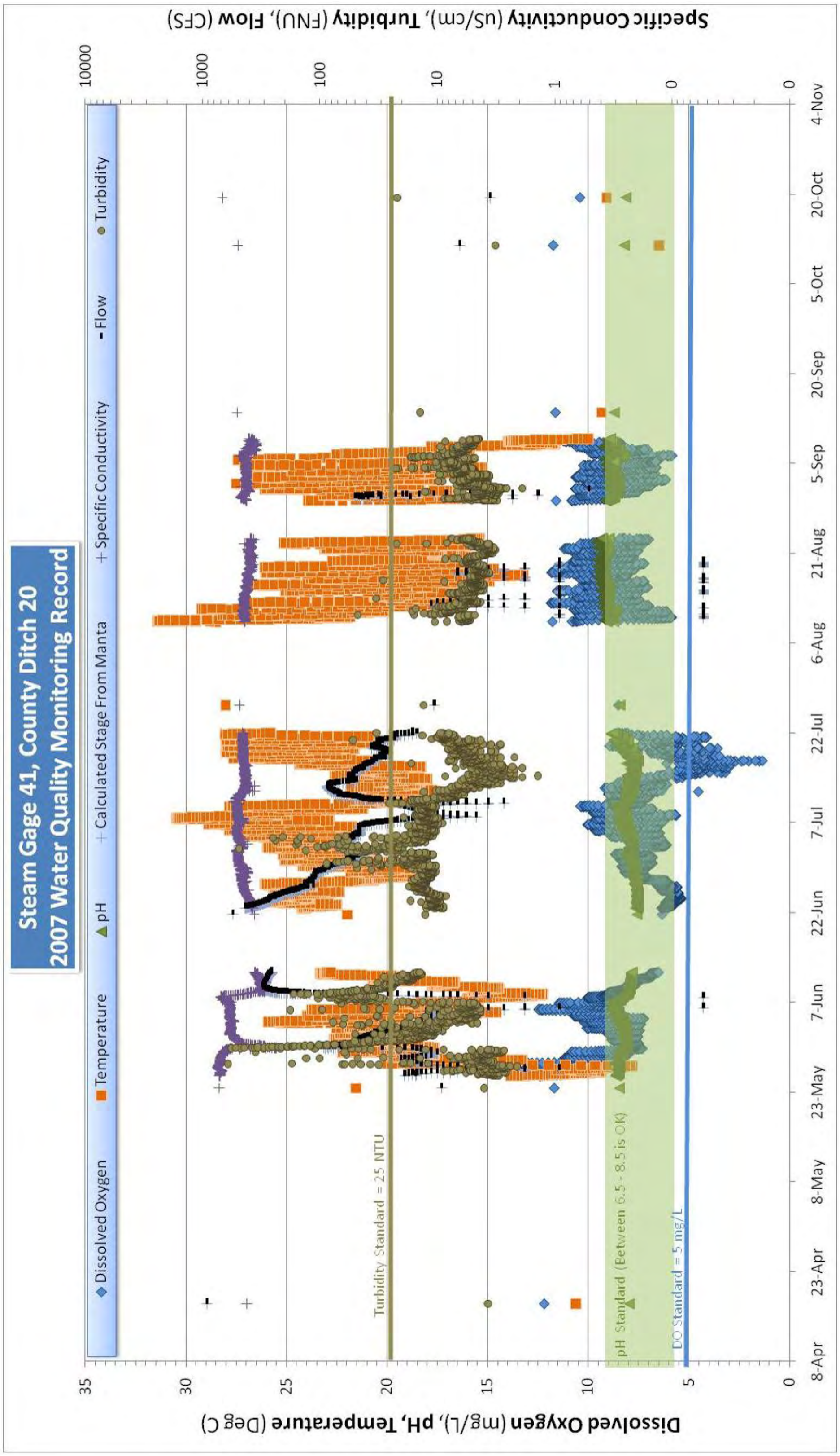


Figure 103. 2007 continuous water monitoring record at stream gauge 41 on Marshall County Ditch 20

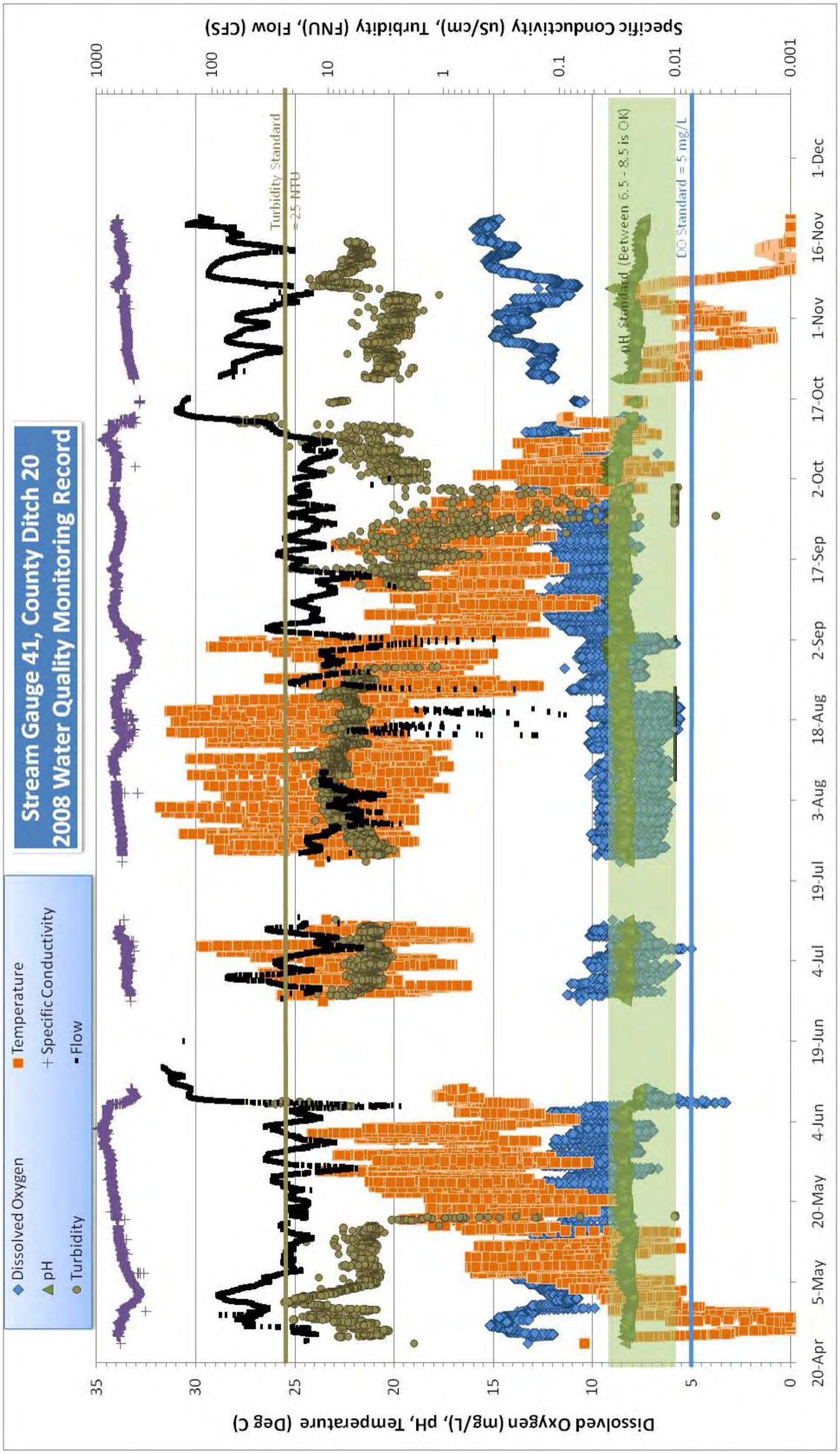


Figure 104. 2008 continuous monitoring record at stream gauge 41 on Marshall County Ditch 20

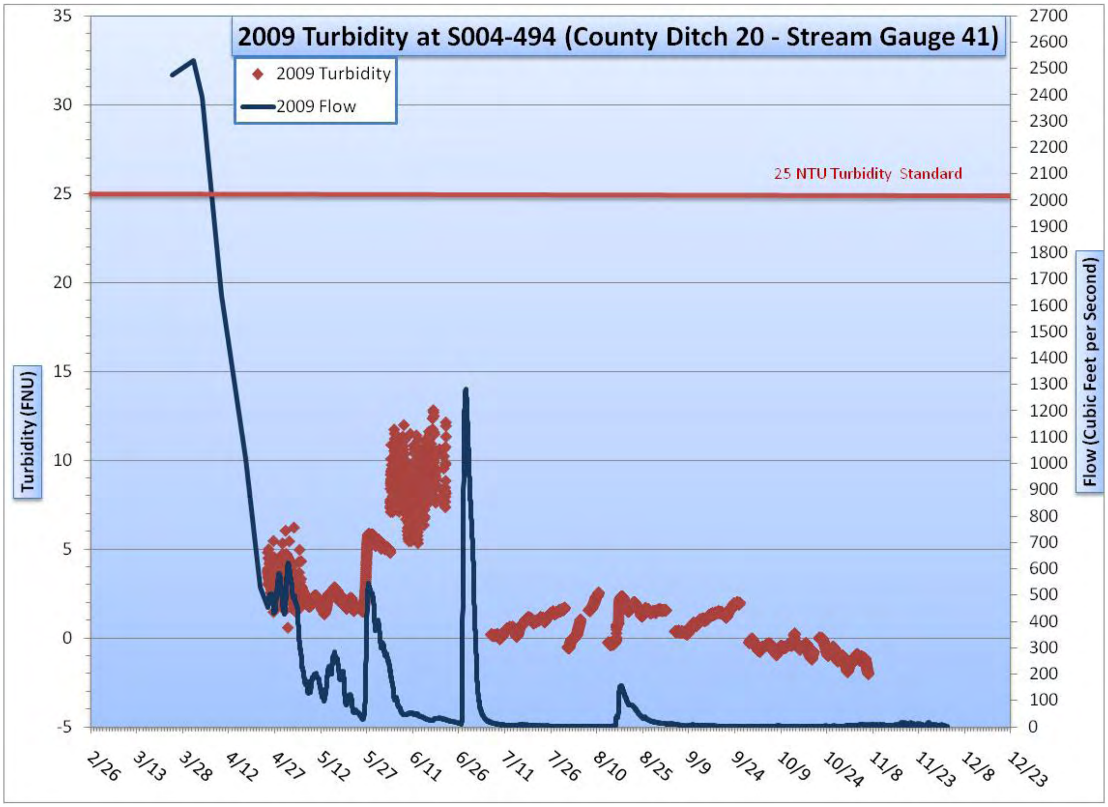


Figure 105. 2009 Turbidity and flow at S.G. 41 on CD20

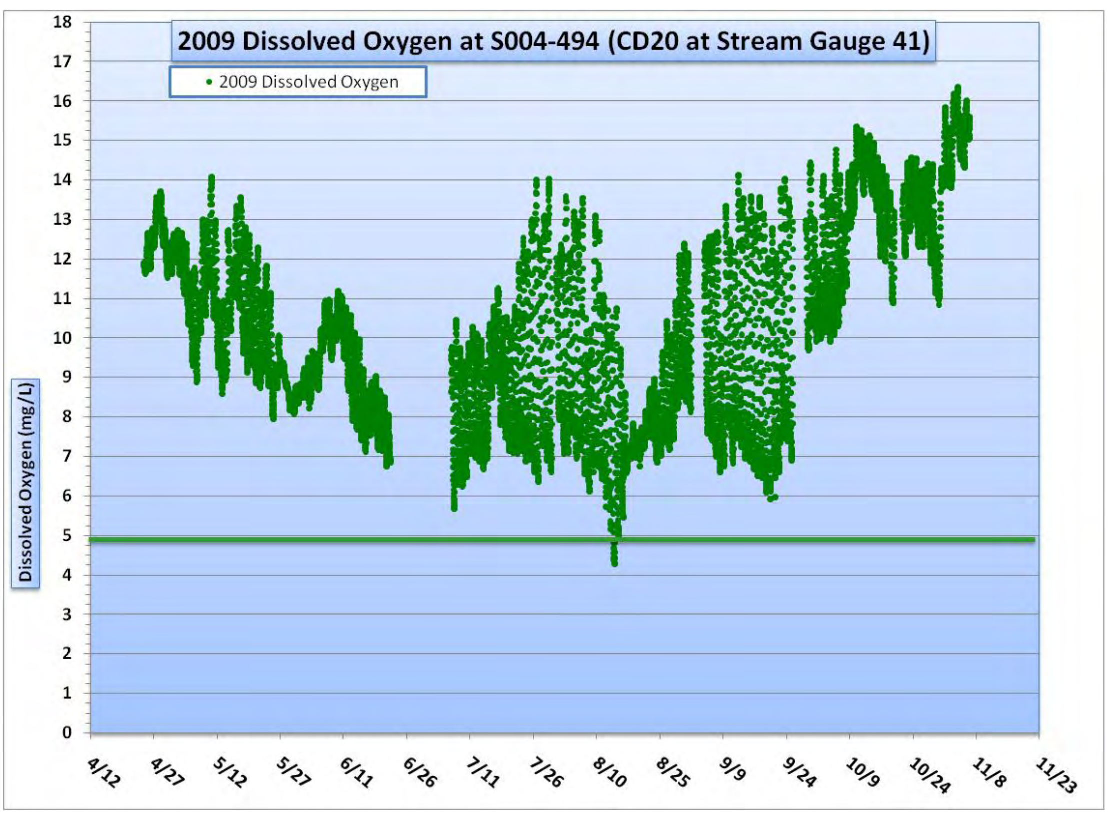


Figure 106. 2009 dissolved oxygen at S004-494 (CD20 at Stream Gauge 41)

Ditch 200

The turbidity levels in Branch 200 of Judicial Ditch 11, referred to as Ditch 200, only exceeded the standard during drawdowns of Farmes Pool and during a construction project at the outlet off Farmes Pool.

The Eureka Manta multi-probe sondes were deployed in a PVC pipe on the east bank of the ditch on the downstream side of the crossing. The pipe was angled into the deepest part of the channel.

Dissolved oxygen levels frequently fell lower than the 5 mg/L dissolved oxygen standard. When the water is cold enough in the spring and fall, the water can hold more dissolved oxygen. But as the water warms up and becomes stagnant in the summer, the oxygen levels dip below the standard nearly every day.

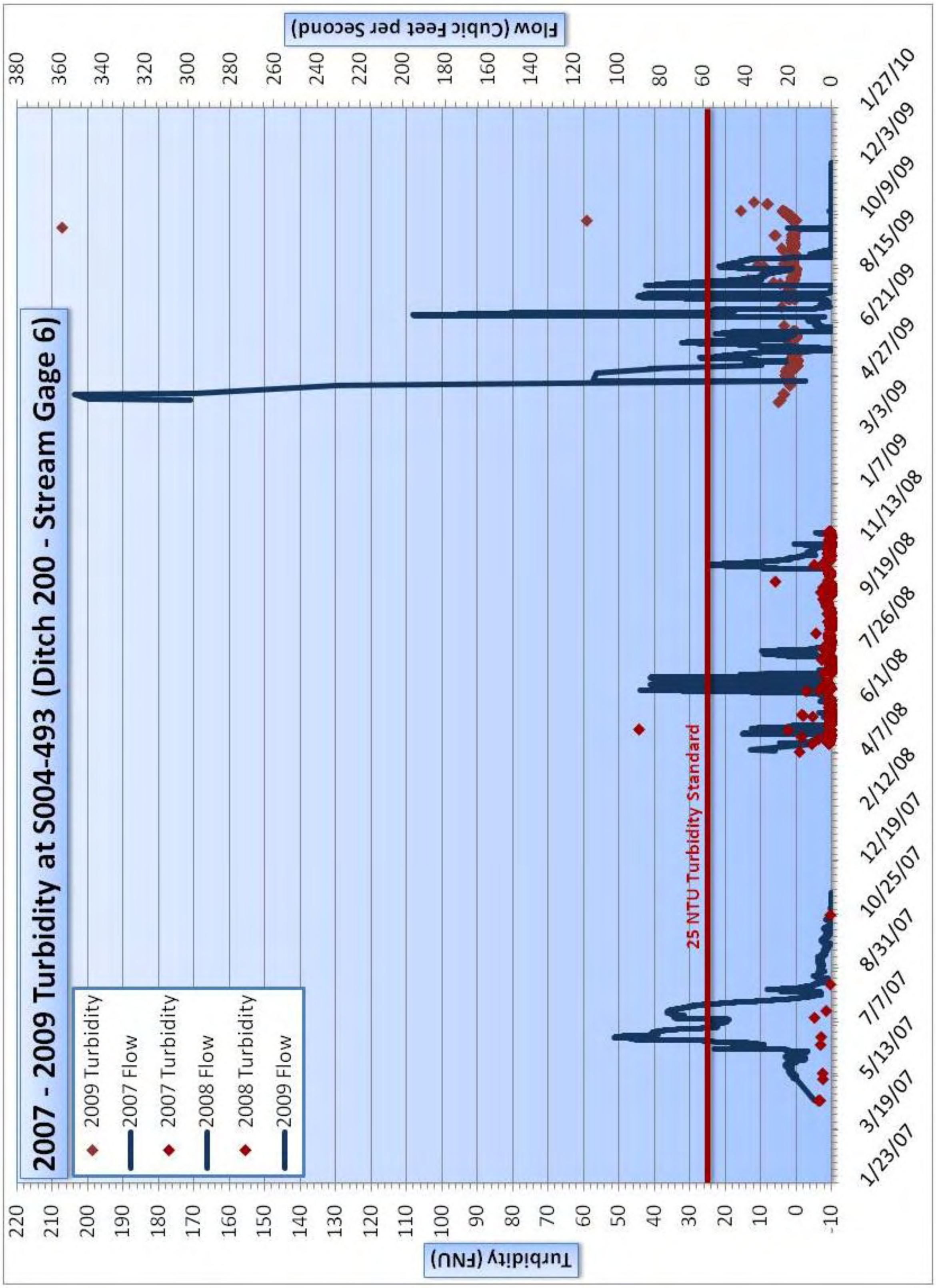


Figure 107. 2007 - 2009 turbidity and flow record in Ditch 200 at Stream Gauge 6

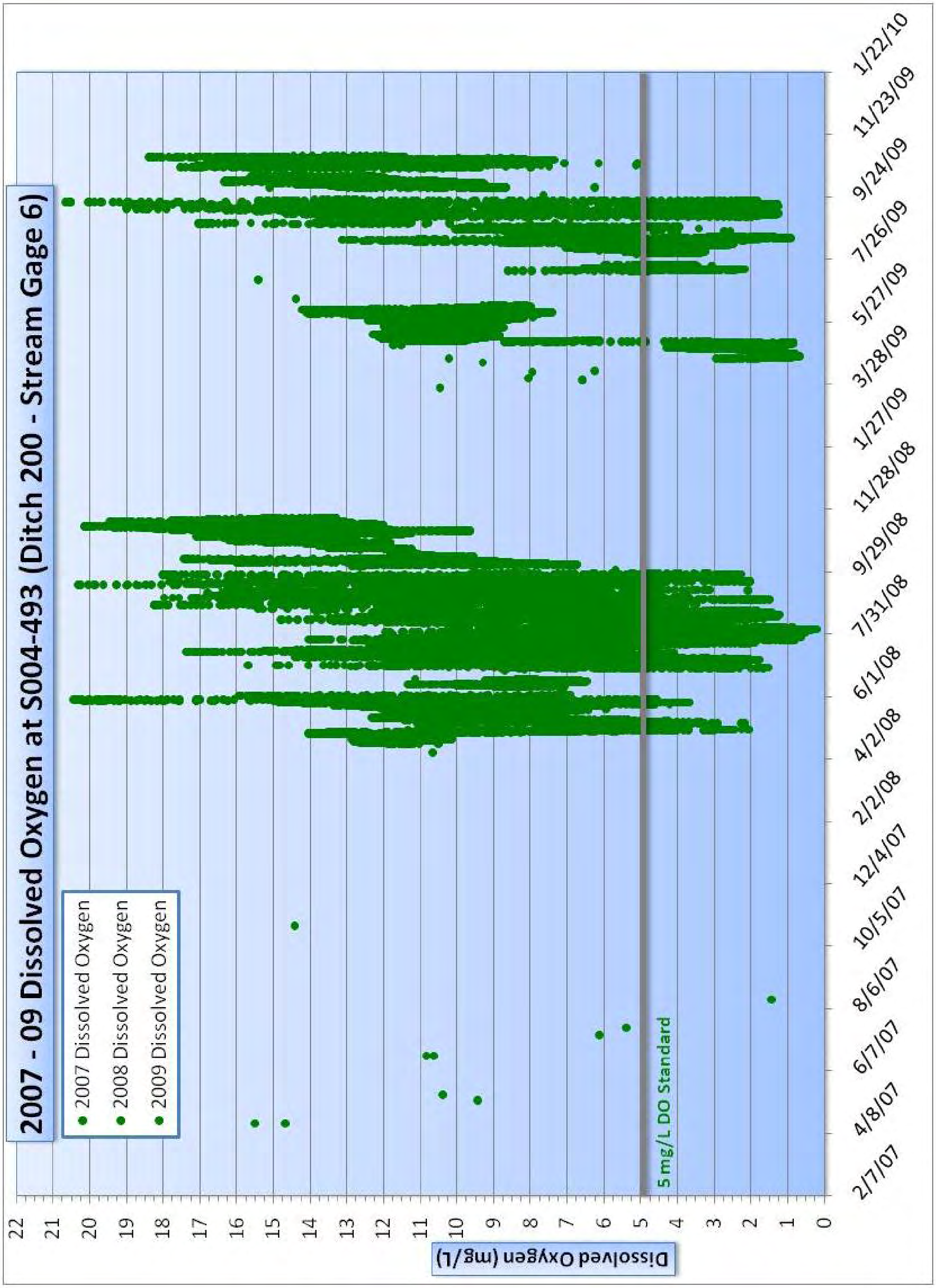


Figure 108. 2007 - 2009 complete dissolved oxygen record in Ditch 200 at Stream Gauge 6

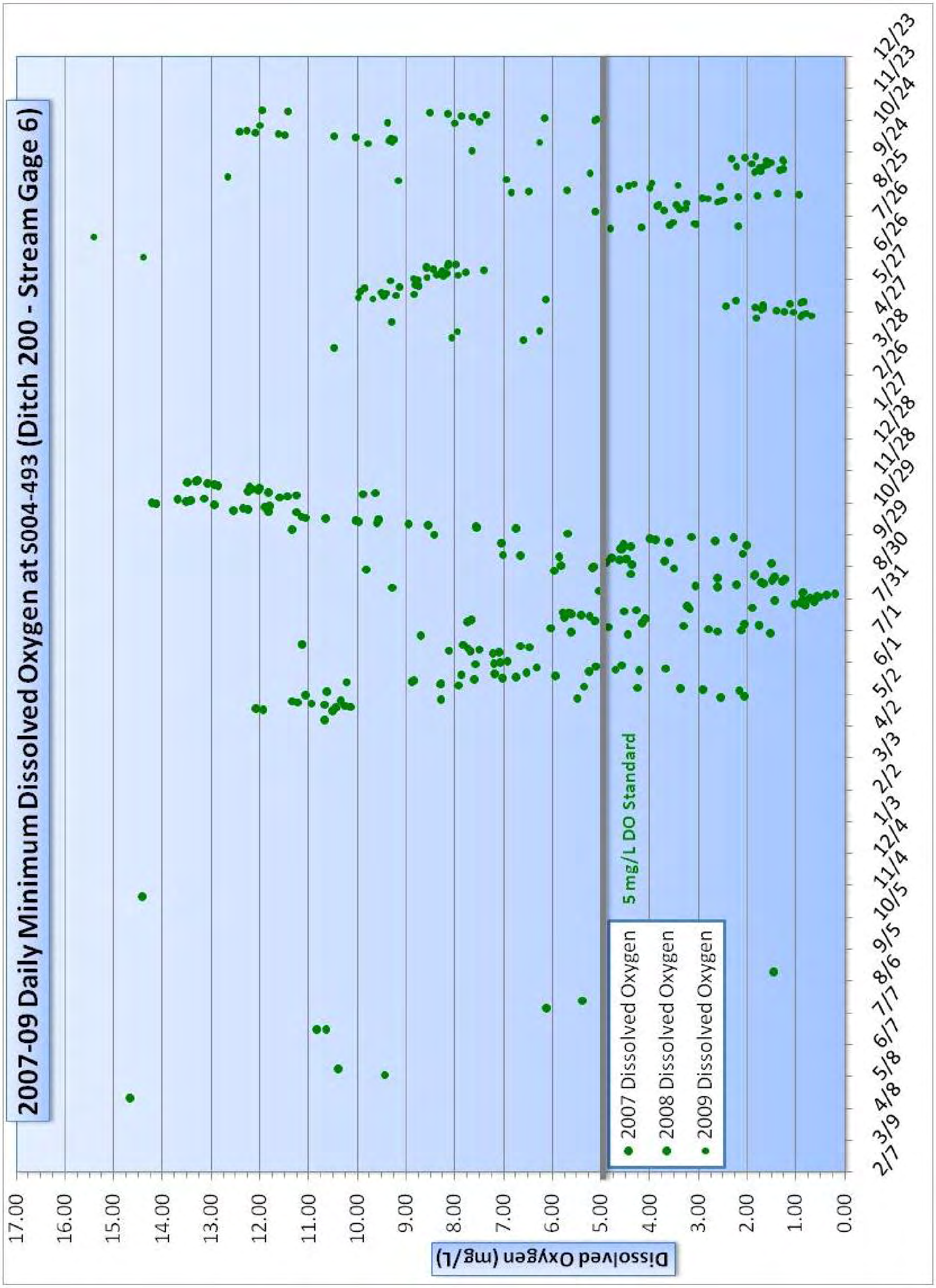


Figure 109. Daily minimum dissolved oxygen levels at the stream gauge 6 monitoring site on Ditch 200

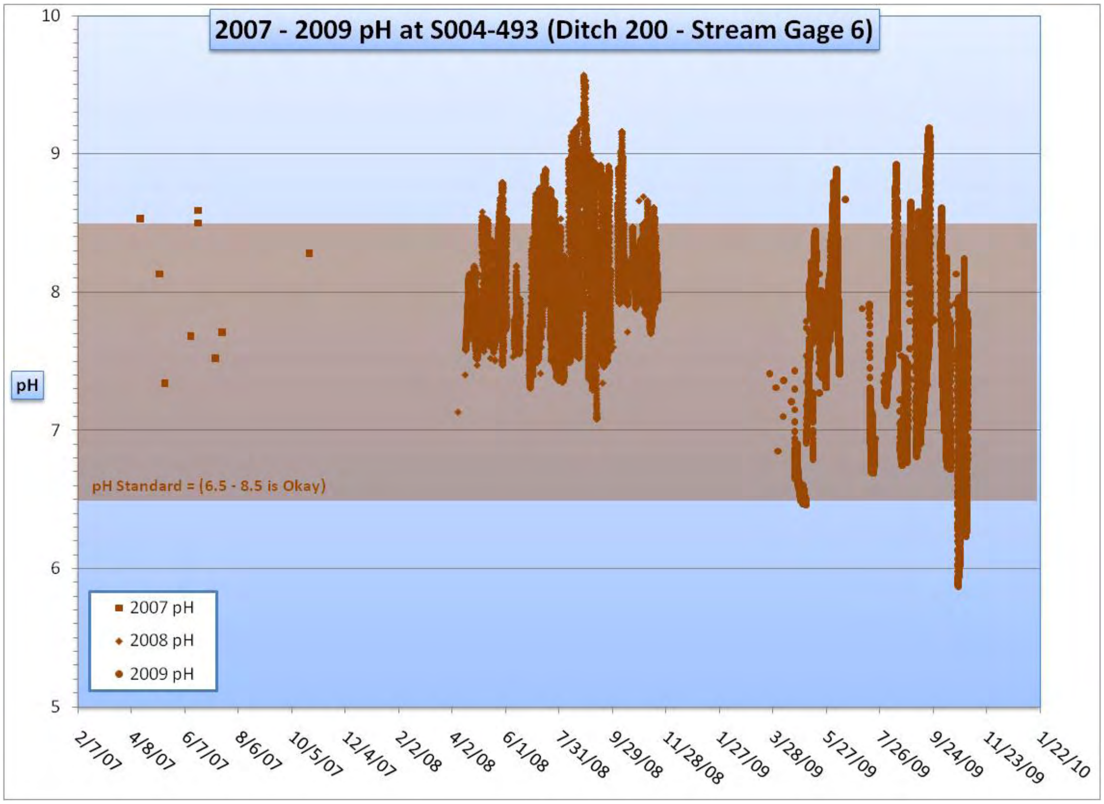


Figure 110. 2007 - 2009 pH levels in Ditch 200

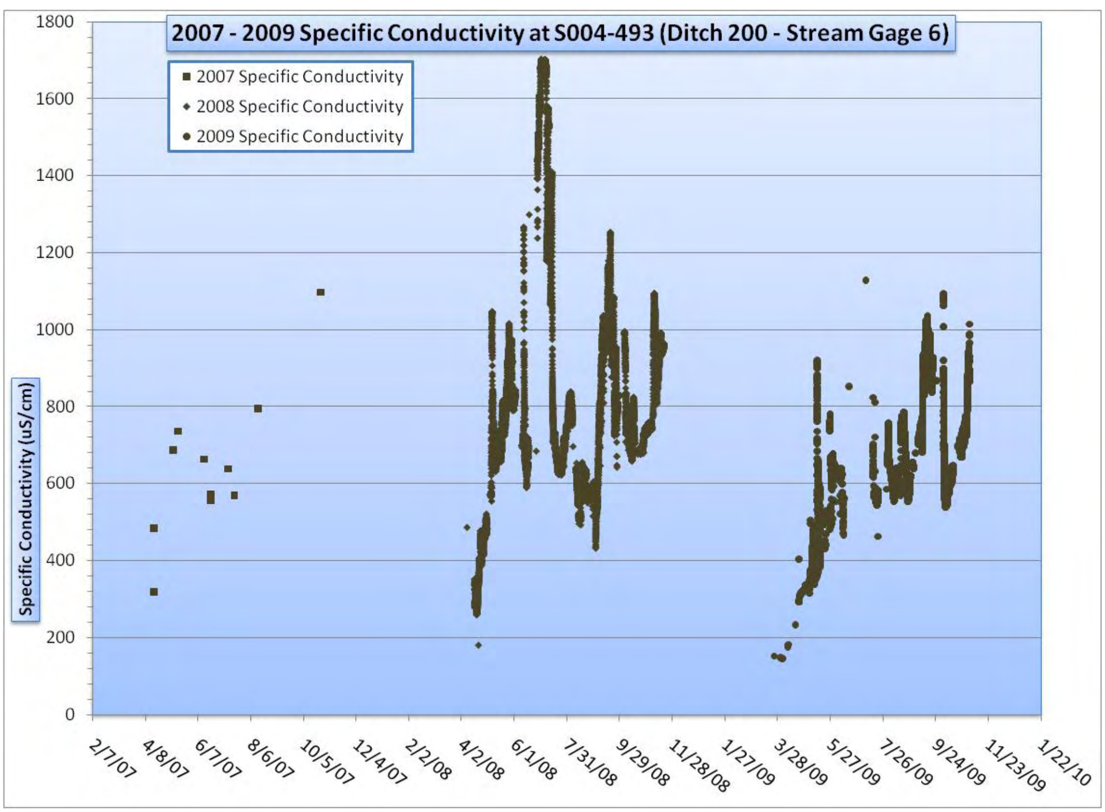


Figure 111. 2007 - 2009 Specific Conductivity in Ditch 200

Mud River

The continuous and discrete measurements at the Highway 89 monitoring site on the Mud River have shown that the river is actually, just barely, meeting the dissolved oxygen water quality standard.

Mantas were deployed, at first, under the bridge within a PVC pipe that was angled into the thalweg. Bridge replacement in 2009 forced the removal of the deployment pipe. It was re-installed upstream of the crossing, on the north riverbank, after the construction was completed.

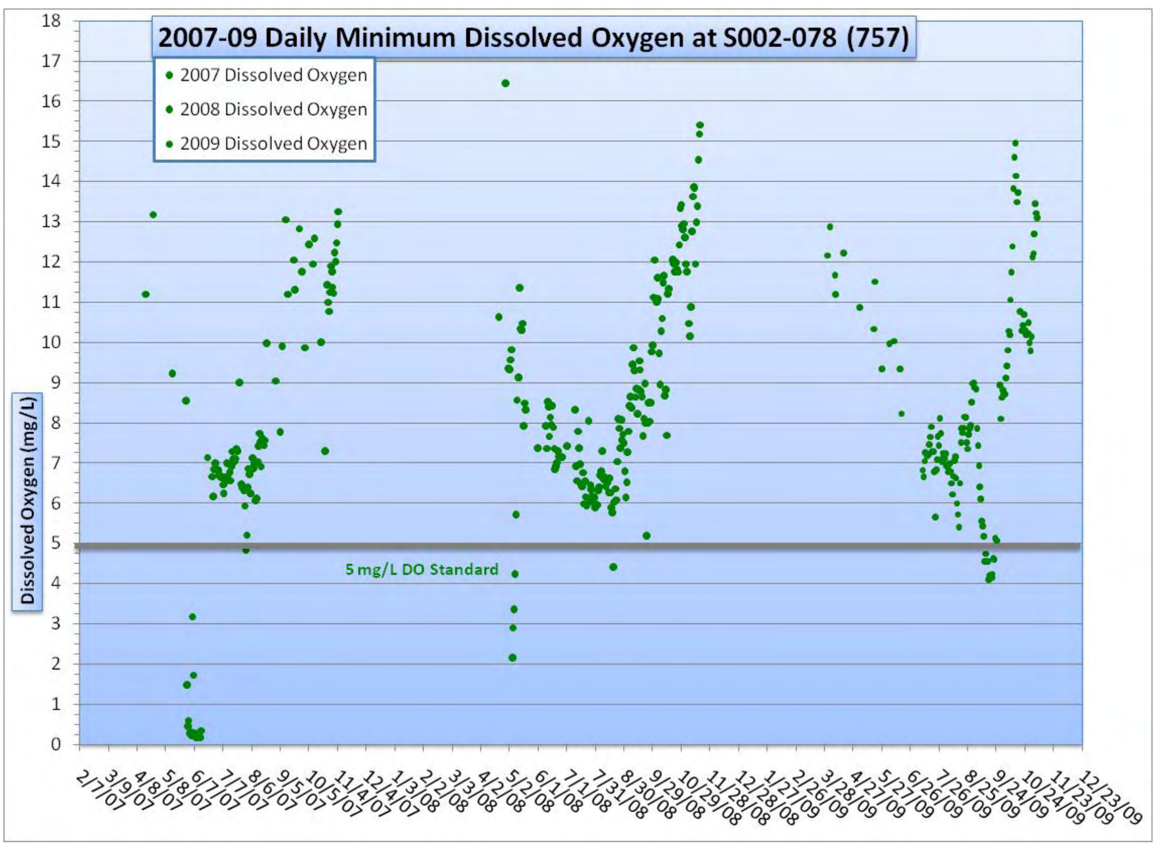


Figure 112. 2007 - 2009 daily minimum dissolved oxygen concentrations in the Mud River at Hwy 89

