# Table of Contents

# List of Figures

## Contacts/Distribution List

| Name | County/Agency/Position | Street Address | City | Phone, email |
|---|---|---|---|---|
| Corey Hanson | Project Manager – RLWD | 102 Main Ave N<br>P.O. Box 803 | Thief River Falls | 218-681-5800<br>coreyh@wiktel.com |
| Keith Swenson | Red Lake | Rural Brooks 56715 | Brooks | 218-796-5280 |
| Melvin Johnson Jr. – Lambert Twp Chairman | Red Lake | 22514 260th Ave SE | Brooks | 218-796-5376 |
| Darrell Schindler | Red Lake DNR | | Red Lake | 218-679-3959<br>dschindl@paulbunyan.net |
| Nate Dalager | HDR Engineering | | Thief River Falls | 218-681-6100 |
| Gary Sands | Associate Professor and Extension Engineer, University of Minnesota | 209 Biosystems and Agricultural Engineering Bldg., University of Minnesota, 1390 Eckles Avenue | St. Paul, MN 55108-6005 | (612) 625-4756<br>grsands@umn.edu |
| Hans Kandel | Extension Education/Professor, University of Minnesota Crookston | University of Minnesota Crookston, Owen Hall 251D, 2900 University Avenue | Crookston, MN 56716 | (218)281-8688<br>kande001@umcrookston.edu |
| Janet Crossland | EERC Grad Student | 2339 S 17th St. Apt. 23 | Grand Forks, ND 58201 | 218-779-1276,<br>turtle_145@excite.com |
| Kevin Yaggie | Farmer Near Brooks | 19752 250th St. SE | Brooks, MN 56715 | 218-698-4422 |
| Paul Ihmle | Owner – Pine Lake Wild Rice Farms | | | 218-268-4404 |

| | | | | |
|---|---|---|---|---|
| LeRoy Carriere | Farmer Near Brooks | | Brooks | 218-698-4643 |
| David Bachand | Red Lake Co. Farmer | 706 State Highway 222 | Oklee, MN 56742 | 218-796-5765 |
| Lisa Newton and Cheryl Sistad | Marshall-Beltrami SWCD | Box 16 | Grygla, MN 56727 | 218-294-6144 |
| John Gunvalson | Wild Rice Farmer | | Gonvick | 218-487-5788 |
| Todd Stanley | Marshall/Beltrami Co farmer | 72552 Highway 89 NW | Grygla, MN 56727 | 218-294-6303<br>218-294-6309<br>800-914-1399 |
| Rod Skoe | Clearwater Rice | Route 2, Box 80 56634 | Clearbrook | 218.776.3420<br>651.296.4196<br>sen.rod.skoe@senate.mn |
| Don Barron | Soil Scientist, Clearwater Rice | 103 Markley Ave. S. | Thief River Falls, MN 56701 | (218) 681-3684 |
| Tanya Hanson | District Manager & Water Plan Coordinator, Red Lake SWCD | 2602 Wheat Dr | Red Lake Falls, MN 56750 | 218-253-2593<br>tanya.hanson@mn.nacdnet.net |

## Project/Task Organization

The project partners involved in implementation will be the Red Lake Watershed District, Marshall-Beltrami SWCD, HDR Engineering, Red Lake SWCD, and the Red Lake DNR. Any work these partners can accomplish for the project will help minimize the expenses incurred by the RLWD. The Marshall-Beltrami SWCD can conduct monitoring within Beltrami County and Marshall County. The Red Lake SWCD can help with sampling within Red Lake County. The assistance with sampling will be especially valuable in the case that tile is flowing, but RLWD staff are not able to collect samples. The Marshall-Beltrami SWCD will likely collect the majority of the samples collected at the Marshall and Beltrami County sites because they are willing to do so and also because these sites are "out of the way" for RLWD staff and are not located near any other RLWD monitoring projects. HDR Engineering will assist the RLWD in designing an accurate flow monitoring system for making comparisons between tile drainage and surface drainage.

<u>Project Participants and Advisors</u>

- **Corey Hanson**, Red Lake Watershed District Water Quality Coordinator
- **Nate Dalager**, Engineer, HDR Engineering
- **Lisa Newton**, District Technician, Marshall-Beltrami Soil and Water Conservation District
- **James Blix**, Water Quality/Natural Resources Technician, Red Lake Watershed District
- **Darrell Schindler**, Aquatic Biologist, Red Lake Department of Natural Resources
- **Hans Kandel**, Extension Educator/Professor, University of Minnesota Crookston
- Red River Watershed Management Board Technical Advisory Committee
  - **Charlie Anderson**
  - **Dan Thul**
  - **Ron Adrian**
  - **Jerry Bents**
  - **Nate Dalager**
- **Gary Sands**, Associate Professor and Extension Engineer, University of Minnesota
- **Dave Bachand**, Landowner and Farmer, Red Lake County
- **Kevin Yaggie**, Landowner and Farmer, Red Lake County
- **Red Lake Band of Chippewa**, Wild Rice Producer, Clearwater County
- **Clearwater Rice**, Wild Rice Producer, Clearwater County
  - **Rod Skoe**, Owner
  - **Don Barron**
- **Stanley Farms, Inc.**, Landowner and Farmer, Marshall and Beltrami Counties
  - **Todd Stanley**
  - **Arnold Stanley**
- **James and Steven Sparby**, Landowners and Farmers, Marshall County

# Problem Identification/Background

## *Background*

The Red Lake Watershed District has received a $17,500 grant from the Northwest Minnesota Foundation to study the effects of tile drainage on water quality. The Red Lake Watershed Farm to Stream Project will compare different tiling techniques, tile drainage with surface drainage, and agricultural drainage with natural drainage. The original cost of the project is $35,000. Due to increasing interest in the project, additional funding for accurate flow monitoring was provided by the Red River Watershed Management Board. The Marshall-Beltrami SWCD also received a grant for collecting tile drainage water quality samples in Beltrami County. The study will be conducted in 2005 and 2006 with the possibility that flow monitoring may continue into the future. Results will be presented in the form of a scientific report and will be summarized for informational pamphlets as well. Study results will also be available on the RLWD website (http://www.redlakewatershed.org/projects.html).

The amount of tile drainage within the Red River Valley has been increasing, as has interest in its effects upon water quality and flow volume. Tile drainage may reduce the amount of soil erosion, total suspended solids loadings, and total phosphorus concentrations. One criticism of tile drainage is that it may be introducing high concentrations of nitrates to steams and rivers. Some drainage management practices may be able to reduce nitrogen losses through increased denitrification and reduced leaching. These methods include proper nutrient management, shallow tile drainage, and controlled tile drainage.

Water quality samples will be collected and analyzed for total suspended solids, total phosphorus, total nitrogen, and nitrates. Field measurements will be conducted for dissolved oxygen, temperature, conductivity, pH, turbidity, and transparency where possible. Turbidity analysis will be conducted at all sampling sites. Flow will be monitored continuously at each monitoring site so that loads can be calculated and compared. If additional funding is received, flow will be monitored from tile drained fields surface drained fields to determine the effect of tile drainage on peak flows and total flows when compared to surface drainage. Monitoring sites will be chosen for each comparison (water quality and/or quantity) so that land use and soil characteristics are comparable. The different types of tile drainage outlets that will be compared include gravity outlets, pumping stations, and water control structures. The primary goal of this study is to successfully collect water quality and flow data from gravity tile drainage outlets, pumped tile drainage outlets, controlled tile drainage outlets, surface drainage, and reference sites. Study areas will be located in the Clearwater River watershed in Red Lake and Clearwater Counties, and also in the Thief River watershed near Grygla.

## *Project Goals*

1. Document sediment and nutrient concentrations from tile drainage in the Red River Basin.
2. Document sediment and nutrient concentrations from different types of tile outlets.
3. Compare sediment and nutrient concentrations from tile drainage with concentrations from surface drainage and natural background levels.
4. Accurately study the effect that tile drainage has upon flow.
    a. Peak flow volumes versus surface drainage
    b. Total flow volume versus surface drainage
5. Collect an amount of data that is sufficient for drawing conclusions.
6. Provide information that can be used for decision making within the Red River Basin.

## Project/Task Description

### *Project Budget*

**Red Lake Watershed Farm to Stream Project Budget**

| Expenditures | NWF | Other Sources Cash | Other Sources In-Kind | TOTAL |
|---|---|---|---|---|
| **I. PERSONNEL** | | | | |
| A. Salaries and Wages | $13,500 | | $7,250 | $20,750 |
| B. Fringe Benefits | $0 | | $0 | $0 |
| **II. CONSULTANTS & CONTRACT SERVICES** | | | | |
| **III. NON-PERSONNEL** | | | | |
| A. Space Costs | | | | $0 |
| B. Rental, Lease, or Equip. Purchase | | $3,250 | | $3,250 |
| C. Technology Related Expenses | | | | $0 |
| D. Consumable Expenses | | | | $0 |
| E. Travel | | | | $0 |
| F. Telephone | | | | $0 |
| G. Evaluation (not to exceed 5% of total project cost) | | | $1,500 | $1,500 |
| H. Laboratory Analysis | $4,000 | $5,000 | $0 | $9,000 |
| I. Printing Costs | | $200 | | $200 |
| J. Construction Materials (monitoring station setup) | | $300 | | $300 |
| **TOTAL COSTS** | $17,500 | $8,750 | $8,750 | **$35,000** |

| | | | | |
|---|---|---|---|---|
| NWMF % | 50.00% | | | |
| Match % | 50.00% | Cash | 50.00% | of Match |
| | | Inkind | 50.00% | of Match |

**Requirements**

1 50% Match
2 No more than 50% of the match can be in-kind
3 50% of the match, or 25% of the whole project, must be cash

| Match Budget Explanation | | |
|---|---|---|
| **Organization** | **Cash** | **In-Kind** |
| RLWD | $8,750.00 | $3,750.00 |
| RLDNR | | $2,000.00 |
| RL SWCD | | $1,500.00 |
| M-B SWCD | | $1,500.00 |
| MPCA | | |
| **Totals** | $8,750.00 | $8,750.00 |
| **Percentages** | 50.00% | 50.00% |
| **Grand Total** | $17,500.00 | |

**Payment Schedule:**

Unless specifically agreed to in writing by NWF, the grant award shall be requested and paid as indicated below (payment can be requested by completing the Interim Activity Report and Request for Payment form):

| Payment Date | Payment Amount |
|---|---|
| December 1, 2004 | $4,375.00 |
| July 1, 2005 | $4,375.00 |
| January 1, 2006 | $4,375.00 |
| July 1, 2006 | $4,375.00 |

## Project Statistics

| Water Quality Analysis Costs | |
|---|---|
| Nitrates | $10.00 |
| Total Suspended Solids | $9.00 |
| Total Phosphorus | $12.00 |
| Orthophosphorus | $9.00 |
| Total Nitrogen* | $22.00 |
| Total | $62.00 |

*Need to verify

- Total number of samples that can be collected according to the budget: 145
- Number of samples per year: 72 – 73
- Number of weeks in study period: Up to 30 open-water weeks
- Number of sites at a bi-weekly schedule – 7

## *Sampling Sites*

Monitoring for this project is essentially taking place in three areas. These areas include Red Lake County – near Brooks, Clearwater County wild rice paddies, and Marshall County – near Grygla.

The Red Lake County sites on Bachand and Yaggie land will be used to monitor water quality and quantity. The sites are located east of Brooks, MN in Red Lake County. The flow monitoring at the Red Lake County sites is sponsored by the Red River Watershed Management Board and involves installation of specialized flow measurement structures. The flow monitoring is directed by Nate Dalager from HDR Engineering. The RLWD conducts regular water quality monitoring at these sties and provides assistance to the water quantity monitoring part of the project.

The Clearwater County monitoring sites compare water quality among different types of drainage and outlet types in wild rice paddies. In 2005, Red Lake Band of Chippewa rice paddies were monitored. The types of drainage compared include surface drainage via internal ditches, pattern tile drainage that flows to internal ditches, and main line tile drainage that is piped through a dike and into a grassed waterway. In 2005, some sites were scouted on the Clearwater Rice farm. It is possible that these sites may be monitored during the summer of 2006 in place of the Red Lake Nation sites if a comparable mix of drainage types can be found. The Red Lake Watershed District conducts the water quality monitoring at these sites.

The sites in Marshall and Beltrami County are located within 7.7 miles of each other and compare water quality among gravity tile, pumped tile, surface drainage, and natural background (non-impacted) sites. These sites are primarily monitored by Lisa Newton of the Marshall-Beltrami County Soil and Water Conservation District.

### Site Descriptions

**Red Lake County Sites:**

Bachand Tile + Surface.

This site was monitored and sampled at the beginning of the project, before flow measurement structures were installed at the Bachand monitoring site. Samples and field measurements were taken from the upstream end of the culvert. The water at this site originated from both surface and tile drainage. Samples are no longer collected here, but instead are collected at the Bachand Surface and Bachand Tile monitoring sites. This site and the Bachand Tile and Bachand Surface sites are located along Hwy 92, east of Brooks, Minnesota. This field is located in Section 8 of Lambert Township in Red Lake County. Drainage is monitored where it crosses Highway 92 on the south side of Section 8.