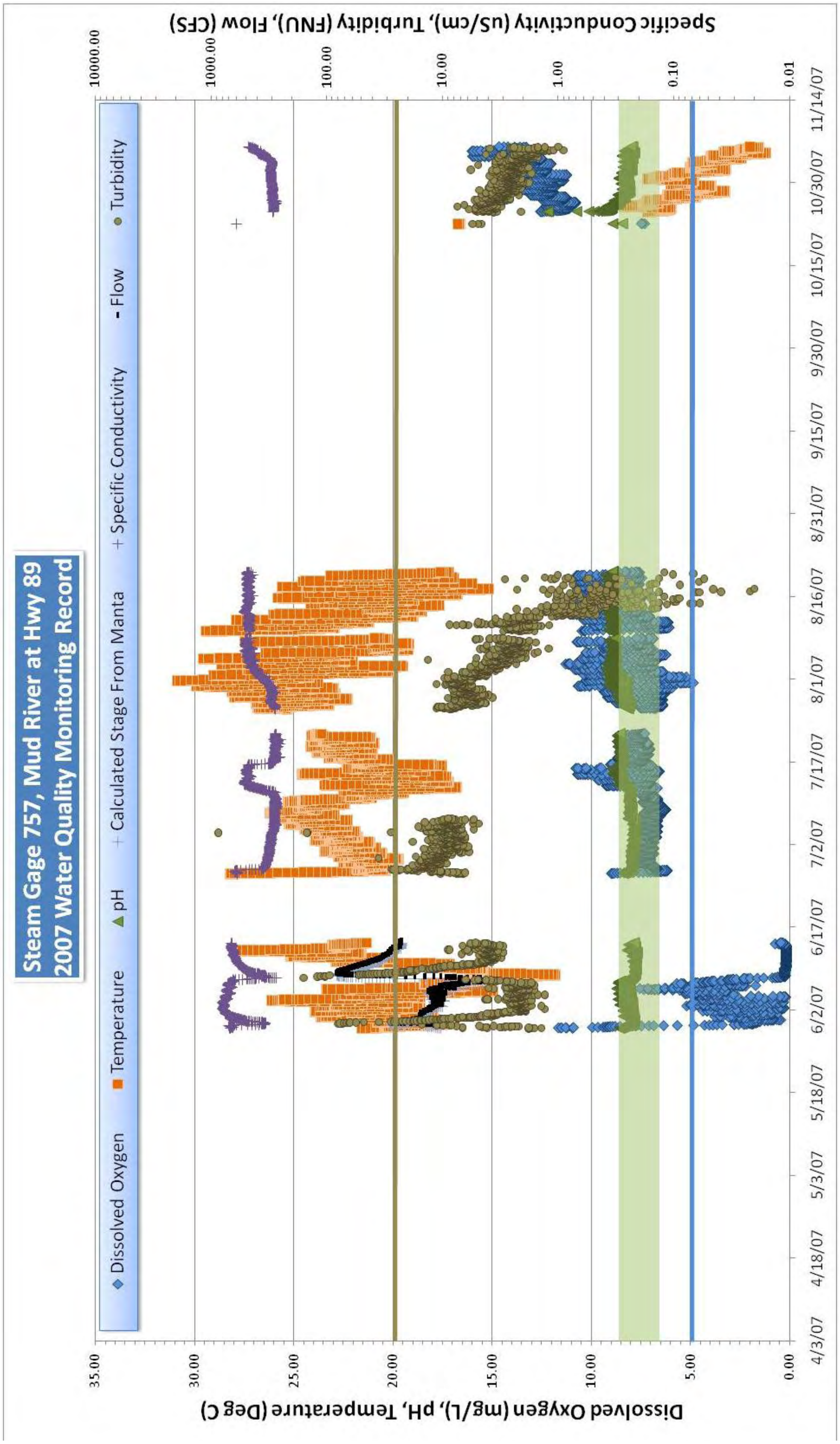


Figure 113. 2007 Continuous water monitoring record for the Mud River at Hwy. 89

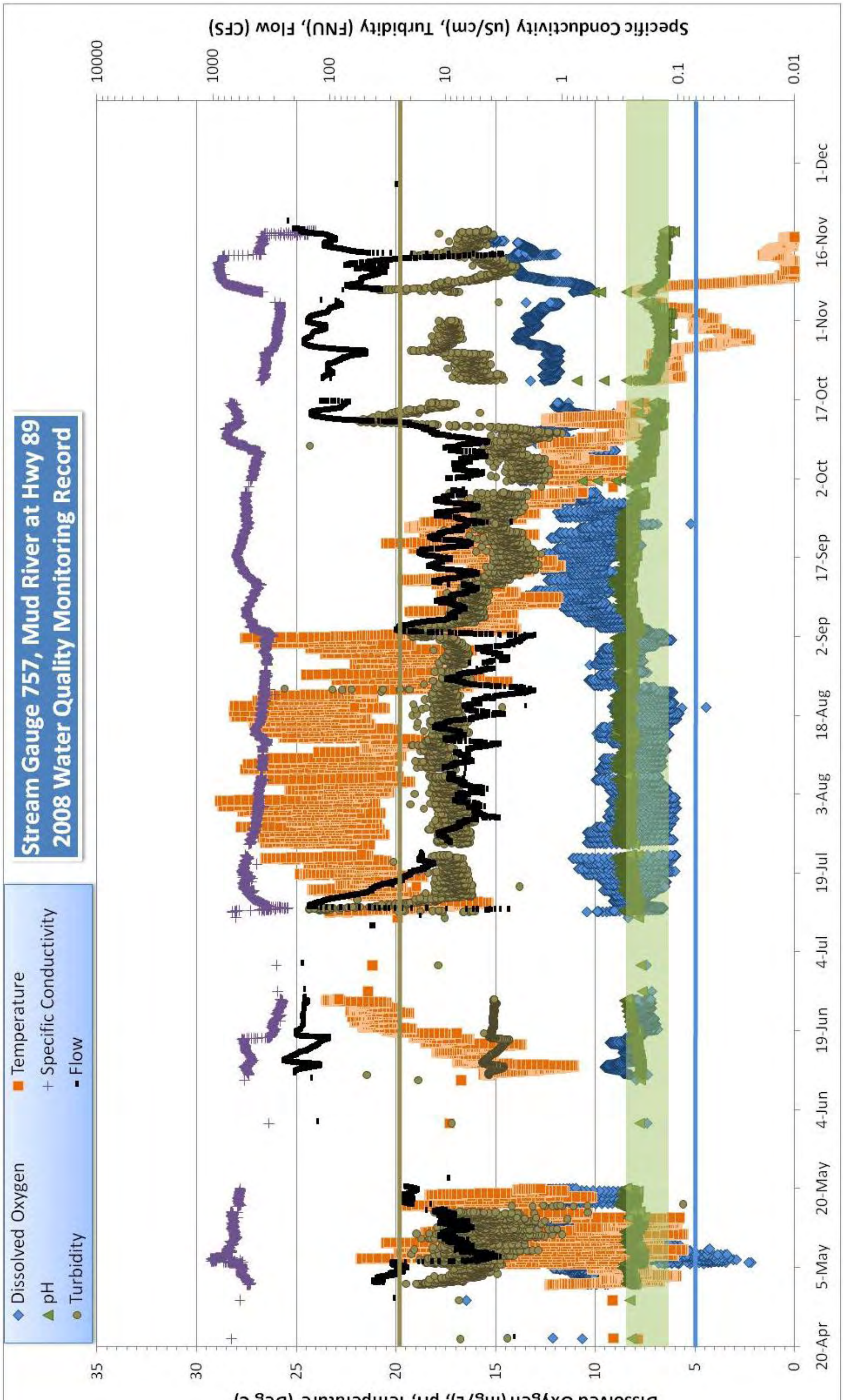


Figure 114. 2008 Continuous water monitoring record for the Mud River at Hwy. 89

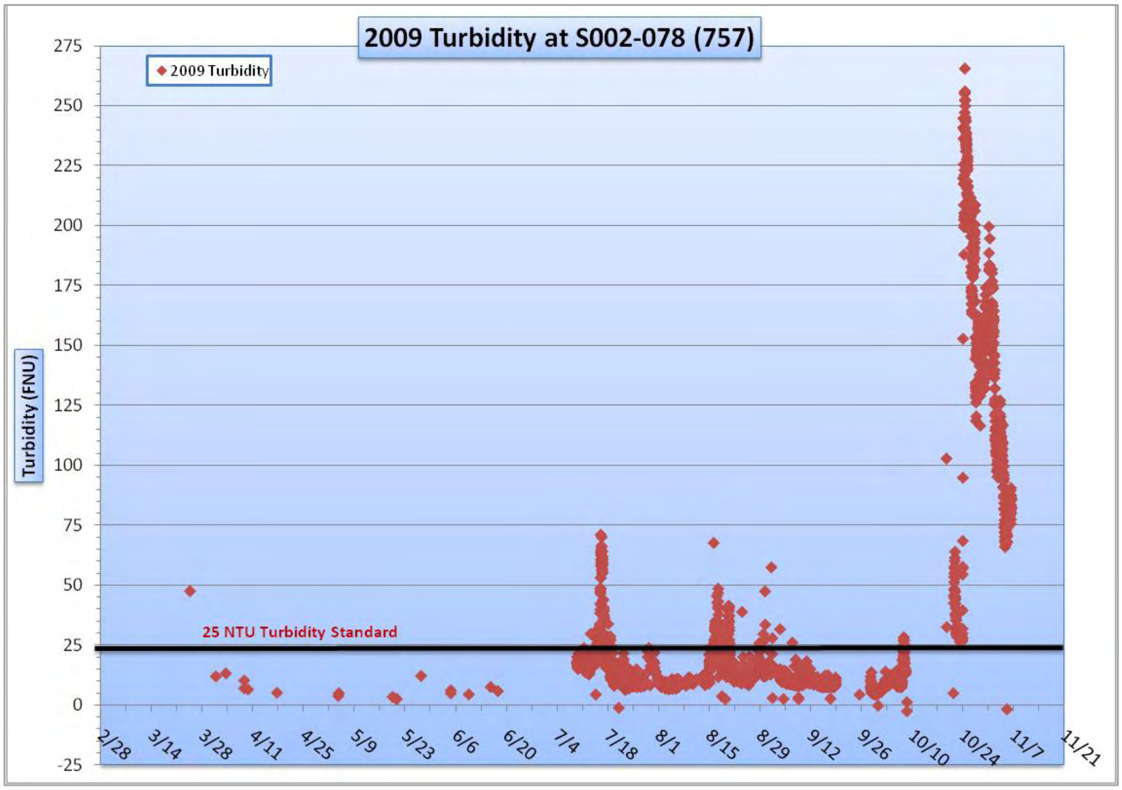


Figure 115. 2009 turbidity record for the Mud River at Hwy. 89

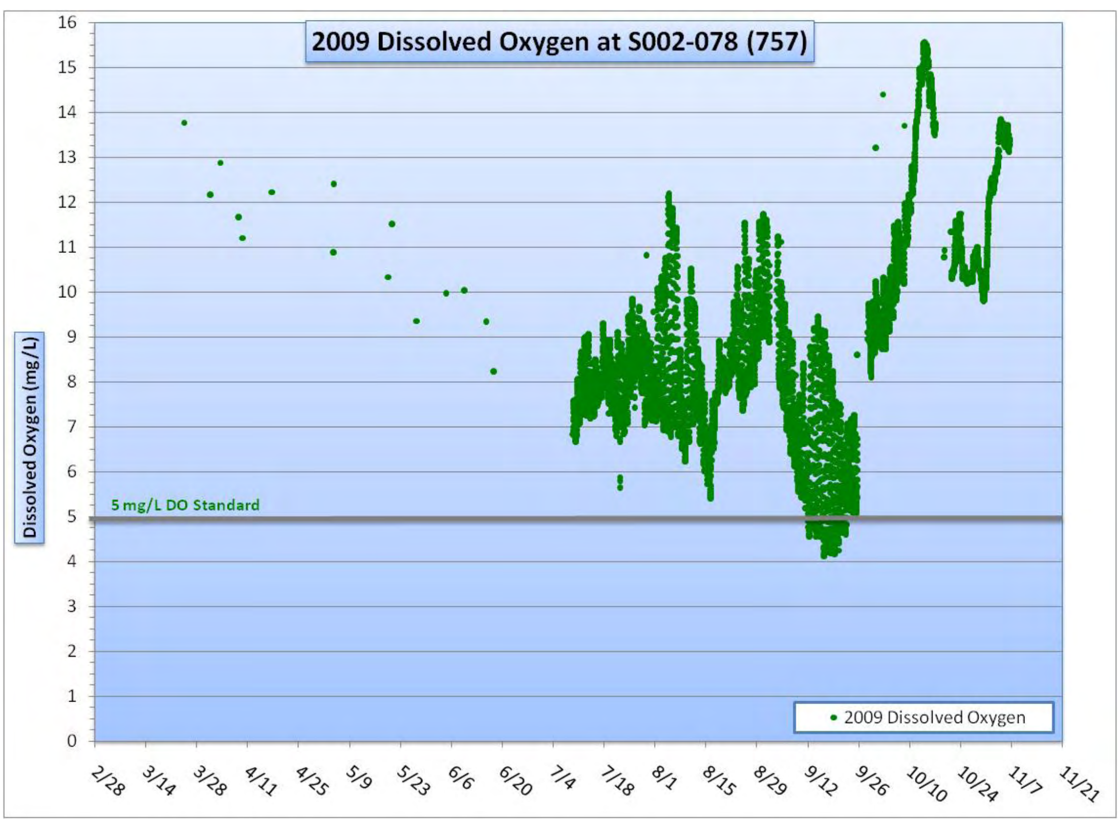


Figure 116. Complete 2009 dissolved oxygen record for the Mud River at Hwy 89

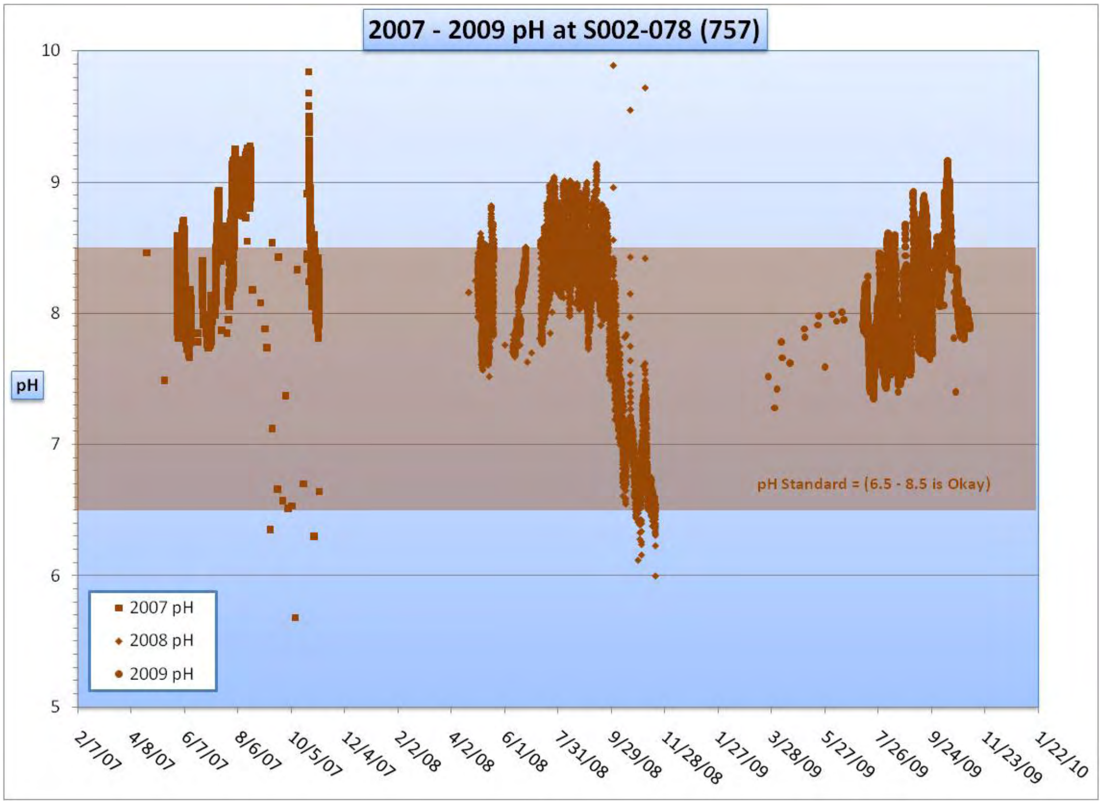


Figure 117. 2007 - 2009 complete pH record for the Mud River at Hwy. 89

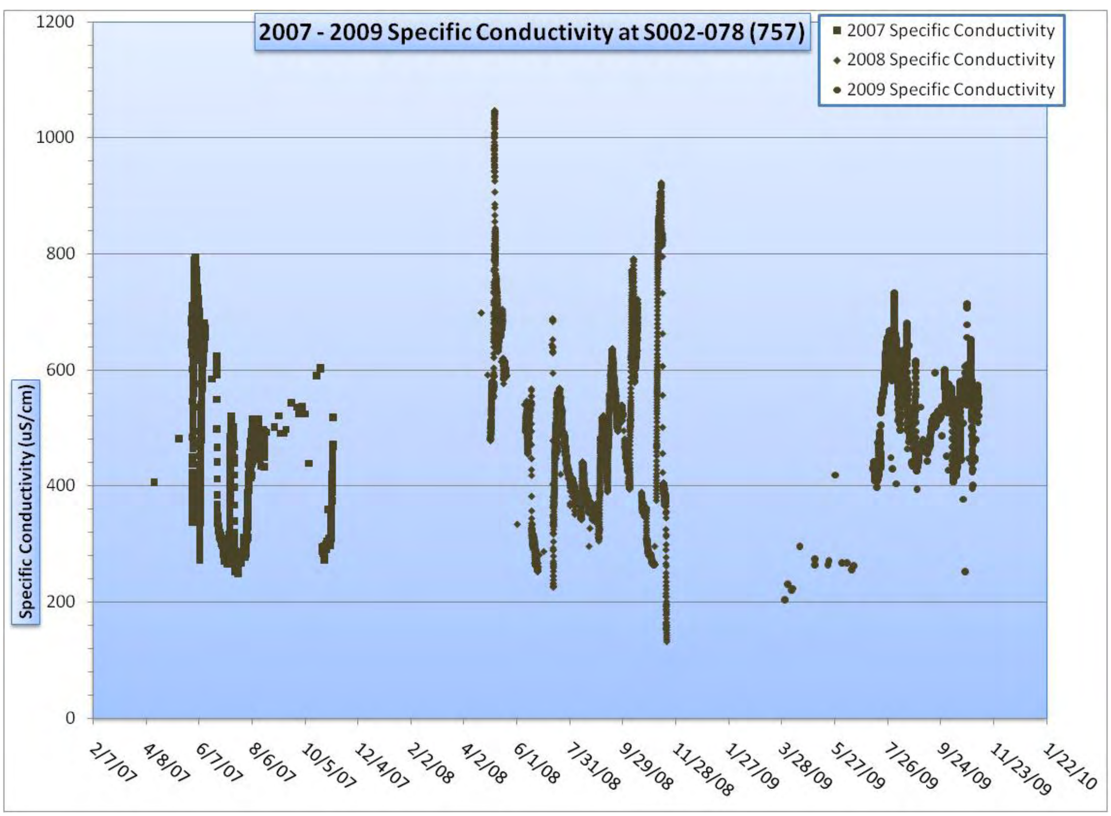


Figure 118. 2007 - 2009 complete specific conductivity record for the Mud River at Hwy 89

Thief River at the Agassiz National Wildlife Refuge north boundary

This monitoring site was used to characterize the water quality of the Thief River as it enters Agassiz National Wildlife Refuge from the north. Minimal water quality monitoring had been done at this site prior to this study. Previous condition monitoring had only sampled water near Thief Lake. The water quality (turbidity in particular) was significantly worse at this site than it was near the Thief Lake outlet.

The Manta at this site was deployed in a vertical PVC pipe that was secured to a bridge railing and to a fence post in the water. While this was a good setup for getting the sondes into the water during high flows, the vertical pipe also was in danger of being damaged by logs floating down the stream. The pipe was moved downstream and installed in the stream at an angle, like the installations at most of the other sites.

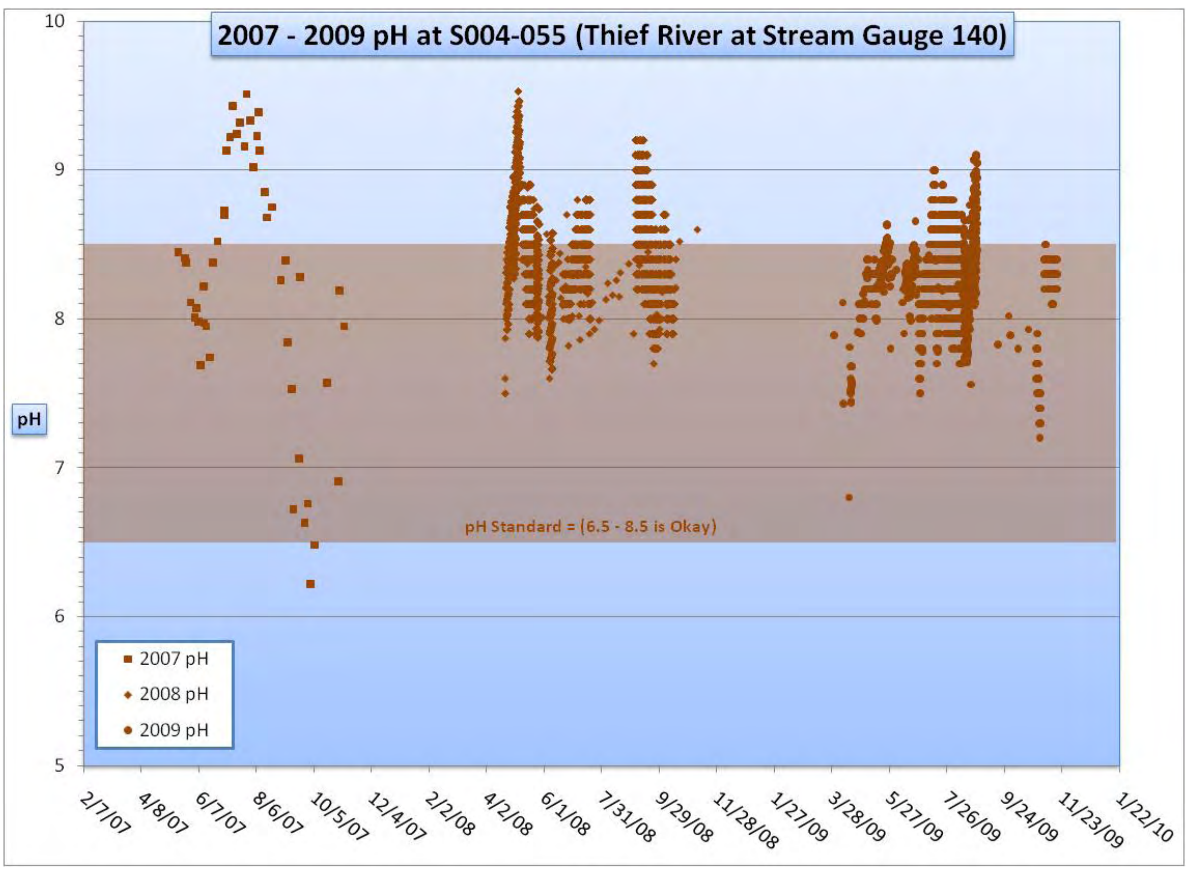


Figure 119. 2007 - 2009 pH record at Stream Gauge 140 on the Thief River

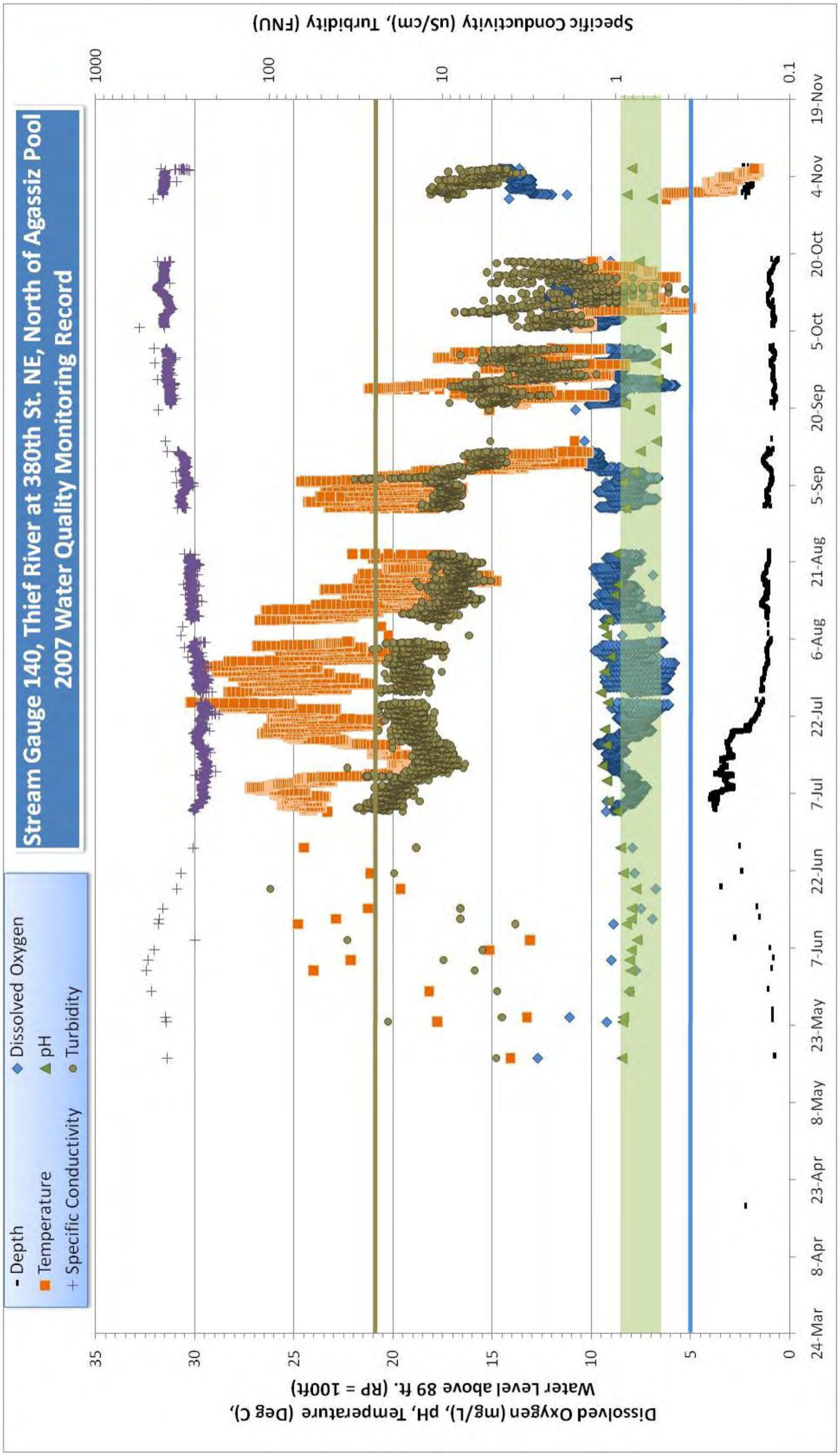


Figure 120. 2007 continuous monitoring record for stream gauge 140 on the Thief River at the northern boundary of Agassiz National Wildlife Refuge.

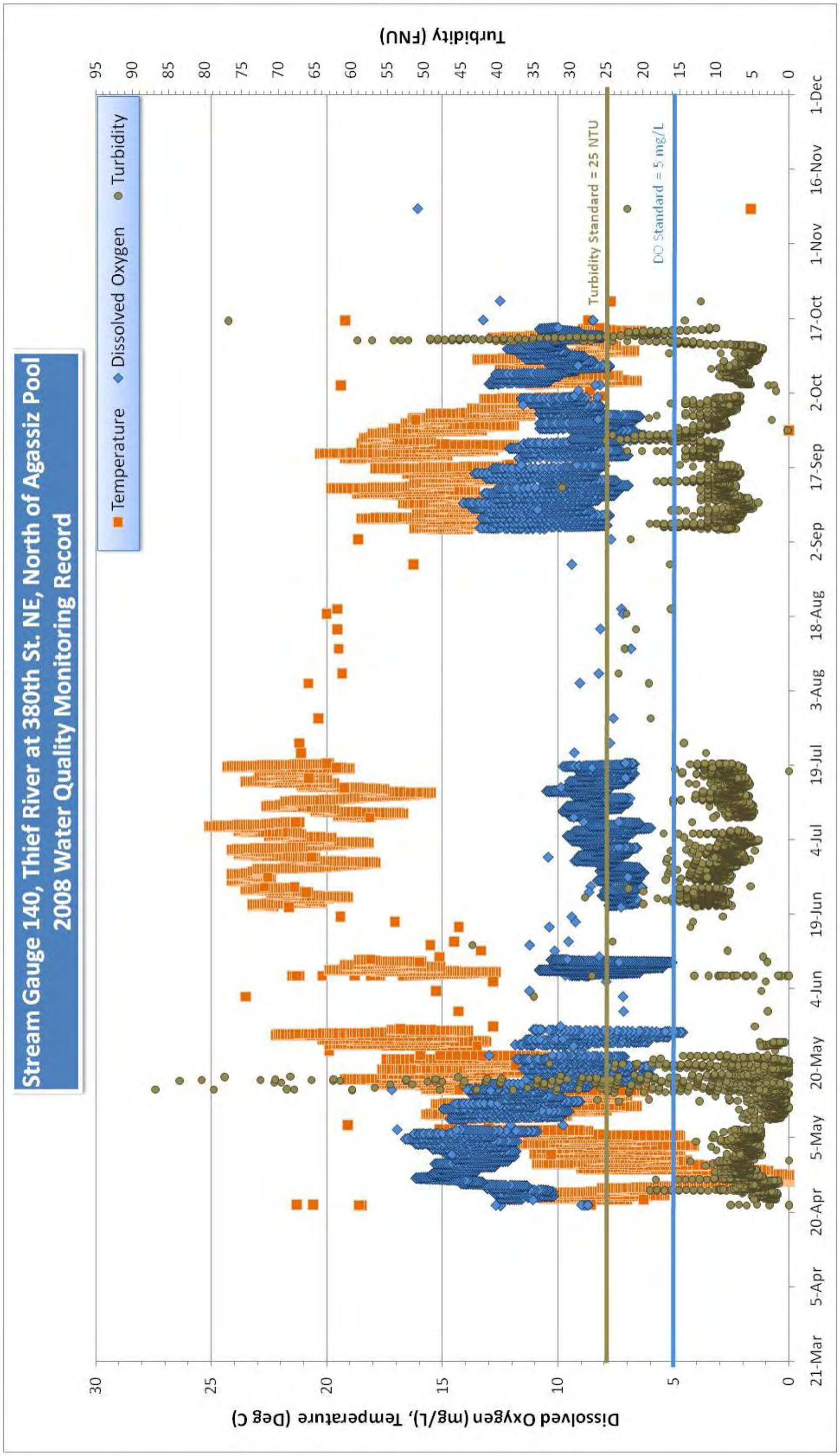


Figure 121. 2007 continuous monitoring record for stream gauge 140 on the Thief River at the northern boundary of Agassiz National Wildlife Refuge.

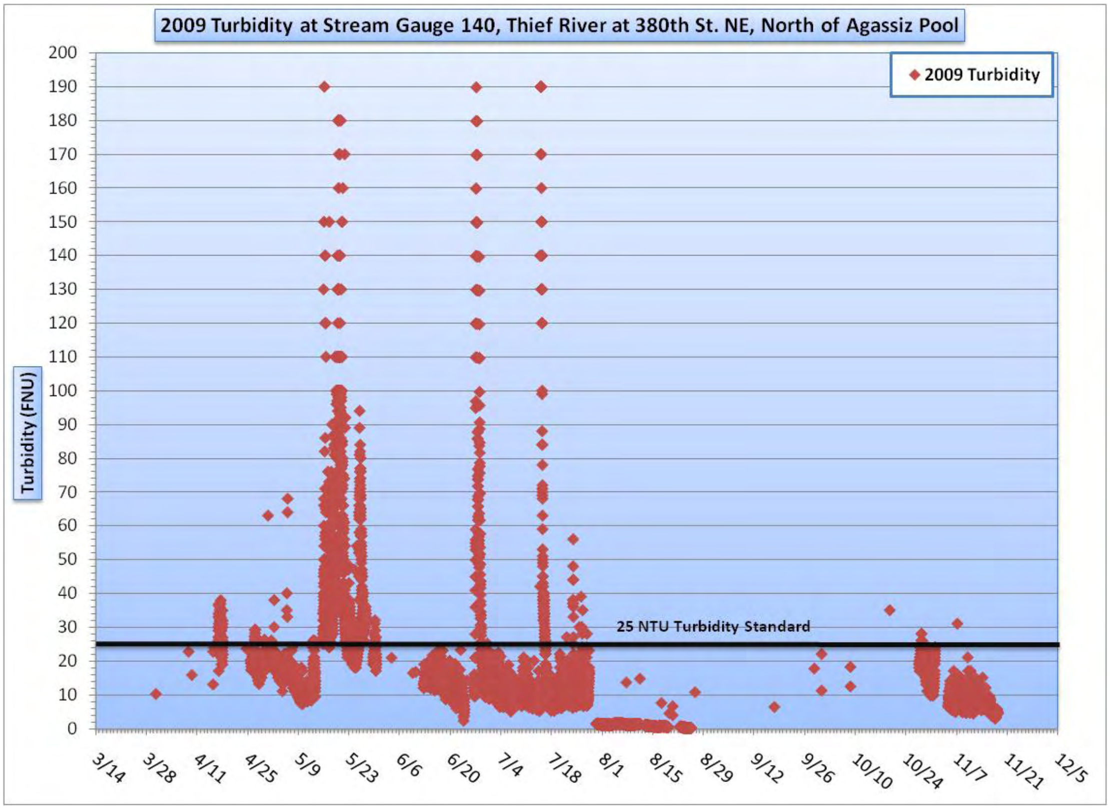


Figure 122. 2009 turbidity record at Stream Gauge 140 on the Thief River

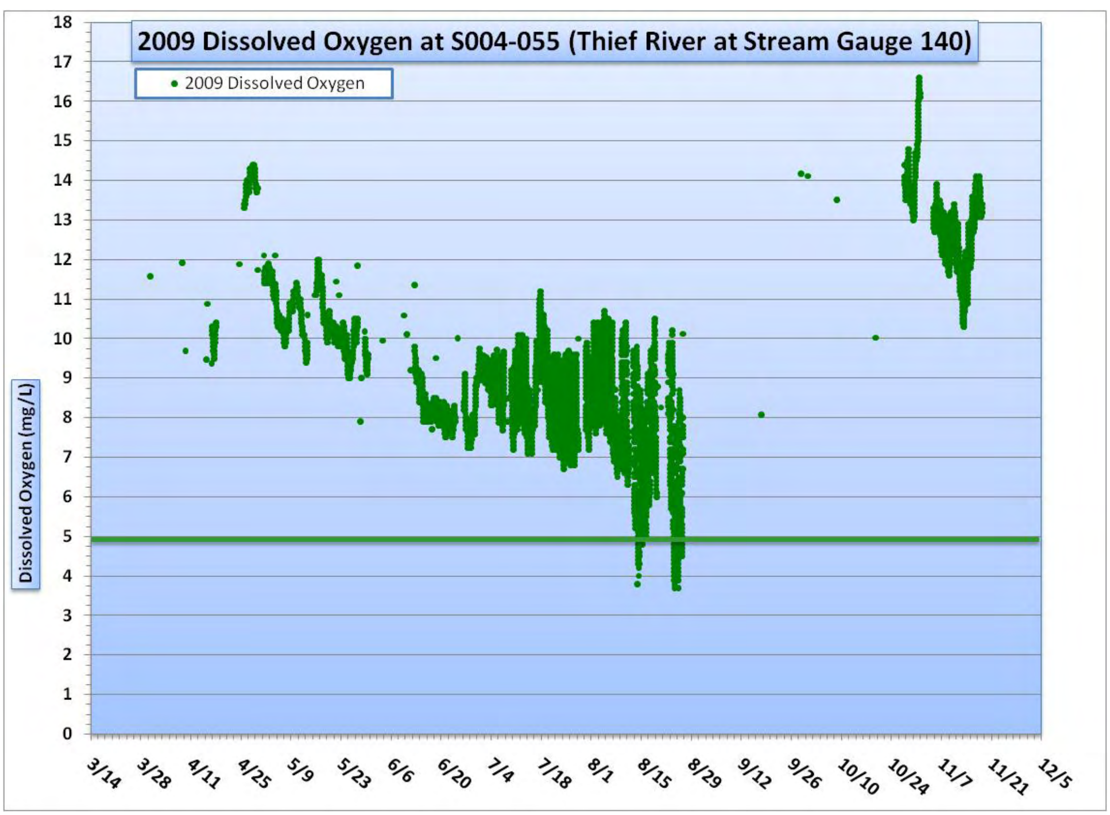


Figure 123. 2009 complete dissolved oxygen record at Stream Gauge 140 on the Thief River

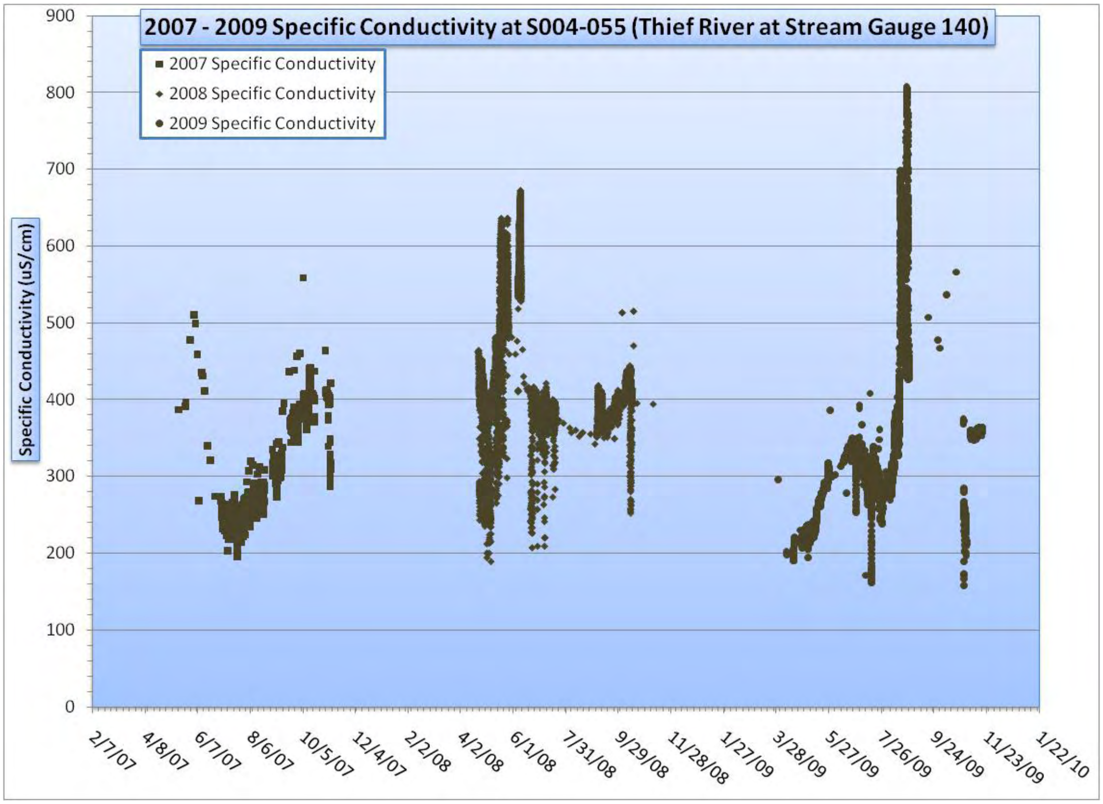


Figure 124. 2007 - 2009 specific conductivity record at Stream Gauge 140 on the Thief River

Moose River at CSAH 54

In the late summer and fall of 2009, a Eureka Midge dissolved oxygen logger was deployed at the CSAH 54 crossing of the Moose River. After each two-week deployment period, a freshly calibrated Midge with new batteries and a new DO probe membrane was brought to the site to replace the one that was deployed. The deployed Midge was brought back to the RLWD lab for data extraction, cleaning, membrane replacement, and calibration.

The daily minimums stayed above the 5 mg/l State standard for dissolved oxygen levels during the deployment of the Midges at this site. They came close at the beginning of the record. So, there is a possibility that there may be some mid-summer mornings when the dissolved oxygen falls below the standard. Further investigation of the daily minimum dissolved oxygen levels at this site will take place during the Thief River Watershed Assessment Project.

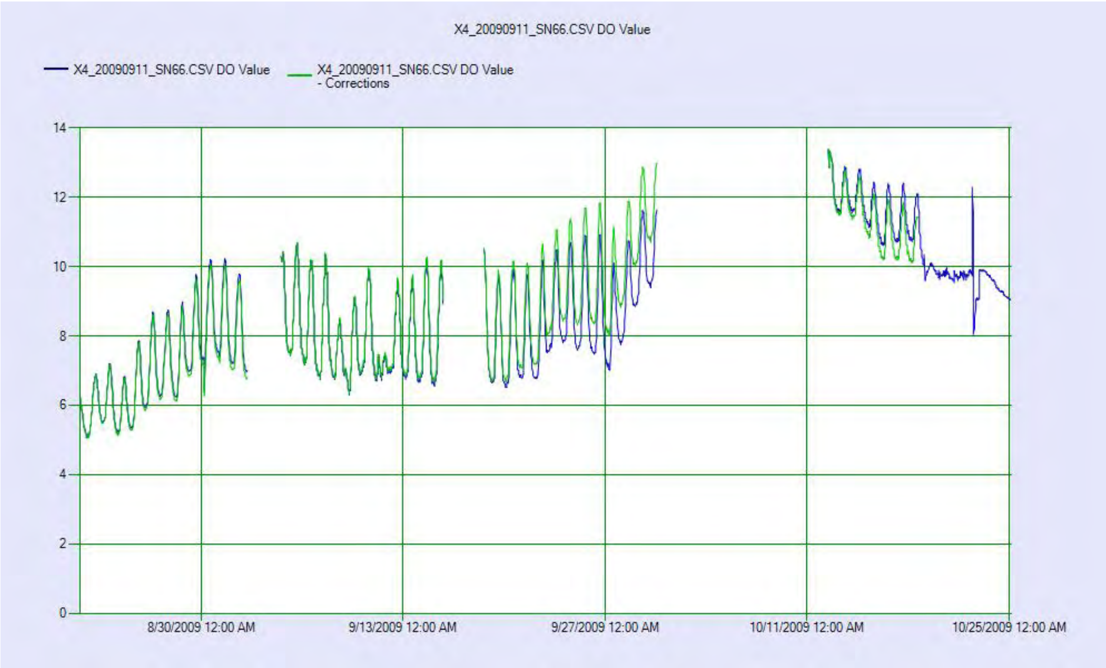


Figure 125. Dissolved oxygen record from Eureka Midges installed in the Moose River at CSAH 54 north of Grygla.

Moose River at the State Forest Road

In-Situ TROLL 9500 multi-parameter logging sondes were used at stream gauge 139 (State Forest Road crossing) to collect a continuous water quality record at the site for the late summer and fall of 2009. The primary goal of this installation was the collection of a continuous dissolved oxygen record. The sondes also collected specific conductivity, pH, water level, and temperature data. If there was a problem with low dissolved oxygen during this time period, this logger installation would tell us if DO levels dropped below 5 mg/L at any time of the day. There were days in the late summer that had daily minimum DO levels below the 5 mg/L threshold. As the water got colder, closer to winter, the water was able to hold more dissolved oxygen and the levels improved. The late summer values at this site were lower than those measured further downstream at Highway 54. Dissolved oxygen concentration apparently increases in the river as it travels from Moose River impoundment downstream to Highway 54.

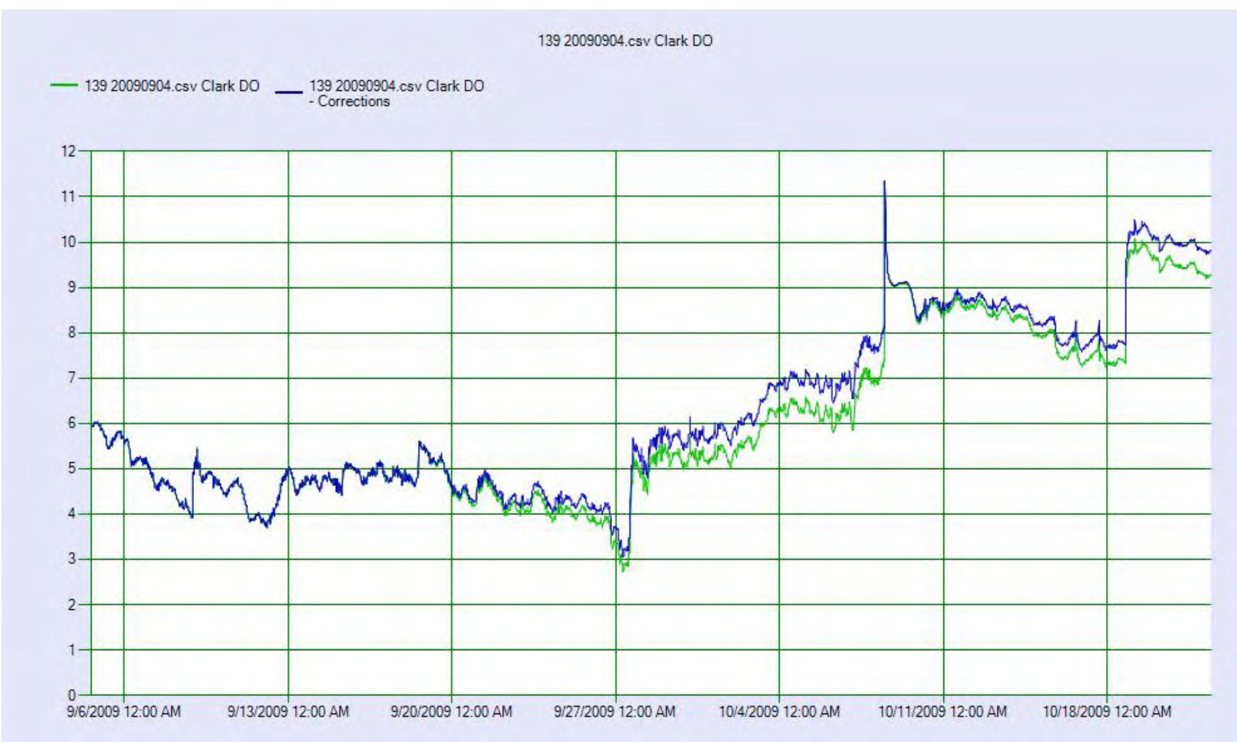


Figure 126. 2009 continuous dissolved oxygen record near the upstream end of the Moose River

Assessment of Combined Continuous Monitoring Data

Table 7. Complete and comprehensive assessments using continuous and discrete monitoring data

Assessment of Combined Records of Spot Measurement and Continuous Monitoring Data for the Thief River Watershed Sediment Investigation											
		2000 - 2006		2007		2008		2009		Combined	
Site	River	Dissolved Oxygen	Turbidity	Dissolved Oxygen	Turbidity	Dissolved Oxygen	Turbidity	Dissolved Oxygen	Turbidity	Dissolved Oxygen	Turbidity
757	Mud River	3.3%	0.0%	24.7%	3.4%	2.4%	2.5%	8.5%	20.2%	9.4%	7.9%
140	Thief River	0.0%	75.0%	0.0%	1.8%	0.7%	3.8%	4.8%	13.9%	2.2%	7.7%
40	Thief River	13.2%	29.2%	9.0%	0.0%	4.3%	24.0%	1.7%	66.1%	5.5%	29.7%
6	Ditch 200	n/a	n/a	10.0%	0.0%	38.6%	1.1%	46.4%	0.8%	26.6%	0.6%
41	CD20	n/a	n/a	9.8%	12.2%	1.6%	1.4%	1.1%	0.6%	2.9%	3.2%
760	Thief River	10.4%	33.3%	1.7%	21.2%	10.2%	15.9%	6.9%	17.1%	7.2%	19.5%
		Percentage of time that standards are not met.									

Table 8. Number of days that were monitored at each site

Number of days Represented in Combined Records of Spot Measurement and Continuous Monitoring Data											
		2000 - 2006		2007		2008		2009		Combined	
Site	River	Dissolved Oxygen	Turbidity	Dissolved Oxygen	Turbidity	Dissolved Oxygen	Turbidity	Dissolved Oxygen	Turbidity	Dissolved Oxygen	Turbidity
757	Mud River	30	17	89	89	167	162	130	114	416	382
140	Thief River	4	4	110	113	138	133	145	144	397	394
40	Thief River	38	24	100	100	162	175	121	109	421	408
6	Ditch 200	n/a	n/a	10	10	189	188	124	138	335	336
41	CD20	0	0	82	82	187	143	184	179	453	404
760	Thief River	67	51	116	104	157	157	188	129	528	441
		Percentage of time that standards are not met.									

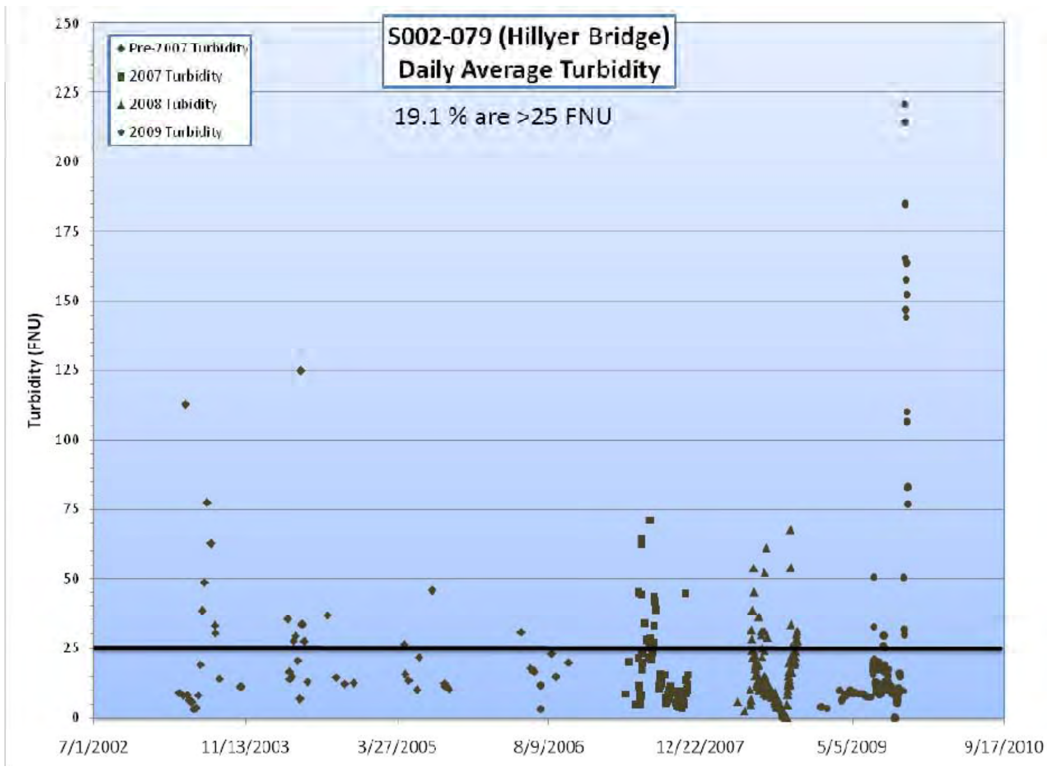


Figure 127. 2009 daily average turbidity

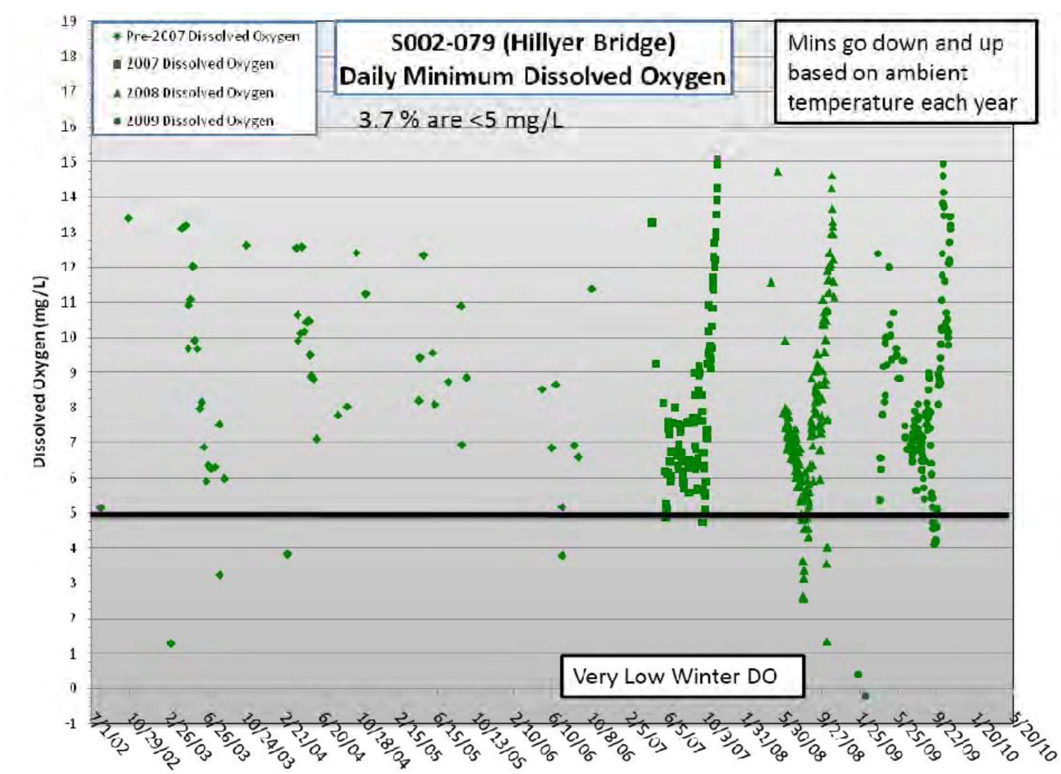


Figure 128. 2009 daily minimum record for dissolved oxygen

Sediment Budget

Turbidity is an optical property of water. Total suspended sediment is a tangible, quantifiable measurement of the amount of suspended solids in the water. In order to translate the continuous turbidity records into total suspended solids records, turbidity and TSS values were plotted against each other. These parameters are closely related and correlate very well. A simple regression equation is produced from this plot. That equation can be used to convert continuous turbidity records into total suspended solids records.

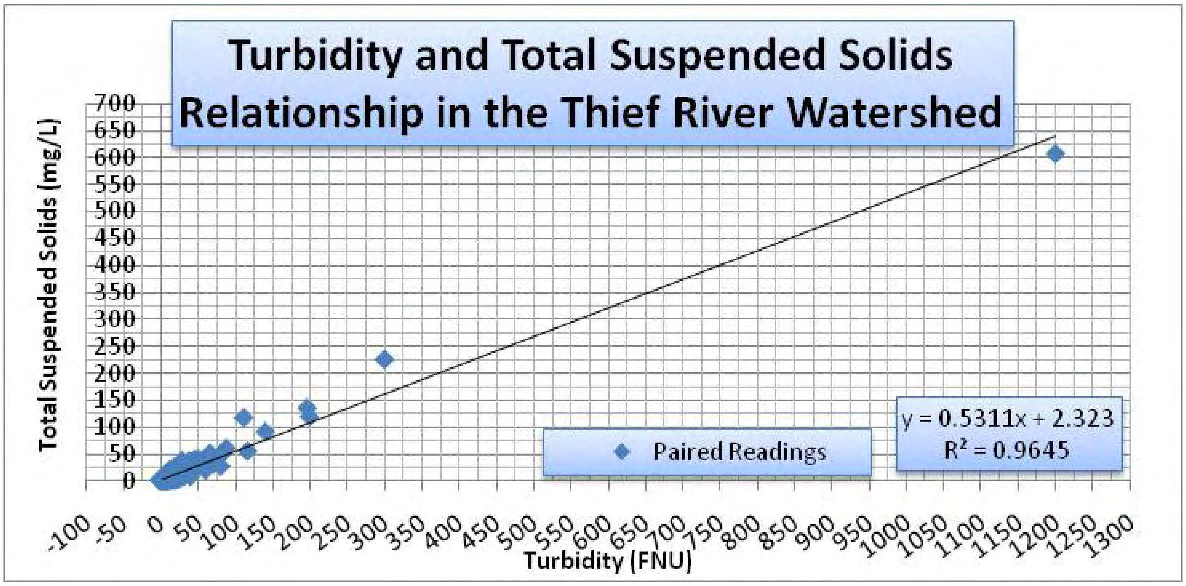


Figure 129. Turbidity and Total Suspended Solids Conversion for the Thief River Watershed.

FLUX modeling was originally planned for this study, but the flow and water quality data set is incomplete until the USGS data has been processed and is ready for use. It was not available at the deadline of this report. Fortunately, the SWAT model provided estimated flow, sediment loads, and more at the inlets and outlets of all the sub-basins in the Thief River watershed.

Looking at the SWAT modeling results graphically for the sub-basins along the Thief River and contributing sub-basins sheds light upon where sediment loads are increasing and where sedimentation is occurring. According to the model, the Thief River drops approximately 1/2 of its sediment in Agassiz Pool from when it comes in from the north to when it leaves to the south. The new outlet is not factored into the model at this time. In reality, flow can now travel along the western dike of Agassiz Pool and exit through the new outlet. All the sediment leaving through this outlet would be sediment that isn't deposited in the pool. The Agassiz NWR water quality study has a goal of quantifying the loads coming out of the new outlet.