Bachand Tile

This is the water control structure that was installed on the end of a main line tile line. Water comes into the structure through the tile line, flows over a v-notch weir, and then exits the tile line. The structure is locked with a RLWD padlock. Samples can be collected from the stream of water coming through the weir without contaminating the sample water. Do not dip sample bottles in the water pooled on the upstream (field) side of the weir. Instead, hold the bottle on the downstream side of the weir and catch the water after it has come through the weir. Use this same method for the turbidity vial. Field measurements for dissolved oxygen, conductivity, temperature, and pH can be taken at this site, with some caution. Rinse the probe with distilled water or water flowing over the weir before inserting the probe into the water pooled on the upstream side of the weir. A HOBO Water Level Data Logger is placed on the bottom of the field side of the water control structure.

Bachand Surface

This monitoring site is the h-flume installed to catch and measure any surface runoff that comes from the Bachand field. Dip samples can be taken from the end of the structure. There is a HOBO Water Level Data Logger installed within the stilling well on the side of the structure. The stilling well has a locking cap that is secured with a RLWD padlock. Some landscaping has been done to ensure that water coming from the field funnels through the structure. Erosion control fiber blanket was installed around the structure to minimize erosion from ground disturbed during installation.

**Figure 1. Stilling Well and Gauge on Bachand Surface Stilling Well**

Yaggie 1

This was actually the second site that was seriously considered as a surface drained site with which to compare the Bachand tile drained site. The first site considered was south of Hwy 92 on a field owned by Keith Swenson - near a University of Minnesota tile drainage research plot. When it was determined that the Swenson site would not work for accurate flow measurement without adverse affects to the farmer's crop, new sites were scouted for the project. The first choice was the Yaggie 1 site. This monitoring site receives water from surface drainage on Kevin Yaggie and LeRoy Robert Carriere land. Initially, the outfall end of the culvert looked like a good place for a flume. Unfortunately, when the Lost River floods it rises to the level of the culvert. This would reduce the accuracy of flow measurements during periods of high flow. The downstream end of the culvert is lower because of the drop structure on the upstream end. So, this site was abandoned in favor of Yaggie 2. The site is located on the north side of Section 1 of Poplar Township in Red Lake County, just east of the middle of the north end of the section.

Yaggie 2

This site is located west of Yaggie 1 along a township road in Poplar River Township. There is more of a fall between the downstream end of this culvert and the Lost River than there is at the Yaggie 1 site. Therefore this site will be the official site for measuring flow from a surface-drained field. Flow will be measured with an h-flume identical to the one at the Bachand Surface site. This site is located along north side of Section 1 of Poplar Township in Red Lake County, near the northwest corner of the section.

**Clearwater County Wild Rice Paddy Sites:**

RLN Surface

This site is located at the outlet of a Red Lake Band of Chippewa wild rice paddy that is drained by internal surface ditches. Samples are collected from the water control structure. This is a good site for flow measurement because the water control structure exhibits weir flow. Flow was measured using a HOBO Water Level Data Logger housed within a stilling well that was attached to the side of the water control structure. An additional HOBO Water Level Data Logger was suspended within the stilling well (near the top) for the collection of data for barometric compensation. Samples at this site are best collected using the Sludge Nabber. Bottles can be filled by lowering them into the structure and holding them under the flow that is falling over the stoplogs. This wild rice paddy discharges directly into the Clearwater River. This outlet is located near the northeast corner of Section 22 of Hangaard Township in Clearwater County.

RLN Tiled

This site is located at the outlet of a Red Lake Band of Chippewa wild rice paddy that has tile drains within the paddy that drain into surface ditches that flow along the inside of the dike surrounding the paddy. Due to backwater from the next paddy, this site doesn't exhibit weir flow very much, so flow will not be quantifiable at this site. Stage records collected with a HOBO Water Level Data Logger and field notes will used to show the relative level and amount of water flowing through the outlet and not the precise amount (water level can be used to help explain sample results). Sampling at this site can either be done carefully with a Van Dorn sampler (avoid disturbing bottom sediment), or can be done using the extended dip method (clamp attached to the end of a pole) described in the Sampling Methods section of this QAPP. This outlet structure is located on a dike that runs east-to-west and is on the west side of an minimum maintenance access road that runs north-to-south along the border of Sections 34 and 35 of Hangaard Township in Clearwater County. The outlet structure and dike are located just north of the midway point of Section 34 of Hangaard Township.

RLN Main Line Tile

This water control structure drains water from a paddy in which tile lines drain into a main line tile. The main line tile then crosses the dike (which is a road) and flows through a water control structure to a grassed waterway. The structure is located on the north side of the northwest corner of the northeast corner of Section 3 of Winsor Township in Clearwater County,  along the south side of the road that runs along the border of Winsor and Hangaard Township.

Clearwater Rice

This wild rice operation is owned by (State Senator) Rod Skoe. Don Barron, a retired soil scientist and advisor to this project, is also involved with this wild rice operation. A downside to using Clearwater Rice is that Stage would be more difficult to measure without obstructing the operation of the water control structures. Stilling wells would need to be place inside the structures instead of beside the structures (as was done at the Red Lake Band of Chippewa paddies. The structures are also narrower and placed within the dike so collecting a sample without disturbing the rust that lines the inner walls of the structure is difficult. One sample was collected in 2005 from a main-line tile outlet. The water level within the structure was low. The small size of the structure meant that a Kemmerer sampler had to be used. Because the water level was low and a vertical sampler was used, only a small amount of water could be collected at a time.

**Figure 2. View down a Clearwater Rice Main Line Tile Water Control Structure**

**Marshall County Sites:**

Stanley GT1 and Stanley GT2

These sites monitor water quality concentrations from tile outlets on a Stanley Farms field. This field is drained by regularly spaced drain tiles that outlet into a township ditch along County Hwy 54. GT1 is the most visible and easily sampled of the tile outlets. It can be accessed by driving on a trail along the edge of the field that begins in Arnold Stanley's yard. GT2 is located near County Road 55 on the north side of the field. GT2 is not as easy to access as GT1 during wet periods, but runs longer into dry periods than GT1. So, GT1 will be sampled during wet periods (or whenever it is flowing) and GT2 will be sampled during dry periods (or whenever GT1 isn't flowing). These sites are located on the west side of Section 13 of Valley Township in Marshall County. They are on the east side of County Highway 54 and are along the field north of Arnold Stanley's home.

Sparby

This field is surface drained and a large section of the field flows to a single point, through a culvert, and into a township ditch. Samples are collected at the outfall of the downstream end of the culvert. This site is located on the west side of Section 7 of Valley Township in Marshall County.