The model also shows that sub-basins 7 (northwest of the north boundary bridge) and 65 (west of Agassiz WNR) are each contributing a very large load of sediment. The average annual load from sub-basin 7 (1,447 tons/yr.) and 65 (1,514 tons/yr.) are each, individually, greater than the average annual load calculated at the County Road 7 bridge over the Thief River (1408 tons/yr.).

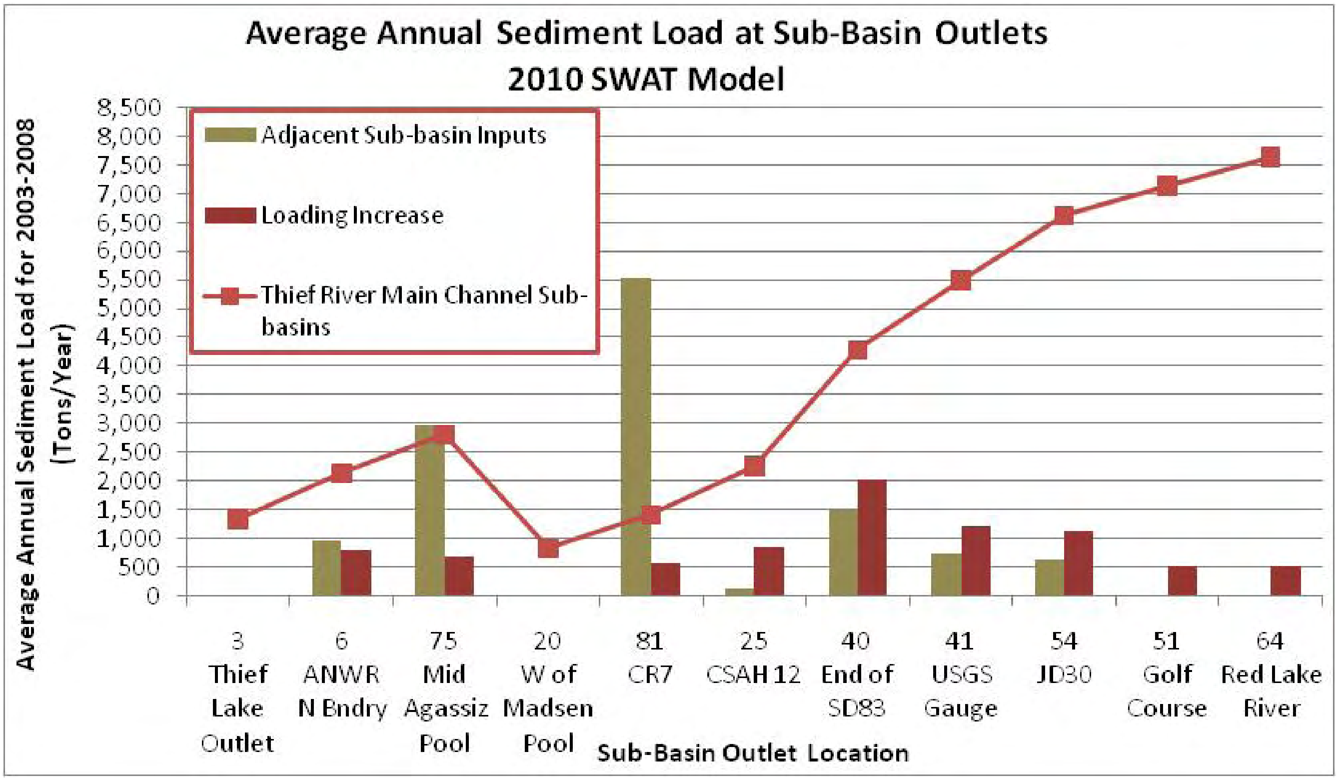


Figure 130. Longitudinal graph of SWAT-modeled sediment loading along the Thief River

There is a lot more sediment coming into the Agassiz Pool sub-basins than what shows up at the CR7 crossing of the Thief River. The rate of increase in sediment loads peaks near the end of State Ditch 83 and decreases downstream of that point.

Sediment budget for Thief Lake

The SWAT model developed for the Thief River watershed was used to estimate the sediment loads entering and leaving Thief Lake. The model tells us the separate loads coming from the Moose River and from Branch 3 of Judicial Ditch 11. It also gives us sediment loads being discharged from the Thief Lake outlet. An imperfection in the model is that the sub-basin that includes the Thief Lake basin also includes the Branch 4 of JD11 drainage area. So, the Branch 4 drainage area will contribute to the discharge at the Thief Lake outlet, but can't be accounted for in the inputs. The first step was to check whether or not the sum of the outputs from the Moose River (sub-basin 69) and Br. 3 JD11 (sub-basin 1) is approximately equal the input for Thief Lake (sub-basin 3). There were several years where they appeared to be approximately equal. In the other years, there was an additional significant source of sediment that is left out (Br. 4 JD11).

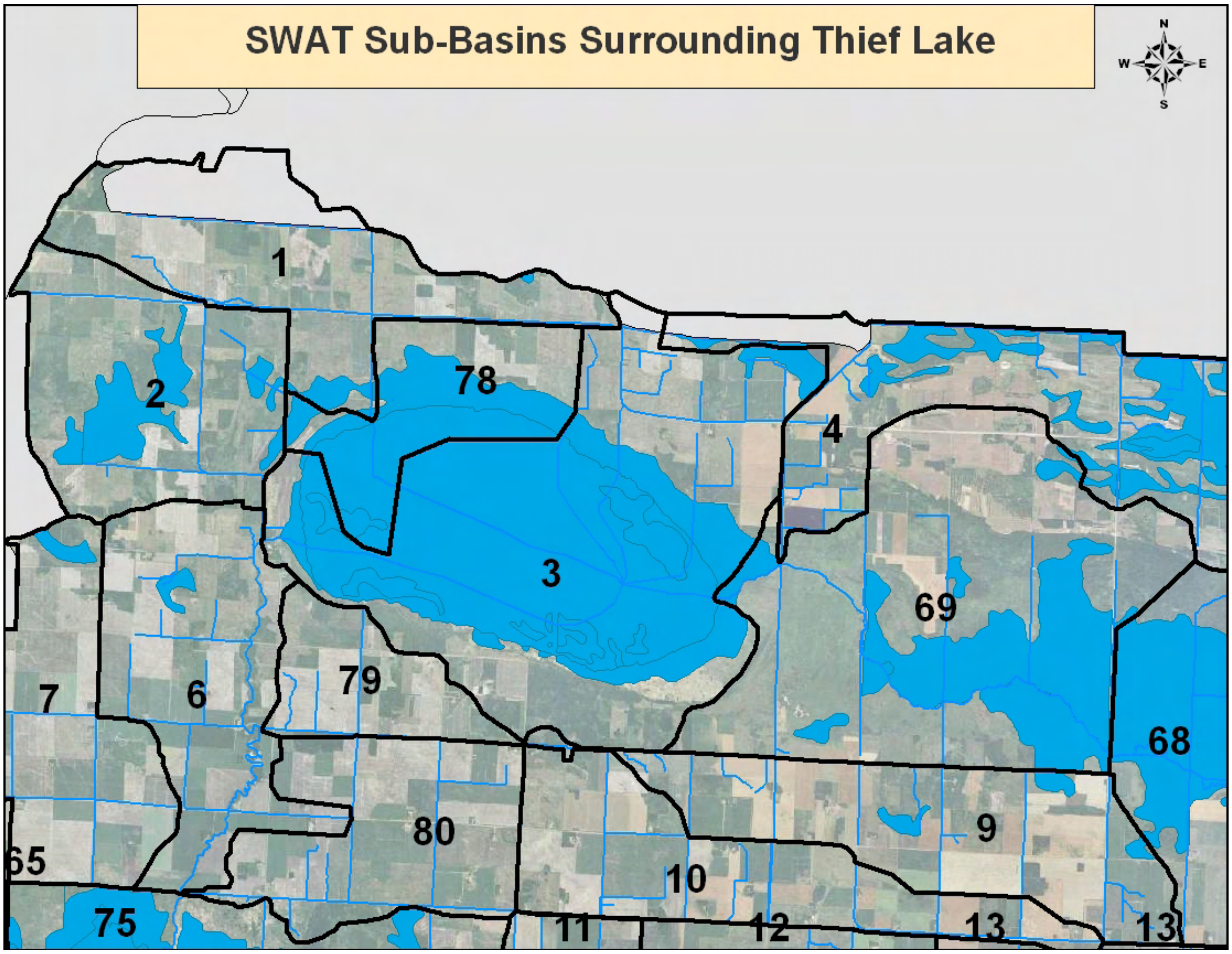


Figure 131. SWAT Model Sub-Basins that Surround Thief Lake

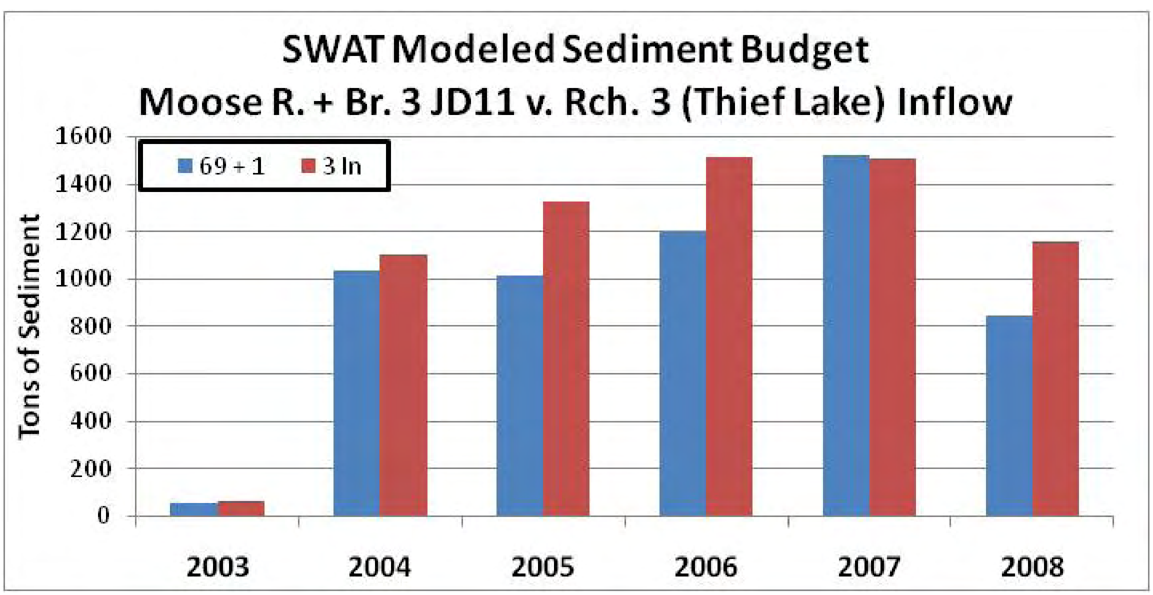


Figure 132. Check to see if correct sub-basins are being used for the Thief Lake Sediment Budget Estimate

A 2003 report by Houston Engineering estimated that the sediment load at the outlet of Thief Lake was greater than the sediment load coming into Thief Lake from the Moose River. A similar result is shown by the SWAT model output. The model shows that the sediment outputs from reach/sub-basin 3 (Thief Lake) are greater than the inputs.

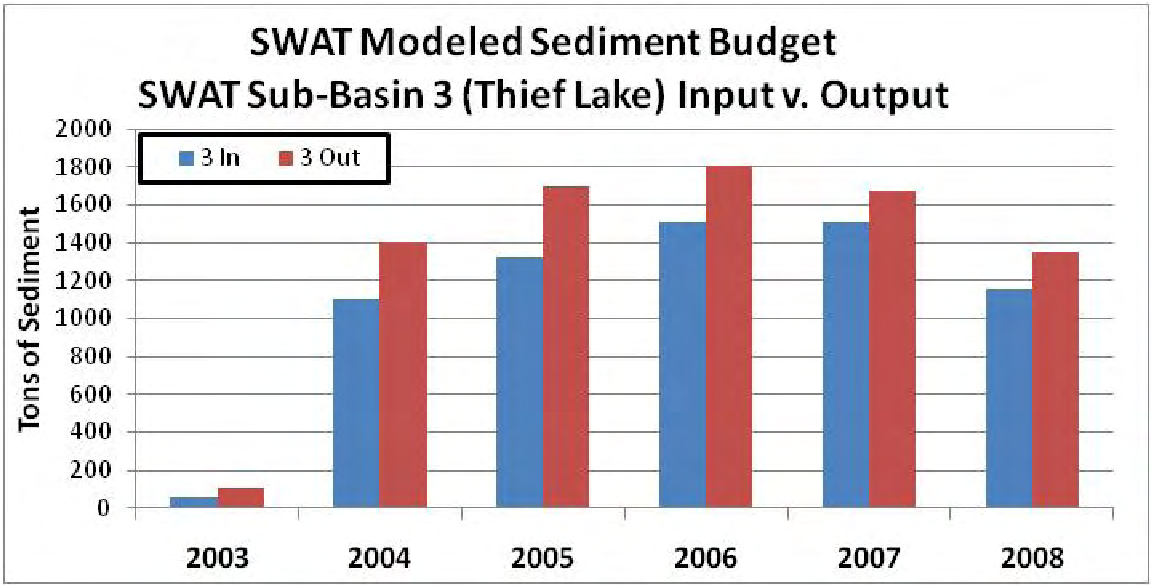


Figure 133. Thief Lake Sub-Basin (3) Sediment Inputs and Outputs

Even when the Br. 3 JD11 contribution is added to the Moose River contribution, the output at the Thief Lake outlet is still greater than the inputs.

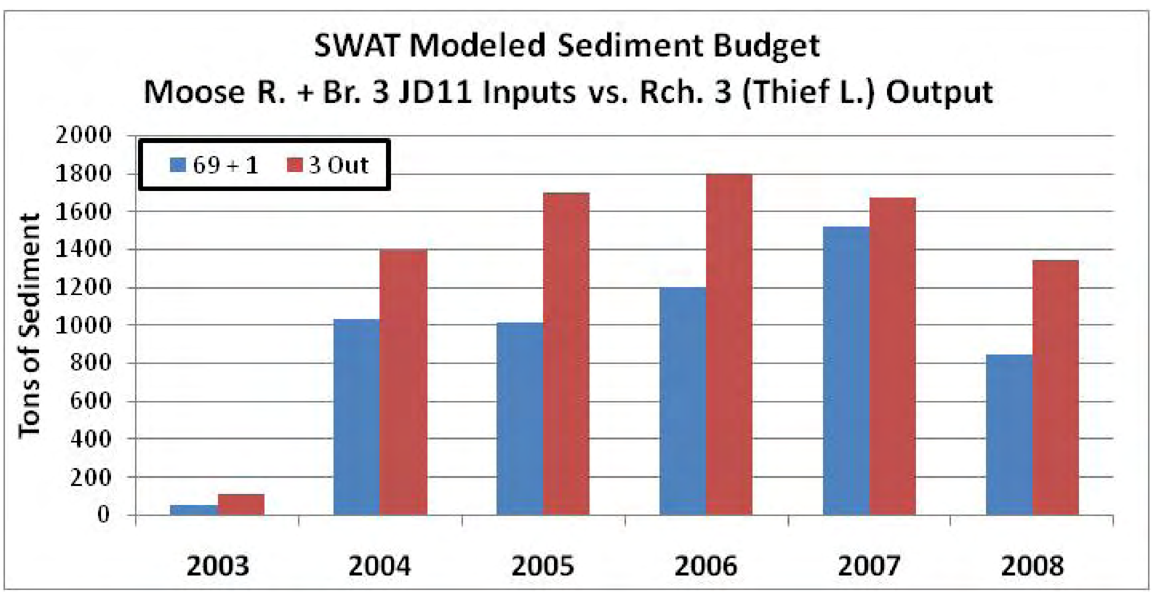


Figure 134. Comparing Moose River and Br. 3 JD11 sediment inputs to the Thief Lake sediment output.

There is no doubt that there still is some sediment deposition within Thief Lake is occurring, regardless of modeling results, as shown by the following aerial photographs.

Sediment Budget for Agassiz National Wildlife Refuge

Despite periodic high turbidity levels in the Thief River downstream of Agassiz National Wildlife Refuge, there is more sediment coming into the refuge than what leaves there refuge. This is according to a SWAT model developed by Houston Engineering for this project.

The *Thief River SWAT Modeling* report by Houston Engineering, Inc. lists sediment loads for three monitoring stations that bracket Agassiz National Wildlife Refuge. This method doesn't take into consideration any processes that are occurring downstream of the "input" monitoring sites. Nonetheless, the numbers show that at least 861 tons of the suspended sediment being carried annually by the Mud River and the Thief River toward Agassiz National Wildlife Refuge does not end up being carried downstream of the Refuge in the Thief River. That is equal to approximately 86 10-ton dump truck loads of sediment. This means that a dump truck load of sediment is dumped into the Agassiz NWR's pools once every four days.

94% of the sediment load entering the Agassiz NWR area is coming from the Thief River. Could the new outlet help bypass more sediment from the Thief River past the main Agassiz Pool area? There still is sedimentation within the east side of Agassiz Pool that would be coming from the Mud River watershed.

Table 9. Sediment loads bracketing Agassiz NWR - from the SWAT model report

Monitoring Station	Average Annual Sediment Load (Tons)
Mud River at Hwy 89 (S002-089)	136
Thief River at the N Bndy Road (S004-005)	2,133
Thief + Mud River Inputs	2,269
Thief River at CR7 (S002-088) (Leaving ANWR)	1408
Average Annual Sediment Deposition in ANWR	861
Percentage of sediment load from the Mud River	6%
Percentage of sediment load from the Thief River	94%
Sediment Deposited from the Mud R. (est. by %)	52
Sediment Deposited from the Thief R. (est. by %)	809
Overall rate of sediment deposition from the Thief and Mud Rivers	38%

Figure 135. Aerial photo of muddy water in the Thief River flowing along the western dike of Agassiz Pool

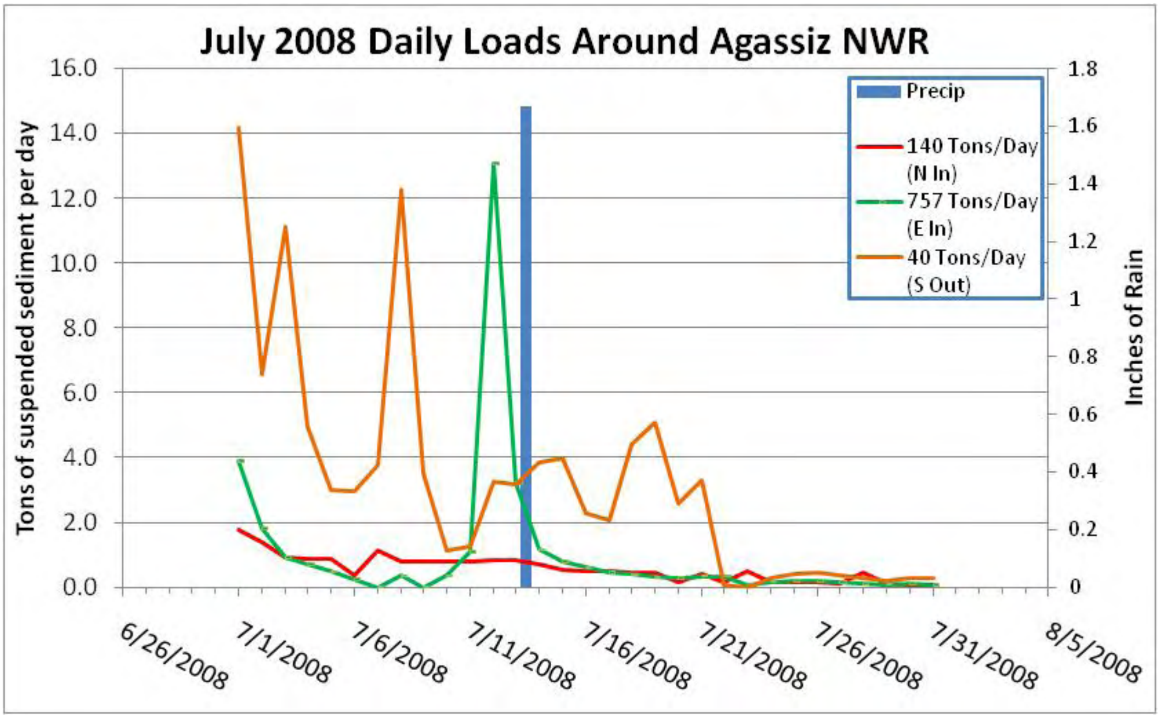


Figure 136. Agassiz NWR bracketing loads during a July 2008 storm event.

The Mud River had flashier flow during a July 2008 rain storm than the Thief River did. It is possible that most of the rain fell east of the Refuge. The flows coming into Agassiz NWR from the Thief River are moderated by Thief Lake and the Thief Lake Dam.

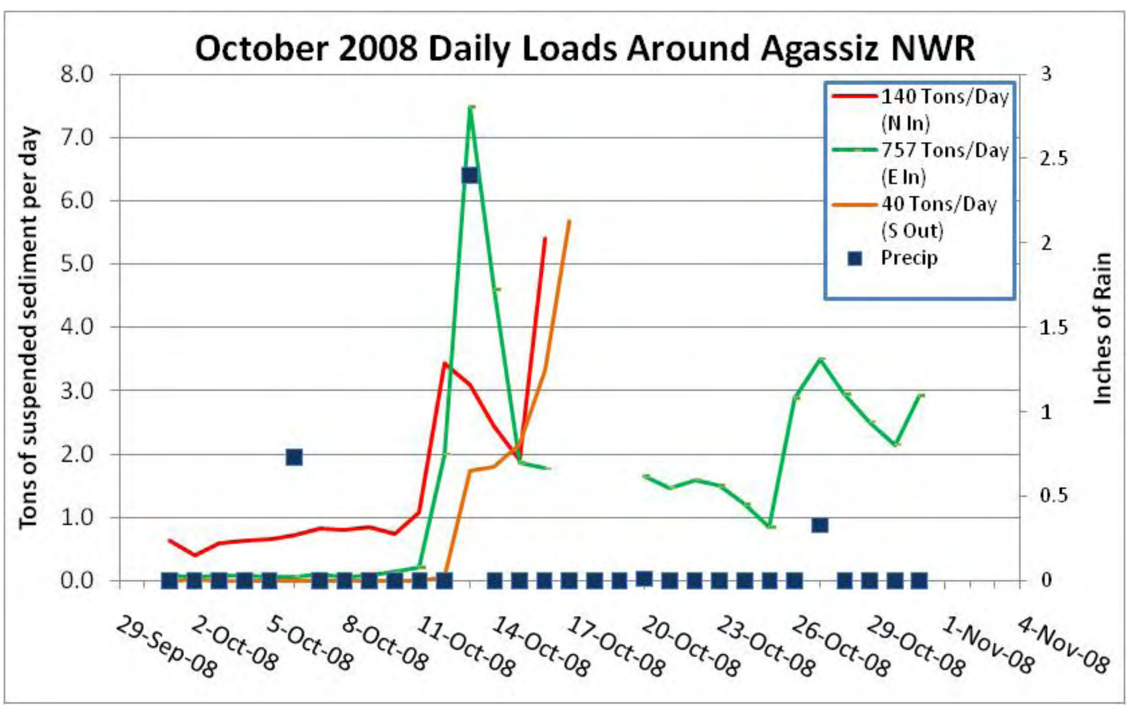


Figure 137. October 2008 daily TSS loading at sites that surround Agassiz NWR

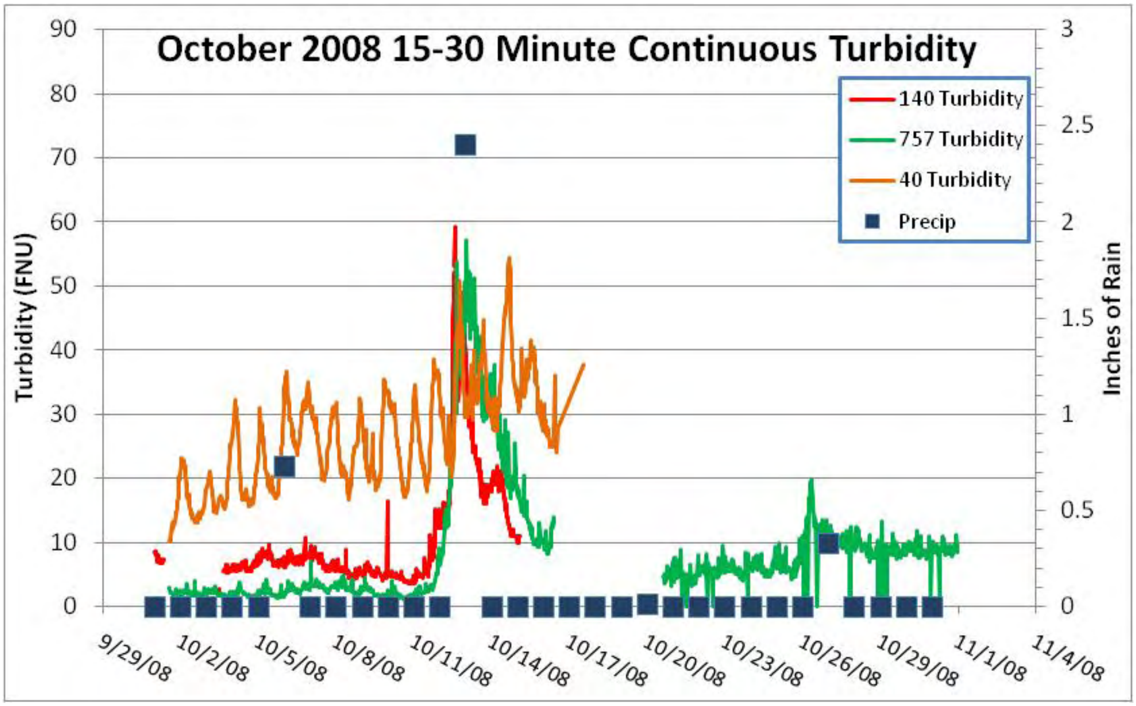


Figure 138. October 2008 continuous turbidity data bracketing Agassiz NWR.

A 2.4 inch rainfall event was recorded on October 13th, 2008 nearby the Agassiz National Wildlife Refuge. The October 2008 turbidity and TSS load records show the flashiness of the Mud River. TSS loads shot up high during the October 13th storm event, but the peak was not sustained for a long time. The river was only above the 25 NTU/FNU mark for two days. If the site was visited on either side of that peak for a condition monitoring program, it would appear that the stream is meeting water quality standards. This would even hold true on October 14th, the day after the rainfall was recorded. The peak at the CR7 bridge, downstream of Agassiz Refuge, occurred one day after the peak on the Mud River and two days after the peak on the Thief River.

Unfortunately, there is a gap in the turbidity records at these sites after October 17th,, 2008. It appears that the sediment loads in the Thief River downstream of Agassiz Pool at CR7 start to have an increase that mirrors the spike in TSS coming into Agassiz NWR from the north. There was a minimal increase in TSS loading downstream of Agassiz NWR during and shortly after the first peaks that occurred during the rainfall event. This indicates a couple of things. First, it seems as if the Refuge's pools absorb most of the sediment coming in from the Mud River watershed. Second, when there is sufficient water in Agassiz Pool, most of the sediment coming in from the Thief River on the north end of the Refuge is being passed along downstream, likely through the new outlet structure. The new outlet structure could be acting as a bypass that allows sediment laden water to keep moving along the western edge of the pool and exit the pool without being deposited.

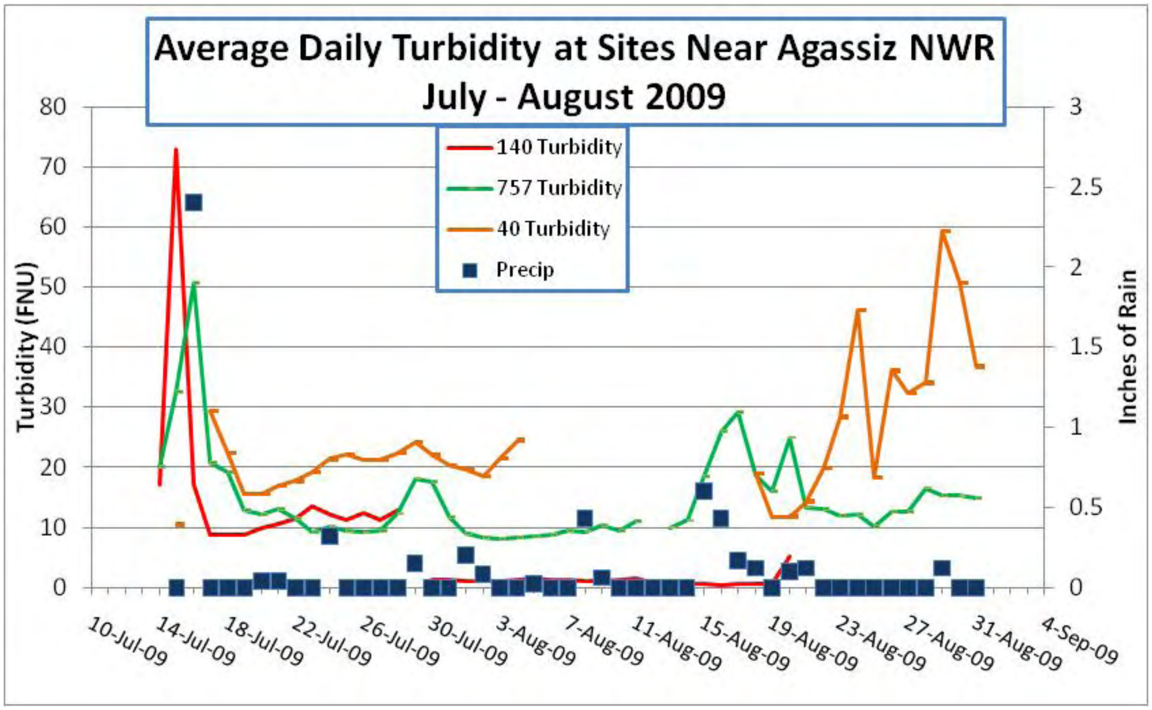


Figure 139. July - August 2009 daily average turbidity concentrations near Agassiz NWR

A 2.4 inch rainfall event that was recorded on July 16th, 2009 caused a large spike in turbidity levels on the Thief River above Agassiz Pool, then the Mud River, and then the Thief River downstream of Agassiz Pool. Mid-August rainfall events caused short-lived peaks in turbidity in the Mud River that didn't immediately affect either of the Thief River sites. The Thief River at CR7, downstream of Agassiz NWR, had high turbidity throughout the latter part of August. This could have been due to discharge from Agassiz Pool.

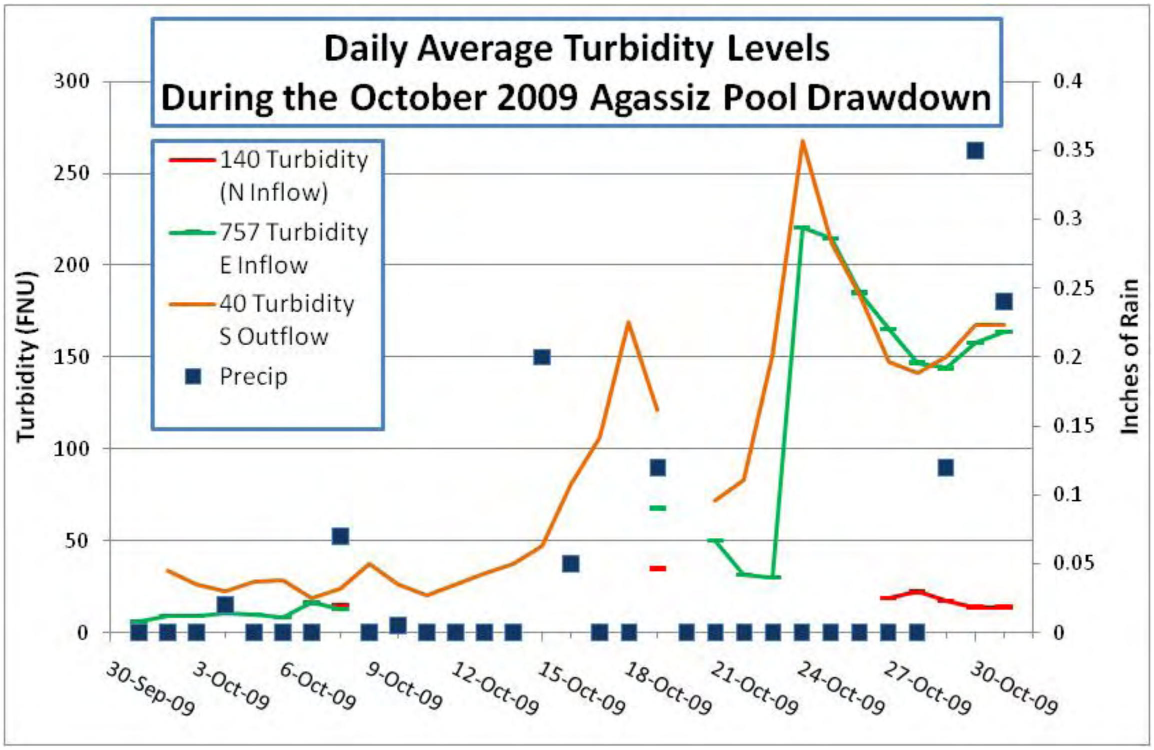


Figure 140. Daily average turbidity levels during the October 2009 Agassiz Pool drawdown

During the drawdown of Agassiz Pool in October 2009, there were prolonged periods of high turbidity in the Thief River downstream of the refuge. Much of this can be attributed to erosion within the pool, but the time-series chart of the monitoring data shows that rainfall events high flows in the Mud River exacerbated the problem. The high flows in the Mud River in late October of 2009 came from discharge from the south pool of the Moose River Impoundment. The high turbidity levels in the Mud River don't seem typical based on what was observed with discrete field measurements. However, there are no discrete measurements taken between October 21st and November 6th to dispute the deployed sonde's record. The November readings from the deployed sonde were very much higher than discrete readings, so that does cast doubt upon the Mud River's high late-2009 readings shown in the graph above.

Sediment Budget for the Lower Reach of the Thief River

Is there more sediment being contributed or deposited along State Ditch 83 downstream of Agassiz National Wildlife Refuge?

What end points would we use for this test?

The first usable output point at the upstream end of this reach is at the CR7 crossing (output of sub-basin 81). State Ditch 83 officially ends shortly downstream of the CSAH 44 crossing. The nearest SWAT model output point upstream of this location is at the eastern border of Section 26 of Excel Township (output of sub-basin 40). Branch 200 of JD11, Marshall County Ditch 20, Branch 227 of JD11, and Marshall County Ditch 2 also contribute flow and sediment along this reach.

Despite the sediment deposition that creates sediment bars within this reach, which are periodically removed as part of the maintenance plan for SD83, erosion within this reach is contributing sediment to the Thief River downstream.

Erosion also contributes to sediment loads in the Thief River downstream of State Ditch 83. This shows up in SWAT modeling results. Stream bank failures and bad erosion problems were identified along this reach in real life during reconnaissance canoe trips down the river.

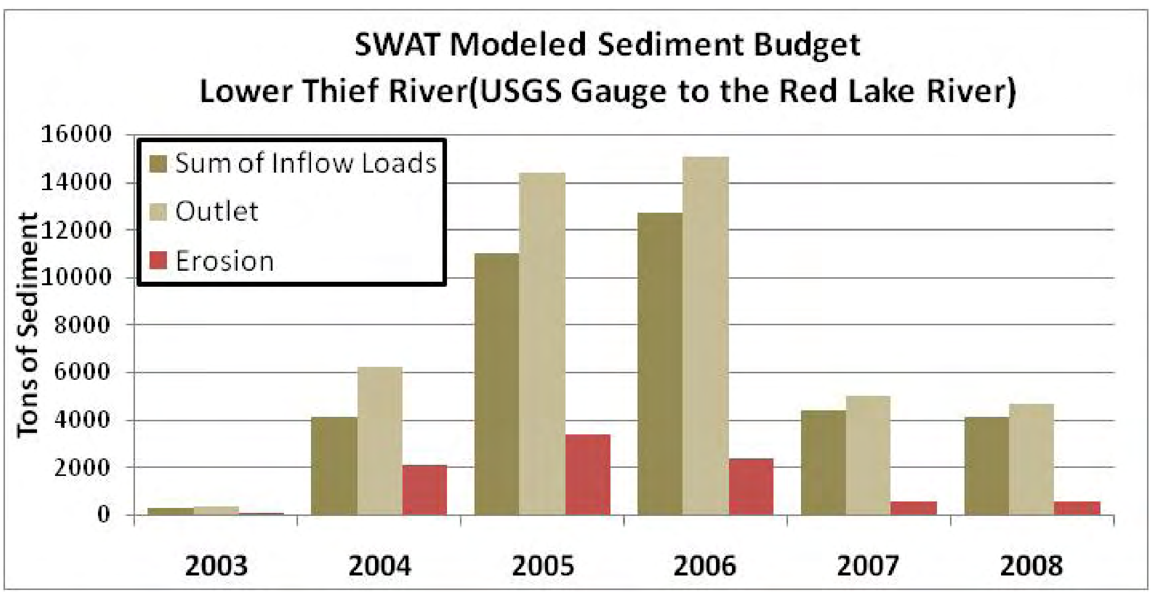


Figure 141. Lower Thief River Sediment Budget using SWAT data

July 2008 provides a relatively complete water quality record during a 1.37 inch rainfall event that was recorded at a gauge located in the lower Thief River Watershed. Preconceived notions about drainage may lead one to suspect the large ditch systems that empty into the Thief River would contribute to the degradation of water quality in the Thief River. Data collected for this study shows that this assumption is wrong. The water quality in the ditches is less affected by rainfall events than the water quality in the Thief River. Turbidity barely increased at all in July 2008 in Ditch 200, despite a 1.37 inch rainfall event that occurred in the area. CD20 had only minimal increases in turbidity during rainfall events in July 2008.

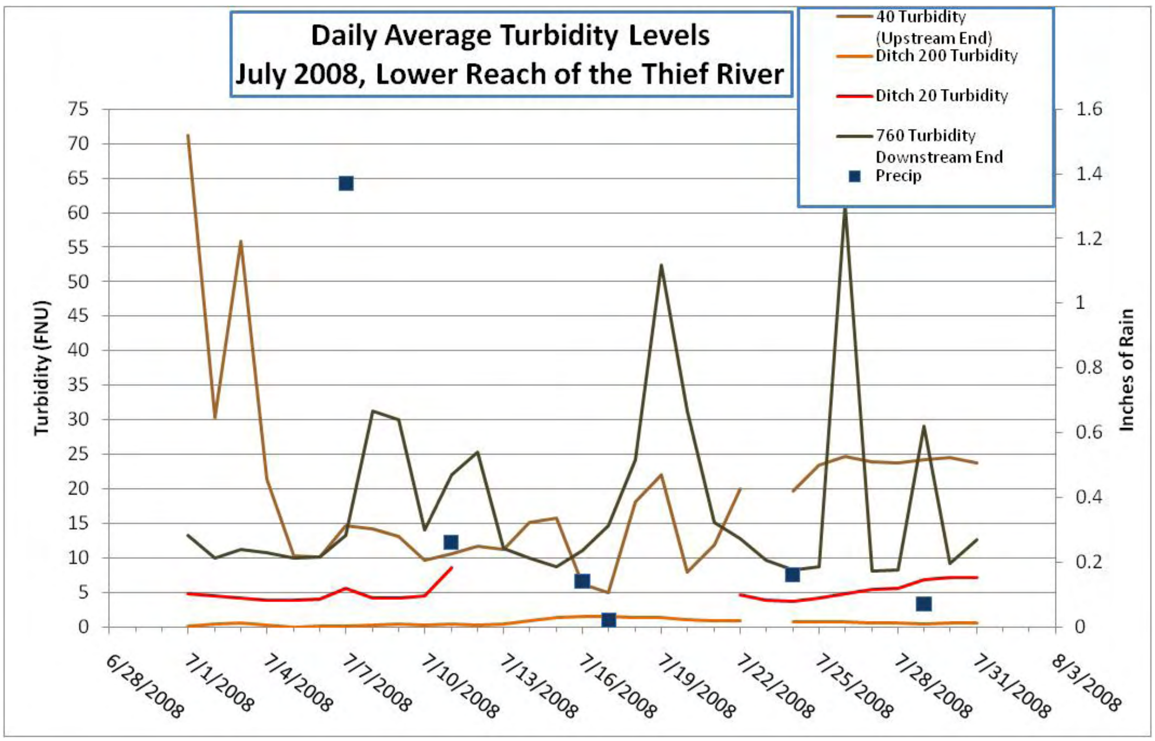


Figure 142. July 2008 daily average turbidity in the lower reach of the Thief River

Ditches probably affect the Thief River by increasing the flow in the river, which exerts more force against its banks and increases erosion. The CD20 record has a gap during between July 11 and July 22 that probably misses a spike in loads like what was recorded in Ditch 200.

The July 7 rainfall event ranged from 1.37” in Thief River Falls to .72” at a station that is located near the eastern edge of the watershed. The Thief River saw a spike in turbidity levels and loads. The two ditches didn’t seem to be affected at all.

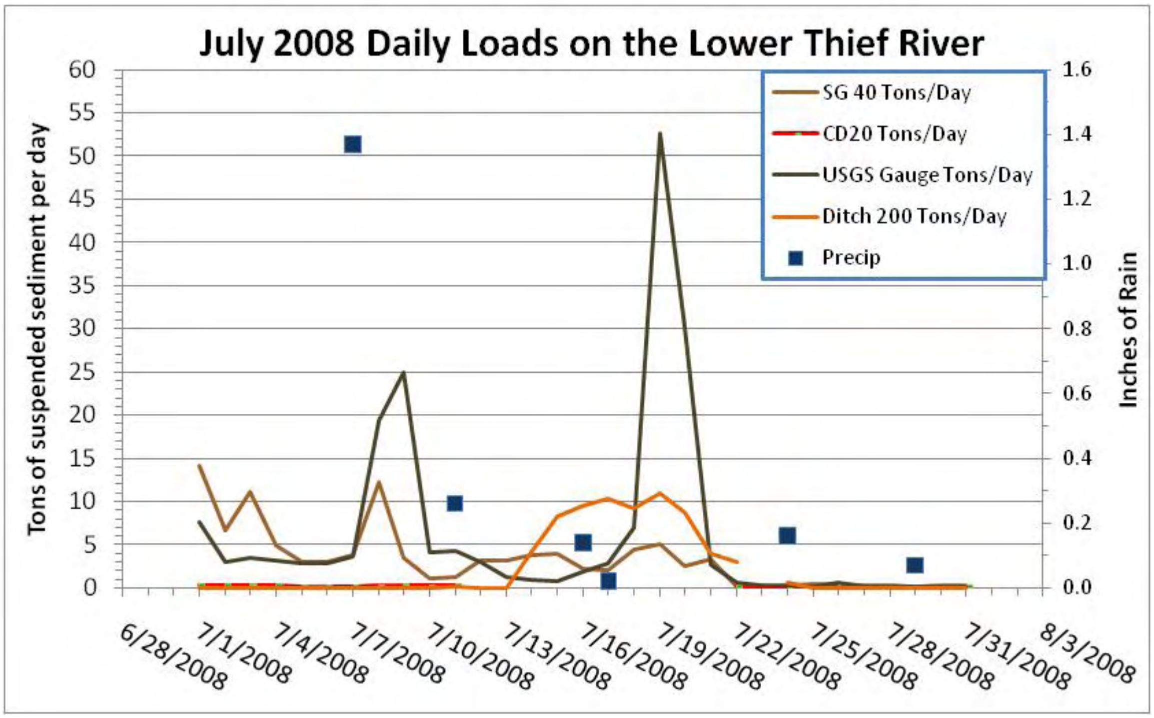


Figure 143. July 2008 daily loads at sites along the lower reach of the Thief River

Water Quality Model (SWAT)

Requests for proposals for SWAT modeling of the Thief River watershed were sent to potential contractors that have expressed interest in the project. The deadline for submission was August 6th, 2009. Houston Engineering was chosen as the (sub) contractor at the August 13th RLWD Board of Managers meeting.

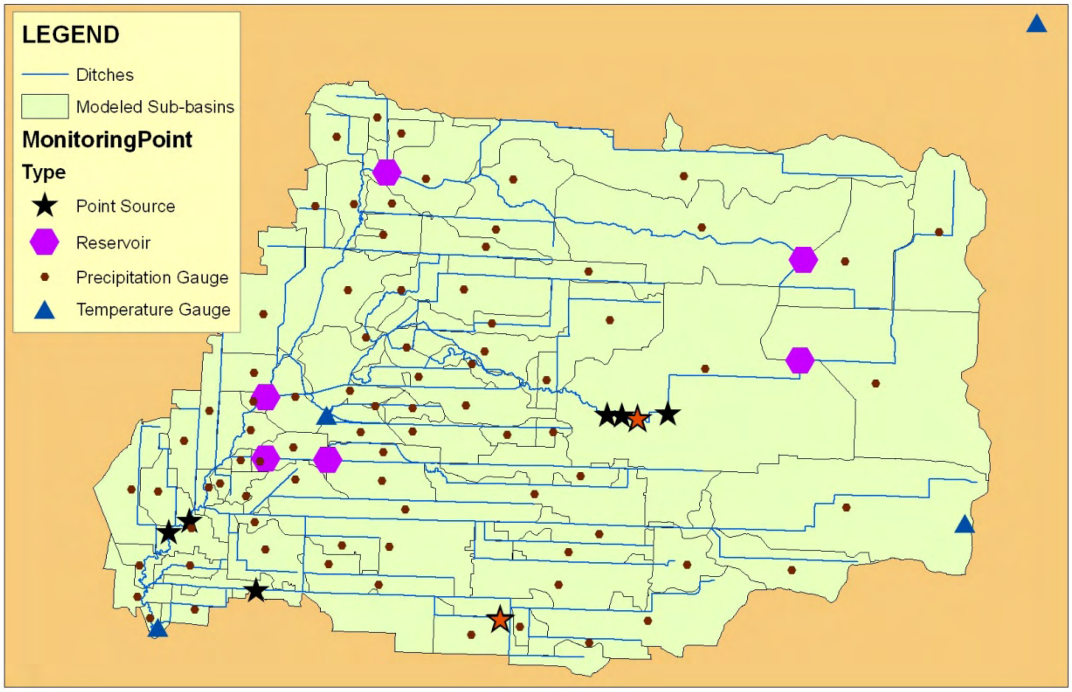
Modeling tasks:

- Develop a model of the Thief River watershed
  - Model will address: discharge and loadings of sediment, phosphorus, and fecal coliform
- Model will be calibrated at one location (USGS Gauge – Thief River at Thief River Falls)
- Use model to simulate future scenarios for load reductions
- Recommendations based on scenario results
- Mid-project memo and draft/final technical memo
- Participate in stakeholder meetings

Model features and inputs:

- 83 sub-basins
- 4 temperature gauges
- 6 reservoirs
- 8 potential point sources
- Start with wastewater treatment plants
- Add others as needed
- Model timeframe: 1/1/2000 – 12/31/2008
  - Warm-up period: 2000-2003
  - Calibration: 2006-2009
  - Validation: 2003-2006
- Management of impoundments (measured outflows & volumes)
  - RLWD, Thief Lake WMA, Agassiz National Wildlife Refuge
- Point source discharges
  - Grygla and Goodridge WWTPs
  - Confined animal feeding operations (CAFOs)
- Tile drains

In order to get an approximation of the amount of tile in the sub-basins of the Thief River watershed, a windshield survey of tiled fields (looked for pumped outlets) was conducted. A GPS/GIS handpad was used to mark the fields that had tile. Based on the percentage of acreage in tile versus the total acreage of fields that was driven by, the RLWD provided HEI with percentages, by sub-basin, of farmed land that is in tile. The RLWD also provided HEI with discharge data from the Moose River pools. Stephanie Johnson of HEI was also able to get discharge data from Thief Lake and Agassiz NWR.

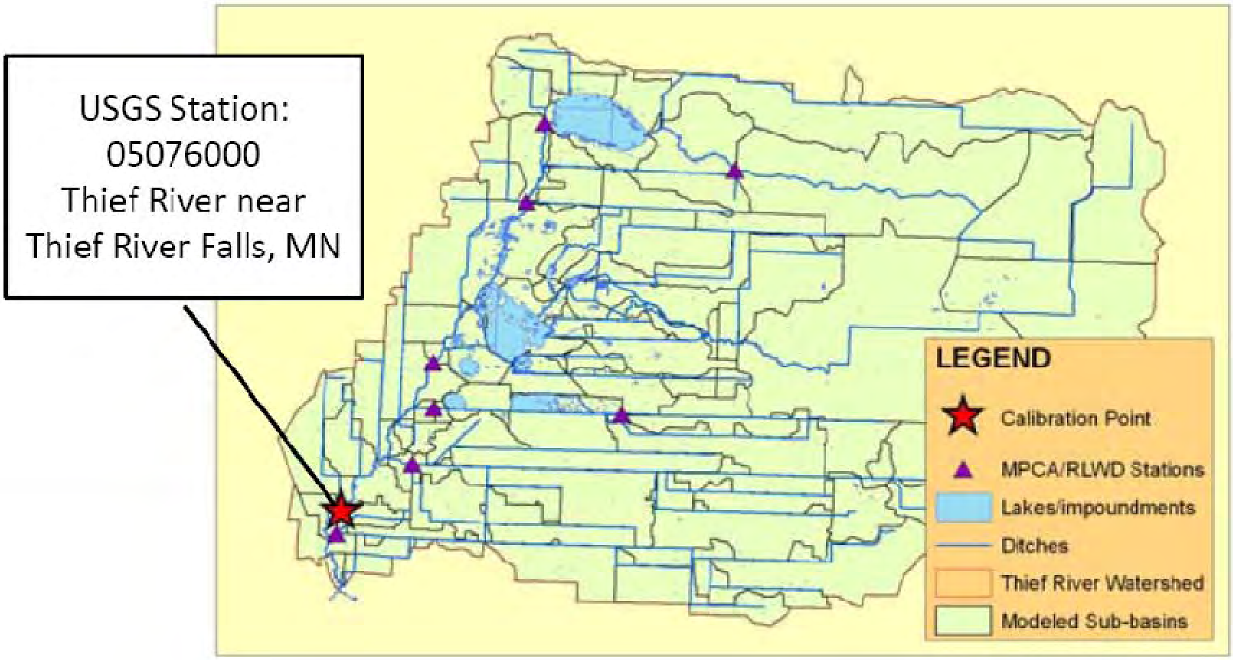


Model outputs:

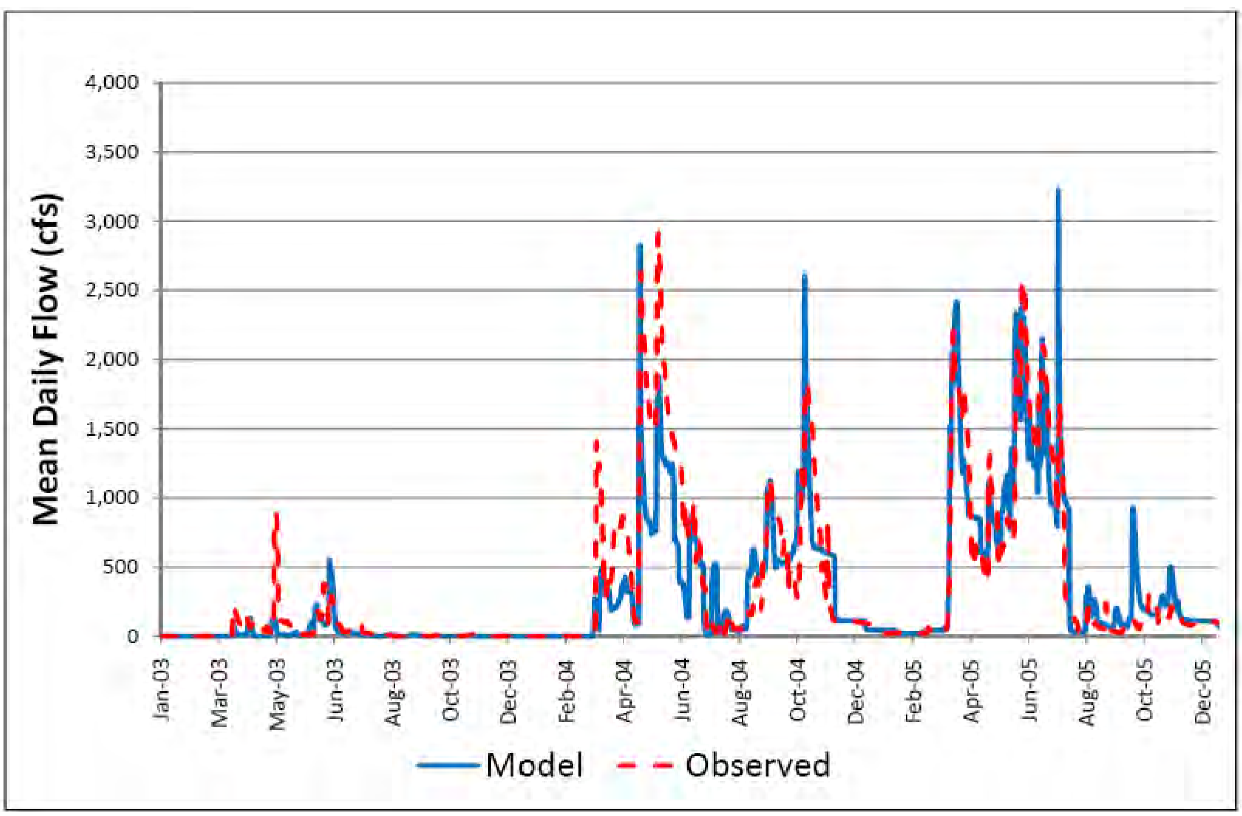
- For each sub-basin
  - Yield of water, sediment, nutrients, bacteria
- For each reach
  - In: flow, sediment load, nutrient load, etc.
  - Out: flow, sediment load, nutrient load, etc.
- For each waterbody/reservoir
  - In: flow, sediment load, nutrient load, etc.
  - Out: flow, sediment load, nutrient load, etc.
  - Internal: volume

Calibration:

- The primary target location for calibrating the model was the one USGS gauge in the watershed which is located at the Hillyer Bridge north of Thief River Falls.



- Validating hydrology and loads
  - Observed flow/loads were compared to modeled flow/loads
  - Accuracy was quantified using Mean Square Error, Nash Sutcliffe Coefficient, Mann-Whitney P value, and average percent difference statistics.



RLWD Staff provided Houston Engineering with data that could used during the calibration process to improve the accuracy of the model:

- Clearwater River SWAT data
- Flow records from 2007 and 2008 from monitoring sites in the Thief River watershed.
- Reviewed the delineation of the Thief River subwatersheds and flow patterns that will be used for the SWAT model. There were a few improvements made to the existing data based on ground-truthing.
- Impoundment operation information
- Feedlot locations
    - Registered feedlots
    - Unregistered livestock operations that are having an identifiable impact on the land that is similar to the effect of the registered operations
    - Feedlots that are located next to rivers and streams
- Found the correlation between turbidity and total suspended solids for this watershed. I used this correlation to convert the continuous monitoring turbidity records into TSS records for use in calibrating the SWAT model.

SWAT Model Products:

- Flow and pollutant contributions for each of the 83 sub-basins
- Evaluation of load reduction scenarios
- Loading to impoundments
- Pollutant yield and yield reduction maps
    - Yield = Load/Area
- Final report

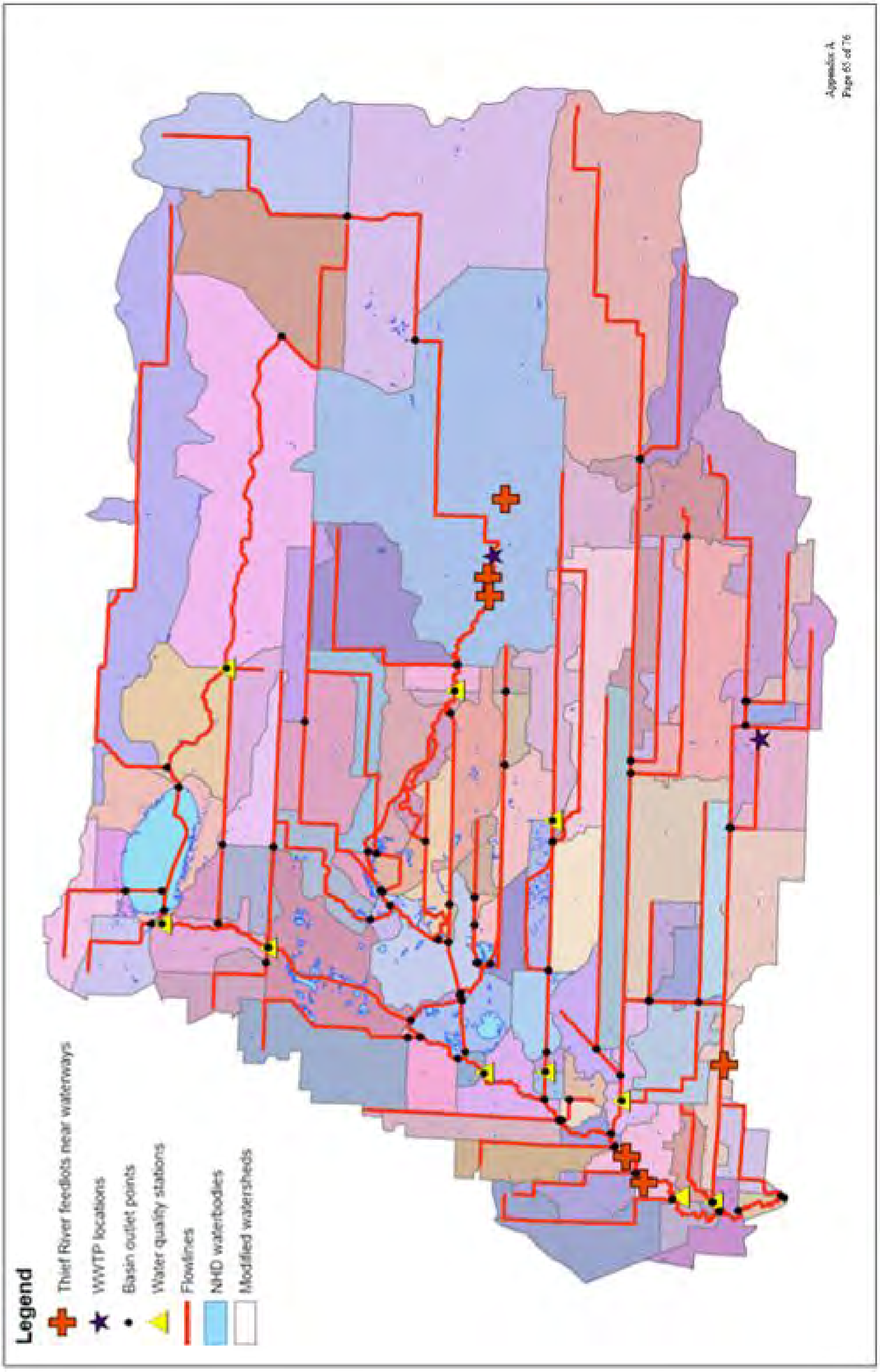


Figure 144. Thief River SWAT model sub-basins and flow pathways.

Table 10. Management scenarios modeled in the Thief River watershed

Scenario Number	Scenario Name	General Approach	Comment
1a	Filter Strips - 50 feet	Apply a 15.2 m filter strip to the edge of all HRUs that have agricultural land use and border a channel/stream.	
1b	Filter Strips - 100 feet	Apply a 30.5 m filter strip to the edge of all HRUs that have agricultural land use and border a channel/stream.	
2 min	Convert to Permanent Cover - Minimum Area	Change tilled crop to Alamo switchgrass, remove management operations, and change CN to reflect permanent cover.	Converted the smallest agricultural HRUs (maximum of 25% of sub-basin area) in each sub-basin.
2 max	Convert to Permanent Cover - Maximum Area	Change tilled crop to Alamo switchgrass, remove management operations, and change CN to reflect permanent cover.	Converted the largest agricultural HRUs in each sub-basin.
3a	Distributed Temporary Storage (Limited implementation)	Changed 30 feet of cultivated land along watercourses to wetlands.	Side-inlet controls along half of adjacent watercourses.
3b	Distributed Temporary Storage (Full implementation)	Changed 30 feet of cultivated land along watercourses to wetlands.	Side-inlet controls along all adjacent watercourses.

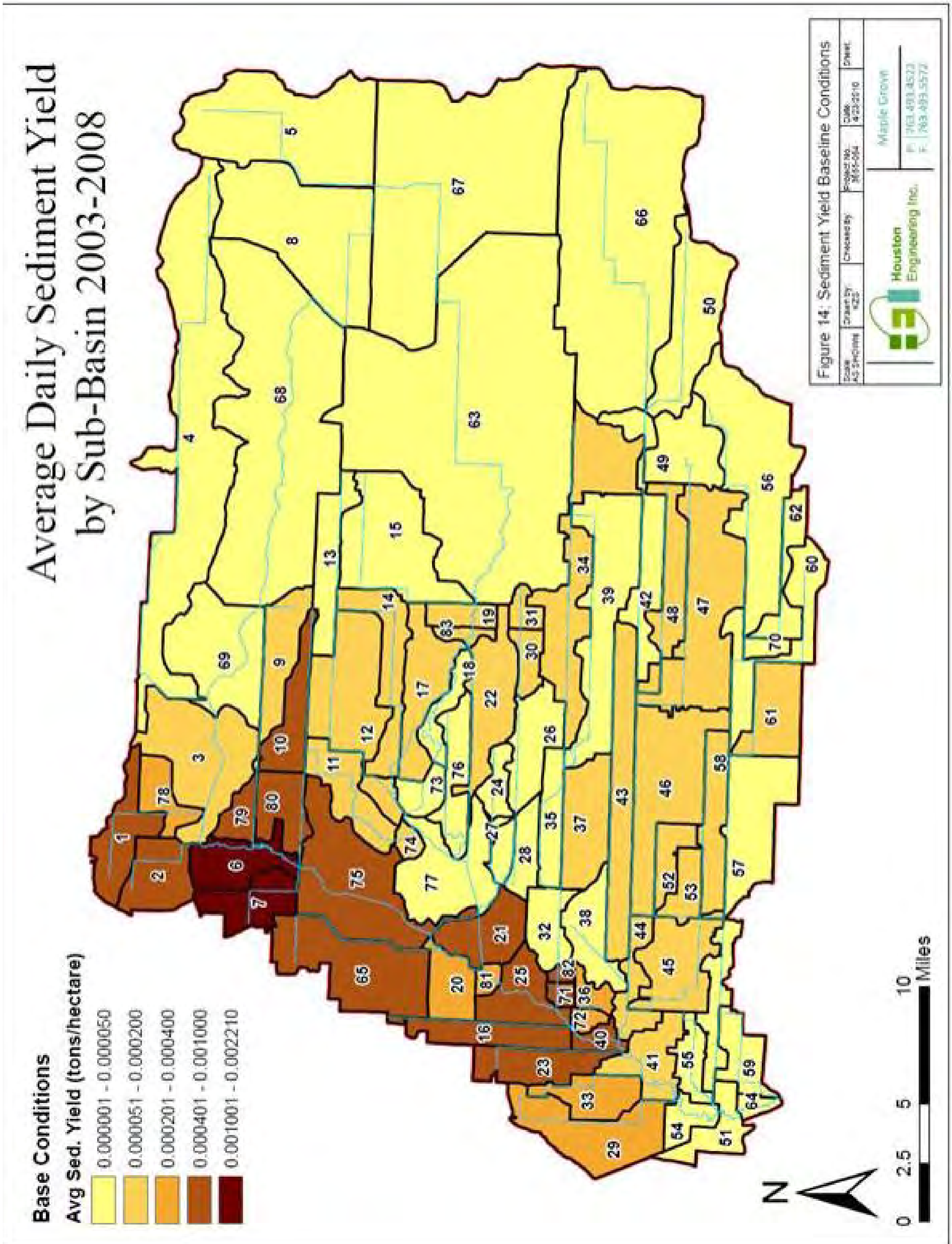


Figure 145. Base condition sediment yields

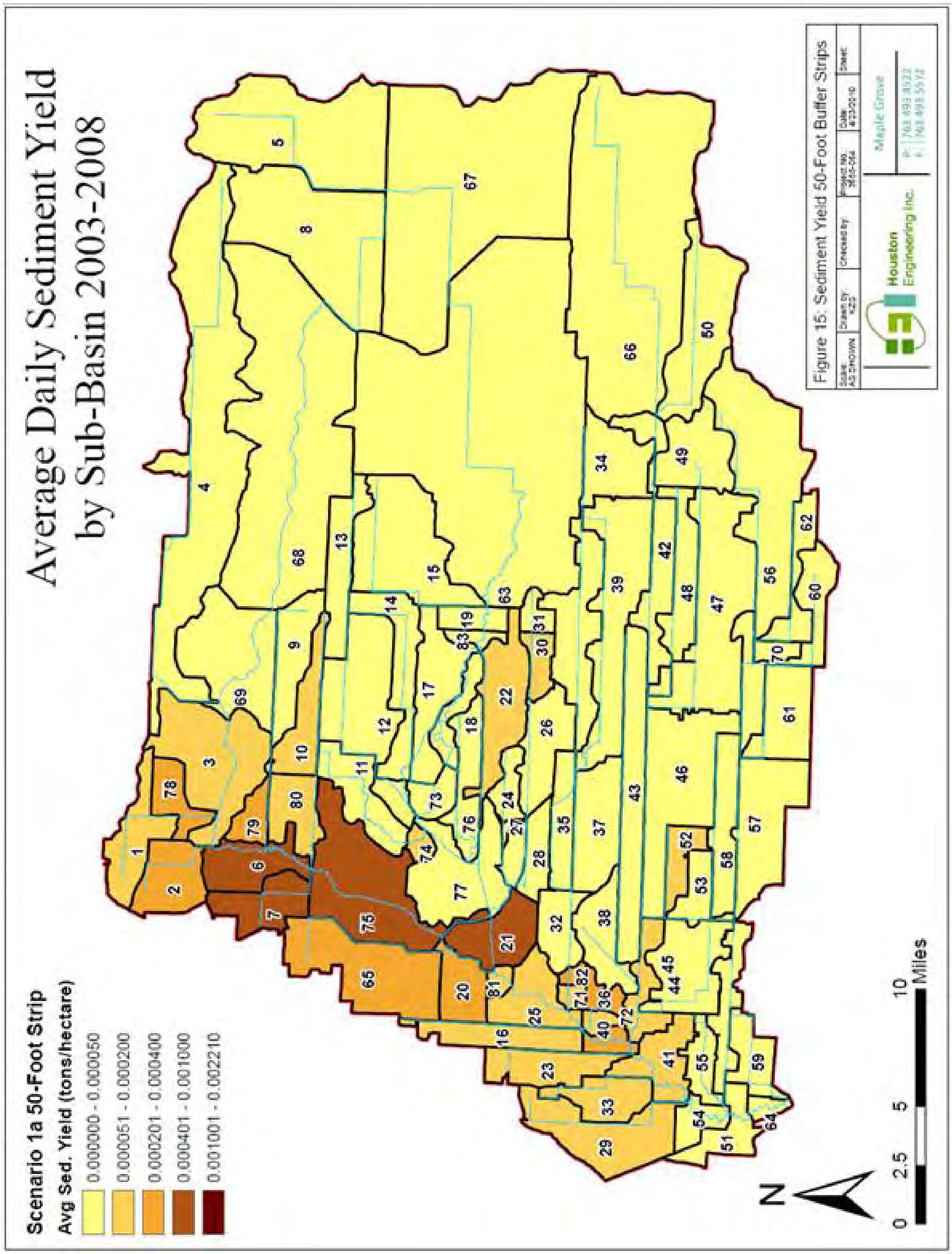


Figure 146. Sediment yields after implementation of 50-foot filter strips

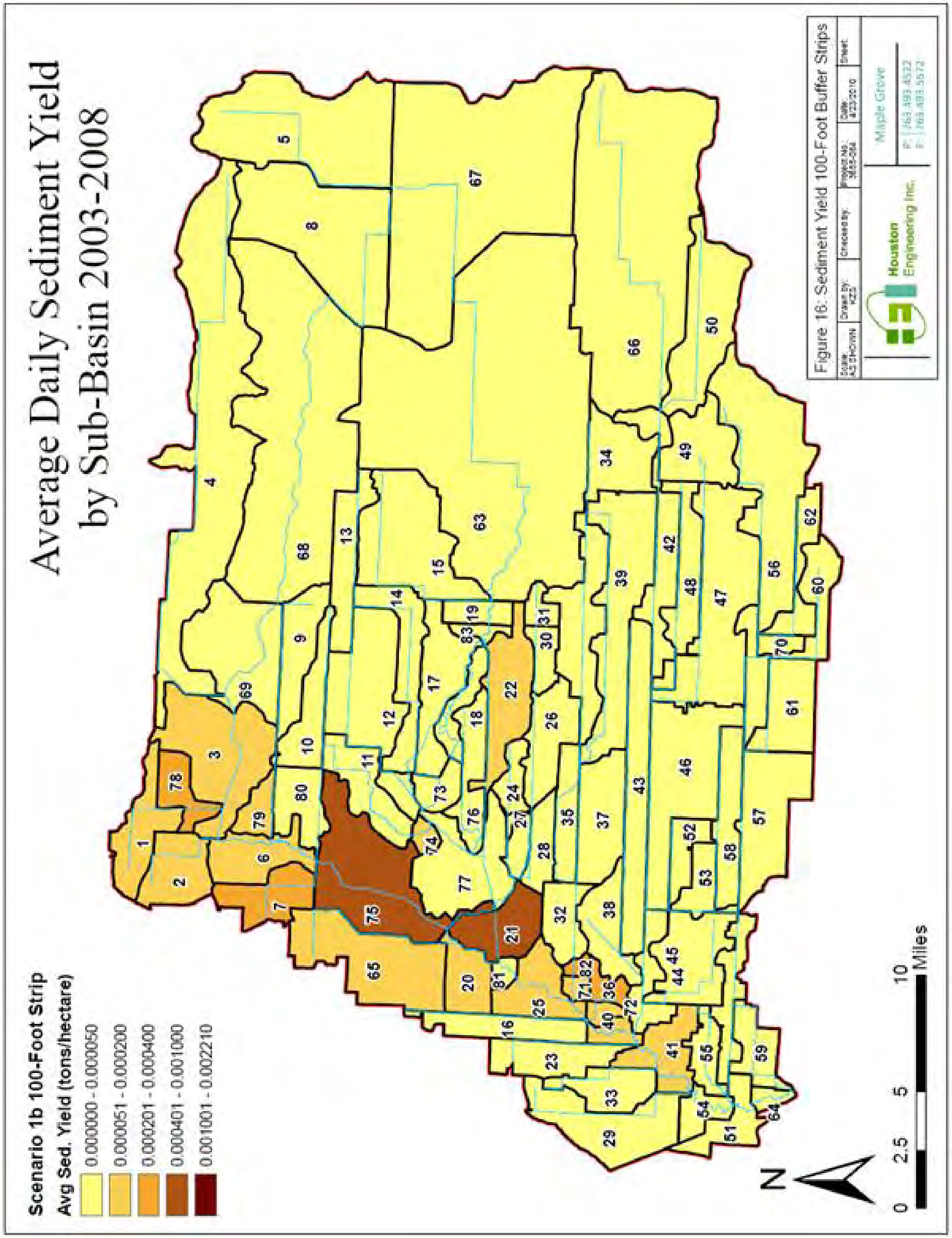


Figure 147. Sediment yields after implementation of 100-foot filter strips

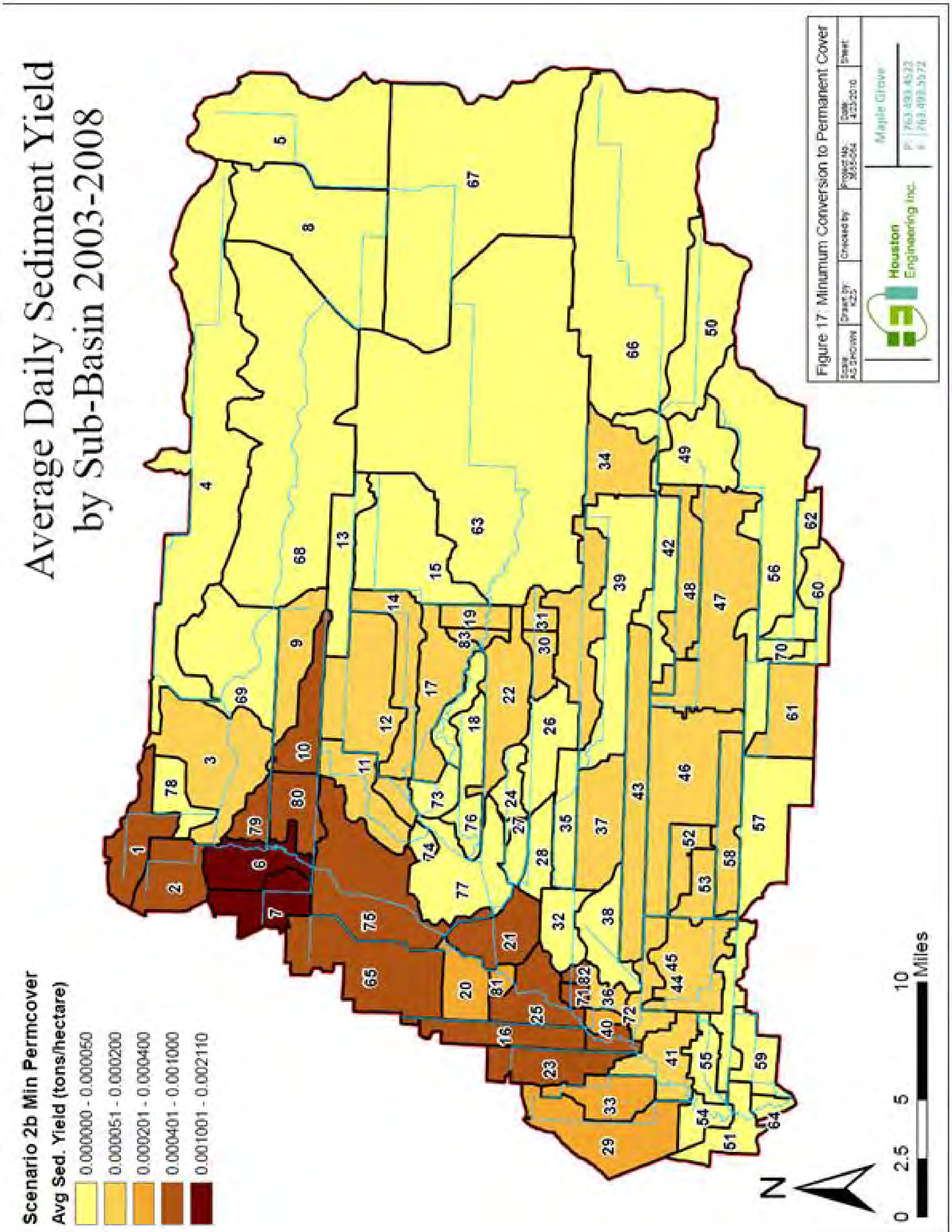


Figure 148. Sediment yields after minimum conversion of riparian agricultural land to permanent cover.

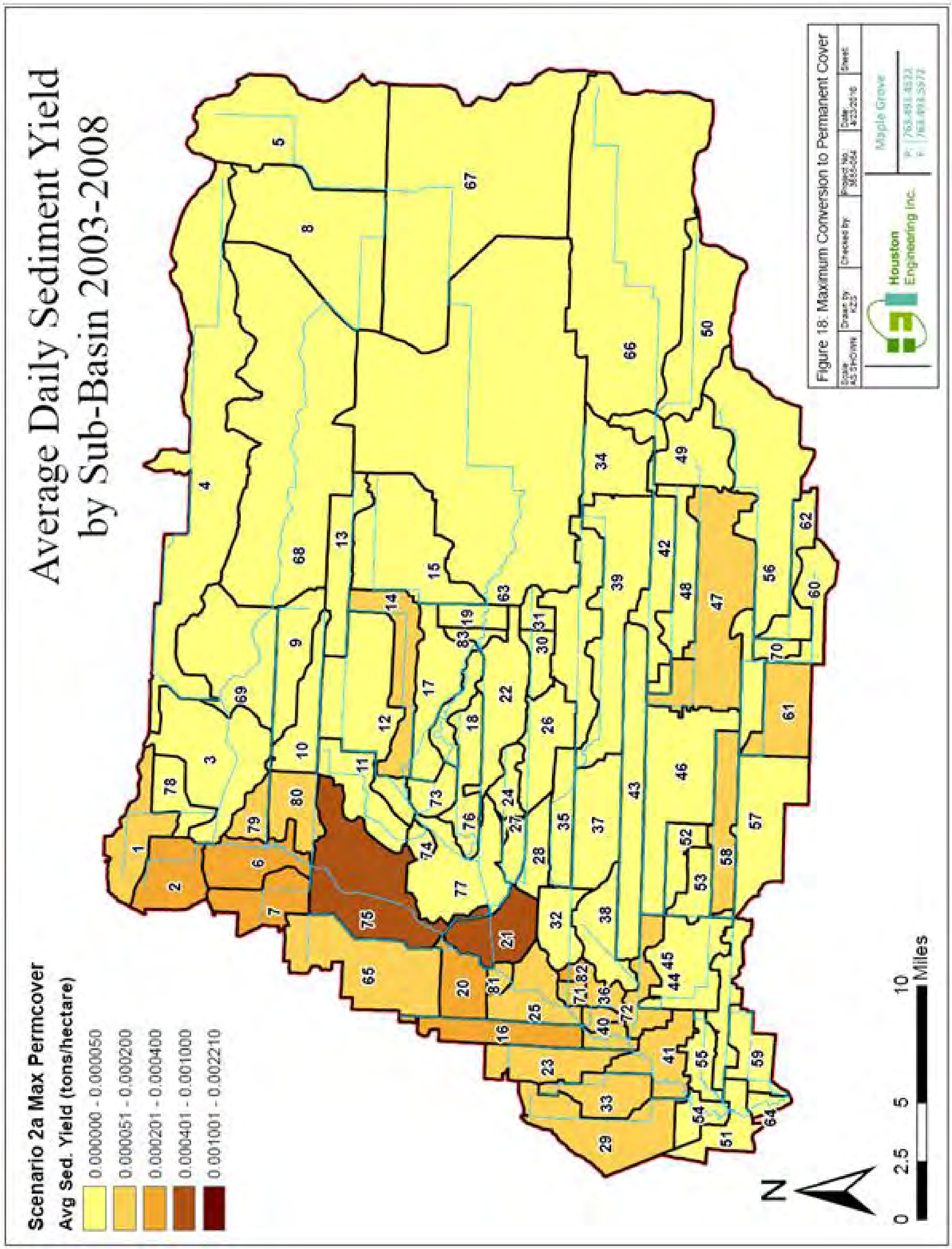


Figure 149. Sediment yields after maximum conversion of agricultural land to permanent cover.