**Beltrami County Sites:**

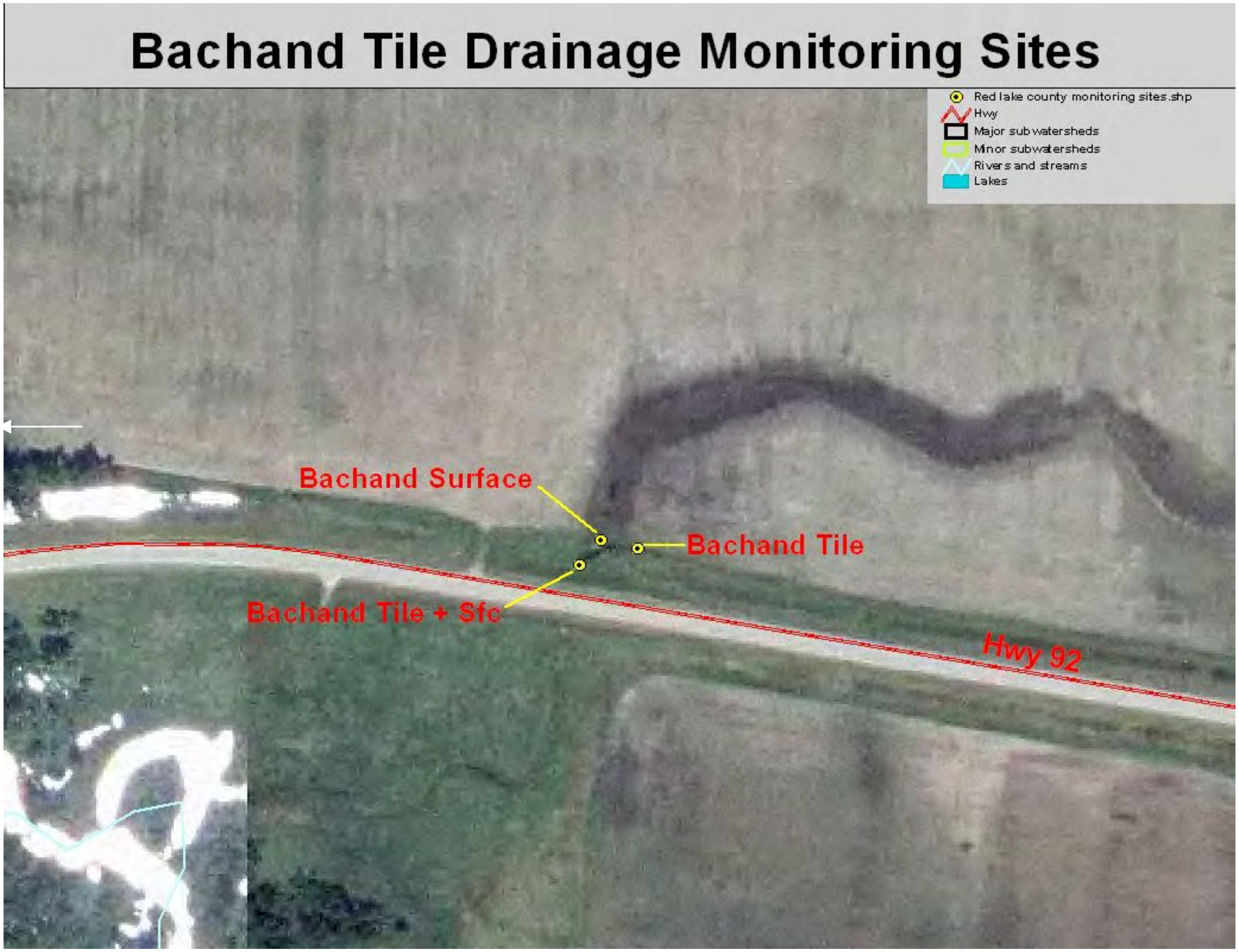
Stanley PT

This is a Stanley Farms' pumped tile outlet. Samples are collected at the end of the black corrugated outlet pipe while the pump is running. The pump can be triggered to run by opening the cover to the reservoir and raising the float. A new pump was installed in the fall of 2005. Samples are collected from the pump that is closest to the road. This site is located where Sections 12 and 13 of Marshall County and Sections 7 and 18 of Beltrami County meet. The pumps are along the north side of Marshall County Highway 55/Beltrami County Highway 44 (gravel road) at the section line.

Beltrami Natural

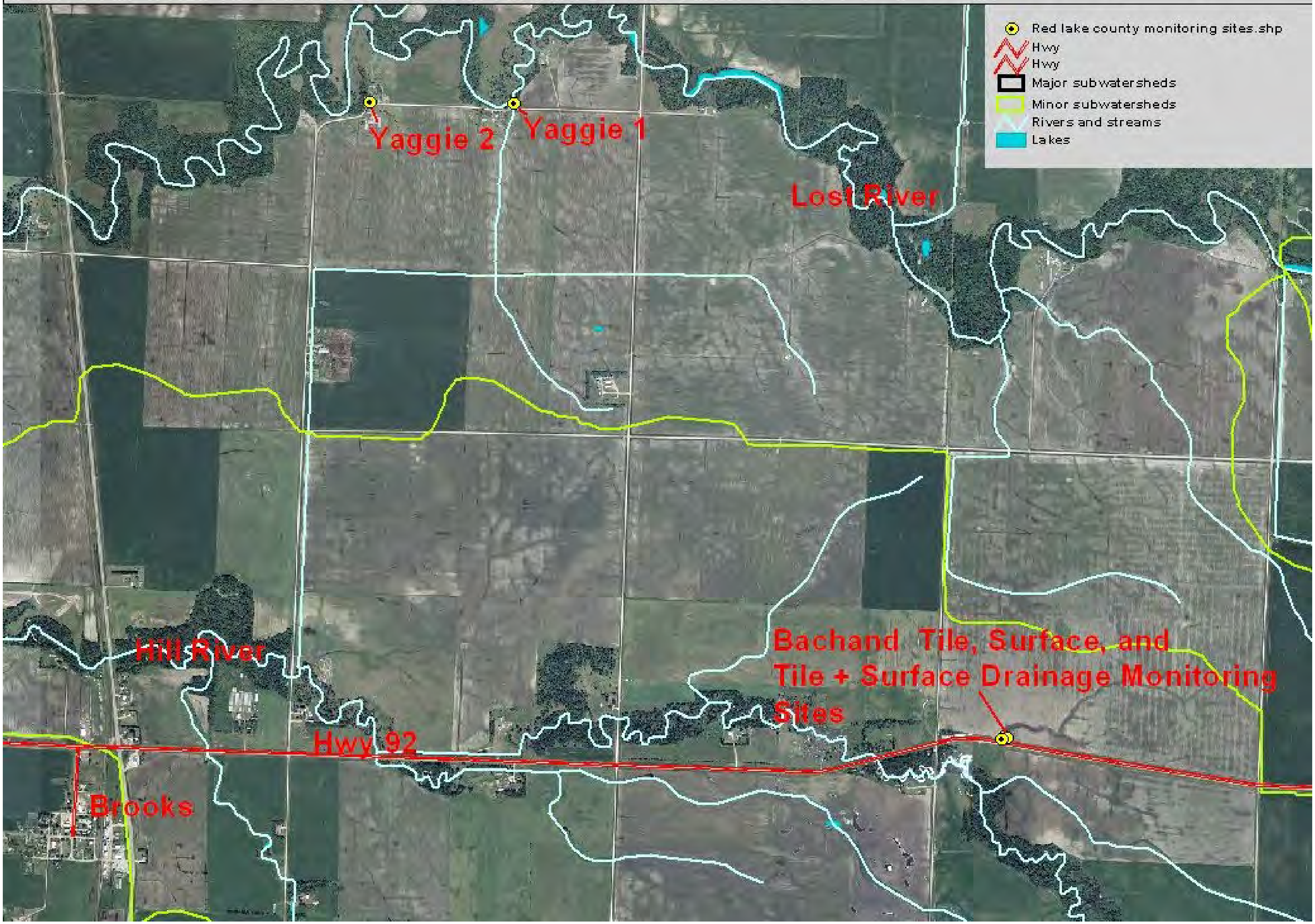
This site is used to collect data on natural background water quality concentrations in the Marshall-Beltrami County area. The water that flows through this site comes from forested public land on the east side of the project area. The monitoring site is located where Benwood Road NW turns north along the north side of Section 3 of Benville Township.

**Maps**

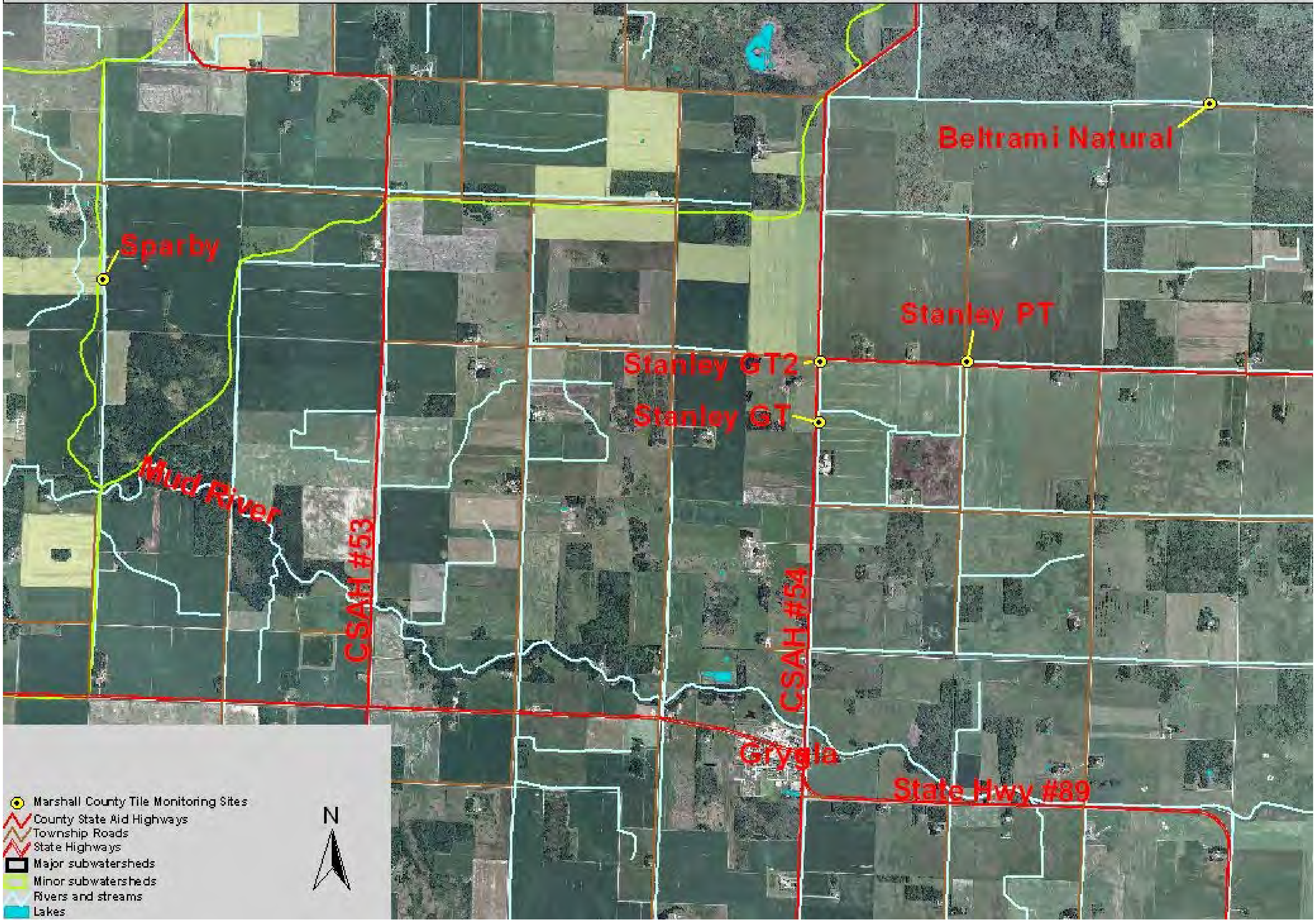


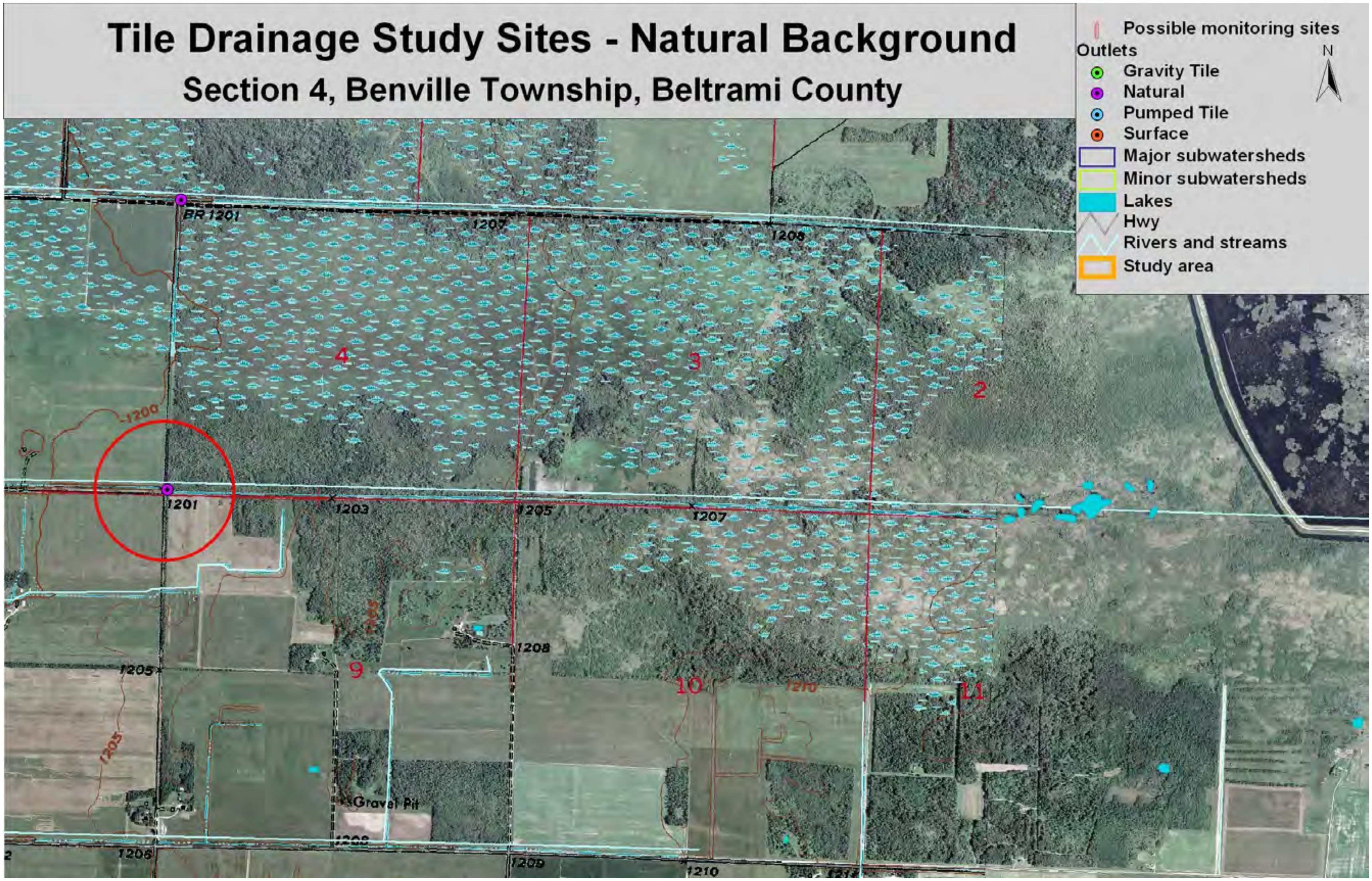
Bachand Tile Drainage Monitoring Sites
Red lake county monitoring sites.shp
Hwy
Major sub watersheds
Minor subwatersheds
Rivers and streams
Lakes
Bachand Surface
Bachand Tile
Bachand Tile + Sfc
Hwy 92

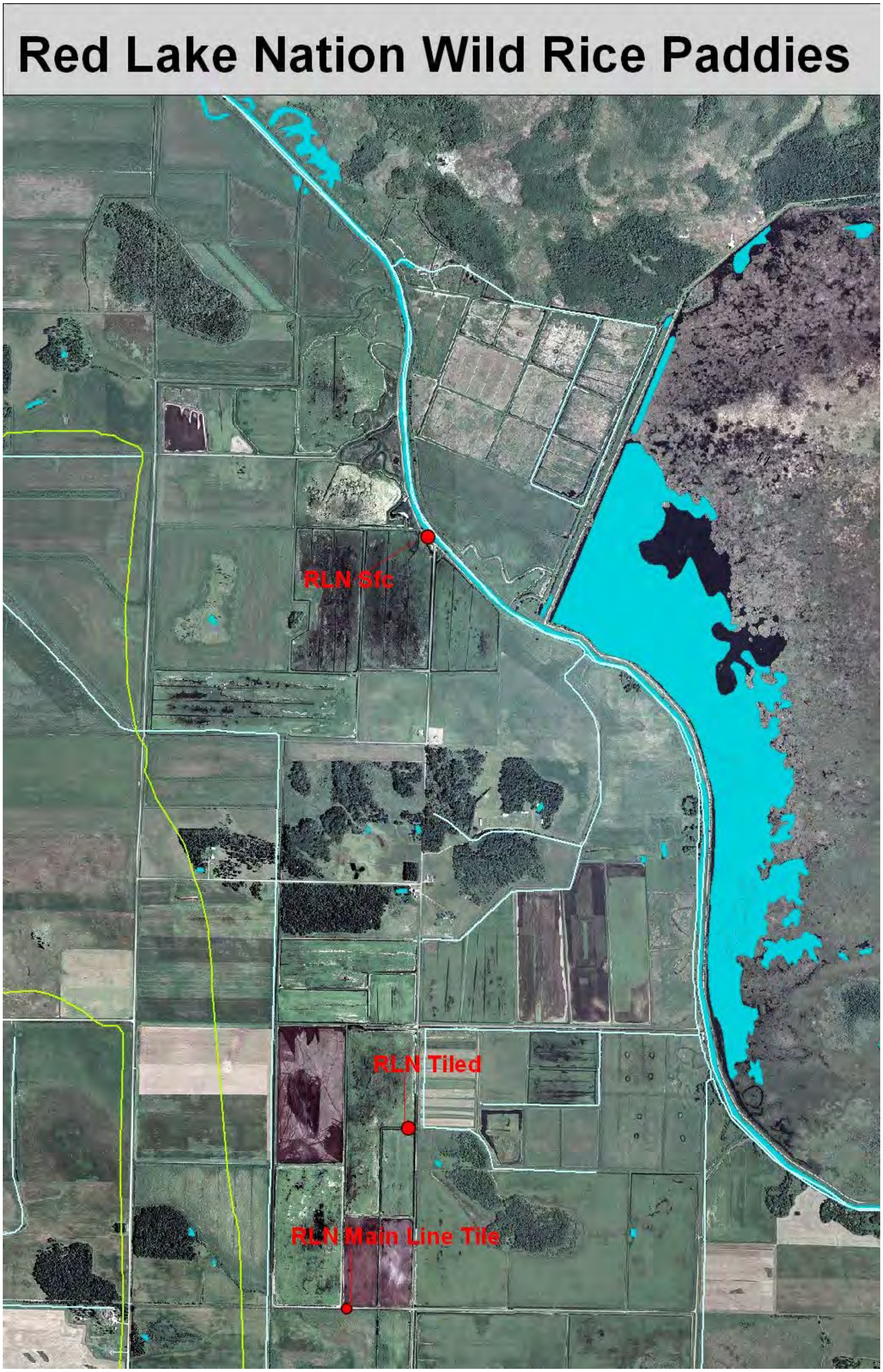
# Red Lake County Tile Drainage Monitoring Sites



# Marshall/Beltrami County Tile Drainage Monitoring Sites




Tile Drainage Study Sites - Natural Background
Section 4, Benville Township, Beltrami County
Possible monitoring sites
Outlets
Gravity Tile
Natural
Pumped Tile
Surface
Major subwatersheds
Minor subwatersheds
Lakes
Hwy
Rivers and streams
Study area
N
BR 1201
1207
1208
4
3
2
1200
1201
1203
1205
1207
1208
1205
9
10
11
Gravel Pit
1206
1209
1210


Red Lake Nation Wild Rice Paddies
RLN Sfc
RLN Tiled
RLN Main Line Tile

**Site Photos**

Bachand Site – Tile and Surface Drained Field Monitored for Flow and Water Quality