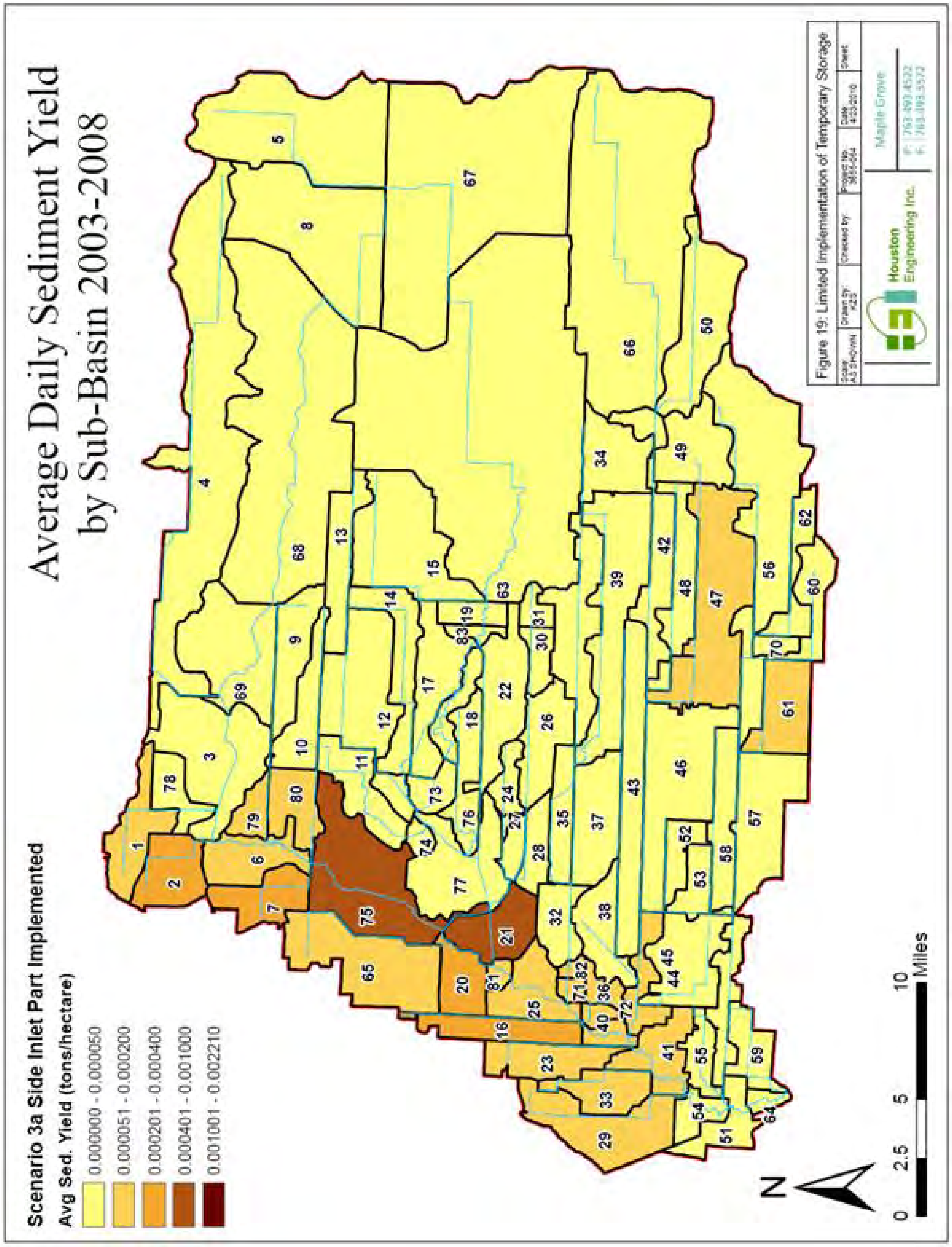


Figure 150. Sediment yields after partial implementation of side inlets

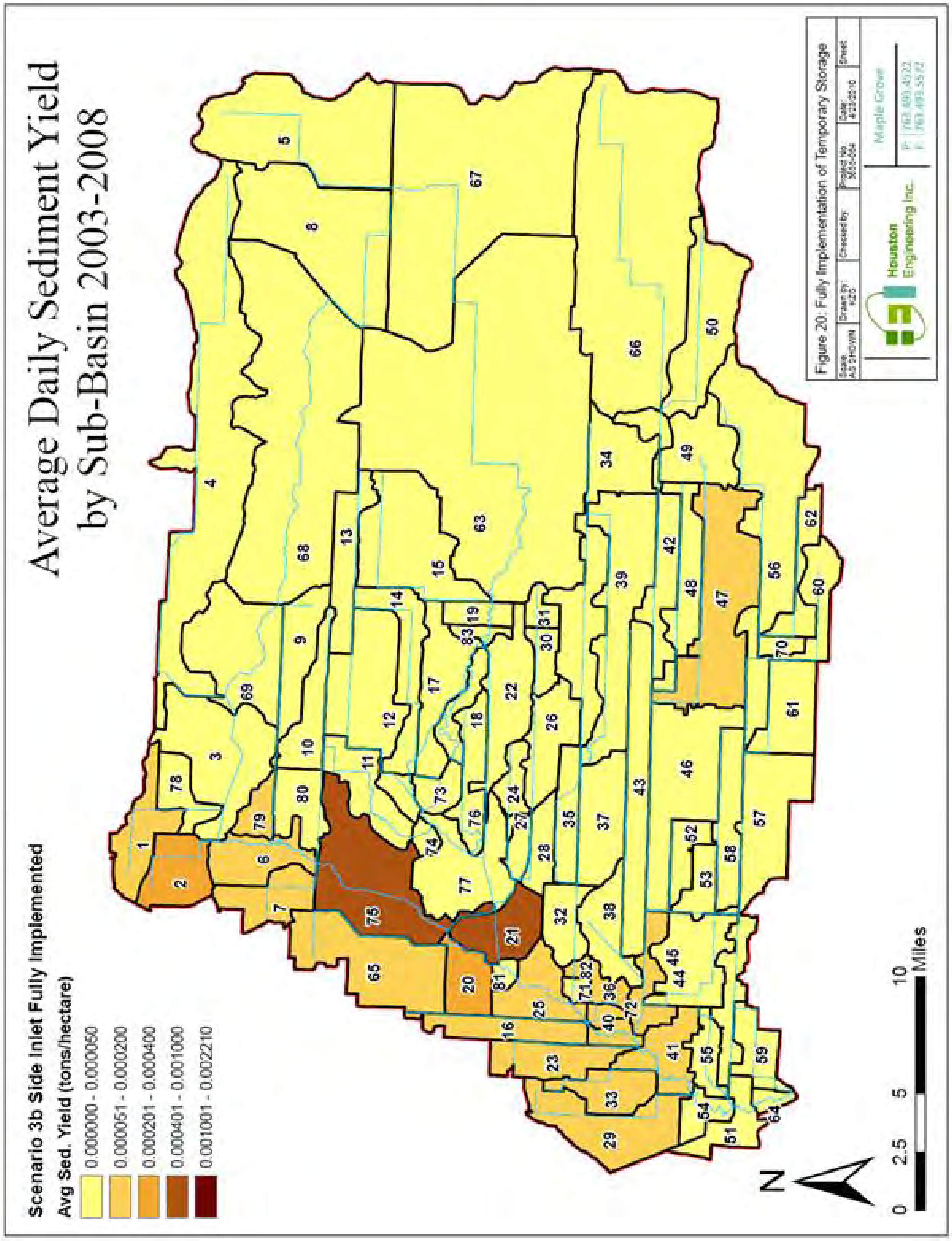


Figure 151. Sediment yields after full implementation of side inlets

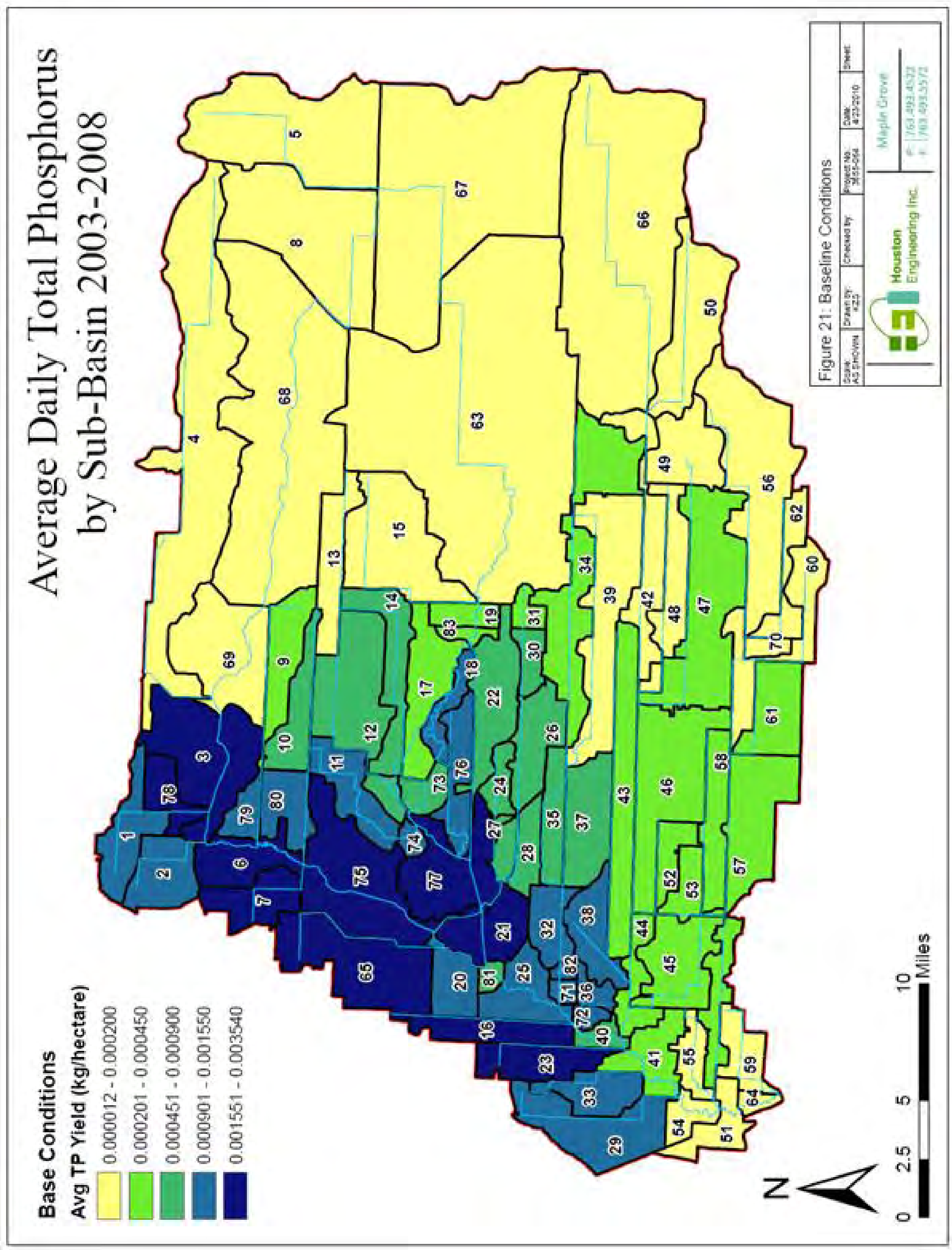


Figure 152. Base condition phosphorus yields

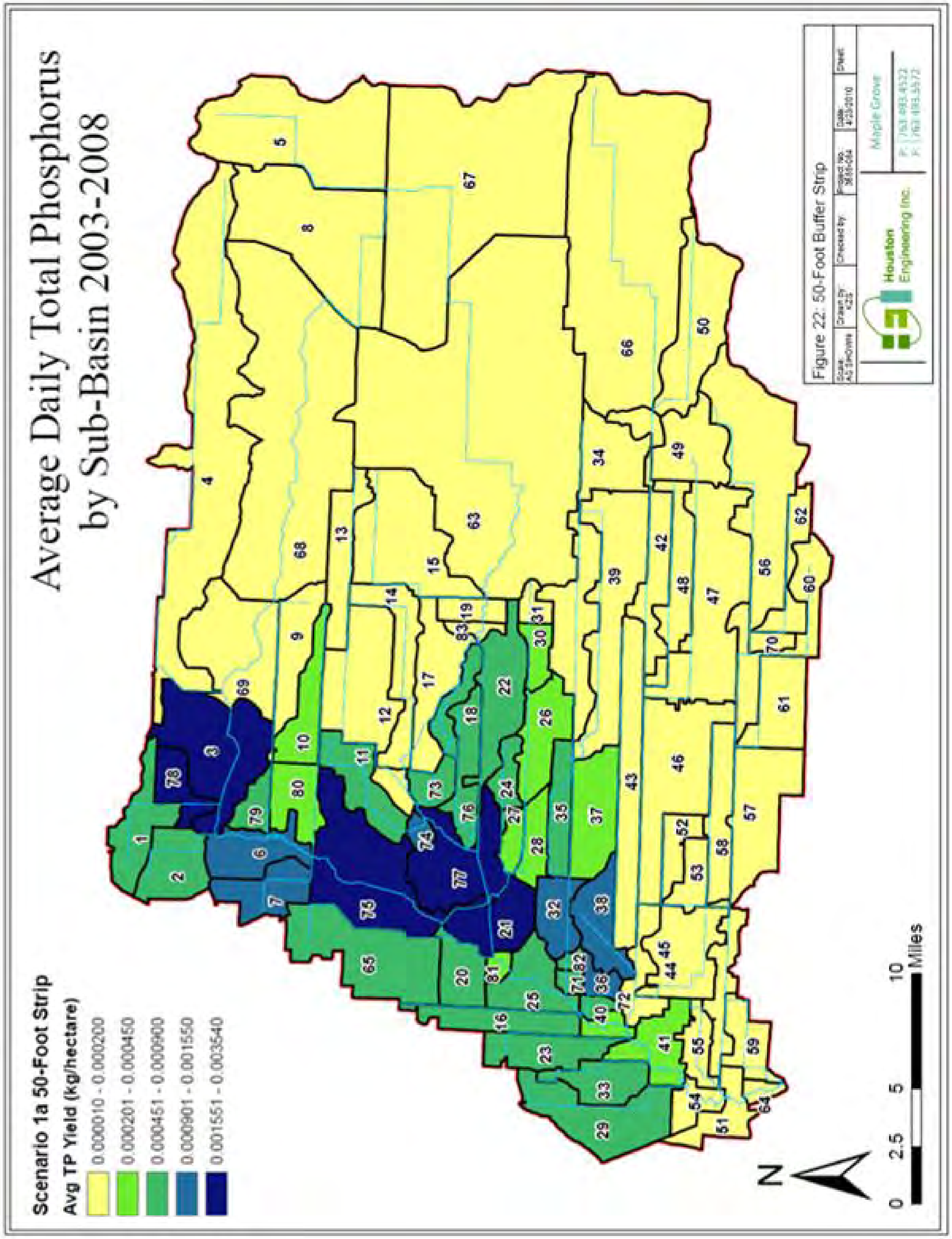


Figure 153. Phosphorus yields after implementation of 50-foot filter strips

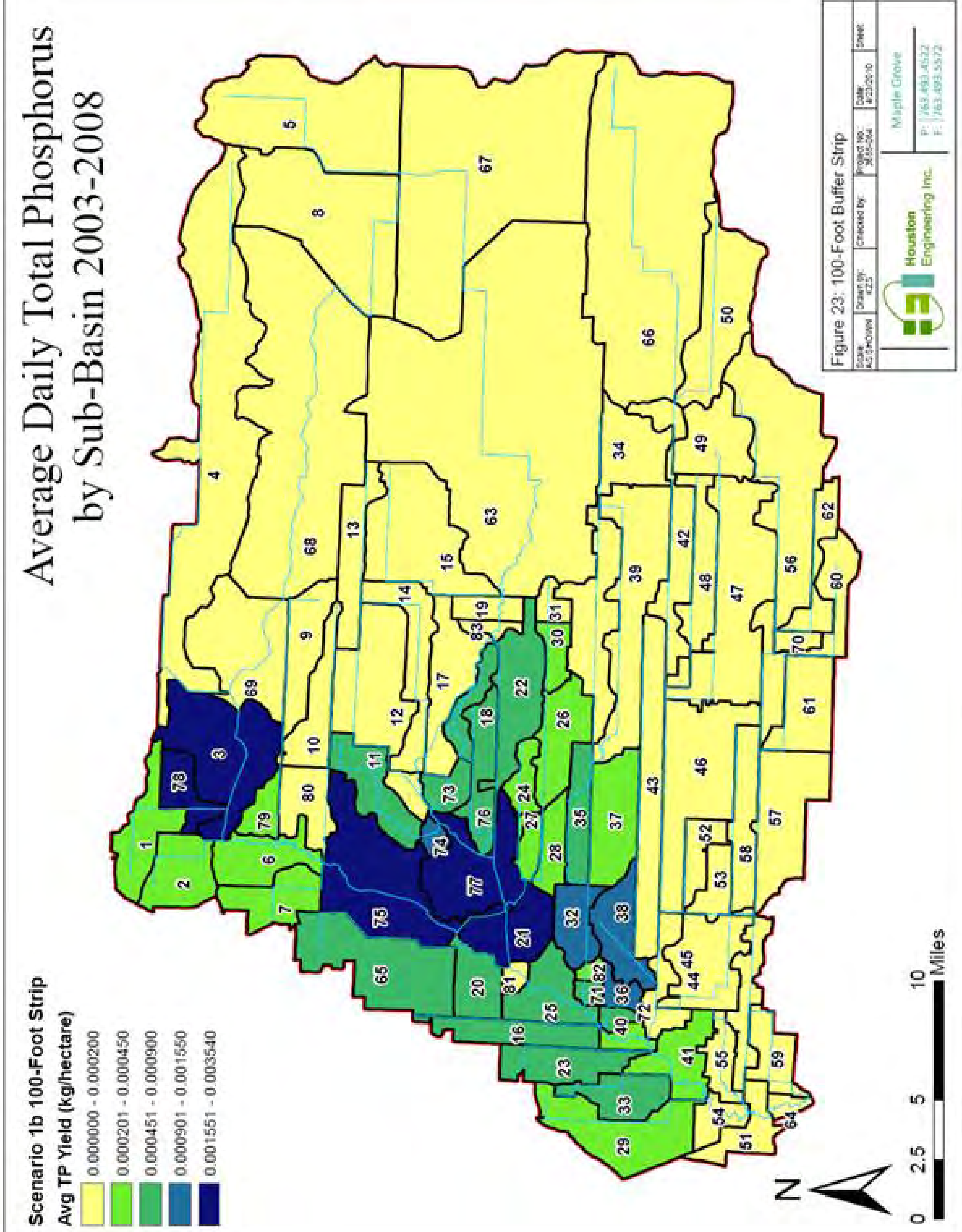


Figure 154. Phosphorus yields after implementation of 100-foot buffer strips

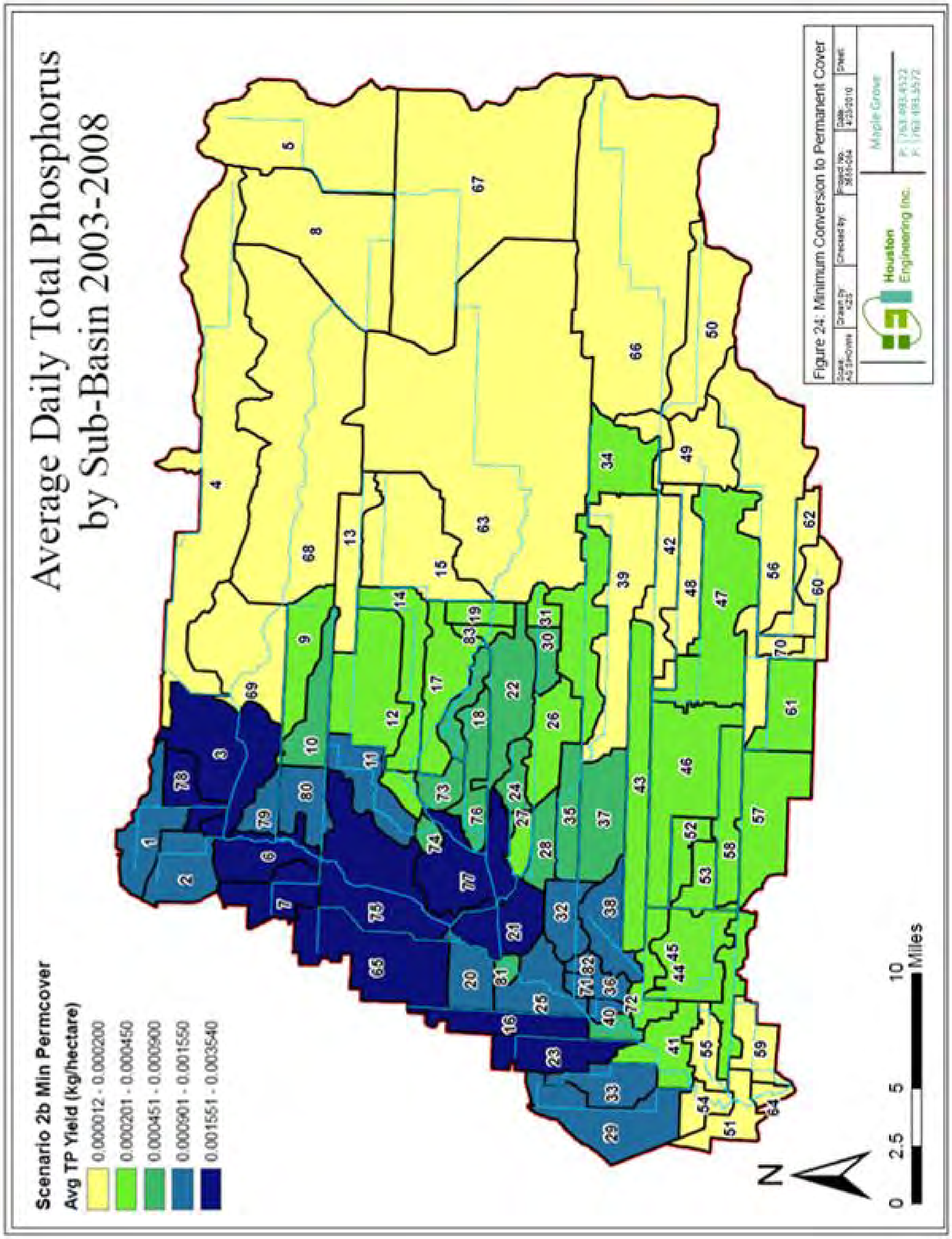


Figure 155. Phosphorus yields after minimum conversion of riparian agricultural land to permanent cover

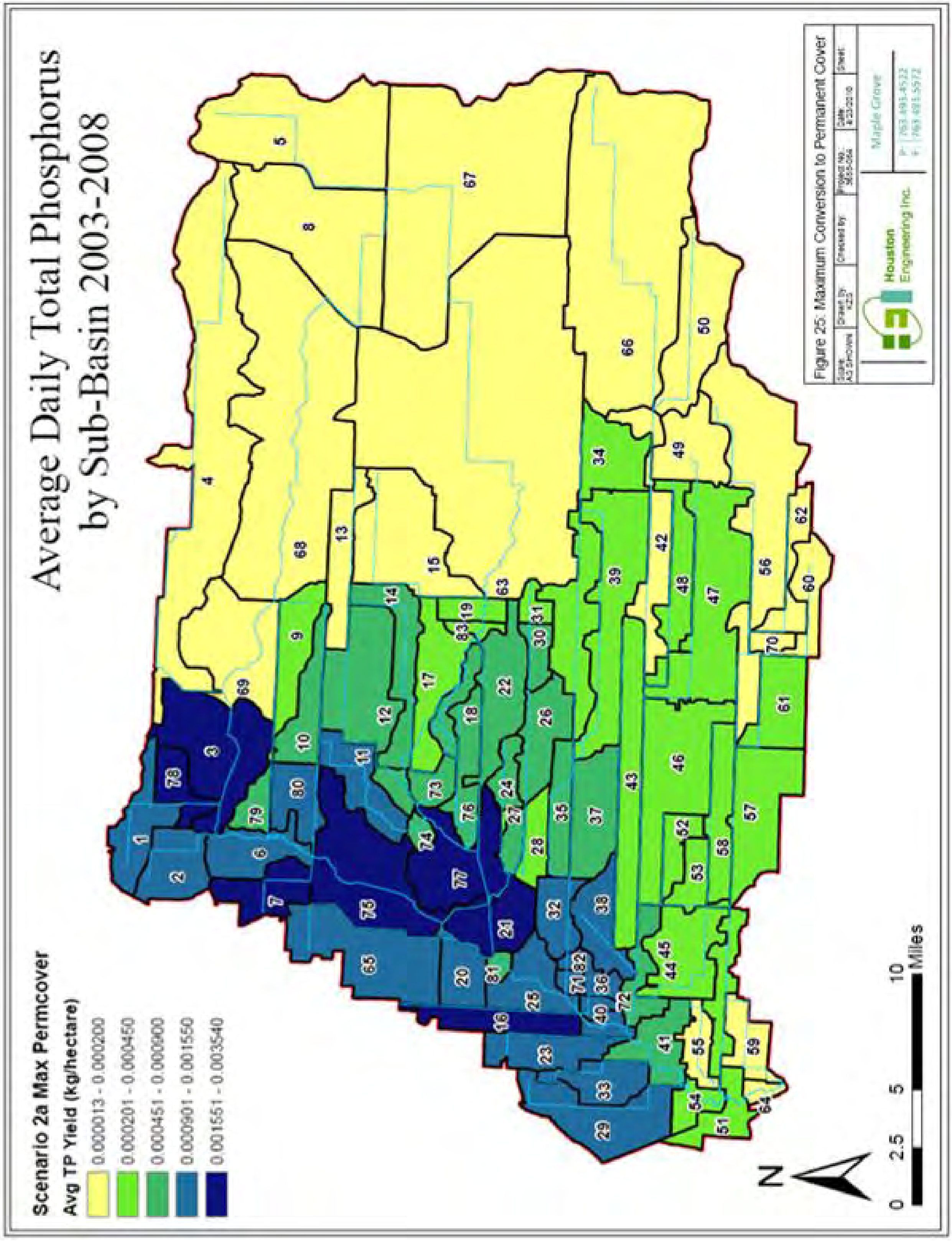


Figure 156. Phosphorus yields after maximum conversion of riparian agricultural land to permanent cover

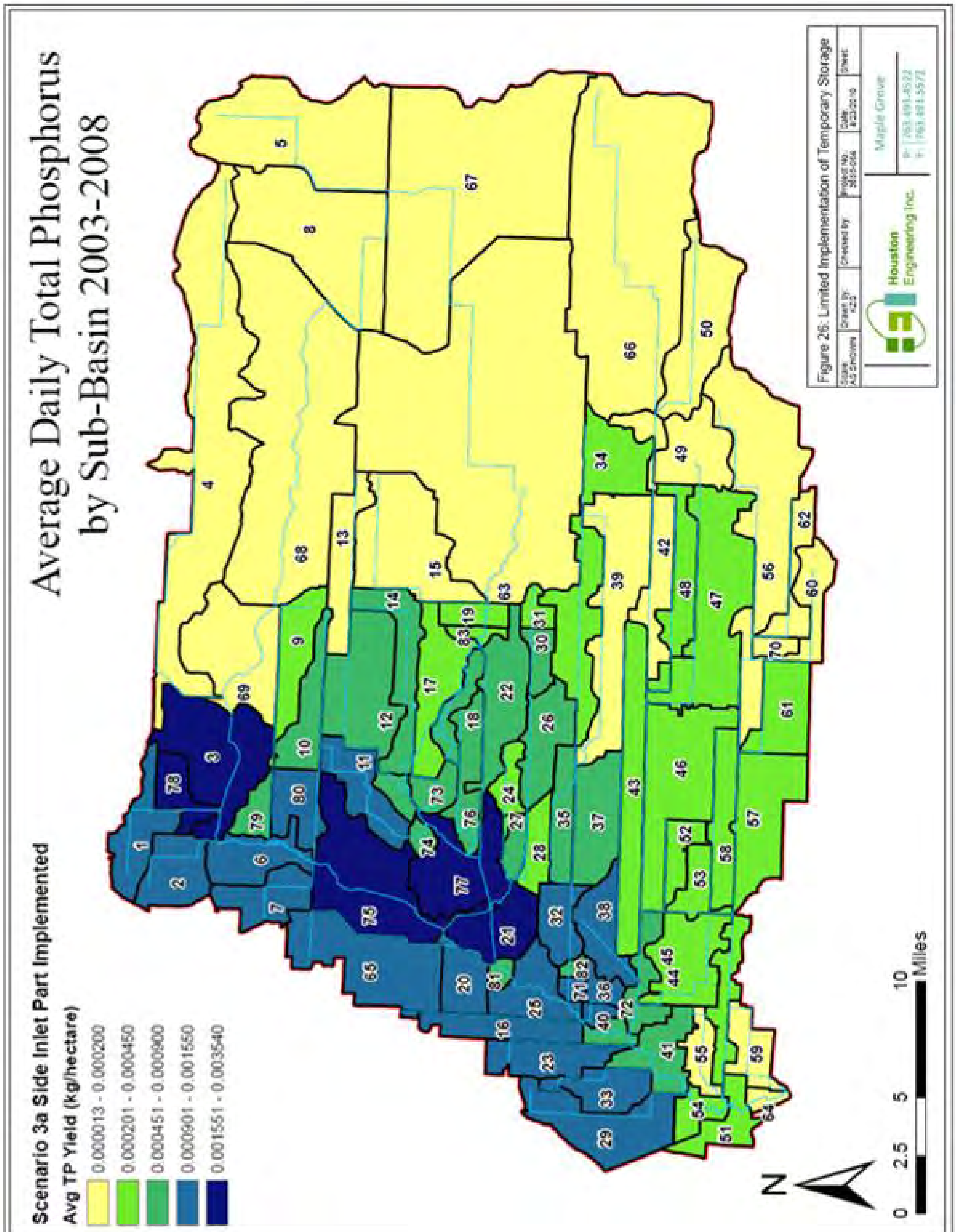


Figure 157. Phosphorus yields after partial implementation of side inlets

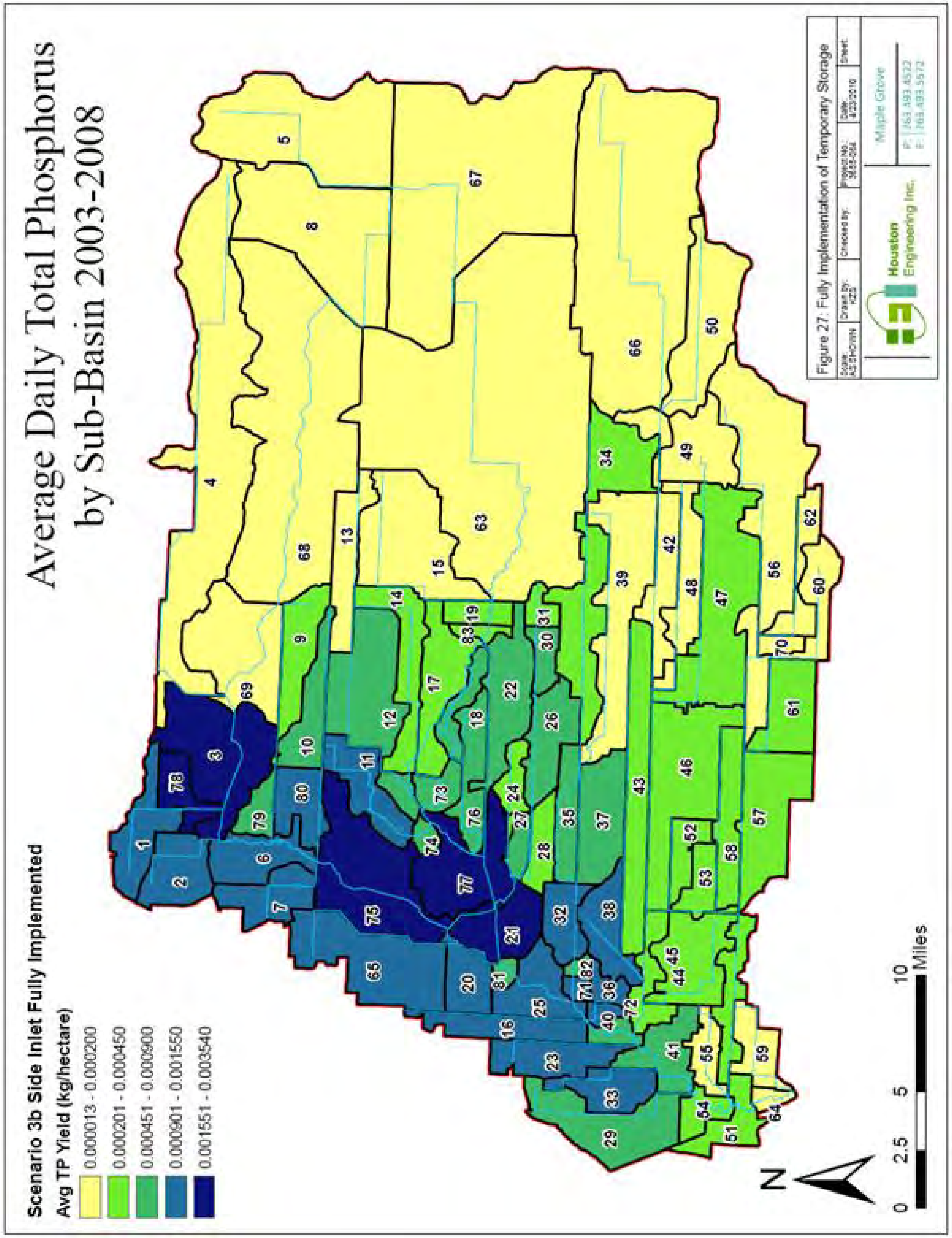


Figure 158. Phosphorus yields after full implementation of side inlets

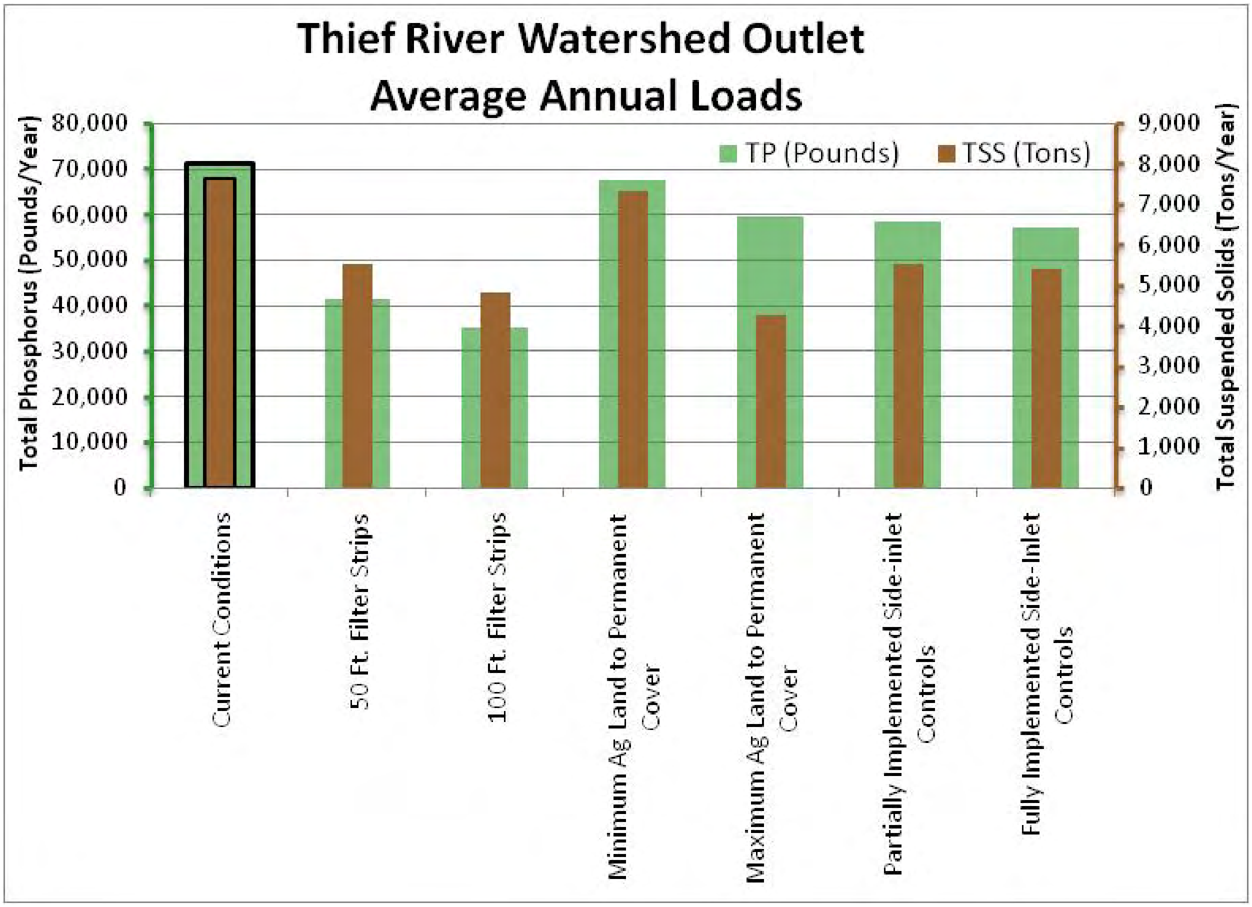


Figure 159. Average annual loads for baseline conditions and BMP scenarios

Table 11. SWAT modeling results at the watershed outlet (i.e. Reach 64)

Scenario	Average Annual Streamflow (acre-feet)	Average Annual Sediment Load (Tons)	Average Annual Total Phosphorus Load (Pounds)	Average Annual Fecal Coliform Load (CFUs)
Baseline: Existing Conditions (2003-2008)	175,000	7,640	71,200	$2.89x10^{15}$
1a: 50 Foot Filter Strips	175,000	5,510	41,600	$2.89x10^{15}$
1b: 100 Foot Filter Strips	175,000	4,820	35,300	$2.89x10^{15}$
2 min: Minimum Ag land to permanent cover	175,400	7,350	67,500	$2.72x10^{15}$
2 max: Maximum Ag land to permanent cover	180,000	4,280	59,700	$1.98x10^{15}$
3a: Partially Implemented Side-Inlet Controls	180,000	5,530	58,500	$1.51x10^{15}$
3b: Fully Implemented Side-Inlet Controls	180,000	5,400	57,200	$1.43x10^{15}$

Table 12. Percent change in annual inflow loads compared to baseline for reservoirs in the Thief River Watershed (averaged over 2003 - 2008)

Reservoir	50-foot Filter Strip		100-foot Filter Strip		Minimum Permanent Cover		Maximum Permanent Cover		Partial Side Inlet		Full Side Inlet	
	TSS	TP	TSS	TP	TSS	TP	TSS	TP	TSS	TP	TSS	TP
Thief Lake	-16%	-14%	-23%	-17%	-3%	-3%	-37%	-11%	-38%	-11%	-39%	-12%
ANWR	-18%	-32%	-29%	-38%	-2%	-6%	-18%	-15%	-20%	-16%	-22%	-17%
Lost River	-21%	-38%	-31%	-46%	2%	4%	5%	10%	2%	8%	-1%	4%
Farmes	-29%	-31%	-38%	-37%	-20%	-23%	-14%	27%	-18%	21%	-17%	11%

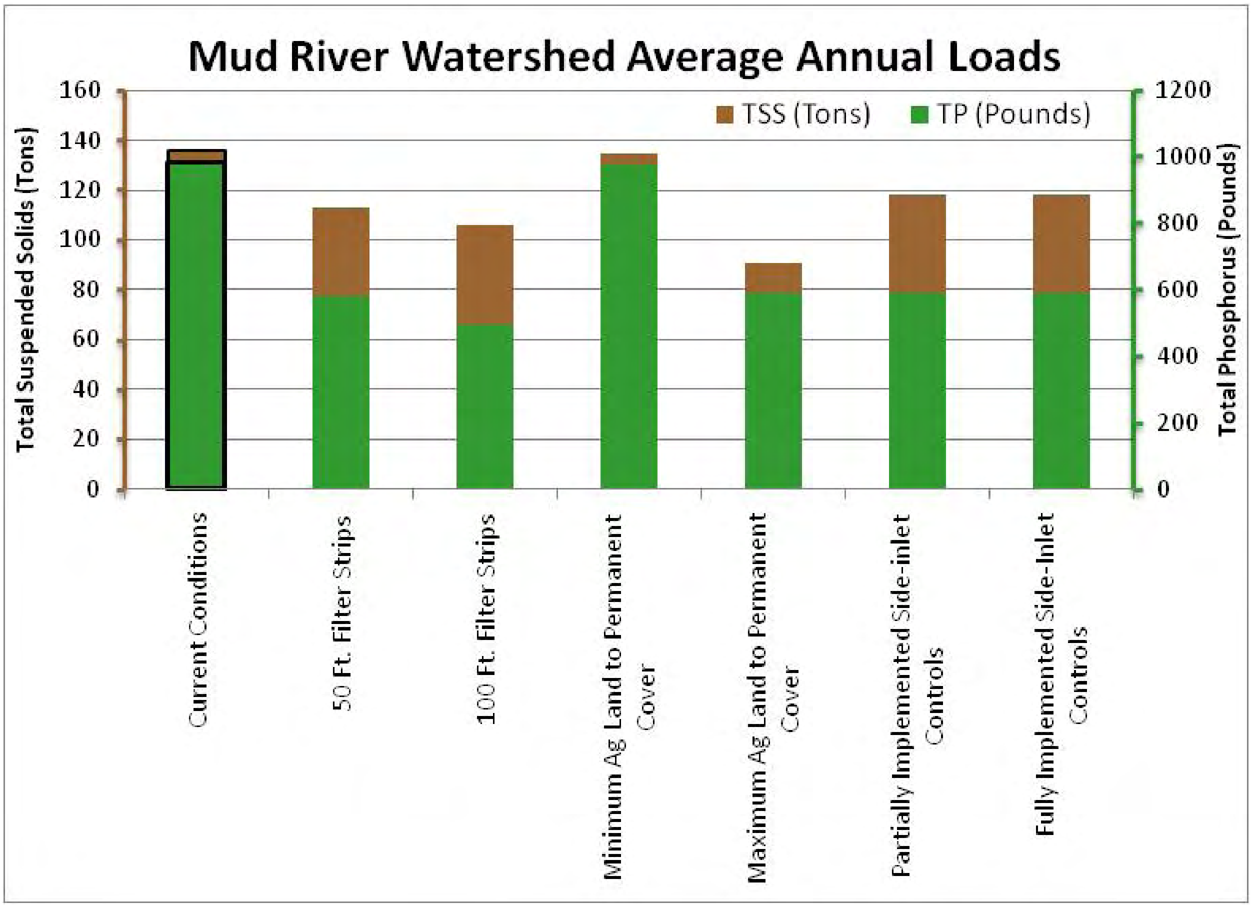


Figure 160. Average annual loads for the Mud River watershed from baseline condition and BMP implementation scenarios.

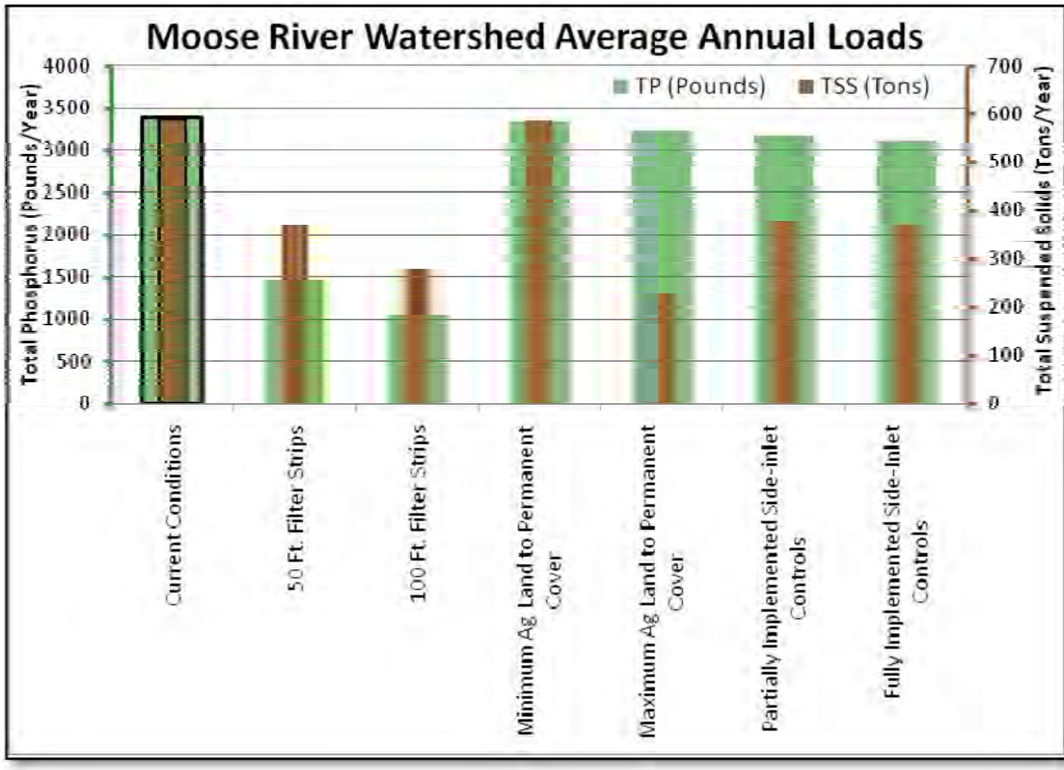


Figure 161. Moose River average annual loads for BMP scenarios and baseline conditions

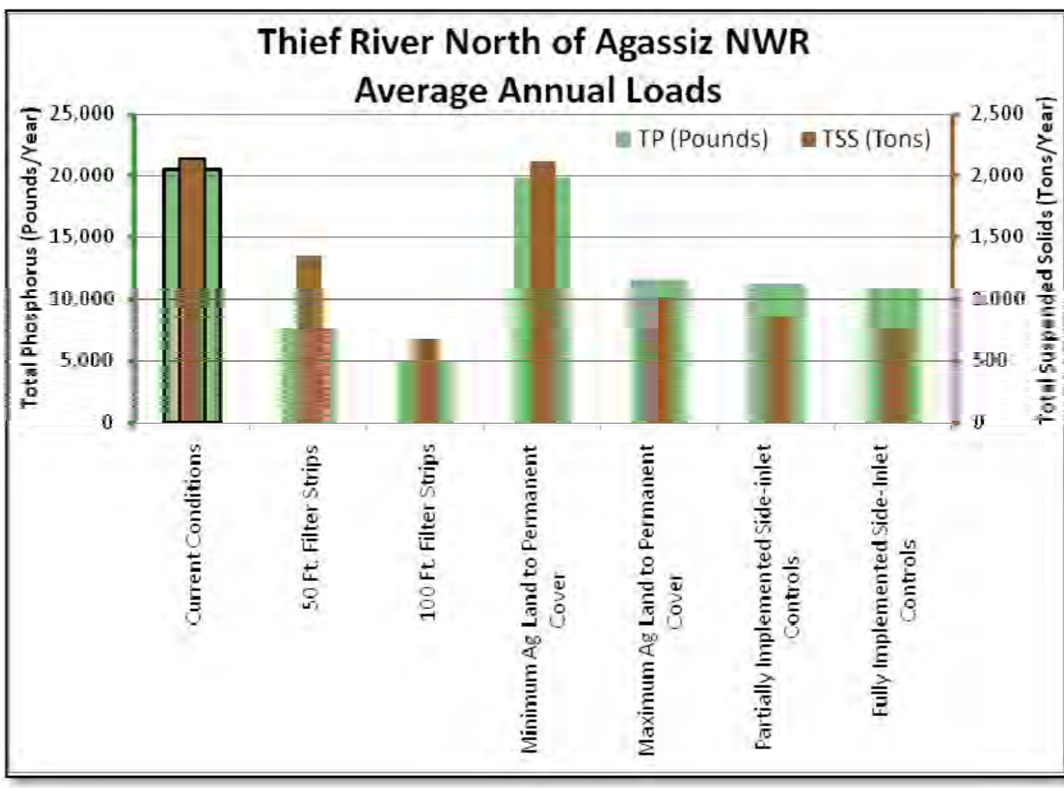


Figure 162. Average annual loads for the Thief River north of Agassiz National Wildlife Refuge from BMP implementation scenarios and base conditions

A product of the SWAT modeling project was the identification of target areas for BMP implementation:

- Along the Thief River on the western edge of the watershed.
- CD20
- Ditch 200
- Br. 2 SD 83 – Ditch near the north boundary of Agassiz NWR

Some BMP scenarios are very effective (filter strips), while others (permanent cover) have minimal results. Most of the sediment loading entering Agassiz NWR is coming from the Thief River. Thief Lake still appears to be contributing sediment. This could mean a couple different things. One is that there may be some drainage entering Thief Lake that is contributing sediment, but hasn't been accounted for in two different studies. The other conclusion we could draw from the Thief Lake sediment budget results is that the budget appears to be fairly balanced. Enough sediment is being passed on through the outlet to minimize sedimentation from inflows.

A full copy of the final draft of the SWAT report can be downloaded at:
http://www.redlakewatershed.org/waterquality/TRW_Report.pdf

Literature Research and Previous Studies

Agassiz National Wildlife Pool Management

- 1139.5 is the summer pool elevation
- 1139 even is the desired fall pool elevation
- The main Agassiz Pool outlet is a dam with two radial gates and a screw gate.
- A new stop-log outlet structure was constructed to the northwest of the radial gates structure.
- Agassiz NWR began releasing water on October 16th, 2009 to draw down the Agassiz pool.
    - The USGS continued to collect samples during the continued drawdown of Agassiz Pool.
    - The water quality of the discharge was very bad. A turbidity level of 132.5 FNU was recorded on 10/16 (the standard is 25). This was the highest recorded turbidity level at this site in the history of the RLWD monitoring program.
    - Turbidity in the Mud River was also quite high during this time (103 FNU measured on 10/19).

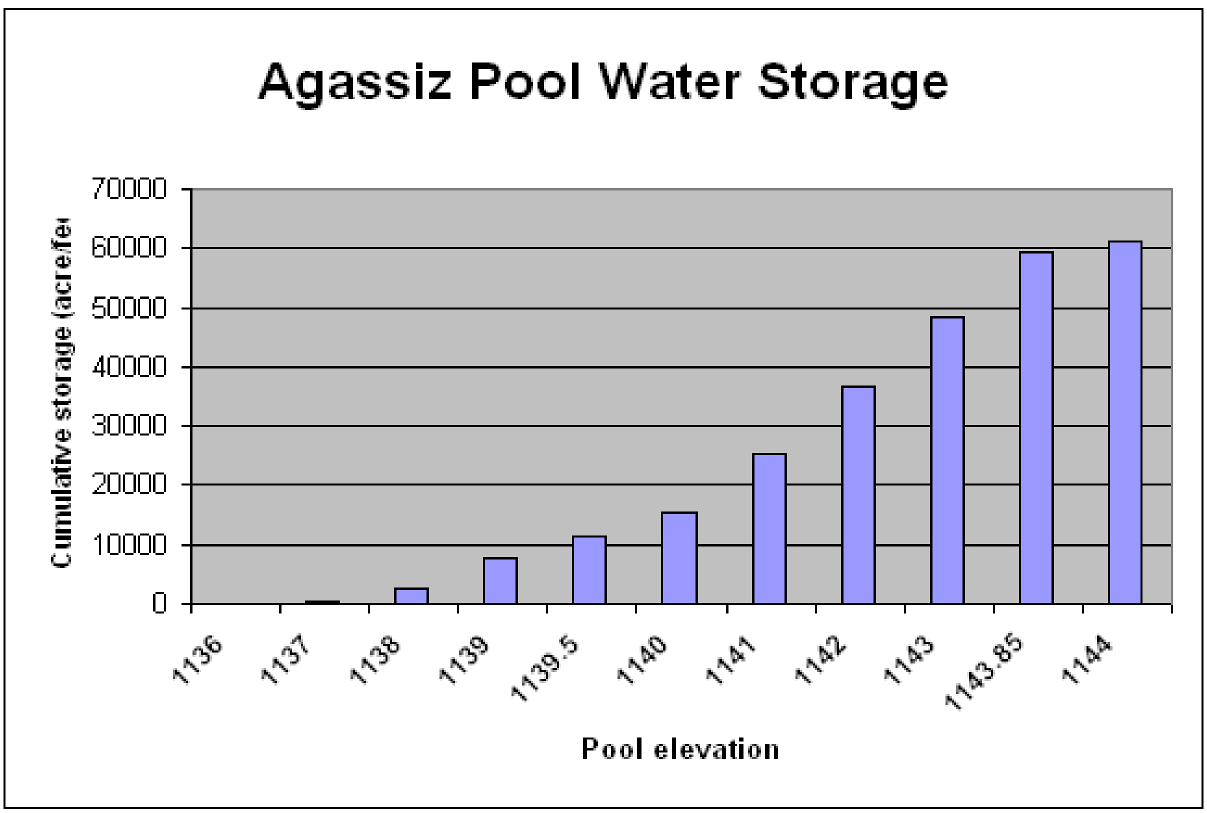


Figure 163. Agassiz Pool water storage.

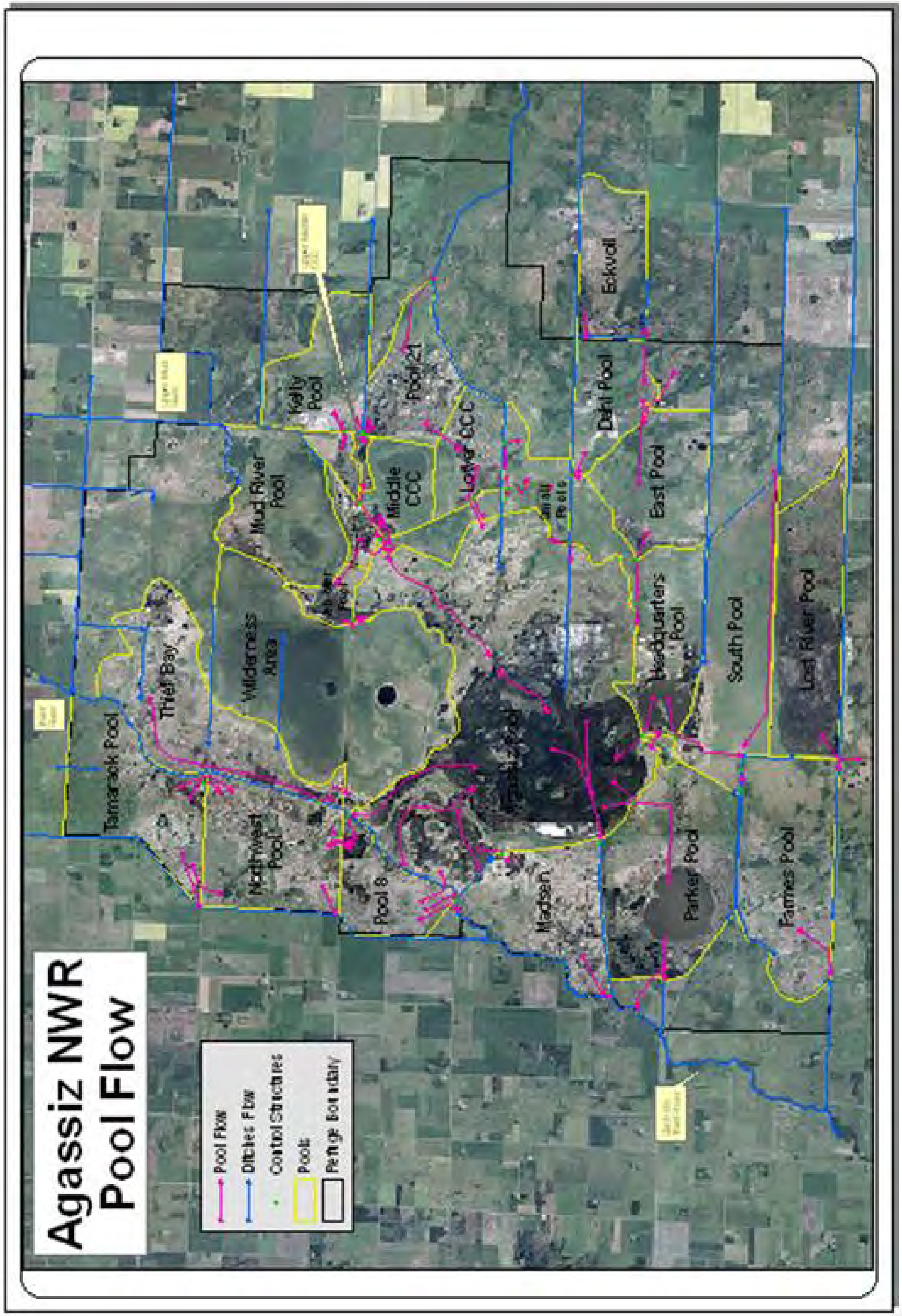


Figure 164. Flow pattterns and pools within Agassiz National Wildlife Refuge

Moose River Impoundment

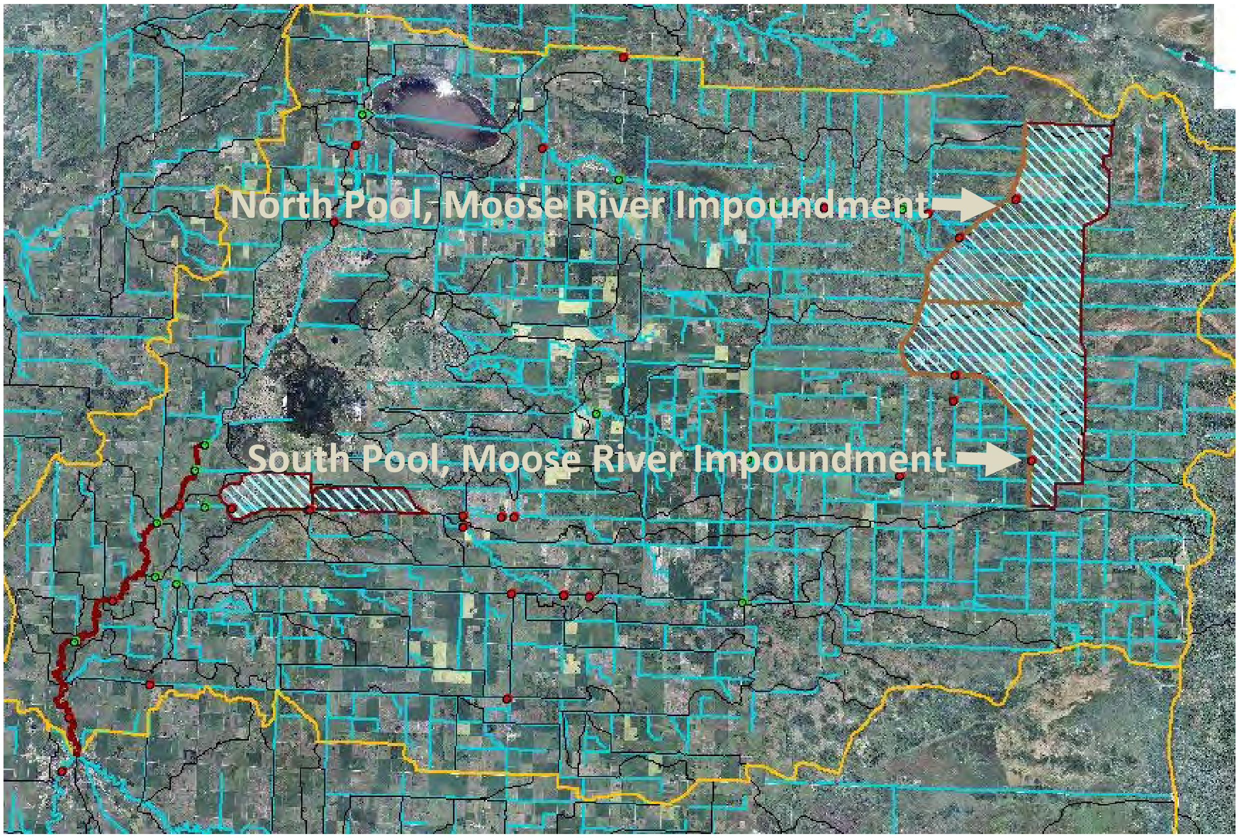
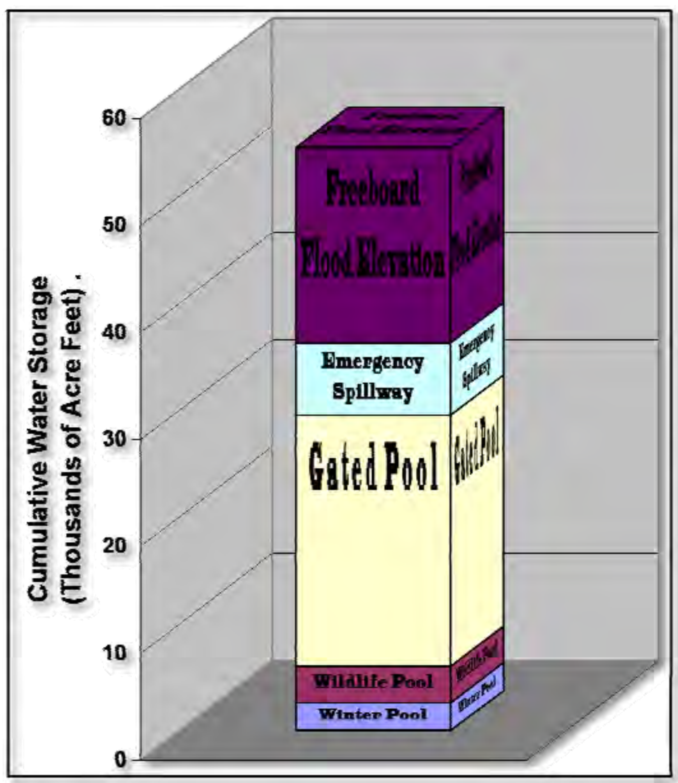


Figure 165. Moose River Impoundment location



The Moose River Impoundment became operational in 1988 and is the product of a cooperative effort between the RLWD and the MN DNR. The two pools of the impoundment were designed to reduce flooding downstream and provide wildlife habitat. The north pool discharges to the Moose River and the south pool discharges to the Mud River (JD11). The RLWD is responsible for the operation of the outlet structures. A local resident monitors and records water level elevations in the pool, monitors stream gages, and operates the gates of the outlets as directed by the RLWD. Outflows from pools are coordinated with Agassiz NWR and Thief Lake WMA.

A point of disagreement/controversy with the Moose River Impoundment is the amount of water retained in the pools. Some feel that this doesn't allow for much storage. The facts show that the amount of water kept in the pool (winter/wildlife pools) is very small compared to the overall amount of water storage.

Table 13. Moose River Designed Storage.

Level	Pool	Elevation	Design Storage (ac/ft)	Total Storage (ac/ft)
Top of Dam (Max)	North	1218.0		
	South	1220.0		
Freeboard Flood	North	1217.2	16,250	54,500
	South	1219.3	38,250	
Emergency Spillway	North	1216.0	12,000	36,250
	South	1218.0	24,250	
Gated Pool	North	1215.3	9,750	29,500
	South	1217.4	19,750	
Typical Summer	North	1211.7	2,000	6,000
	South	1213.6	4,000	
Typical Winter	North	1210.5	800	2,600
	South	1212.4	1,800	
Max No-Flood	North	1212.5	3,000	9,000
	South	1214.5	6,000	

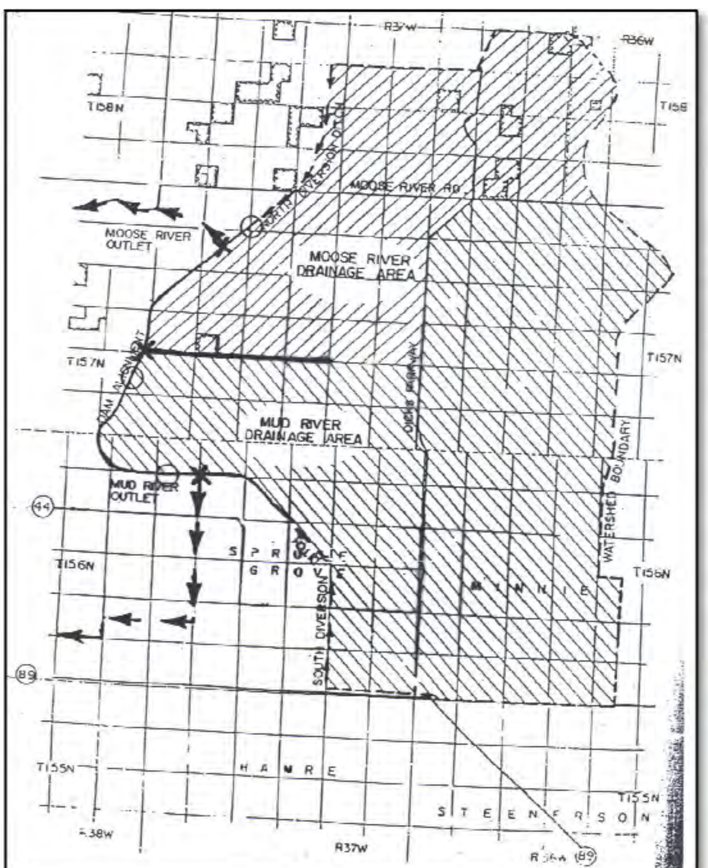


Figure 166. Moose River Impoundment Diagram

Erosion Sedimentation and Sediment Yield Report for the Thief and Red Lake Rivers Basin, April 1996

- The Thief River and Red Lake River watersheds were split into 8 sub-basins for evaluation. The "evaluation unit" with the highest gross erosion per square mile was, basically, all the land that flowed into the Thief River from the west.
- 65% (24 river miles) of the streambanks are eroding on the Thief River. Over 60% of this erosion is considered severe.
- In contrast, only 15% (9 miles) of the streambanks along the Red Lake River are eroding.
- The more extensive streambank erosion on the Thief River may be explained in part by the greater water level fluctuations that occur on it. The channel is not as wide as the Red Lake River, yet it has a larger uncontrolled drainage area than the Red Lake River.
- Of the total annual gross erosion of approximately 2.8 million tons, only about 53,900 tons of sediment is yielded to the ditches and streams annually. The rest is deposited on land.
- Of the 53,900 tons of sediment yielded to streams:
    - 22% (11,700 tons) is from sheet and rill erosion
    - 14% (7,900 tons) is from wind erosion
    - 1% (400 tons) is from classic gully erosion
    - 5% (2,700 tons) is from ditchbank erosion
    - 58% (31,200 tons) is from streambank erosion
- The average annual rate of deposition in the Thief River Falls reservoir was estimated at 5,330 tons over the 1966-1990 time period.
- Future options for reduced sedimentation:
    - Do nothing
        - Water quality conditions would gradually become worse.
    - Land treatment
        - Return cropland to permanent grass cover.
        - Accelerate the application of conservation tillage, crop residue use, field shelterbelts, and filter strips.
        - Accelerate the installation of grade stabilization structures and side-water inlets.
        - Adequately revegetate legal drains after their cleanout.
    - Structural measures
        - Streambank stabilization measures
        - Trap sediment before it is yielded to the reservoir.
    - Dredging
        - Cost estimated at over 1 million dollars (in 1996 – it would be much more today)
        - 25 year project life.
        - Combine dredging with periodic drawdown.
        - Combine dredging and land treatment measures.

Conclusions of the *Erosion Sedimentation and Sediment Yield Report:*

1. Even though 98 percent of the gross erosion occurs on cropland, this kind of erosion accounts for only 37 percent of the sediment yielded to ditches, streams, and the reservoir. Soil erosion on cropland, however, causes more damage on-site by reducing soil productivity, damaging growing crops, losing fertilizers and chemicals, and reducing net income.
2. Wind erosion accounts for 94 percent of the gross erosion but only 14 percent of the sediment yield to streams, ditches, and the reservoir.
3. The major source of sediment yielded to streams and ditches is from streambank and ditchbank erosion (63 percent).
4. Current sediment deposited in the reservoir accounts for about 18 percent of the total volume. Annual deposition over the past 24 years amounts to 5,330 tons (RLWD data). Future depositions are expected to be less, unless current sediment accumulations are removed and CRP acreage is returned to crop production.
5. Even though sediment yield values are considerably lower than in other parts of the state and nation, considerable local interest exists, especially among the recreationalists and city officials in Thief River Falls, for reducing the sediment yield to the reservoir. Similar interest also exists for the wildlife management areas.
6. Opportunities exist for using the sediment budget to determine impacts of various treatment scenarios.

Red Lake Watershed District 10-Year Comprehensive Plan

The May 2006 *Comprehensive 10-Year Plan for the Red Lake Watershed District* lists water quality, natural resource, and flood control goals for the Thief River watershed.

The planning team reviewed natural resource and flood damage reduction issues for each sub-watershed. In the Thief River subwatershed, the following natural resource issues were ranked "high":

1. River and ditch bank failures
2. Ditch 20 sloughing and erosion on laterals
3. Active erosion Section 1 Northwood Twp; MC TH 54 and bridge on Moose River
4. Ditch erosion
5. Overall sloughing and sedimentation
6. SD 83 sedimentation, bank erosion
7. CD18/30 bank sloughing
8. Sedimentation deltas Thief Lake, Agassiz, Elm Lake
9. Channel and streambank erosion

The following flood damage reduction issues were rated "high" for the Thief River watershed (the issues are ranked by priority):

1. Farmstead flooding
2. Farmstead ringdikes
3. Goodridge flooding
4. Ag land flooding
5. Overland flooding
6. Ditch 20 system problems (maintenance)
7. Ditch 20 to 200 (reach of the Thief River)
8. Better maintenance on public systems; extensive ditch systems draining non-productive lands
9. Beaver problems
10. Thief River flows into Agassiz
11. Extended periods of high flow in Thief River (SD # 83); extended periods of low flow in TR; flashiness in flow from Agassiz to NWR

Agassiz National Wildlife Refuge Comprehensive Conservation Plan, Chapter 2 (excerpts)

Suggestions received by certain individuals during scoping that Agassiz NWR should be managed primarily as a flood control facility for the benefit of surrounding and downstream landowners contradicts the founding purpose of the Refuge and the spirit and mission of the National Wildlife Refuge System. For the interests of wildlife to be relegated to a secondary purpose of a national wildlife refuge or merely an incidental benefit of its presence would require Congressional or Presidential action…

Some people said that farmers on the west side of Agassiz NWR could benefit from small changes in water management. In the opinion of some people, a diversion ditch or a better (or repaired) outlet for the Refuge could prove to be a positive move. Analysis by flood control engineers has shown there would be little impact on downstream flooding from a diversion ditch or improved outlet. Some people said that Agassiz NWR staff should continue to participate in a comprehensive watershed management plan that brings together many diverse and sometimes conflicting parties and interests.

The major threat of flooding at Agassiz is the result of spring runoff of snowmelt following wet winters. Flood peaks are affected by the amount of moisture in the soil at freeze-up, amount of accumulated moisture at the start of the spring melt, and weather conditions during the spring melt. Spring and summer thunderstorms that drop more than 5 inches of rainfall on a single day occur occasionally and can cause severe flooding.

Flooding is one of the key issues affecting the Refuge – both its habitat and its facilities – as well as the neighboring region. Not only does flooding affect the Refuge and surrounding private lands, roads, and infrastructure directly, but it also has a big impact on relations between the Refuge and property-owners and officials in the surrounding community. Floods occur most often during March, April and May, when spring rains may combine with snowmelt to exceed channel capacity. The largest flood discharge ever recorded at the Thief River Falls gauge 15 miles downstream of the Refuge was 5,610 cfs in May 1950. During that flood an estimated 108,000 acre-feet of water was stored in the Refuge's various pools. During the 1997 flood event, inflows to the Refuge averaged 5,985 cfs for six consecutive days (April 15 to April 21, 1997). The average outflow at the Refuge was 808 cfs during the same time period, resulting in over 10,350 acre-feet of water put into storage on the Refuge per day, making a dramatic difference in reducing the level of flooding in downstream communities.

Agassiz NWR includes 26 impoundments (known variously as lakes, ponds, pools, or moist soil units) and three natural lakes. Whiskey Lake and Kuriko Lake are located in the Wilderness Area and Webster Lake is located in the northeast area of the Refuge. The artificial impoundments vary widely in size, ranging from 30 acres to the approximately 9,000 acres that comprise the Agassiz Pool. Water is contained within the impoundments by an extensive network of dikes, and water levels can be raised or lowered in any given impoundment by adjusting water control structures at pool outlets. Agassiz's impoundments with their marshes, mudflats, and open water are the dominant geographic features of the Refuge. They are also the focus of the Refuge's aquatic habitat management efforts on behalf of migratory birds.

The federal Conservation Reserve Program (CRP), administered by the USDA Farm Services Agency, pays farmers to keep marginal croplands out of production. Often these are sites with poor natural drainage that were wetlands prior to conversion to agriculture fields. Such areas are plentiful in flat northwestern Minnesota and readily lend themselves to being restored into wetlands, simply by plugging drainage ditches. For a number of years, Agassiz NWR staff have been engaged with numerous wetland restoration projects within the RMD. The year 2000 was an exceptionally active year in this regard. The Mississippi Headwaters/Tallgrass Prairie Ecosystem and Regional Office Refuges and Private Lands Offices had recognized the need to make CRP signups with wetland restorations a priority in Marshall County and other areas within 20 miles of Agassiz NWR. In a monumental undertaking that came to be known as "The Agassiz Adventure," 20 Service employees – including biological and engineering technicians, heavy equipment operators, biologists, Refuge operation specialists, and maintenance mechanics from 10 field stations – working over a period of 472 days, contacted 186 landowners, checked 1,031 wetlands, and restored 832 wetlands. This resulted in a total of 2,722 wetland acres restored. The following year, 45 Service employees assisted with the effort, surveying 924 basins on 548 properties and contributing to the restoration of 4,200 acres of wetlands. Little upland habitat restoration is requested off-Refuge, since these private farmlands are generally being used for agricultural production.

Agassiz NWR's water management program is very complex and involves 26 impoundments. Pools are frozen for about 5 months of the year, November to April. During periods of "ice-out," May to October, water management not only must balance competing considerations of wildlife and habitats on the Refuge itself, but it must deal with the requests of off-Refuge neighbors upstream and downstream as well as other township, county, state, watershed, and flood control agencies.

Regulating water levels – whether at maximum pool levels or in drawdown (emptying pools almost entirely of water) – is a vital management tool for waterfowl, shorebirds, and wading birds. Over the years, water management has been further complicated by increased land clearing, drainage and stream channelization on private lands upstream of the Refuge, which increase flood flows and sediment transport onto the Refuge. In addition, over the last 10 years the area has experienced an extremely wet cycle causing repeated severe flooding, which results in rapid pool level increase, or "bounce," of two to three feet. Bounces during the breeding season negatively affect nesting efforts of many species. For instance, the June 11, 2002, event essentially wiped out a production year for many species. Managers must be cognizant of conditions throughout the watershed, exercise good judgment, and at times be willing to deviate temporarily from Refuge objectives when downstream cities and towns are experiencing extreme flooding events.

Agassiz NWR's Marsh and Water Management Plan (1987) guides management of the Refuge's marshes, open water, water levels and discharges. The plan states that production and maintenance of waterfowl are the primary objectives at Agassiz NWR, and that to fully achieve these objectives, a diversity of habitats must be provided to meet the life history requirements of waterfowl for nesting, brood rearing, and migration. The presence or absence of water, its depth, and the seasonal timing of water depth fluctuations are all manipulated to produce various stages of marsh habitats on which different water-dependent birds rely.

An annual marsh and water management plan is written every winter. This plan summarizes operations during the previous year, describes major water management problems, and documents construction and rehabilitation projects. It also identifies proposed pool elevations for the upcoming years along with stated objectives for each management unit. Agassiz Pool, by far the largest on the Refuge, serves as an example. Its spillway elevation is 1,141 ft. above mean sea level (MSL), its drawdown elevation is 1,136, it was last drawn down in 2000, and the next planned drawdown is in 2010. Objectives in 2001 were to maintain and reestablish hardstem bulrush and limit the increase of cattails by flooding out new plants

Refuge management is continually adjusting scheduled water manipulation in response to the vagaries of the weather or maintenance of water control structures. For instance, in 2002, spring runoff was insufficient to recharge eight pools that were in drawdown in 2001. Therefore, it was decided to keep the same pools in drawdown and continue to hold water in the six pools originally scheduled for a 2002 drawdown. Continual maintenance and repair of aging water control facilities such as gates, pilings, gauges, dikes, bridges, riprap, and channels are necessary to keep facilities and controls operable, and thus to meet water and marsh habitat management objectives.

In the early 1980s, five impoundments were developed in the Golden Valley and Goose Pen farm fields as moist soil units, which are valuable habitat for both waterfowl and shorebirds. Difficulties with managing water in these units led to their neglect from the late 1980s to the late 1990s, but in 1998 staff began a concerted new effort to manage them with frequent drawdowns timed to coincide with shorebird migration. All water control structures were replaced in 1999 and 2000 and burning and discing can be used when the units are dry enough to run a tractor across them. Annual outflows have a wide range of fluctuation at Agassiz NWR, depending on precipitation. Outflow can range from virtually zero discharge from the Refuge into the Thief River during dry years to over 300,000 acre-feet in wet years with one or more large storms. The largest annual outflow, since record keeping began in 1965, was 414,147 acre-feet in 1999.

Total Suspended Sediment Loadings: Red Lake, Thief, Mud, and Moose Rivers

This study was completed by Houston Engineering on June 6, 2003 for the Pennington County Soil and Water Conservation District. It is available in PDF format from the RLWD website at:

http://www.redlakewatershed.org/projects/TSS%202003.pdf

- Estimated inflows and outflows at the Thief Lake Dam, Thief Lake, and Agassiz National Wildlife Refuge.
- Suspended sediment samples were collected from 1995 through 1997.
- FLUX modeling was conducted for the inflow/outflow monitoring sites.
- TSS loads were estimated for each year (1995-1997) using the FLUX model.
- The large reservoirs of Thief Lake and Agassiz National Wildlife Refuge are discharging a significant amount of sediment, although Agassiz Pools appear to be retaining about 2/3 of the sediment inflow.
- The load estimates and average TSS concentration data for Thief Lake indicate that more sediment is flowing out of Thief Lake than is flowing in. This seems contrary to "common sense" and may be a result of assumptions made to compute discharge.

Corresponding Studies

The United States Fish and Wildlife Service received money for several study efforts that expanded upon the goals of the Thief River watershed Sediment Investigation by focusing on water quality in and around Agassiz National Wildlife Refuge.

- Install streamflow-gaging stations at three locations where flow enters the Refuge and three locations where flow leaves the Refuge.
    - We decided on using the existing sites, plus the stream gage #140 on the Thief River, stream gage #6 on branch 200 of JD11, and a new site at the newly constructed structure on the Thief River.
    - There was only enough money budgeted for one more water quality multiprobe. The consensus was that the money should be used to buy a profiling (spot measurement) multiprobe instead of a logging (deployed) multiprobe. The USFWS has been using the RLWD's old Hydrolab Datasonde 4a multiprobe, but it began to have battery problems later in the year and a notice was recently distributed by HACH that they will be discontinuing maintenance on that particular model (but are offering a trade-in deal). Also, we felt that it would be important for the USFWS to use a Eureka Manta multiprobe for field measurements so the spot measurement data would be more comparable to the data collected from the deployed, logging Eureka Manta multiprobes.
    - There will actually be 7 sites utilized for this study. The USGS can't afford to monitor the 7th site, which is stream gauge #6. This site is part of the RLWD's Thief River Study. So, there will be an exchange of services between the USGS and the RLWD where the USGS will take care of the 16 flow measurements at the stream gauge #140 site if the RLWD takes care of all the 16 flow measurements at site #6. This should result in less flow measurement work for the RLWD in the long-run, since at least 10 measurements at each site would have been needed anyway to create rating curves for the Thief River Watershed Sediment Investigation. There will, however, have to be an effort made to coordinate sampling efforts with the USGS and collect sufficient measurements at different levels of flow within a two year period.
    - 6 sites selected in ANWR
    - 2 outflow locations\
        - Judicial Ditch 11 below Agassiz Pool (radial gate structure) (A2)
        - Northwest outlet of Agassiz Pool (new structure) (A5)
    - 4 inflow locations
        - Thief River inlet to ANWR (SG140)
        - Judicial Ditch 11 above Agassiz Pool (A3)
        - Br 200 of Judicial Ditch 11 (A4)
        - Br 1 of Judicial Ditch 11 (A1)
- Collect sixteen (8/yr) discharge measurements at each gaging station to develop a stage-discharge relationship.
- Collect sixteen (8/yr) width and depth integrated samples for suspended sediment and nutrient analyses at each gaging station.
- Operate four continuous water quality sondes to aid in development of a relationship between streamflow and water quality.
- Collect daily dip samples at the two gaging stations for which there are o continuous water quality sondes and analyze for specific conductivity and turbidity.

    - The USFWS plans to hire a seasonal employee for the project.
- Compute daily streamflow at each gaging station.
- Develop relationship between streamflow and turbidity measurements at the gages and suspended sediment, total phosphorus, and ammonia plus organic nitrogen concentration at each station.
- Identify the true sources of water quality problems by quantifying turbidity, dissolved oxygen levels, nutrients, and ammonia flowing into and out of Agassiz NWR
- Take on sediment core sample at two deltas within Agassiz pool and analyze to determine the rate and content of sediment deposition for the last 200 years
- Sampling recently was extended to 2010 to include 8 more samples and measurements
- Discrete samples are analyzed for:
    - Suspended sediment concentration, Kjeldahl nitrogen, ammonia, nitrate, nitrite, orthophosphate, total phosphorus
- Quantify the extent of Refuge contribution to the impairments in question
- In cooperation with the RLWD, TSS samples are being collected and analyzed by RMB Labs
- Measurements and samples have been collected over a range of flows, concentrations, and seasons.
- In 2007, the USFWS was able to purchase four Eureka Manta water quality logging sondes that were installed in sites A1, A2, A3, and A4. The USFWS partnered with the RLWD to fund an intern position for the collection of water quality spot measurements, maintenance of the continuous water quality equipment, and data management. Kristin Fritz was hired as the intern for this study in 2007 and returned for 2008. USFWS Biologist Gregg Knutson and seasonal employee Maria Fosado also helped with data collection in 2007.
- In 2008, the USFWS at ANWR received
    - Hired a seasonal employee for the study (Kristin Fritz)
    - Hired a summer intern for the study (Kelly Kerfeld)
- Data lost due to equipment issues, one more year of data will be collected in 2010, both continuous and discrete data will be collected
- Using discrete samples paired with continuous data, regression equations will be developed
- Continuous data and regression equations will then be used to compute continuous loads
- Determine an appropriate hydrologic and water quality sampling scheme for subsequent years of monitoring at Agassiz NWR
- Provide manages of similar wetland systems/complexes at other NWRs with data related to identification of water quality issues, as well as guidance on monitoring strategies that may be effective for their particular wetland(s)
- The Agassiz NWR study is planned to continue through 2010, at a minimum. So, the final results from the Agassiz NWR study will not be available at the time of the completion of this report in August 2010.
- A final report will be prepared in 2011

Stakeholders' Meetings

<u>January 21, 2010 meeting:</u>

- 22 people attended
- Introduction to the project
    - History of the Thief River Watershed
    - Chain of events that led to the initiation of this project
    - Project goals
    - Cooperation
    - Funding
    - Sites
    - Methods
- Resource condition
    - Assessments based on discrete water quality measurements made before and during the study.
    - Extent of impairments
    - Potential sources of impairments
- Progress of the water quality projects in the Thief River watershed
    - Sampling
    - Samples of continuous monitoring results (water quality and flow)
    - Project ideas
- Agassiz National Wildlife Refuge Water Quality Study
    - Reason for doing the study
    - Site locations
    - Continuous and discrete data collection
    - Monitoring data
- Soil and Water Assessment Tool (SWAT) modeling by Houston Engineering
    - Goals and objectives
    - Processes modeled
    - Limitations
    - Expected output
    - Scenarios to model
- Future plans for the study

<u>July 9, 2010 Meeting:</u>

- 21 attendees
- Presentations
    - What We've Learned from This Project
    - Soil and Water Assessment Tool (SWAT) Modeling Results
    - Implementation Project Ideas
    - Local Impacts and Outcomes of TMDL Studies

- Introduction to the Thief River Watershed Assessment Project (Watershed-Based TMDL)

- Attendee comments and discussion
  - Try modeling the combination of a 50 foot buffer (compromise) and side-inlets.
  - Streambank erosion is probably the most significant source of sediment in the Thief River north Agassiz NWR (Brad Berg). Landowners mentioned that there isn't a lot of erosion coming from their fields.
  - Agassiz National Wildlife Refuge is conducting sediment source fingerprinting analysis on sediment samples collected from their pools. Final analysis (conducted by the Science Museum of Minnesota) should be done sometime in September.
  - There was some discussion about what is the "natural" or "acceptable" level of sediment in the river.
    - State water quality standard for turbidity = 25 NTU
      - Thief River meets this standard north of Agassiz; could meet it in the lower reach with some water quality protection efforts.
    - Minimize sediment loads to slow sedimentation within pools
      - Agassiz NWR**,** Thief River Falls Reservoir.
    - How does turbidity affect vegetative communities?
    - Tough to set a "perfect" water quality standard
  - We should model the effectiveness of stream stabilization projects.
  - There is a ditch that enters the Thief River (State Ditch 83) from the West, somewhere north or west of Agassiz Refuge that could be contributing a lot of sediment. County Ditch 35?
  - The SWAT modeling results maps should have shown the lakes/impoundments layer.
  - If we put in setback levees along the Thief River north of Agassiz NWR, where would we get the clay for the dikes? The local soils are mostly peat. That is part of the reason why the streambanks and ditchbanks are relatively more erodible. Does it make sense to be hauling in lots of soil? What if we did a bunch of stream stabilization with rip-rap instead?
  - The Pennington SWCD has received a Clean Water Legacy grant for $65,000 for streambank stabilization along the housing development north of the golf course.
  - JD30 outlet restoration/stabilization is another project idea we should look at (Bryan Malone)
  - Status of the Agassiz Pool (Ditch 11) outlet restoration:
    - High water is slowing things down
    - North and south side construction is done
    - Raw dikes during high flows actually held up better than expected.
    - Whole projects should be done sometime this year.
    - Rock riffles in the ditch downstream of the outlet.
  - Other Agassiz NWR projects:
    - Aerial photos show deltas within the pools
    - Sediment coring
    - Channel restoration on the East end of the refuge
    - Continue monitoring the JD11 outlet – see if the restoration is a success.
    - Rip-rap by weir on Ditch 194
  - No end date to TMDL implementation plans – no time line in the Clean water Act.
    - Just required to work (reasonably) toward compliance.
  - During the 1997 flood, CD20 carried as much water as the Thief River.

Recommendations

Additional Needs

This study provided a huge dataset that can be used to answer questions about water quality issues throughout the Thief River watershed. There are some gaps in the data. Equipment didn't work perfectly all of the time. Not every stream in the watershed was monitored during this study. Many of these gaps will be addressed during the watershed-based TMDL study. Although the Agassiz National Wildlife Refuge Water Quality Study and the Thief River Watershed Sediment Investigation were interconnected in some ways and meant to complement each other, the Agassiz study was not completed by the deadline for the Thief River Watershed Sediment Investigation. Equipment problems hindered their previous years' efforts, so they pursued and received funding for an additional year of monitoring. There will be information from this report that can be used in the Agassiz water quality report. There will also be information and data from the Agassiz study that could be used to supplement this report. Some of the flow records from the Agassiz study will be needed in order to do FLUX modeling for the Agassiz NWR area. The Agassiz study also focuses more closely upon the refuge, so it should be able to more precisely describe the sediment budget of Agassiz Pool, for example.

Here are some other needs that could be addressed in future projects and studies:

- Monitoring additional sub-basins
- Continuous DO monitoring on the Moose River.
- Biological monitoring.
- Stream channel stability assessment (Rosgen).
- Explore the sub-basins along the western boundary of the watershed to identify areas that are contributing to the high sediment yields in these priority areas.
- Incorporate the data and findings of the Thief River Watershed Sediment Investigation with the results of the Agassiz National Wildlife Refuge Water Quality Study and vice versa.
- There was a lot of data collected for this study. There is potential for this data could be used for other investigations and to answer more questions about water quality in the Thief River Watershed.
- Sediment rating curves can be developed to aid in the development of the TMDL, or for other purposes.

Identification of Problems Areas and Pollution Sources

- RLWD staff paddled a reach of the Thief River/SD 83 (CR7 to CSAH 12) in October 2008 to inspect the channel for sediment bars and erosion problems.
- The RLWD Water Quality Coordinator canoed the Thief River from the Rangeline Road into Thief River Falls with Jim Courneya (MPCA Project Manager). Erosion sites were GPS'd and photographed along the way.
- Monitoring on Branch 200 of JD11, downstream of Farmes Pool, recorded significant, but temporary, flushes of sediment that were created by the construction activity at the Farmes Pool outlet in September of 2009.
- Runoff from the JD21 along Hwy 54, which was under construction, was carrying plume of sediment into the Moose River in October 2009. This ditch didn't get a chance to grow vegetation prior to the spring floods of 2010, so there was a significant plume of sediment during that runoff as well. Large gullies formed at many points along the east bank of this ditch.

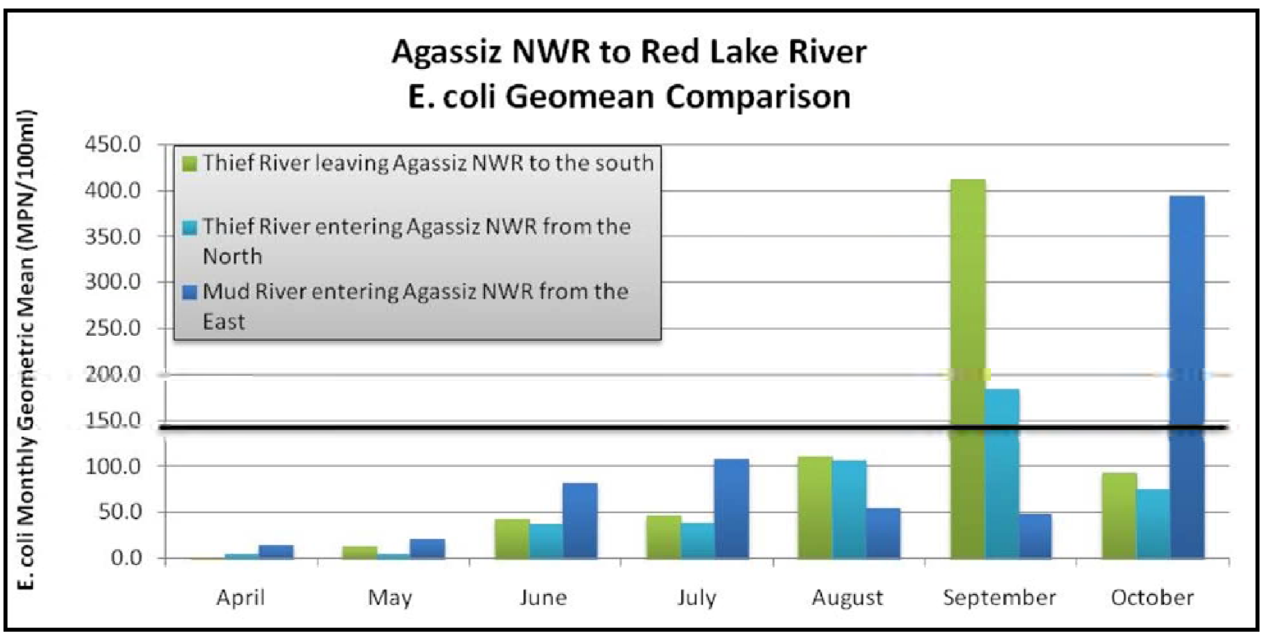


Figure 167. Agassiz NWR E. coli inputs and outputs.




- The lower each of CD 20 is a suspected source of sand deposited in the Thief River at the confluence of the two waterways. Minor headcutting in CD20 is suspected. Headcutting is especially evident in lateral ditches flowing into CD20.
- There is a significant decrease in water quality from the outlet of Thief Lake to the northern boundary of Agassiz National Wildlife Refuge. Investigative monitoring indicates that the problems are coming from somewhere in the lower half of the Thief Lake-to-Agassiz portion of the Thief River.
- Between Agassiz NWR and the Red Lake River, the Thief River exerts a lot of power upon its banks. The bank is heavily scoured up to a point. The roots of trees and shrubs do a lot to help the banks resist this shearing action, but there are still many places where the streambank is failing rapidly.

Waterfowl banding

It is possible that waterfowl concentrations at banding sites could be having a negative effect on water quality in the Thief River. This problem has been identified based on high late summer E. coli levels on the reach of the Thief River between Thief Lake and Agassiz National Wildlife Refuge. The connection to the suspected source was made when we learned that there is a banding area along the outlet channel of Thief Lake. Birds are baited to this location, bringing in an unnaturally high concentration of birds. The reach has now been put on the 303(d) List of Impaired Waters because of high E. coli concentrations, so something will eventually need to be done to adjust the banding operations and minimize their impact on water quality.

Potential Sources of the Mud River E. coli Impairment

Data collected at the Mud River monitoring site at Highway 89 (site #757) indicated that the Mud River was impaired by high levels of E. coli bacteria. Aerial photos show that there are some livestock operations along the Mud River upstream of Highway 89. The Grygla WWTF also discharges to the Mud River. To investigate the impact of these potential sources, several sets of longitudinal profile samples were collected along the Mud River from Hwy 89 upstream to Hwy 54. Also, kayak stream reconnaissance trip down the river identified a couple of sites where livestock are accessing the river. Although the livestock area just downstream of CR 53 has severely affected stream stability, the livestock in Section 28 of Valley Township appears to be having a greater impact on E. coli concentrations. There was an increase in E. coli on the downstream end of this reach during the early August sampling and the readings were there were tied for the highest found in the late August sampling.

High E. coli concentrations were found at the Hwy 54 crossing of the Mud River in Grygla, which indicates that there are sources upstream of there that would also need to be addressed.

Streambank and Ditch bank Erosion

The 1996 *Erosion Sedimentation Sediment Yield Report for the Thief and Red Lake Rivers Basin* estimated that 53,900 total annual tons of sediment is yielded to ditches and streams. Of this total yield, 2,700 tons (5%) was estimated for ditchbank erosion and 31,200 tons (58%) was estimated for streambank erosion. This adds up to a total of 64% of the sediment that enters rivers and streams comes from streambank and ditchbank erosion. Observations throughout the watershed and stakeholder feedback are in agreement that the majority of the sediment is coming from bank erosion.

Along State Ditch 83 and the lower reach of the Thief River, a lot of shear stress is exerted upon the banks of the Thief River.

In August of 2009, RLWD and MPCA staff canoed a reach of the Thief River to look for erosion problems. Many erosion sites were identified in the trip. Some can be given higher priority than the others if they are threatening buildings.

MPCA, MN DNR,and RLWD staff paddled the Thief River again in May of 2010. New erosion sites were identified along the way. Also, there were some notable erosion sites and other problems that had gotten worse since the previous summer.

The intensive monitoring conducted for the corresponding Thief River Watershed Sediment Investigation and Agassiz National Wildlife Refuge Water Quality Study was able to catch spikes of sediment and/or turbidity entering Agassiz National Wildlife Refuge.

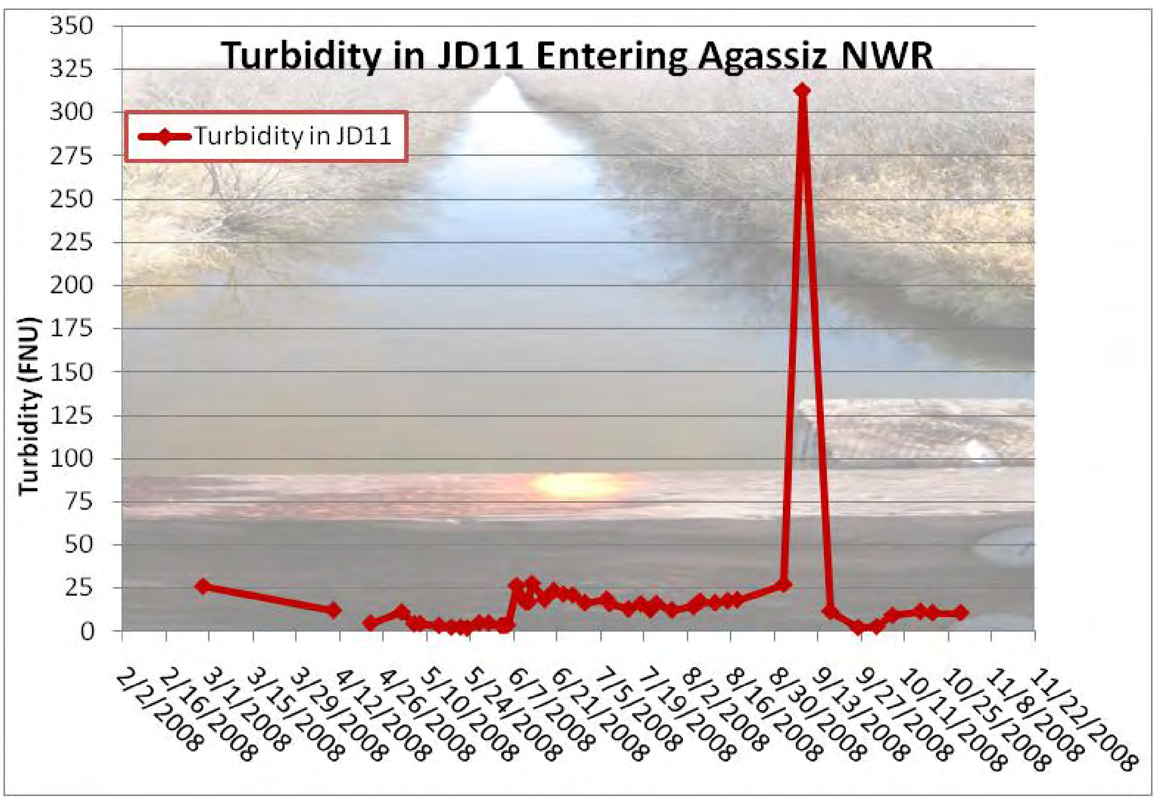


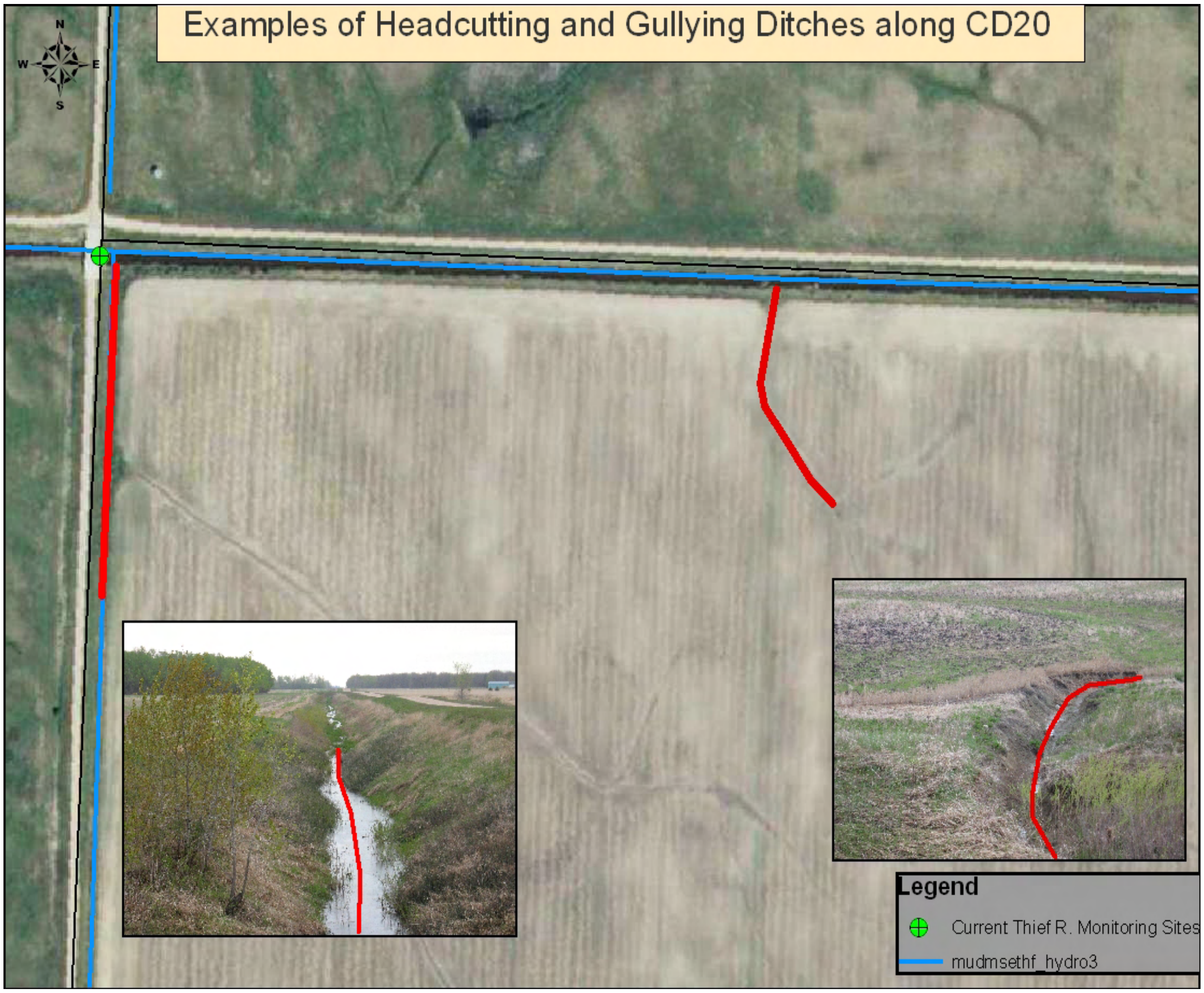
Figure 168. Spike in turbidity in JD11 on the east side of Agassiz NWR during a storm event

While major ditch systems were found to have relatively clean water, they can be negatively affected by smaller, poorly maintained ditches that empty into them.

Gully Formation and Headcutting

Gully formation and headcutting can occur at the outlets of either public or private drainage. Gullies often form at outlets of private drainageways. Headcutting then extends the erosion uphill and further into the field. There are some public drainage ditches that are exhibiting headcutting and channel degradation that originates where they empty into a larger ditch or river. With either of these situations, one just needs to multiply the width of the gully by the depth and by the length to understand the large quantity of sediment that is sent downstream. Headcutting or lowering of the streambed elevation in CD20, for example, has likely had an impact on the ditches that flow into it. Lowering the elevation of the outlets of those ditches causes headcut erosion to work its way up those channels. Rock riprap, side-inlet structures (with flap gates), grassed waterways, grade stabilization structures, and filter strips can all be used to address the problem of gully formation.

Plume of Sediment Entering CD20 from a Road Ditch that is Headcutting.



Impoundment Discharge

The water quality in impoundment drainage depends upon the location of the pool within the watershed and the nutrient/sediment inputs that flow into the pool. The water quality coming out of the Moose River impoundment meets water quality standards. The water looks clean (with some tea-stained coloration) and actually has sufficient dissolved oxygen concentrations.

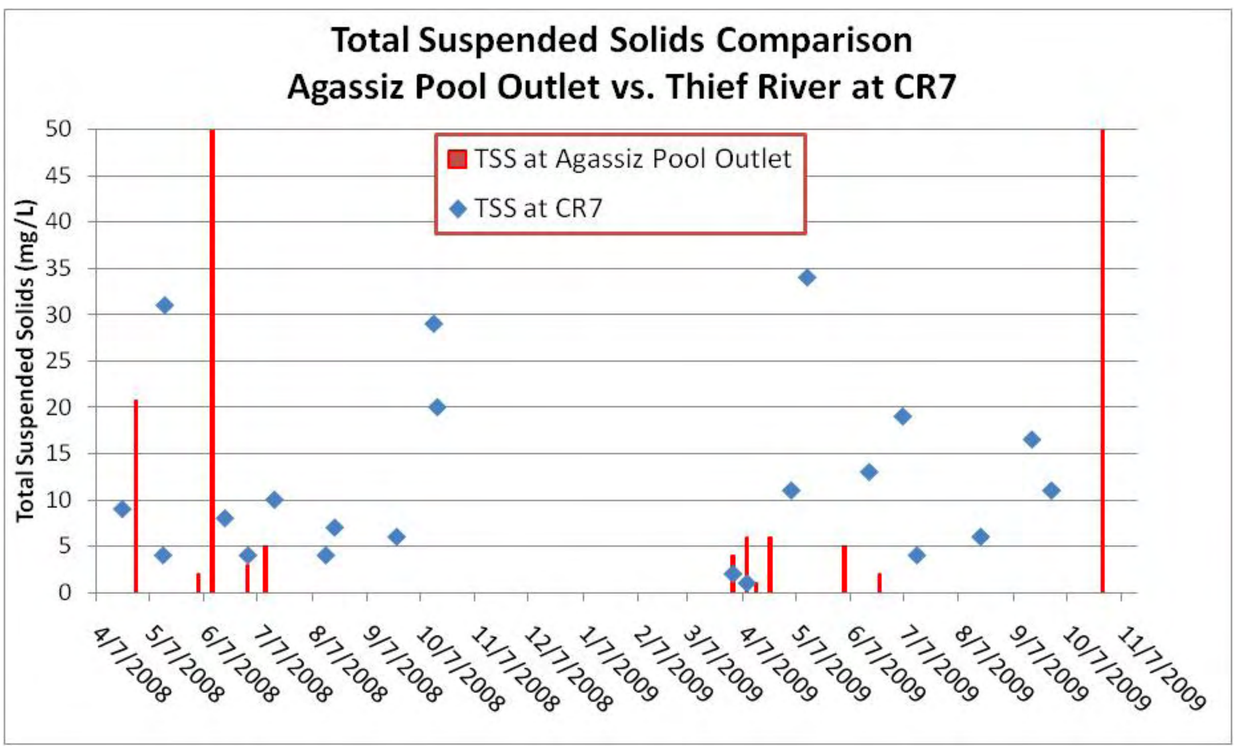
The water leaving Thief Lake is a little cloudier than the water in the upper Moose River, but has acceptably low sediment concentrations. Downstream of Thief Lake, however, the Thief River exhibits a significant increase in sediment concentration by the time it reaches Agassiz National Wildlife Refuge.

Agassiz National Wildlife is made up of a complex network of pools. The pool that receives the most attention in water quality discussions, however, is Agassiz Pool. The Thief River flows directly into Agassiz Pool from the north. Drainage from the Mud River and several branches of JD11 enter the refuge from the east. A lot of sediment is carried into the Agassiz NWR pool system by those rivers. This means that there is a lot of sediment that can be picked up and carried out of the impoundment while it is discharging.