**Figure 3. Bachand Tile Drainage Water Control Structure**

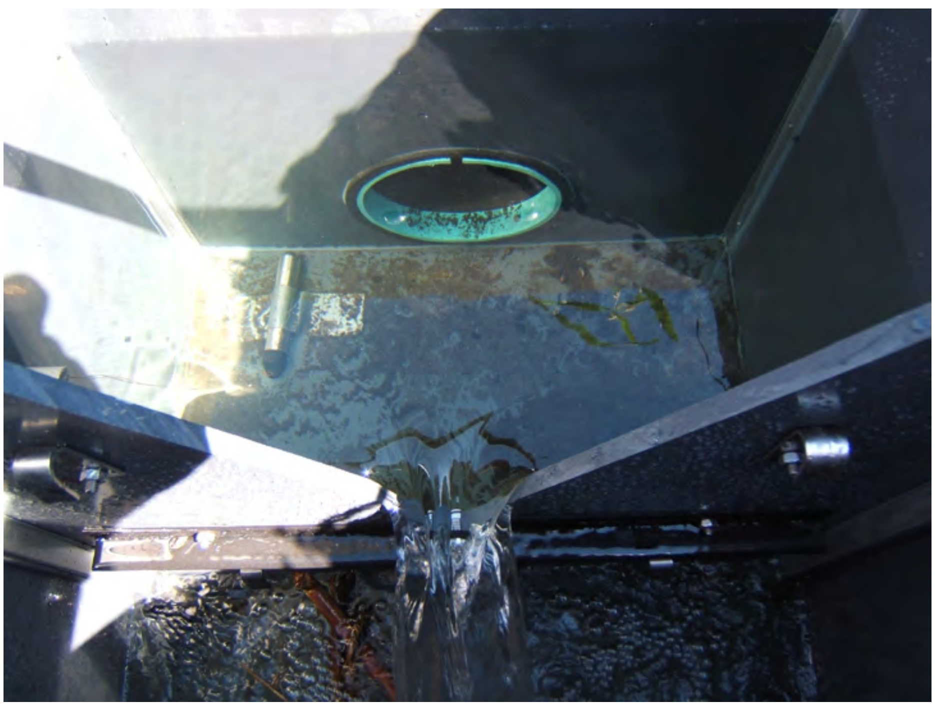


**Figure 4. V-Notch Weir and HOBO Water Level Data Logger in the Bachand Water Control Structure**

**Figure 5. H-Flume for Surface Flow Measurement at the Bachand Site**

**Figure 6. Rainfall and Barometric Pressure Monitoring Equipment at the Bachand Site**

**Figure 7. Bachand Field, Post-Harvest 2005**

Yaggie 2 Site – Surface Drained Field Monitored for Flow and Water Quality

**Figure 8. H-Flume on Downstream End of Yaggie 2 Culvert**

**Figure 9. Upstream View from Yaggie 2 Monitoring Site**

<u>Yaggie 1 Site – Surface Drained Field Dropped in Favor of the Yaggie 2 site</u>

**Figure 10. Downstream End of Yaggie 1 Culvert**

**Figure 11. Drop Structure at the Upstream End of Yaggie 1 Culvert**

Stanley GT – Gravity Tile Drain Outlet Monitored for Water Quality

**Figure 12. Stanley GT1 Gravity Tile Monitoring Site**

**Figure 13. Stanley GT 2 Alternate Gravity Tile Monitoring Site**

**Figure 14. Stanley GT2 Tile Outlet**

Stanley PT – Pumped Tile Outlet Monitored for Water Quality

**Figure 15. Stanley Farms Pumped Tile Outlet**

Sparby – Surface Drainage Site Monitored for Water Quality

**Figure 16. Sparby Surface Drained Field**

**Figure 17. Culvert at Sparby Monitoring Site From Which Samples Are Collected**

<u>Beltrami Natural – Unimpacted Site for Monitoring Natural Background Water Quality</u>

**Figure 18. Beltrami County Reference Monitoring Site and View Upstream**

RLN Surface – Wild Rice Paddy Drained with Only Interior Surface Ditches

**Figure 19. Surface Drained Wild Rice Paddy, Outlet, and Stilling Well**

**Figure 20. Surface Drained Wild Rice Paddy Outlet Structure**

RLN Tiled – Wild Rice Paddy with Tile Drains Emptying into Interior Surface Ditches

**Figure 21. Pattern Tiled Wild Rice Paddy, Outlet, and Stilling Well**

RLN Main Line Tile – Tile Drained Paddy with a Main Line Outlet and No Ditches

**Figure 22. Main-Line Tile Drained Paddy - Note the Absence of Ditches**

**Figure 23. Main Line Tile Outlet Structure**

## Sampling Process Design

### *Site Selection*

Priority sites should be selected based upon whether or not all flow from the field can be quantified. Even if a field is tiled, the amount of surface drainage should be quantifiable as well. Such fields will be considered for the supplemental flow monitoring part of the study that is being funded by the Red River Watershed Management Board. This is not an easy situation to find, particularly with pumped systems. Due to the fact that fields often have complicated flow patterns that cannot be easily monitored at a single location, or even at just a pair of locations, flow monitoring at all water quality sites may not be feasible. Concentration comparisons using water collected directly from a tile outlet may be the only option available in some cases. Knowing the concentrations of parameters is still useful information. These concentrations can be compared to concentrations found within the rivers to which the drainage flows. They can also be compared with any standards that exist, such as ecoregion nutrient standards, wastewater discharge standards, and drinking water standards. There is an argument that high concentrations of a parameter in a small amount of flow will have a minimal effect upon water quality in a large watercourse. A counter-argument is that the cumulative effect of a large number of small flows with high concentrations can definitely begin to affect water quality in a larger watercourse. So, as tile drainage expands within the Red River Basin, the concentrations within watercourses will begin to be increasingly affected by the concentrations from tile drainage. This study will give us a better idea of whether this affect will be positive and/or negative.

## Addressing Comparability

Potential monitoring sites for this project are spread throughout the Red Lake Watershed District, yet are clustered in 3 close groups. The goals of the project involve comparing water quality from tile drainage to natural background and surface drainage water quality. Comparability can easily come into question if sites are located too far apart. Soils can vary spatially and rainfall can vary both spatially and temporally. Pairs of sites will be needed to make comparisons between different types for drainage. Ideally, the study would monitor tile drainage (multiple outlet types), surface drainage, and natural background sites within a reasonable distance of each other. Fortunately, four types of sites have found near Grygla, Minnesota in Marshall and Beltrami Counties. Water quality will be monitored at these sites

Finding sites with similar land use is another necessity when comparing types of agricultural drainage. If possible, the watershed of a drainage monitoring site should almost completely consist of single type of land use. This study is being done to compare different types of drainage, not different types of land use. The one exception would be Beltrami Natural site, which is specifically chosen for its land use characteristics, but is used as a standard against which to compare all the sites in Marshall and Beltrami Counties.