Erosion along Judicial Ditch 11 Downstream of the Agassiz Pool Outlet

This study found that most of the time, the water coming out of the radial gate outlet of Agassiz Pool (when just the screw gate is being used) can be okay. Spikes in TSS provide evidence that opening the radial gates causes flushes of sediment because water is being pulled from the bottom of the pool. Moving water along the bottom of a pool pulls sediment along with it. Corresponding monitoring downstream during discharge, however, found elevated total suspended solids and turbidity levels. This confirmed what was obvious to an observer of the JD11 channel. The JD11 channel downstream of the Agassiz Pool radial gates outlet was actively eroding. When it was first constructed, the ditch banks and dikes along the channel contained peat soil. This soil type is highly erodible, which led to very active erosion all along the channel.

The USFWS received funding to repair this reach of JD11 and the project should be done by the end of 2010. More information on this project can be found in the "Implementation Plan" section of this report.



Agricultural BMPs are needed along State Ditch 83

The SWAT model identified sub-basins along the western side of SD 83 that are dumping a relatively large amount of sediment into the Thief River and SD83. This study documented the degradation of water quality that occurs along the Thief River as it flows from Thief Lake to Agassiz National Wildlife Refuge. With the exception of some late summer E. coli issues, the water leaving Thief Lake is relatively good. On the other end of the reach, at the northern boundary of the Refuge, the water is often very muddy. Agricultural BMPs are needed in order to reduce the amount of sediment and other pollutants that are being carried to the Thief River in ditches such as CD28, Branch 1 of SD83, Branch 3 of SD 83, and CD35. Plotting daily turbidity data from the Thief Lake Outlet and the northern boundary of the Refuge shows how much higher the turbidity is when it arrives at the refuge boundary than it is when it is leaving Thief Lake.

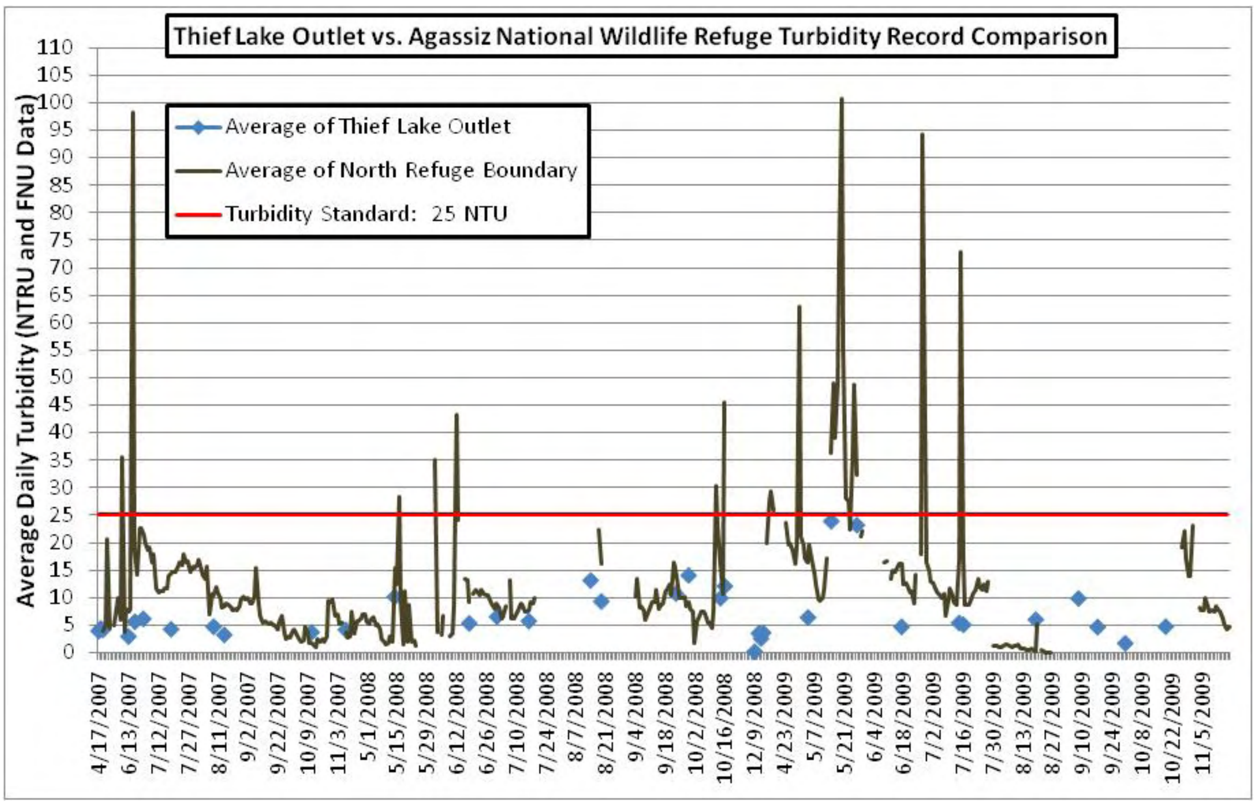


Figure 169. Turbidity at the Thief Lake Outlet vs. turbidity at the northern Agassiz NWR boundary

Implementation Plan

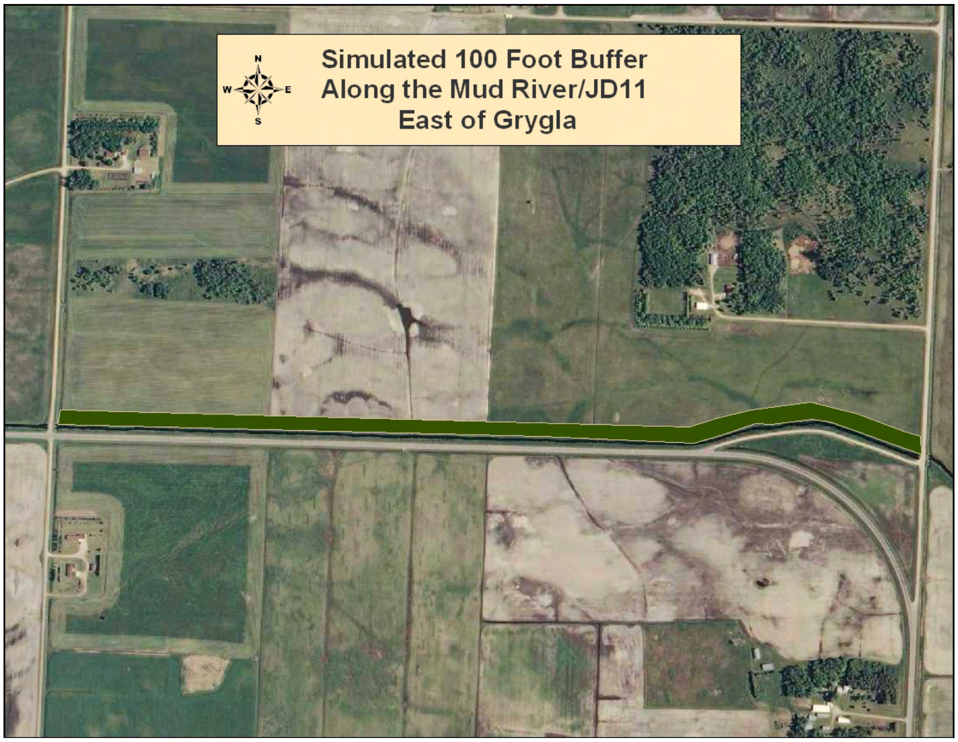
During the span of this project, many potential projects and problem areas were identified throughout the watershed. Projects were identified through reconnaissance, observations, input from stakeholders, and the SWAT model. This section will address those issues. Some of them are general and scattered throughout the watershed. Other project ideas focus upon a specific location. In addition to the projects discussed in subsequent subsections, there are a handful of general best management practices that should continue to be promoted and implemented throughout the watershed:

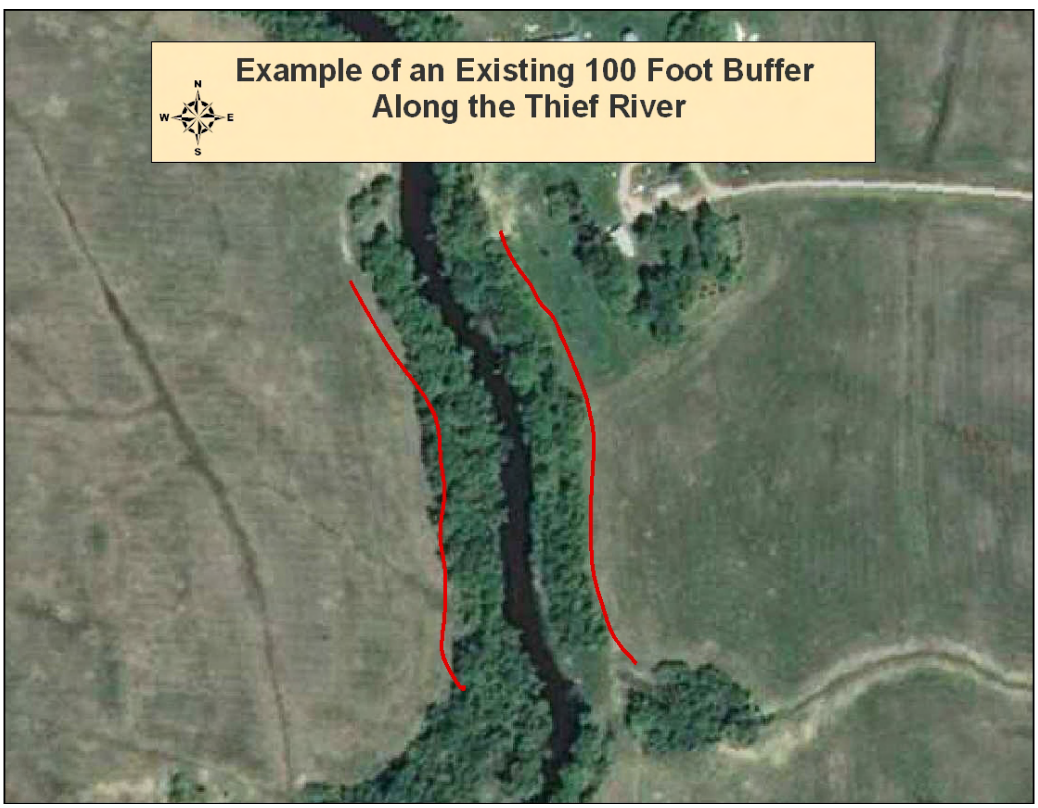
- Buffer and Filter Strip Implementation
- Grade stabilization, especially at drainage outlets.
- Streambank stabilization
- Grassed Waterways
- Residue management
- CRP, EQIP, WHIP NRCS assistance programs
- Windbreaks

Riparian Buffers

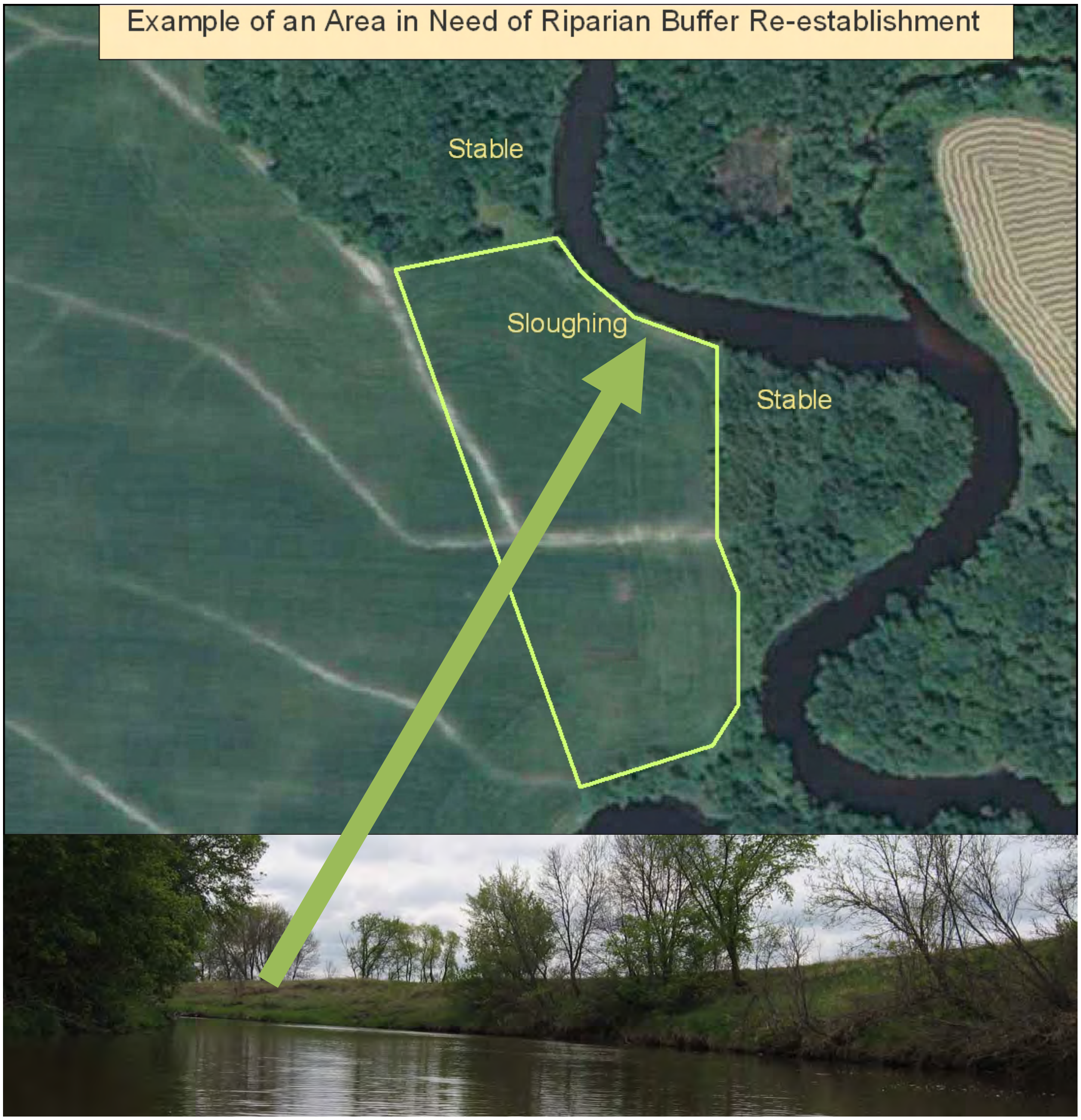
Traveling along the rivers, streams, and ditches makes a person even more aware of the importance of riparian buffers. There is a distinct contrast between neighboring stretches of streambank when one travels past a bank that is well buffered and vegetated to a bank that has had its riparian forest buffer removed. There are good examples throughout the watershed of how trees and their roots (especially willows) are doing a lot to protect the streambanks by holding soil in place. Often, these stretches of streambank are followed by stretches that have been farmed to their edge and are severely failing. The photos below show a portion of the Mud River (JD11) that is being farmed up to and into the edge of the ditch bank. This should be a priority area for the establishment of a buffer strip.

Modeling has shown that 100 foot filter strips are sufficient for water quality protection. The following photos show that a buffer of this size is not overly obtrusive.





The photos on this page show an area where trees are protecting the bank where they remain and the bank is failing where they have been removed. When traveling in a downstream direction, you see that the bank immediately begins failing and sloughing where the trees have been removed for farming. Conservation programs should be used to restore trees, brush, and native vegetation to this area. The field could be “squared-off” to allow for efficient farming and the farmer could receive compensation for the land taken out of production.



County Ditch 20 Grade Stabilization

Figure 170. Confluence of CD 20 and the Thief River/SD 83

Marshall County Ditch 20 appears to be head-cutting up to a point near the confluence with Branch 3 of CD20. The channel is incising and the banks are slumping where the toe has been eroded. The stream banks appear to be more stable upstream of this area. Willows and low brush lines the ditch banks and helps keep them stable. The amount of channel incision also decreases upstream of this reach. There still are some erosion issues where smaller ditches enter CD20. There are some spots with erosion at the outlet of the ditch. There are some other confluences where the lateral ditch is clearly dumping a lot of sediment into CD20. One spot in particular could be problematic if the sediment accumulation starts to push flow into the opposite bank and threatens the township road. Lateral ditches within the headcutting reach are also headcutting, exacerbating the problem of excess sediment being transported from this drainage area.

An inspection of CD20 reveals that there are some stability issues downstream of where the Branch 3 of CD20 (angle ditch) enters the main channel, approximately 2.5 miles upstream of the Thief River confluence. County Ditch 20 is then fairly stable for a long distance upstream of the Branch 3 confluence.

Other sources of sediment along CD20 would be gullying/headcutting lateral/private ditches and stream bank stability issues that can be found near the CSAH 54 crossing. When headcutting is occurring within the main channel of a ditch, it also causes headcutting up into the ditches that feed the main channel, unless they are stabilized with rip-rap and/or side-water inlets. An inspection of CD20 found some ditches that were headcutting. Two ditches are headcutting and gullying along the south side of CD20 upstream of the 180th Ave NE crossing of CD20. One is the road ditch and the other is a field drainage ditch about three tenths of a mile upstream of the crossing.

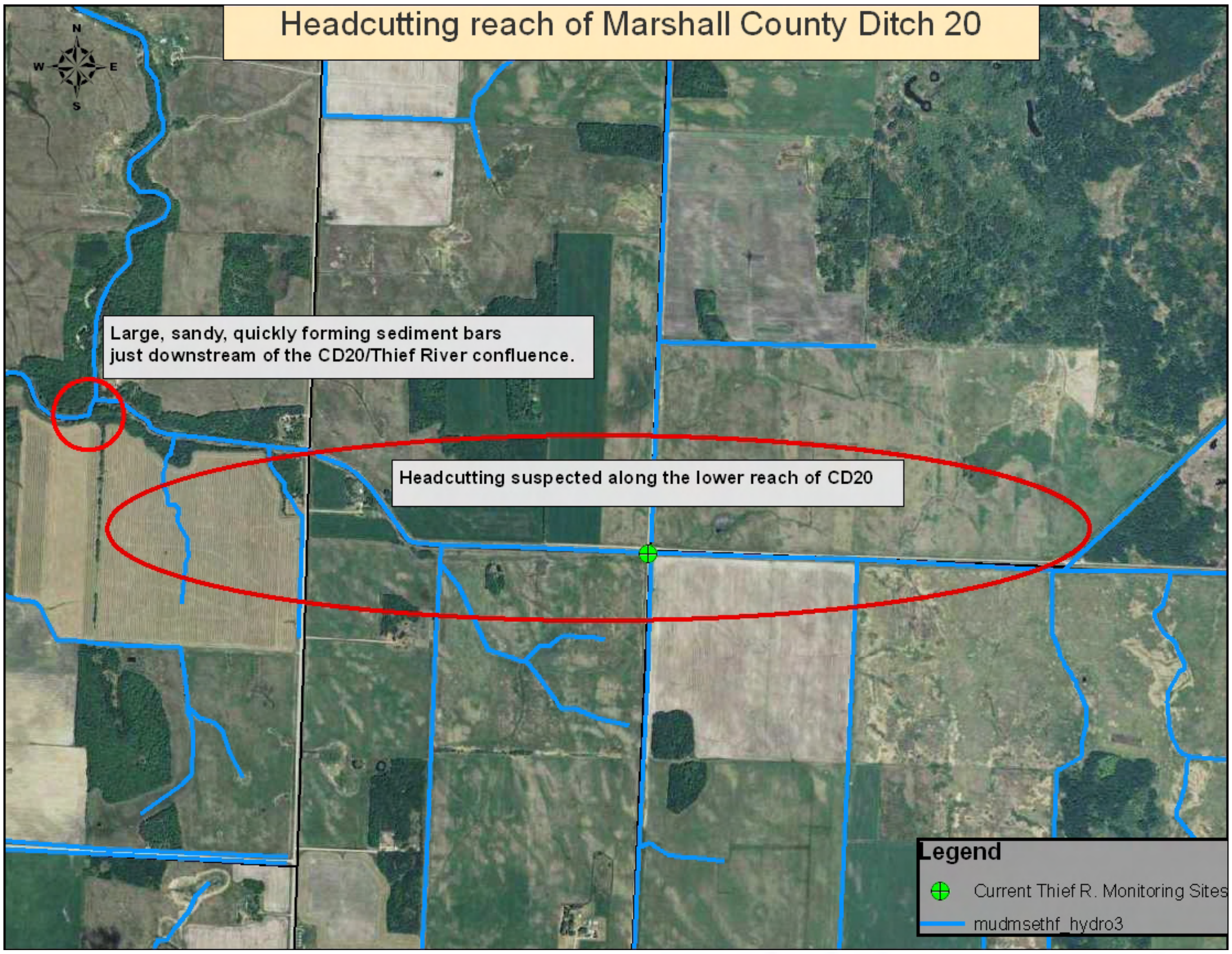
About 20 miles upstream of its confluence with the Thief River, the banks of CD20 are sandy and there are some stream bank erosion problems. There is higher shear stress on the banks and there has been some removal of vegetation. Vegetation is sparse in general and the banks get steeper. The sandy sediment from this area could be contributing to the sedimentation problem in the Thief River. Sand would be carried downstream, even if it is just part of the bedload and isn't detected by water quality sampling.

There also are some opportunities for the installation of sediment basins in some locations along County Ditch 20.

Thoughts on the CD20 project that could be used for a grant application.

- Outcomes
    - Pre-project water quality monitoring has already been done
    - Post project monitoring would be part of the TMDL study and/or a SWAG grant
    - Continuous turbidity and TSS sampling
- Prioritization
    - Impaired watershed
    - Active erosion
    - Significant benefit from the project
    - Reducing erosion and sedimentation on the Thief River is a goal in both the Red Lake Watershed District 10-year plan and in the Marshall County Water Plan
    - This will be on the list of recommended projects that comes from the Thief River Watershed Sediment Investigation project
- Readiness to Proceed
    - RLWD water quality monitoring
    - RLWD is actively maintaining the SD83 portion of the Thief River
    - Arrangement with the County for surveying
- Augmented Funding
    - County and RLWD match
- Long Term Public Benefits

- The amount of sediment loss/erosion can be quantified using Thief River Watershed Sediment Investigation data and SWAT modeling results
    - Will decrease maintenance costs of SD83
    - Will help decrease water treatment costs in Thief River Falls
    - Protection of the fishery in the Thief River and Red Lake River.
- Consistency with Source water Assessments
    - Thief River Falls Source Water Assessment document



Even where there are side inlet structures, there is a need for some stabilization near the pipe outlets.

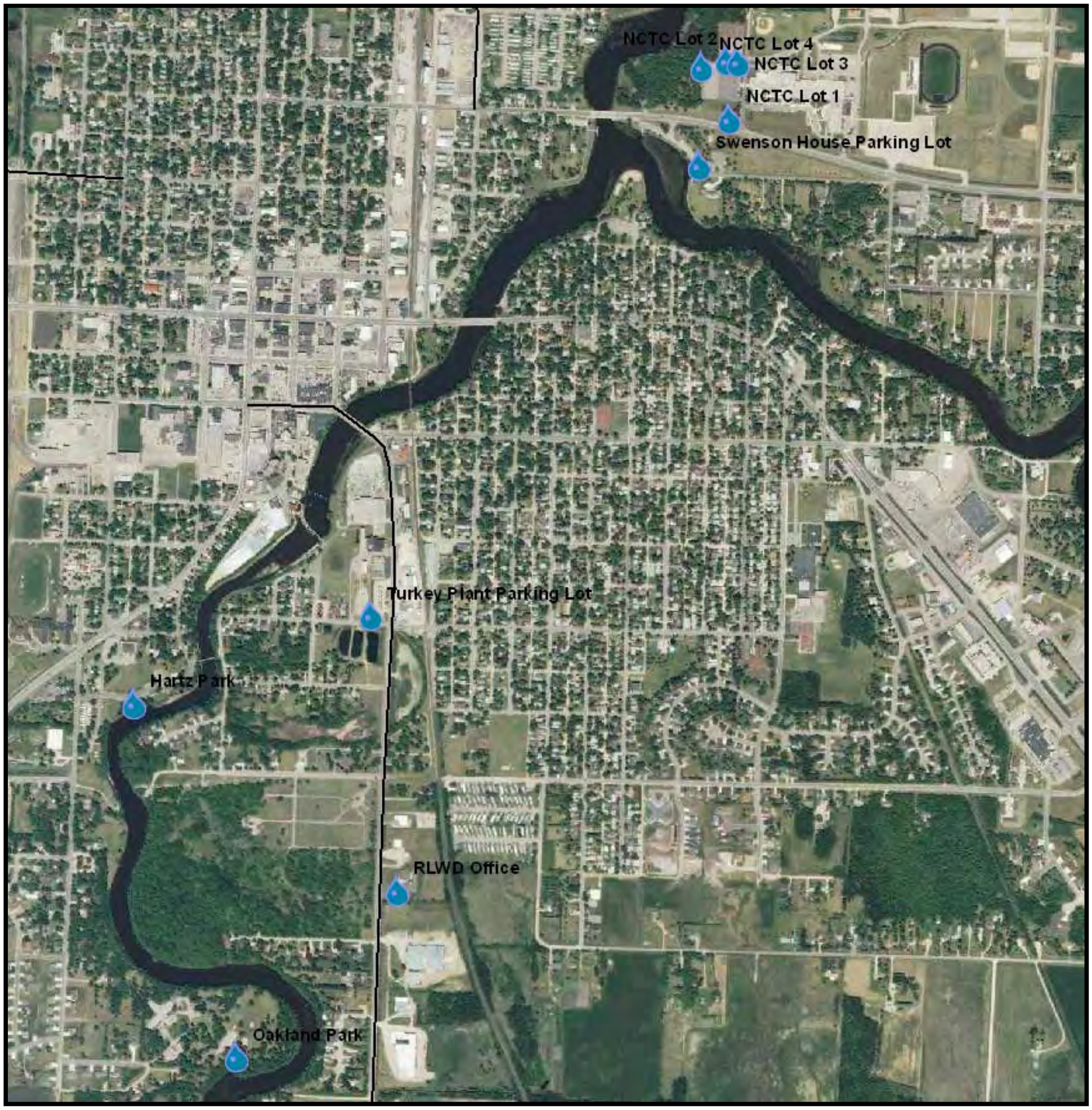
Grade Stabilization in ditches

This is an erosion reduction strategy proposed by the 1996 *Erosion sedimentation Sediment Yield Report* for the Thief River watershed. It can be used to halt the progress of headcutting, make streams and ditches more stable, and reduce the sediment contribution from stream channel erosion. When the stream channel erodes downward during headcutting, it also destabilizes the toe of the streambanks. Chunks of the streambank then start falling into the water. Also, if the main channel of a ditch or stream is headcutting, that process will extend up into its tributaries.

Figure 171. Example of a grade stabilization structure within a ditch.

Rain Gardens

Installation of rain gardens is a way to reduce stormwater runoff that is a more aesthetically pleasing alternative to stormwater ponds. There are some potential locations on commercial/public property in the City of Thief River Falls.



Several of the best potential locations for rain gardens are located near the Northland Community and Technical College. There are several locations that could capture runoff from the NCTC parking lot. Across the highway is another location that would collect runoff from the parking lot near the Swenson House. The Pennington County SWCD has identified a need for rain gardens near the Ralph Engelstad Arena in Thief River Falls to alleviate stormwater drainage problems that are occurring in that part of town.

Restoration of the Thief River north of Agassiz National Wildlife Refuge

The Thief River transitions from a relatively stable "C" channel to an unstable "F" channel near the CSAH 6 crossing. Downstream of this crossing, there is uniform scour on both sides of the dredged channel. The river/ditch is entrenched, meaning it doesn't have access to a floodplain. Without access to a floodplain, greater force and stress is exerted on the banks of the stream. The banks are actively eroding throughout the reach from CSAH 6 (instability actually starts upstream of this crossing) to the north boundary of Agassiz National Wildlife Refuge. The worst part of this section is the half mile of straightened channel upstream of the North Boundary Road (380th St. NE). The old meanders of the Thief River are still visible in an aerial view. The recommended fix to this problem is the restoration of the meanders in conjunction with setback levees to retain flood protection for the farmers. Stabilizing this reach would reduce the amount of sediment that is being transported into Agassiz Pool via the Thief River. This would, in turn, reduce the amount of sediment that can get flushed downstream during pool drawdown periods.

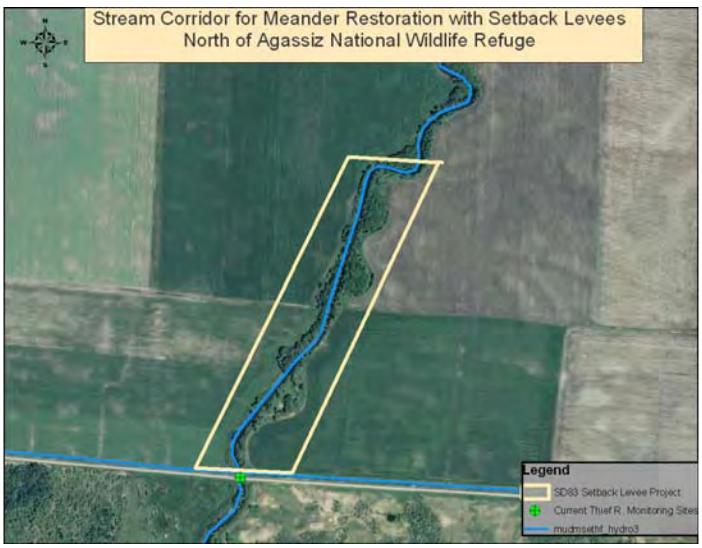


Figure 172. Thief River Restoration Project Idea

Figure 173. Examples of stream corridor restoration with setback levees and meanders.

Stabilize Cutbanks that are Threatening Homes

There are multiple places in the Thief River watershed where streambank erosion is threatening a home. One location where there is an immediate need for a project is located on the west side of the river near the Thief River Falls Golf Club. The river is now just feet from the corner of the home. The Pennington County SWCD is currently applying for grant funding to fix this erosion problem.

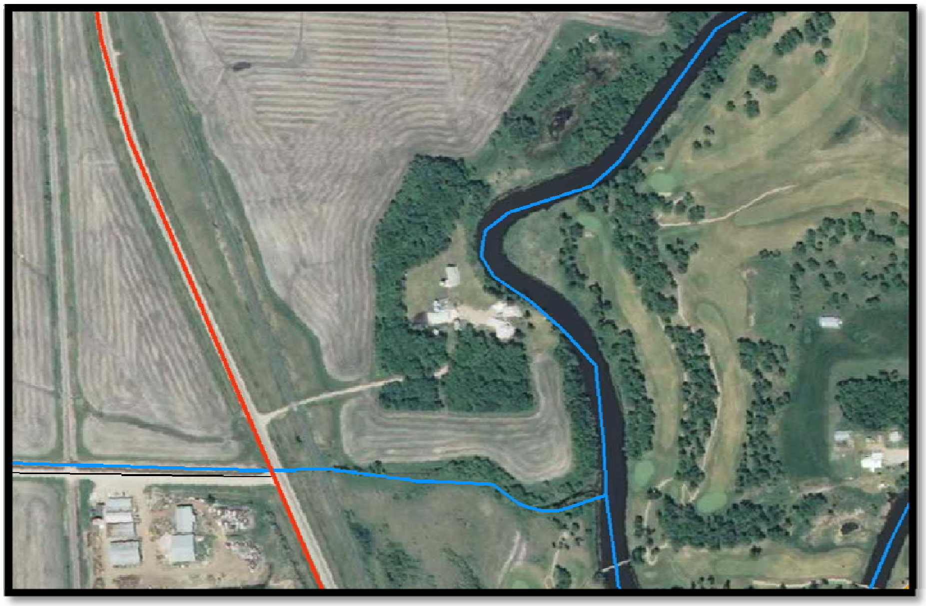


Figure 174. Aerial view of the Section 16, North Twp. home in Pennington Co. that is threatened by erosion.

Figure 175. Actively eroding cutbank nearing a home.

Agassiz Pool outlet modification and restoration

The Judicial Ditch 11 channel that carries water from the outlet of Agassiz Pool to the Thief River was unstable and contributed to sediment-related problems in the Thief River. Much of the soil in the banks of JD11 was peat, which is highly erodible. The USFWS received funding to re-construct the main JD11 outlet channel, rebuild the existing outlet structure, and construct a new outlet structure at a different location.

The new Agassiz Pool outlet structure was the first of these components to be completed. It is located in alignment with the Thief River (State Ditch 83). Water from the river enters Agassiz Pool from the north and much of it flows along the western side of the pool. The new outlet is a stop-log structure that allows much of this water to return to the main channel of SD83 without having to travel through the pool to the radial gate outlet.

The JD11 outlet channel repair project features resloping and stabilization of banks, boulders lining the bank for 100 yards downstream of the outlet, and rock riffles. The rock riffles not only stabilize the grade of the channel, but also allow for some re-oxygenation of the water after it leaves the massive wetland.

Figure 176. New outlet for Agassiz Pool (Site A5)

Figure 177. Ditch 11 - outlet construction

Figure 178. Stabilization of ditch 11 (before)

Figure 179. 2008 progress on restoration of Ditch 1

Straight pipes

E. coli bacteria problems exist on the Thief River. One way that we can minimize the impact of people upon this problem is by making sure that septic systems are in compliance along the Thief River. The amount of residential wastewater entering the Thief River is unknown, but stream reconnaissance did find a site where some form of wastewater is draining into the river.

Moose River Meander Restoration

One cause of streambank instability in the Moose River along the Moose River road is that the channel is incised and not accessing a flood plain. Without access to a floodplain, the river exerts all of its force against the stream banks. Willows on the stream banks are doing a lot to keep the banks as stable as possible. One way to stabilize the river and give it a floodplain to access is by restoring the meanders. A setback levee can be used to protect neighboring fields from flooding.

There is one reach in particular where there is potential for the construction of a meander restoration along the Moose River channel. The pre-dredging meanders are still visible and the project would have only a minimal impact upon farming operations. Much of the potential project area is not farmed. The neighboring field could be "squared off" to leave a buffer and allow the farmer to avoid having to try to farm through wet areas, as is the case currently. This project would also move the main channel away from the road throughout the reach. Grade stabilization structures may be needed on the downstream end in order to step the channel back down to the channelized grade gradually. There are several reaches where meanders could be restored. The reach pictured below could be the most feasible one to start with.

This particular reach seems to be more feasible because the loss of farmland would be minimal. Some of the land that is currently farmed appears to have drainage problems. It was very wet during the May 2010 stream reconnaissance. It is important to note that the farmer would receive compensation for any land taken out of production.

If this site doesn't work, there is another potential restoration site located upstream where the land is owned by the Minnesota Department of Natural Resources.

Figure 180. Example of a candidate area for stream channel restoration

The approach for restoring streams to provide flood damage reduction and water quality benefits, as outlined by Aadland, Jutila and Anderson in *Working Paper #5 – Stream Restoration for Flood Damage Reduction in the Red River*, includes:

1. Reconstruction of the channel using dimensions, patterns, and profiles derived from stable reference reaches in the watershed and regional reference data for stable stream reaches, or by reconnecting isolated oxbows if present.
2. Revegetating the riparian corridor and stabilizing the new stream banks by establishing bank vegetation and, where appropriate, using tree revetments or rock vanes.
3. Construction of setback levees outside of the meander belt with top elevations corresponding to a 10-year event.
4. Optional construction of off-channel storage areas outside the levees.

Aadland, Jutila, and Anderson also listed the benefits of these stream restoration projects:

1. Protection of adjacent farmland outside of setback levees for events up to a 10-year flood.
2. Elimination of flood damages adjacent to the stream by conversion to non-flood prone land uses.
3. Increased channel storage.
4. More efficient use of flood plain storage during large events as areas outside of the setback levees would be reserved for flows greater than 10 year stage.
5. Reduction or elimination of maintenance costs due to stable channel design and the ability of the channel to move incoming sediment.
6. Restoration of diverse aquatic habitat for fish, mussels, and other invertebrates, amphibians, reptile3s, birds, mammals, etc. The restored channels would provide riffle/pool sequences and a variety of instream habitats which are key to the productivity and diversity of aquatic communities.
7. Restoration of wetland and wooded riparian habitat associated with the river corridor. This would provide habitat connections for deer, small game, song birds, and numerous species which depend on these migratory pathways. This corridor would eventually provide harvestable timber, old growth, and snag habitat for both aquatic and terrestrial species.
8. Substantially reduced bank erosion, sediment supply, and soil loss.
9. Improved water quality due to reduced erosion and buffered field runoff.

Side-Inlet Controls

Gully formation at the outlets of field ditches is a significant source of sediment in the rivers, streams, and ditches throughout the watershed. While some sediment may pass through the culverts, they also keep a lot of sediment in the field that would have otherwise washed into the stream. Erosion can occur around the outlet of the side-inlet control pipe, so it is helpful to protect the bank around the pipe with rock. Side-inlet control structures are installed at low points along ditches. The benefits of these structures include:

- Reduced peak flows through temporary storage of water on the land
- Reduced sediment delivery by allowing sediment to settle-out of runoff before it enters a ditch or stream.
- Reduction in nutrient loads due to the reduced sediment loss.
- Reduced stream erosion association because of the reduction in peak flows.
- Preserved productivity.

The Thief River SWAT model completed by Houston Engineering modeled the effects of installing side-inlet control structures throughout the watershed. "Adding partial side-inlet controls has a substantial effect in reducing sediment yields from many sub-basins. Fully-implementing side-inlet controls does little to reduce yields compared to partial implementation."

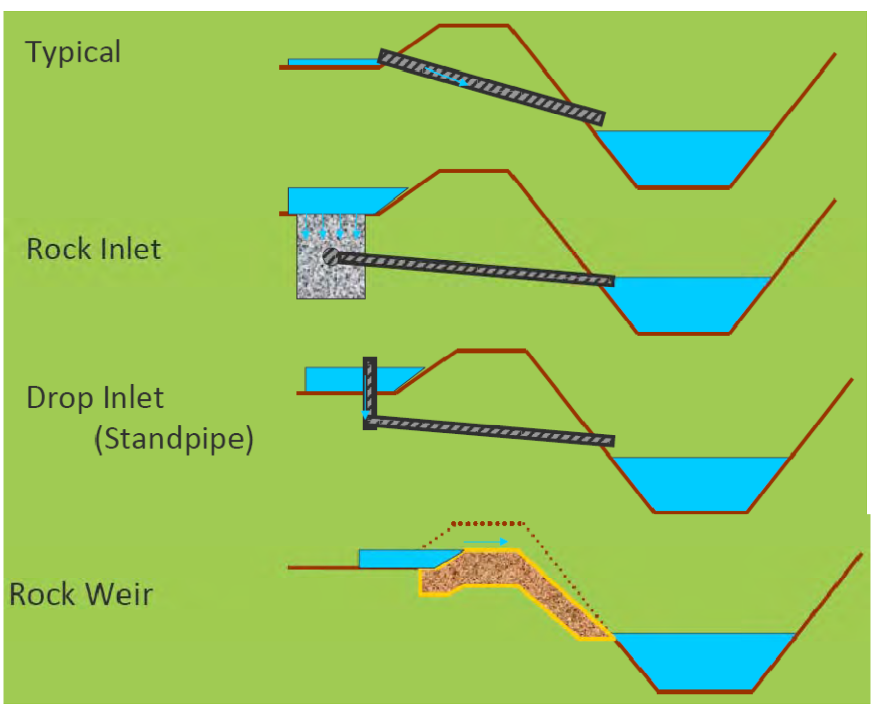


Figure 181. Types of side-inlet control structures (from the Minnesota Board of Water and Soil Resources)

Sedimentation Basins

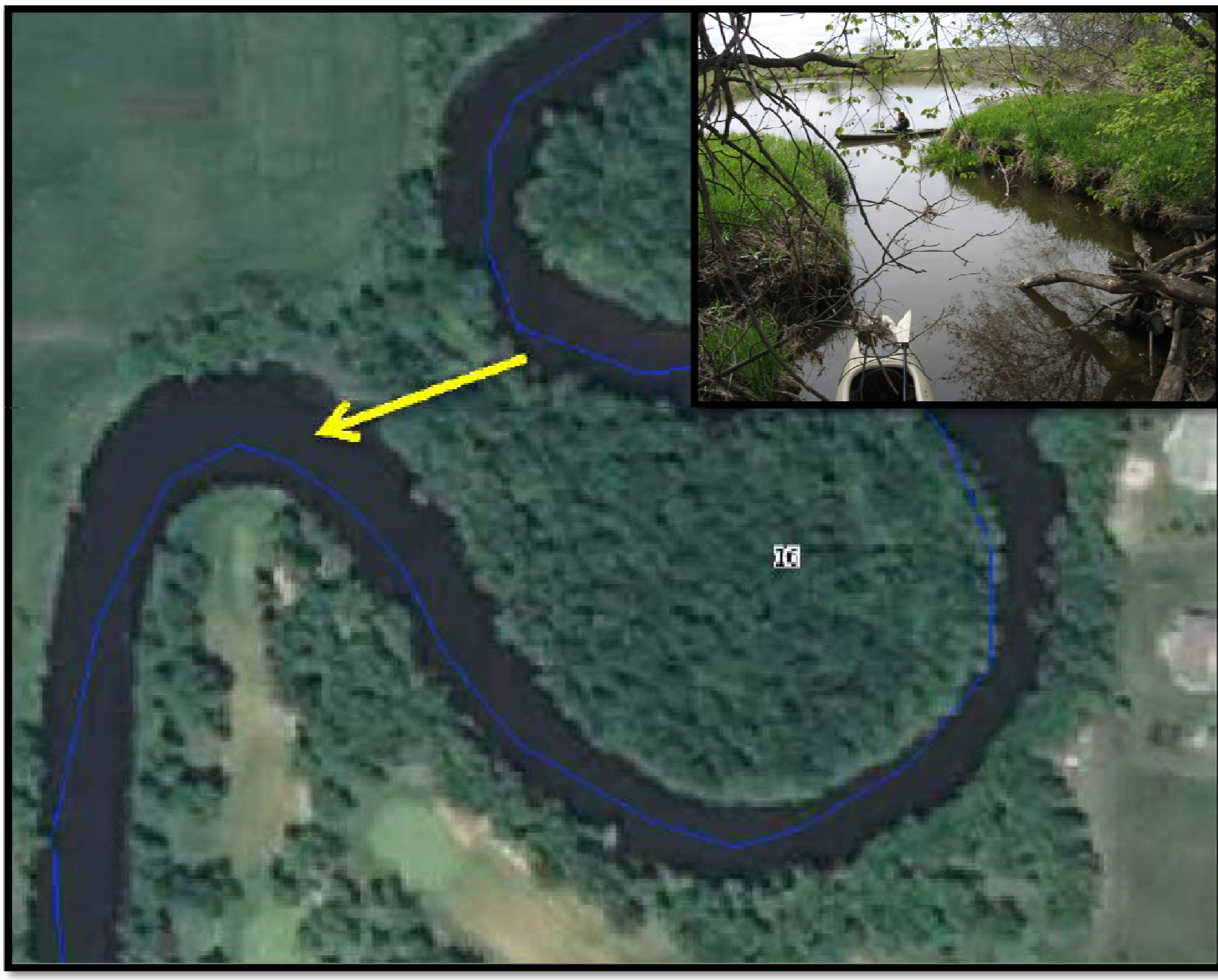
An erosion control practice that has been implemented within the Thief River watershed in the past is the installation of sedimentation basins. For example, the Marshall-Beltrami Soil and water Conservation District installed this type of structure on the lower end of a field along the Moose River that had problems with gully erosion during storm events.

Grazing Management

Cattle with unrestricted access to a stream will exacerbate turbidity and E. coli problems by destabilizing streambanks and defecating in the water. Runoff from feedlots and heavily pastured areas will carry harmful E. coli bacteria into the water and increase turbidity. Grazing management typically involves fencing along the river, alternative water sources, stream crossings, and runoff management. The exclusionary fencing creates a buffer along the stream and, combined with runoff management in feedlots, helps filter pollutants and keep them out of the stream. Cattle remove vegetation and vegetation is critical to streambank stability. The following photo is an example of the immediate steam instability that occurs in an area with cattle. The streambanks are bare, so they become more erodible. The stream widens and gets shallower.

Halt Progress of a Meander Cut-off

Across the river from the northwest end of the Thief River Golf Club, there is a gully forming across the narrow part of a meander in the stream. This cut-off channel may have been forming for a few years, but it is now more noticeable. During May 2010 river reconnaissance, there was only about 5 feet of ground separating water standing in the upstream and downstream portions of the cut-off channel. So, why is this significant? If the stream cuts across at this point, erosion will be increased directly downstream and the slope of the channel will be increased for a distance upstream. Increasing the slope of the channel will lead to more unstable streambanks.



Remove a Log Jam and Stabilize a Streambank on the Mud River

During the May 2010 stream reconnaissance on the Mud River, an erosion spot was discovered that appears to have been initiated by a fallen tree. This large tree caused a log jam in the stream. The stream has blown out the eastern stream bank at this location as flow was redirected by the debris jam. There also is a deep hole on the downstream side of the debris pile.

Thief River Watershed Assessment Project (Watershed-Based TMDL) Workplan

One of the main goals of this project was to prepare for the completion of an official TMDL study not only by collecting much of the data that is needed for a TMDL, but also by writing a TMDL work plan for the watershed. At the beginning of this project, most TMDLs were being addressed on a reach-by-reach and impairment-by-impairment basis. The State is transitioning to a watershed-based TMDL process in which there is a more comprehensive assessment of the watershed and all the assessed reaches and parameters are addressed in one study. Largely because of the extensive data collection and other work already done for this Clean Water Partnership study, the Thief River Watershed Watershed Assessment Project (the name given to the watershed-based TMDL study and the additional work that will be associated with it) was given high priority and funded by the MPCA for the 2010 funding cycle. A work plan was written for this new project under the "Develop Impaired Waters Study Work Plans" objective of the Thief River Watershed Sediment Investigation.

RLWD staff attended watershed-based TMDL planning meetings at the Detroit Lakes MPCA office. RLWD staff also identified stream/ditch reaches that will need to be monitored as part of the watershed-based TMDL and/or Surface Water Assessment Grant project. Surface Water Assessment Grant funding will be sought to pay for the monitoring needed for re-assessment and verification of impairments for the 2011 and 2012 monitoring seasons. SWAG monitoring would then coincide with the MPCA's intensive watershed monitoring program's monitoring that will be taking place in the Thief River Watershed in 2011.

Project Activities and Schedule

Project activities will be directed by the Red Lake Watershed District (RLWD) Water Quality Coordinator and the Minnesota Pollution Control Agency (MPCA) Project Manager. This project will be accomplished through cooperation among the RLWD, MPCA, Minnesota Department of Natural Resources (DNR), stakeholders, United States Geological Survey (USGS), United States Fish and Wildlife Service (USFWS), Marshall County Water Planner, Pennington County Soil and Water Conservation District, and others. Decisions will be guided by the MPCA Project Manager, RLWD Board of Managers, a technical advisory committee, and stakeholders. This project is based on the watershed-based TMDL development methods. This pilot project will go beyond a basic TMDL study to be a comprehensive assessment of the watershed. It will provide the information for TMDLs on both current and future impaired reaches.

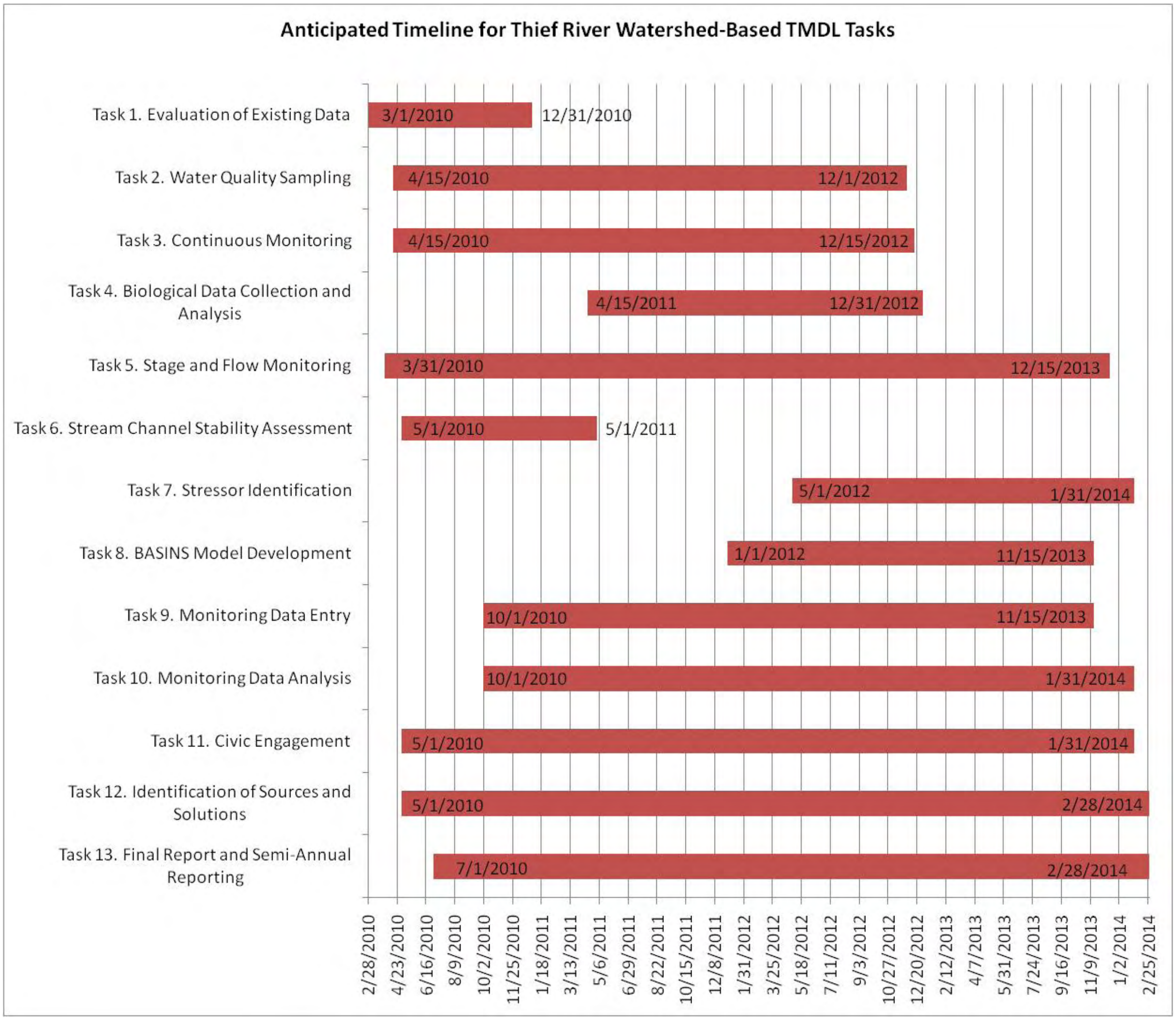


Figure 182. Anticipated Timeline for the Thief River Watershed-Based TMDL

Task 1. Evaluation of Existing Data

A large amount of data has been collected within the Thief River watershed by the Red Lake Watershed District, Marshall County Water Planner, Pennington SWCD, USGS, USFWS, and the Grygla River Watch condition monitoring programs. Intensive monitoring was conducted throughout the watershed during the Thief River Watershed Sediment Investigation and the coinciding Agassiz National Wildlife Refuge Water Quality Study (USFWS/USGS/RLWD). Much of this existing data will be compiled, assessed, and analyzed during the final stages of the Thief River Watershed Sediment Investigation Clean Water Partnership project. One of the first tasks of this watershed assessment will be too inventory the data we have and to form a strategy for filling in the gaps where more data is needed. An inventory of this data will be compiled and shared with the MPCA and stakeholders.

LIDAR (**Li**ght **D**etection **A**nd **R**anging) data and maps will become available for the watershed sometime during the early phases of the project. It will be used where possible for mapping, watershed delineation, and/or modeling. The area has been flown and the data is being processed. The data should become available sometime in 2010.

A significant portion of this phase can be accomplished with funding available to the Thief River Watershed Sediment Investigation. Some preliminary examination of possible monitoring gaps had to be done to plan the watershed-based TMDL. A thorough gap analysis will be conducted for the watershed that will look for gaps in the spatial properties of the current monitoring network, temporal aspects of existing monitoring data, and the parameters that have been sampled.

Task 2. Water Quality Sampling

A large amount of data has been collected within the Thief River watershed from regular condition monitoring programs and for the Thief River Watershed Sediment Investigation CWP project. However, the scope of these projects did not include every assessment unit within the Thief River watershed. So, there will need to be some additional monitoring to assess the significant waterways that have insufficient data and to verify existing assessments. To establish a TMDL for each reach, the data collection will need to go beyond the minimum amounts needed for assessment. Confident calculation of TMDLs relies upon a good flow record, collection of continuous data from deployed sondes (for some parameters), sampling for potential stressor pollutants, stressor identification, modeling, and more.

The monitoring effort conducted for this project will be part of an iterative (multi-stage) process. The three years of sampling conducted for the Thief River Watershed Sediment Investigation will serve as the first iteration. The initial monitoring for the assessment will fill data gaps that are found during a review of the existing data and continue the condition monitoring that is currently underway. The data from the first two iterations will be used to assess the waterways and subwatersheds. Some sampling may be needed to aid the stressor identification process. This will be the third iteration.

Much of the existing data was collected for the purposes of assessments and load determinations. During the stressor identification phase of the project, new monitoring sites may need to be established to collect data and evidence to support or eliminate suspected sources. Monitoring will likely need to go beyond condition monitoring at pour points to include the collection of some longitudinal profiles of dissolved oxygen, turbidity, and pollutants.

The RLWD may subcontract with the Marshall County SWCD and Pennington County SWCD for some of the water quality sampling. The Thief River is a priority watershed for the 2011 round of Surface water Assessment Grants. The work plan budget is based on the assumption that money will be available from the SWAG program for the 2011 monitoring season.

Monitoring Site Locations

Monitoring sites will be located in each of the sub-basins identified for this project. Some of the more lengthy reaches may require more than one monitoring site for a comprehensive assessment and/or stressor identification.

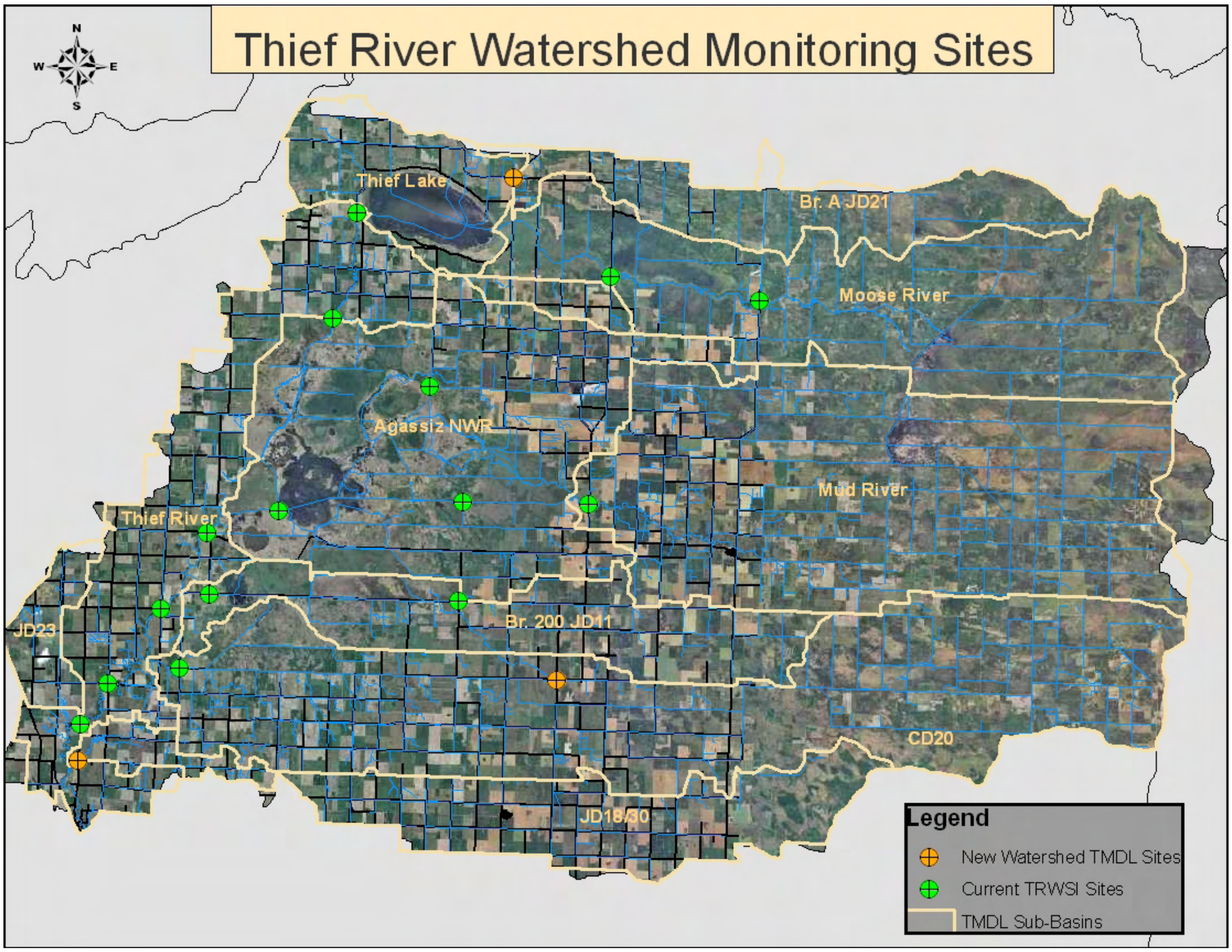


Figure 183. Potential Monitoring Site Locations and assessment sub-basins

Task 3. Continuous Water Quality Monitoring

Continuous water quality monitoring will be used to review and verify assessments of dissolved oxygen and turbidity. Continuous monitoring is very important because the true daily minimum dissolved oxygen concentrations occur in the early morning, prior to working hours.

Continuous monitoring of turbidity will also provide a high resolution record of turbidity values. Runoff events and the duration of their effect will be documented. Spot measurements may be sufficient to provide the minimum number of data points technically needed to assess a stream. However, it is important for TMDL projects to minimize uncertainty. Continuous turbidity monitoring certainly does minimize the uncertainty of aquatic life support assessments.

Continuous monitoring has been conducted at five sites in the Thief River watershed by the RLWD and at six additional sites through the cooperation of the USGS and USFWS. This study will expand this monitoring to the remaining subwatersheds in the watershed. The project budget sets aside funds for the purchase of an additional sonde. Highest priority for sonde installation will go to the sites on newly monitored reaches and to the USGS gauging site. If additional equipment funding becomes available, a greater number of sites can be monitored simultaneously. This study focuses on loading during the months in which water quality standards are applicable. Multi-parameter sondes will be deployed during the months of April through October (turbidity). Sites that do not have multi-parameter sonde deployments may have dissolved oxygen logging equipment installed.

Dissolved oxygen logging can be limited to summer months. For the 5-month period of May through September, the MPCA no longer considers spot measurement taken after 9 am to represent daily minimums. Therefore, sites that are being continuously monitored for only dissolved oxygen and stage will have dissolved oxygen monitoring equipment deployed during May, June, July, August, and September.

The duration of the continuous monitoring effort for this study has been budgeted at two years. The RLWD will work with local MPCA staff to get the continuous monitoring data entered into the State's HYDSTRA database.

Equipment Purchases

The Red Lake Watershed District possesses all of the equipment needed for regular spot sampling and field measurements of water quality parameters. This includes a portable Eureka Manta multi-parameter sonde, handpad, horizontal water sampler, survey rod, measuring tape, HACH 2100P portable turbidimeter, transparency tubes, sampling bottles, and coolers. The RLWD also owns flow measurement equipment that includes wading rods, current meters, AquaCalc 5000 digital readout, and bridge cranes. Much of the continuous monitoring equipment needed for this TMDL study was purchased and utilized during the Thief River Watershed Sediment Investigation Study. HOBO water level loggers will be used to collect stage records. Five Eureka Manta multi-parameter logging sondes, five pairs of Eureka Midge dissolved oxygen loggers, an In-Situ TROLL 9000, and a pair of In-Situ TROLL 9500 multi-parameter sondes are available for this study. There are several sub-basins for which continuous monitoring as not yet been collected. Additional equipment and/or relocation of equipment will be needed in order to meet the data needs for these sub-basins.

PVC pipe, cable, and other hardware will be needed throughout the course of this study to keep continuous monitoring equipment deployed during the open-water months. A data gap encountered during previous monitoring has occurred during very high flows on the main channel of the Thief River. The existing deployment pipes will have to be modified to allow safe access to the pipes during high flows.

Depending on funding, it may be necessary to move continuous monitoring equipment from current sites to the sites that need continuous data. Some of the existing continuous monitoring equipment should remain in-place. The Thief River USGS gauging site should have the highest priority for staying in-place. In-Situ TROLL 9500 sondes will be used to monitor dissolved oxygen in the Moose River, where turbidity has not been a concern.

Task 4. Biological Data Collection

Biological monitoring will be conducted to identify reaches within the Thief River in which the biota is being impacted. Fish communities, aquatic invertebrate communities, and habitat will be evaluated. Biological data will be interpreted through the calculation of an Index of Biological Integrity (IBI). An IBI compiles an assemblage of measured characteristics (metrics) of biological communities to describe the environmental condition. It is good to combine the metrics into an overall IBI score because different metrics describe different forms of disturbance and human influence. An assessment of physical stream habitat is also important for achieving an integrated assessment of stream water quality conditions.

Station features, including water chemistry are assessed further using the worksheets found in the MPCA's *Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites* document.

The biological data collection, compilation, and IBI calculation for the Thief River watershed-based TMDL will be conducted by the MPCA biological monitoring unit, with some assistance from RLWD staff. This monitoring effort is planned for 2011. Fish results are typically ready in the late fall following the summer sampling period. The invertebrate results are usually completed in the late summer or early fall of the following year.

Task 5. Stage and flow monitoring

Having a flow record is critical for determining total maximum daily loads. Creation of a simulated flow record with a hydrological model is possible, but adds more uncertainty to the TMDL results. The RLWD, USGS, and the DNR will monitor stage and flow throughout the watershed. The majority of these sites will be located at the pour points of the watersheds or at the closest location to that point that allows for the establishment of a reliable flow rating curve. A minimum of two years of flow data will be collected at each site.

Flow rating curves have been developed as part of the Thief River Watershed Sediment Investigation project. As the USGS does at its sites each year, these sites should be re-visited to refine the existing rating curves and verify that they are still correct. Flow should be measured at multiple points throughout the range of flows at the sites with existing rating curves. There will also be several sites that have not yet been monitored and that will need completely new rating curves developed. These new sites are located on ditches. The uniform channels in the ditches should allow for easy creation of reliable flow rating curves.

Stage is mostly being recorded continuously using Onset HOBO water level loggers. A USGS gauging site is located on the downstream end of the watershed. Flow data will need to be compiled and analyzed when determining the TMDLs and creating load duration curves.

Task 6. Stream Channel Stability Assessment

Erosion and sedimentation are significant problems within the Thief River watershed. Truly understanding theses problems will require an understanding of how these process are being affected by stream channel morphology within the watershed.

The Thief River was dredged to provide agricultural drainage. The dredged portion of the river then became a legal drainage system called State Ditch 83. Dredging a waterway is a disturbance. The spoil banks along the river and the increased depth of the channel separate the river from its floodplain. After such a disturbance, the morphological processes of degradation and aggradation work to return the river to a state of equilibrium.

Will this equilibrium ever be possible in the Thief River? Do the ditch maintenance, removal of trees, and removal of sediment bars have an effect on channel evolution (positive or negative)? How does the impoundment and discharge of water affect channel evolution? These are some of the questions that will need to be answered by an assessment of stream channel morphology on the Thief River.

Minnesota Department of Natural Resources staff are the most knowledgeable professionals on this subject within the Red River Basin. Dave Friedl and Tom Groshens will be the main contacts for making sure that this work is accomplished.

Watershed Assessment of River Stability and Sediment Supply (WARSSS) is a three-phase technical framework of methods for assessing suspended and bedload sediment in rivers and streams. Although the WARSSS process also looks at overland erosion processes, the work done for this project will focus on the in-channel components of WARSSS.

- BANCS model using **B**ank **E**rosion **H**azard **I**ndex, and **N**ear **B**ank **S**tress.

- Predicting and validating stream bank erosion rates in feet of eroded bank and tons of sediment per year.

- Prediction of river stability (vertical and lateral) with channel stability indices including riparian vegetation, degree of incision, succession state, sediment competence, sediment capacity, debris/blockages, depositional patterns, meander patterns, degree of confinement, bank height ratios, BEHI/NBS, and Pfankuch channel stability.

An early summer reconnaissance is planned for 2010. The actual geomorphology work is planned to take place in August of 2010 as a combined effort among DNR staff, RLWD staff, and others. It will likely take two weeks to complete the geomorphology work.

Task 7. Stressor Identification

The exact actions taken during this phase of the TMDL will be influenced by the findings of the previous actions. It will be important to factor the water quality, biological, and morphological data together. While the application of the stressor identification process to the Thief River watershed may not include every form and step detailed in the EPA's Stressor ID document, it will be important to employ the basic steps of the process.

1. List candidate causes of impairment.
2. Analyze the evidence.
3. Characterize the causes.

From the beginning of the project, there will need to be a monitoring effort designed to identify the stressor and pollutants that are influencing dissolved oxygen in the watershed. This means that Biochemical Oxygen Demand (BOD) will need to be added to the suite of parameters being sampled. Ideally, these pollutant samples should be collected as early in the morning as possible and while there is a continuous dissolved oxygen logger installed in the stream. The pollutant concentrations can then be correlated with the daily minimum dissolved oxygen concentrations.

The RLWD will work with MPCA staff to find the best feasible application of the Stressor ID method for the impairments that are found within the watershed.

Task 8. BASINS Model Development

BASINS is a multipurpose environmental analysis system designed for regional, state, and local agencies that perform watershed and water quality-based studies. The acronym BASINS stands for Better Assessment Science Integrating point and Nonpoint Sources. This system makes it possible to quickly assess large amounts of point and non-point source data in a format that is easy to use and understand. Installed on a personal computer, BASINS allows the user to assess water quality at selected stream sites or throughout an entire watershed. This invaluable tool integrates environmental data, analytical tools, and modeling programs to support cost-effective approaches to watershed management and environmental protection, including the development of Total Maximum Daily Loads (TMDLs).

A Soil and Water Assessment Tool (SWAT) model for the Thief River watershed will be completed by April 2010. Ideally, this data should be incorporated into the BASINS model. RLWD staff will coordinate with modeling staff in the Detroit Lakes MPCA office to accomplish this task and make sure that the MPCA's goals are met. Mike Vavricka (Detroit Lakes MPCA office) has the responsibility of developing the BASINS models for watersheds in the Red River Basin, including the Thief River. Modeling is planned to begin near the conclusion of the monitoring effort so that quality of the dataset available for the model will be as high as possible.

Task 9. Monitoring Data Entry

Monitoring data will be entered and stored in the RLWD water quality database and will be submitted to the MPCA for entry into the STORET database (or its replacement) using the most recent version of the MPCA's data entry template. After STORET submittal, the final STORET data is returned to the manager of the monitoring project for a data review. As part of this data review, the RLWD will compare a minimum of 10% of the records to the original field data sheets and laboratory reports as a quality assurance measure.

The Red Lake Watershed District will enter spot measurement water quality data into a spreadsheet format suitable for entry into STORET. For each year, the MPCA requests that data is submitted to STORET before November 1st. The most current version of the STORET entry spreadsheet template must be used when submitting data to the MCPA. This template Microsoft Excel file can be found on the MPCA's STORET website: http://www.pca.state.mn.us/water/storet.html. Metadata forms for new sites need to be completed and submitted to the MPCA by June of each calendar year.

After corrections have been made to the continuous monitoring records, they will be formatted for entry into the HYDSTRA database and submitted to the local HYDSTRA data manager (Bruce Paakh, Detroit Lakes MPCA office).

Task 10. Monitoring Data Analysis

Water quality data and flow data will be used in the development of the TMDL and verifying water quality assessments. Continuous water quality records will need to be compiled from the data files collected after each deployment. Fouling and calibration drift corrections will need to be applied. The RLWD has acquired software that will help make this task more efficient. Continuous dissolved oxygen records will be analyzed to find the daily minimum dissolved oxygen concentration for each day for which data exists. Continuous turbidity records can be analyzed to get a record of daily average values. Sampling results and spot-measurement of water quality can be used to conduct water quality assessments. Continuous water level records will need to be translated into stage records and flow records.

Task 11. Civic Engagement

Public participation, education, outreach, and involvement will help assure supporters and participants e that this watershed study results in positive change in the Thief River watershed. TMDL guidelines require that public outreach and education activities are conducted at key points throughout the project and prepare a report or a section of the draft TMDL that describes those activities.

There are several possible topics of disagreement within the watershed:

- Drainage vs. storage
- Flood storage vs. waterfowl habitat
- Drainage capacity vs. aquatic/riparian habitat
- Drainage capacity vs. stream channel stability
- Local government vs. higher government
- Landowners' rights vs. regulations

Because of these opposing views, a facilitator will likely be needed to keep meetings on track and on focus. It will also be important to inform as many stakeholders as possible about what TMDL development will mean to them.

The MPCA is developing a civic engagement manual designed to improve the public participation process and engage citizens and stakeholders as partners in watershed planning. The guidelines in this manual will be used to put an emphasis on the engagement in civic engagement. The goal is to improve the stakeholders' level of involvement and sense of ownership in the resource. The stakeholder involvement process will be more beneficial if this civic engagement process is followed and stakeholders feel that their input is appreciated. It is just as important to hear the experiences and knowledge of the stakeholders as it is to provide educational presentations for the group.

The Clean Water Council is in the process of developing a multi-media toolbox of civic engagement resources for the MPCA. This interactive planning tool will be utilized by the RLWD to:

1. Assess the capacity of Thief River watershed communities for civic engagement
2. Utilize guidance and procedures for encouraging civic engagement throughout the TMDL study development process.
3. Utilize applicable and important academic research materials regarding what is effective in engaging citizens and changing behaviors.
4. Look for opportunities to apply the creative new ideas and practices that will be included in the toolbox.
5. Model activities after the narratives and success stories that will be included in the toolbox.

Potential participants will be contacted via email, direct phone calls, letters, and public notices in local newspapers.

Meetings will be held at milestones in the TMDL study process, which may include one of the following, or a combination of several:

1. Project kickoff meeting. This meeting will be used to inform stakeholders about the goals of the project.
2. Results of the assessment of existing data. Define data gaps. Guide the development of a monitoring plan.
3. Basin modeling results
4. Final monitoring results
5. Develop strategies for expanding citizen monitoring
6. Identification of sources
7. Identification of strategies and solutions to the water quality problems.
8. Total Maximum Daily Load allocations

A steering committee will be convened periodically to guide the overall direction of the project and plan meetings. This committee will include:

- Jim Courneya, MPCA Project Manager
- Corey Hanson, Water Quality Coordinator, Red Lake Watershed District
- Molly MacGregor, MPCA Red River Basin Coordinator
- A citizen stakeholder
- Several other representatives of local government
    - DNR
    - Pennington County Water Planner
    - Marshall County Water Planner
    - Bruce Paakh, RRB Monitoring Coordinator
    - Mike Vavricka, BASINS modeler

The RLWD will coordinate with the MPCA and participate in the formal public notice process for the draft TMDL, which typically includes:

- Organizing a public meeting for the draft TMDL and compiling comments from the public.
- Responding to comments, as needed, on the draft TMDL from technical staff, citizens and other interested parties, and EPA.
- Submitting public outreach materials if developed along with the draft TMDL or final report, such as charts, graphs, modeling runs, fact sheets, presentation materials, maps, etc.

Table 14. Stakeholders and Contacts

Name	Association/Title	Address	Phone	E-mail
Anderson, Maggie	Refuge Manager, Agassiz National Wildlife Refuge	Agassiz NWR 22996 290th St. NE Middle River, MN 56737-9754	218-449-4115 x202	Margaret_Anderson@fws.gov
Aune, Lon	Marshall County Highway Dept.	447 S. Main St. Warren, MN 56762	(218) 745-4816	Lon.Aune@co.marshall.mn.us
Barron, Donald	Clearwater Rice/Pennington Co./Retired Soil Scientist	103 Marley Ave. S. Thief River Falls 56701	(218) 681-3684	gbarron@mncable.net
City of Grygla		Grygla Civic Building 219 West Beltrami St P.O. Box 76 Grygla, MN 56727	218-294-6292	cityofgrygla@gvtel.com
Coe, Lee	Red Lake Watershed District Board of Managers - Beltrami County	3948 Nebish Road NE Tenstrike, MN 56683	218-243-2597 (home), 218-556-8061	leecoe@paulbunyan.net
Courneya, Jim	MPCA Project Manager	714 Lake Ave Ste 220 Detroit Lakes 56501	218-846-8105	Jim.Courneya@pca.state.mn.us
Dwight, Brian	Board Conservationist, Minnesota Board of Water and Soil Resources	701 Minnesota Avenue, Suite 234 Bemidji, MN 56601	(218) 333-8027	brian.dwight@bwsr.state.mn.us
Dyrud, Loiell	Citizen	23484 150th Ave NE Thief River Falls, MN 56701	218-681-6964	
Friedl, David	Clean Water Legacy Specialist, Minnesota Department of Natural Resources	1509 1st Ave N Fergus Falls, MN 56537	218.739.7576 x264	david.friedl@dnr.state.mn.us
Groshens, Tom	DNR Fisheries - Bemidji Red River Fisheries Specialist	6603 Bemidji Ave. N. Bemidji, MN 56601	(218) 308-2365	tom.groshens@dnr.state.mn.us
Grygla Eagle Newspaper				grygla.eagle@gmail.com;
Hanson, Corey	Red Lake Watershed District, Water Quality Coordinator	1000 Pennington Ave S. Thief River Falls	(218) 681-5800; cell 218-686-9691	coreyh@wiktel.com
Huener, Joel	DNR - Thief Lake WMA	42280 240th Ave NE Middle River, MN 56737	218-222-3747	joel.huener@dnr.state.mn.us
Jesme, Myron	Red Lake Watershed District, Administrator	1000 Pennington Ave S. Thief River Falls	(218) 681-5800; cell 218-686-9694	jesme@wiktel.com
Kaspari, Jan	Marshall County Water Planner/Zoning Administrator	Marshall County Water and Land Office 208 E. Colvin Avenue, Suite 3 Warren, MN 56762	218-745-4217	jan.kaspari@co.marshall.mn.us
Kiesow, Gary	Marshall County Commissioner	25430 340th Ave. NE Goodridge, MN 56725	(218) 378-4480	garjul@gvtel.com
Knutson, Gregg	Wildlife Biologist, United States Fish and Wildlife Service	Agassiz NWR 22996 290th St. NE Middle River, MN 56737-9754	218-449-4115, ext 204	Gregg_Knutsen@fws.gov
Lane, Gary	Red Lake Watershed District	1000 Pennington Ave S. Thief River Falls	(218) 681-5800; cell 218-686-9694	gary@wiktel.com
MacGregor, Molly	MPCA - Detroit Lakes	714 Lake Ave Ste 220 Detroit Lakes 56501	218-846-0494	Molly.Macgregor@state.mn.us

Name	Association/Title	Address	Phone	E-mail
Nelson, Dale	Red Lake Watershed District Board of Managers - Pennington County	10367 140th Street NW Thief River Falls, MN 56701	218-681-6403 (home), 218-681-0032 (cell)	ddmmz@wiktel.com
Newton, Lisa	Marshall-Beltrami SWCD	Box 16 Grygla, MN 56727	218-294-6144	ljn@gvtel.com
Niemela, Scott	MPCA Biomonitoring Program	MPCA Brainerd Office 7678 College Road, Suite 105 Baxter, MN 56425	218-828-6076	scott.niemela@pca.state.mn.us
Okland, Gerry	Citizen	23205 160th Ave NE Thief River Falls, MN 5701	218-681-4357	
Olin, Dave	District 01A State Representative	593 State Office Building 100 Rev. Dr. Martin Luther King Jr. Blvd. Saint Paul, MN 55155	651-296-9635	rep.dave.olin@house.mn
Ose, LeRoy	Red Lake Watershed District Board of Managers - Marshall County	15115 229th Street NE Thief River Falls, MN 56701	218-681-7796	leroyose@wiktel.com
Paakh, Bruce	Minnesota Pollution Control Agency, Red River Basin Monitoring Coordinator	714 Lake Ave Ste 220 Detroit Lakes 56501	218-846-8115	bruce.paakh@state.mn.us
Person, Howard	Extension Educator	Box 616 101 Main Ave N, Courthouse Thief River Falls MN 56701	218-683-7030	perso005@umn.edu
Poegel, Jessica	MPCA Biomonitoring Program	MPCA Brainerd Office 7678 College Road, Suite 105 Baxter, MN 56425	218-316-3915	jessica.poegel@pca.state.mn.us
Prachar, Randy	DNR - Thief Lake WMA	42280 240th Ave NE Middle River, MN 56737	218-222-3747	randy.prachar@dnr.state.mn.us
Rude, Arlo	City of Thief River Falls	Box 528 Thief River Falls, MN 56701		arude@citytrf.net
Sailer, Brita	Minnesota State Representative, District 02B	577 State Office Building 100 Rev. Dr. Martin Luther King Jr. Blvd Saint Paul, Minnesota 55155	651-296-4265, 800-920-5867	rep.brita.sailer@house.mn
Severts, Chad	Minnesota Board of Water and Soil Resources	701 Minnesota Avenue, Suite 234 Bemidji, MN 56601	(218) 333-8028	Chad.Severts@state.mn.us
Sistad, Cheryl	Marshall/Beltrami SWCD	Box 16 Grygla, MN 56727	218-294-6144	Cheryl.Sistad@mn.nacdnet.net
Skoe, Rod	Minnesota State Senate, District 02	75 Rev. Dr. Martin Luther King Jr. Blvd. Capitol Building, Room 303 St. Paul, MN 55155-1608	651-296-4196	sen.rod.skoe@senate.mn
Stanley, Todd	Landowner, farmer	72552 Hwy 89 NW Grygla, MN 56727	218-294-6303 218-294-6309	
Stumpf, Leroy	Minnesota State Senate, District 01	75 Rev. Dr. Martin Luther King Jr. Blvd. Capitol Building, Room 208 St. Paul, MN 55155-1608	651-296-8660	
Thief River Falls Times Newspaper				trftimes@trftimes.com
Winter, Rachelle	Pennington County Water Planner	Pennington County Soil & Water Conservation District 201 Sherwood Ave S. Thief River Falls, MN 56701	218-683-7075	Rachelle.Winter@mn.nacdnet.net

Task 12. Identification of Sources and Solutions

Multiple tasks in this project will work together to help identify sources of pollutants throughout the watershed. Once potential pollutants are identified, it will be necessary to spend some time verifying the extent of their impact and verifying the locations of pollutant sources. There will be ground-truthing involved in this process. Coordination with other local agencies and landowners to plan cost-share projects will also be important.

LIDAR Terrain Analysis for Identification of Critical Areas

This process, recently developed by the Minnesota Department of Agriculture, utilizes ArcGIS, the Spatial Analyst extension, and digital elevation model data to identify critical areas with a high potential for erosion. These areas are most likely to carry a disproportionate amount of flow and pollutants during storm events. This process identifies locations that are most likely to have gully and channel erosion.

The process involves these basic steps:

1. Obtain and process the DEM.
2. Use Spatial Analyst to create a slope grid.
3. Use Spatial Analyst to create a flow direction grid.
4. Use Spatial Analyst to calculate flow accumulation.
5. Use the Raster Calculator in Spatial Analyst to calculate a Stream Power Index for all the pixels in the DEM.
6. Use the Spatial Analyst “Filter” command to smooth-out artifacts and distortions.
7. Use the Spatial Analyst “Raster Calculator” to create a Compound Topographic Index.
8. High Stream Power Index Values indicate areas that have high potential for erosion.
9. High Compound Topographic Index values indicate areas that have a high potential for surface accumulation and ponding.

The products of this process will be maps showing the critical areas and the ability to quantify erosion control implementation needs in any area of the watershed.

Without LIDAR, the resolution of current DEM data would be insufficient to run this analysis in the Red River Valley. LIDAR gives us the high resolution DEM needed to accomplish this terrain analysis.

Task 13: Final Report, Semi-Annual Reports, and TMDL Approval

Two semi-annual reports will be produced each year. They will include an update on the tasks and activities identified in the work plan that have been completed, and an update on the budget for the work done. They will be due on February 1st and August 1st of each year of the duration of the contract.

The final report of this watershed assessment will include total maximum daily loads for each reach assessed within the watershed. Load allocations and reductions will not be necessary for reaches that meet the State water quality standards. Reaches that were formerly listed as impaired, but are now meeting standards, will be recommended for delisting. Those reaches identified as impaired will be addressed with load allocations/reductions and will be subject to approval by the EPA. The implementation plan does not need to be part of the draft TMDL submitted to the EPA for approval. Although it is normally conceived after approval of the TMDL, the core components of an implementation plan will be assembled throughout this watershed-based TMDL project.

Should reaches that currently meet standards become impaired in the future, the TMDL information will already be available as a product of this study. The comprehensive final report will also address waters that are not currently impaired and lay out a protection plan for those reaches and sub-basins.

Final Products

- Comprehensive final report
- Draft watershed-based TMDL version of the final report
- Data files
- Model runs
- Source inventories
- Public information materials
- Fact sheets
- Electronic versions of all the products, especially the final reports
- Final progress report with a final financial report submitted electronically.
- Management plan for the watershed
    - Implementation recommendations for sources identified in the TMDL process
    - Integrate the source water protection plan
    - Protection of unimpaired waters.

Draft TMDLs

Current loads and allowable loads will be calculated for all the reaches for all the existing parameters. Draft TMDL reports will contain the information that is required by the EPA *Guidelines for Reviewing TMDL's under Existing Regulations issued in 1992.* Although an executive summary is featured at the beginning of all TMDL reports, a more comprehensive summary section will be added to the end of the report to address the interconnectivity of reaches and impairments throughout the Thief River watershed.

The draft watershed-based TMDL report will follow the general outline specified in TMDL guidance, but may have a slightly altered organization due to the number of reaches and impairments. In response to feedback from the EPA on prior TMDLs, a summary section will be added to the report.

The Thief River Watershed-Based TMDL document will be formatted in a manner that will make it seamlessly customizable. All the reaches will have TMDLs calculated, whether they are impaired or not. Those reaches that are not impaired and don't require load reductions can be removed from the document when it is submitted to the MPCA with TMDLs and load allocations for impaired reaches. The pollutant sources and implementation plans will be organized by sub-basin.

Respond to Comments if Necessary and Help Finalize the Draft TMDL for Submittal to the EPA

This phase of the project will mostly occur outside of the life of the contract between the RLWD and the MPCA. The ultimate goal of this project is EPA approval of the Thief River Watershed-Based TMDL by the end of the contract period (approximately March 1, 2014).

- The MPCA will be publishing new 303(d) lists of impaired waters in 2010, 2012, and 2014. If monitoring can identify all the new water quality impairments in the watershed by the end of the 2011 monitoring season, the TMDL load allocations, etc. can be submitted to the EPA for comments in 2013. The listing information necessary for TMDL submittal to the EPA will be made official on the 2012 303(d) list.
- Assist the process of finalizing a draft TMDL for submittal to EPA prior to the end of the contract. Projects should consider allowing 3-4 months before the end date of their contract for review, comments and revisions for the draft report prior to public notice and submittal to EPA. Therefore, the target completion date for the *Draft Thief River Watershed-Based TMDL Report* should be September 31st, 2013.
- Help revise the draft TMDL as needed based on review and comments from technical staff, citizens and other interested parties, and EPA through the end of the contract period.
- After the contract period is ended, the RLWD will remain involved in the approval process to a reasonable extent that fits within the scope of the RLWD's water quality program.

The draft TMDL will be sent to MPCA for our review and comment, and eventually the final draft document will go on public notice. This phase will likely not be accomplished quickly enough to fall within the window of the contract. Project staff may have to respond to comments and revise the TMDL during this process, to a reasonable extent. They also need to coordinate with the MPCA on the development of a fact sheet, press release, and other outreach materials. A meeting or two with project partners will be held during the review and approval process. The overall product will be a final draft TMDL to be submitted by the MPCA to EPA.

Project Budget

The total funding available for the Thief River Watershed-Based TMDL Study is $250,000. The RLWD will be entering into a contract with the MPCA to complete the project using these funds. Minor cost overruns (e.g. excess in billable rate over the allowed $50/hour, reasonable amount of extra water quality monitoring) will be the responsibility of the RLWD and will be recorded as in-kind contribution. The RLWD may subcontract with the Marshall County and Pennington County Soil and Water Conservation Districts for part of the monitoring effort. Samples will be analyzed by RMB Environmental Laboratories, Inc. The RLWD may subcontract the BASINS modeling. A facilitator may be subcontracted to make sure stakeholders' meetings are productive. The RLWD GIS Technician will be involved in the LIDAR analysis. RLWD engineering staff will assist with the stream channel stability assessment and flow monitoring work.

Some of the goals of this project will be accomplished with the help of work funded by sources other than the $250,000 contract between the RLWD and the MPCA. The Minnesota Department of Natural Resources will be the lead agency in accomplishing the stream channel stability analysis of the watershed. The MPCA Biomonitoring Unit will be visiting the Thief River Watershed in 2011 to collect biological and water quality data throughout the watershed. The RLWD's regular district monitoring program will continue at 5 sites in the watershed and will contribute to the overall dataset. MPCA staff will provide guidance and assistance in the civic engagement process. Surface Water Assessment Grant proposals will be submitted in the fall of 2010 to pay for 2011 (and 2012?) sampling and field measurements. Also, a major portion of the data needed to complete this project has already been collected during the Thief River Watershed Sediment Investigation. A lot of information can be pulled from the final report of the Sediment Investigation project during the process of writing the final TMDL report for this study.

Table 15. Laboratory analysis costs by parameter

TP	OP	TSS	TKN	NO2+NO3	Ammonia N	E. coli	Chloride	BOD	Total
$ 12.00	$ 9.00	$9.00	$ 14.00	$ 10.00	$ 12.00	$ 13.00	$ 8.00	$18.00	**$ 105.00**

Table 16. Budget breakdown

	Task	Description of tasks	Hours/#	Rate	Total Billable Amount	Expenses	Total
1	**Evaluation of Existing Data**		80		$ 2,000.00		$2,000
	RLWD Water Quality Coordinator		40	$50	$ 2,000.00		
	MPCA Staff		40	$0	$ -		
2	**Water Quality Sampling**	Funded by a SWAG for one of the two years of sampling	1086	$50	$ 26,200.00	$ 14,100.00	$ 40,300.00
	RLWD Water Quality Coordinator	Identify and Establish Sites	41	$50	$ 2,050.00		
	MPCA Staff	Identify and Establish Sites	40	$0			
	Marshall County Water Planner	Use 2011 SWAG funding	290	$0			
	Marshall County Mileage	Use 2011 SWAG funding	7250	$0			
	Pennington County Water Planner	Use 2011 SWAG funding	232	$0			
	Pennington County Mileage	Use 2011 SWAG funding	2900	$0			
	RLWD Water Quality Coordinator	Sampling	275	$50	$ 13,750.00		
	RMB Environmental Labs, Inc.	Sampl e Analysis				$ 11,750.00	
	RMB Environmental Labs, Inc.	QA/QC samples (10% rate for blanks and duplicates)		10% x 2		$ 2,350.00	
	RLWD Water Quality Coordinator	Field Measurements	208	$50	$ 10,400.00		
3	**Continuous Monitoring**	2 years, 10 sites	696/30		$ 34,800.00	$ 24,200.00	$ 59,000.00
	RLWD Water Quality Coordinator	Deploy/Retrieve Equipment	264	$50	$ 13,200.00		
	Multiparameter Sondes		2	$10,000		$ 20,000.00	
	10L Turbidity Standard		8	$250		$ 2,000.00	
	10L Conductivity Standard		4	$80		$ 320.00	
	10L pH 7 Standard		8	$80		$ 640.00	
	10L pH 10 Standard		8	$80		$ 640.00	
	Shipping		30	$20		$ 600.00	
	RLWD Water Quality Coordinator	Clean and Calibrate Equipment	432	$50	$ 21,600.00		
4	**Biological Data Collection**	Most work done by MPCA staff. 1 week of assistance from RLWD	3482		$ 2,500.00		$ 2,500.00
	RLWD Water Quality Coordinator		50	$50	$ 2,500.00		
	MPCA Brainerd Bio-Unit	6 people * 1/2 yr. * .55 (39/71 2011 sites)	3432	$0			
5	**Stage and Flow Monitoring**		450		$ 20,500.00	$ 2,000.00	$ 22,500.00
	RLWD Water Quality Coordinator	Continuous Stage Monitoring	96	$50	$ 4,800.00	$ 2,000.00	
	RLWD Water Quality Coordinator	Manual stage measurements	90	$50	$ 4,500.00		
	RLWD Water Quality Coordinator	Flow measurements	200	$50	$ 10,000.00		
	MPCA staff	coordination, help ID sites	40	$0			
	RLWD Water Quality Coordinator	Data management/Rating Curves	24	$50	$ 1,200.00		
6	**Stream Channel Stability Assessment**		520		$ 15,000.00		$ 15,000.00
	RLWD Staff	Assistance to DNR field work	300	$50	$ 15,000.00		
	DNR Staff		160	$0			
	MPCA Staff		60	$0			
7	**Stressor Identification**		160		$ 6,000.00		$ 6,000.00
	RLWD Water Quality Coordinator		120	$50	$ 6,000.00		
	MPCA Staff		40	$0	$ -		
8	**BASINS Model Development**		1160	$50	$ 3,000.00		$ 3,000.00
	RLWD Water Quality Coordinator	Coordination, Gathering Data, interpreti	60	$50	$ 3,000.00		
	MPCA Staff		1100	0	$ -		
9	**Monitoring Data Entry**		160		$ 6,000.00		$6,000
	RLWD Water Quality Coordinator		120	$50	$ 6,000.00		
	MPCA Staff		40	$0			
10	**Monitoring Data Analysis**		240		$ 12,000.00		$12,000
	RLWD Water Quality Coordinator		240	$50	$ 12,000.00		
11	**Civic Engagement**		252		$ 12,000.00		$12,000
	RLWD Water Quality Coordinator	Coordinate meetings	144	$50	$ 7,200.00		
	MPCA Staff	Civic engagement guidance	60	$0			
	Contractor Facilitator	Run meetings	*48*	*$ 100*	*$ 4,800.00*		
12	**Identification of Sources and Solutions**	1076 sq. miles/36 = Approx. 30 Townships x 1 twp/day	400	$50	$ 18,000.00		$ 18,000.00
	Field work, 10 hrs/sub-basin	Field work, 10 hrs/sub-basin	120	$50	$ 6,000.00		
	MPCA Staff		40	$0	$ -		
	LIDAR Terrain Analysis	LIDAR Terrain Analysis, 1076 sq. miles/36 = Approx. 30 Townships x 1 twp/day	240	$50	$ 12,000.00		
13	**Final Report and Semi-Annual Reporting**		1600 hrs		$ 71,450.00	$ 400.00	$ 71,850.00
	Printing	At least 10 copies	10	$40		$ 400.00	
	MPCA Staff		40	$0	$ -		
	RLWD Staff	4wks/sub-basin x 12	1429	$50	$ 71,450.00		
Total							$250,000

Responsible Parties

- ID staff and organizations, what each will be responsible for:
    - Monitoring
        - Water quality – RLWD
        - Flow – RLWD, DNR, USGS
        - Biological sampling – MPCA
        - Biological data assessment – MPCA, DNR
            - Tom Groshens (DNR)
            - Scott Niemala (MPCA)
            - Jessica Poegel (MPCA)
            - Erin Andrews (MPCA)
            - Mike Kelly (MPCA)
            - Mike Kramschuster (MPCA)
            - John Sandberg (MPCA)
            - Kevin Stroom (MPCA)
        - Channel stability – DNR
            - Dave Friedl (DNR), Tom Groshens (DNR), Jim Courneya (MPCA), Gary Lane (RLWD), Loren Sanderson (RLWD), James Blix (RLWD), others
    - Data analysis
        - Corey Hanson, RLWD Water Quality Coordinator
    - Modeling
        - Sub contract with contractor capable of conducting the modeling
    - LIDAR Terrain Analysis
        - James Blix (RLWD)
    - Public outreach and education
        - Corey Hanson, RLWD Water Quality Coordinator
        - Cindy Hillmoe, MPCA
        - Molly MacGregor, MPCA
        - Jim Courneya, MPCA Project Manager
    - Allocation
        - Corey Hanson, RLWD Water Quality Coordinator
    - Implementation plan.
        - Stakeholders
        - Corey Hanson, RLWD Water Quality Coordinator

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