## *Sampling Methods*

Nearly all sampling and quality assurance/quality control (QA/QC) procedures for this project will closely follow the methods described in the *Standard Operating Procedures for Water Quality Monitoring in the Red River Watershed* (SOP). Sampling from outlet structures, however, requires some additional techniques that aren't mentioned in the SOP.

Before conducting any monitoring for this project, the sampler should be familiar with the SOP, particularly sections 3, 4, 5, 7, 8.1 - 8.1.D., 9, and 10.

Sampling from the wild rice paddy structures with weir flow requires the use of a Sludge Nabber sampler. Water control structures that are not exhibiting weir flow and are not accessible for direct (dip) sampling can be carefully sampled with a Van Dorn sampler, Kemmerer sampler, or an extended dip method such as the one described below. The most accurate (least possibility of contamination) method of sampling is direct (dip) sampling, so the water coming into or out of a structure should be sampled this way wherever it is possible.

With the Sludge Nabber, a sample bottle (the 500 ml phosphorus bottle fits best) can be filled by lowering it into the stream of water coming over the stoplogs. After the phosphorus bottle is filled, it can be used to fill other sample bottles and the turbidimeter sample vial (make sure to keep water well-mixed). When the other bottles and vial have been filled, the phosphorus bottle can be filled one last time. The Sludge Nabber is extendable, so it is possible to collect a sample from the top of the water control structure even when water levels are low. It can only be used effectively in weir flow, however, because it can't be used to lower a bottle down into the water (except when modified – this will be explained in the next paragraph) because the bottle will float up and out of the bottle holder.

**Figure 24. Sludge Nabber**

Even if the water is out of reach and there is no weir flow, samples may still be directly collected with a bottle using an extended dip method. This can be done by attaching a clamp (meant for use on a ring-stand) attached to a pole (or even to the Sludge Nabber). The bottle can be clamped and lowered into the water as if it was an extension of the arm. The downside to this method is that it is difficult to completely fill all the bottles. But, since there are only a limited number of parameters for this project, as long as the bottle is filled close to the top, the lab hasn't had a problem with performing analysis.

**Figure 25. Clamp Attached to Sludge Nabber for Extended Dip Sample**

Using a Van Dorn or Kemmerer sample is very tricky for this project and should be done with great care. These samplers should only be used if it is impossible to use any of the methods described above. If sampling from a water control structure, lower the sampler carefully into the water without touching and disturbing the bottom sediment. Also, in narrow water control structures that necessitate the use of a Kemmerer sampler, avoid touching the sides of the structure as much as possible to avoid knocking flakes of rust into the water and contaminating the sample. There may be a better option for sampling from these smaller structures, such as a well bailer but the RLWD doesn't currently possess any of this equipment.

The flow monitoring for this study will involve the use of HOBO Water Level Data Loggers. These are water level measurement devices that feature internal data logging, an internal 5-year battery, and an optical port for uploading data. They record pressure and temperature. Because they don't have a vented cable, it is necessary to compensate for barometric pressure. This is done by having an additional level logger suspended in the air nearby the loggers that are in the water. Follow the methods included with the loggers and the HOBOWare software.

**Figure 26. HOBO Water Level Data Logger**

Rainfall monitoring will be done with the equipment at hand– two Stevens tipping bucket rain gauges paired with Stevens AxSys data loggers. These are placed at the Bachand site and the Stanley PT site. Rainfall logging doesn't require much power, so a fully charged battery should last all summer. However, the battery voltage should be checked using the data recorder on a regular basis. Downloading data on a monthly basis is also recommended, just in case something happens to the data logger.

Also, the Red Lake Band of Chippewa wild rice operation helped out with the study by collecting daily rain gauge readings. These readings were taken using a digital electronic wireless tipping bucket rain gauge made by Rainwise, Inc. and on loan from the Crookston River Watch program.

**Figure 27. Rainfall Monitoring Station at the Bachand Site**

### Monitoring Schedule

The Sampling at the Bachand tile drainage site and its corresponding control site should be conducted weekly whenever the tile is flowing. The rest of the sites will be sampled bi-weekly (twice per month), depending upon flow. Monitoring should begin by June of 2005. The sampling season for the field agricultural sites will include all open-water months.

Sampling at the wild rice paddies will only occur while the paddies are discharging in preparation for harvest.

## *Analytical Methods*

### Parameters

Total Phosphorus*, Orthophosphorus, Total Suspended Solids*, Total Nitrogen (TKN plus nitrate and nitrites), Nitrates*
*Priority Parameters

Ideally, rainfall would be monitored at each site. Rainfall will be measured, at a minimum, in each county. Monitoring stations have been located at the Bachand site, the south shop of the Red Lake Band of Chippewa wild rice paddies in Clearwater County, and at the Stanley Pumped Tile site in Beltrami County.

Bottles – 500 ml, 1000 ml, 250 ml

Samples are shipped via Speedee Delivery Service to RMB Environmental Laboratories for analysis. A completed chain of custody form should accompany each set of samples shipped to the lab.

### Monitoring Equipment

Supplying project partners with the means to collect samples shouldn't be a problem. The RLWD has plenty of extra coolers and bottles. Additional coolers and bottles can also be requested from RMB Environmental Laboratories at no additional cost. The RLWD will ship samples collected by the RLWD and the Marshall-Beltrami SWCD. When the SWCD collects samples, the RLWD is able to get the samples for shipping by meeting SWCD staff at a halfway point near the town of Goodridge. The collection of water quality samples and stage/flow data are the most important pieces of data that will be collected for this study. Field parameters such as dissolved oxygen, conductivity, temperature, pH, and transparency, are secondary for the study but should be collected where possible. Turbidity is a field parameter that is considered a parameter of primary importance. Turbidity, transparency, and conductivity may be the most useful of all the field measurements.

The Marshall-Beltrami SWCD does not have water quality monitoring equipment, although the Marshall County SWCD does have some. If the Marshall-Beltrami SWCD wants to do some of the monitoring/sample collection, they will have to acquire some monitoring equipment. One way they could do this is by borrowing equipment from the Marshall SWCD. Borrowing (existing) equipment from the RLWD would defeat the purpose of their monitoring efforts, which is to assist the RLWD in collecting samples to save the RLWD driving time, etc.

A turbidimeter and a transparency tube were purchased for the Marshall-Beltrami SWCD to use for the study using the equipment budget of the project. They were provided with coolers, bottles, preservative, data sheets, training, and chain of custody forms. None of the tile drainage sites within Marshall and Beltrami Counties are conducive to sonde monitoring, so a multiparameter sonde won't be purchased and measurements won't be collected for dissolved oxygen, temperature, conductivity, or pH in Marshall and Beltrami Counties.

## *Preliminary Monitoring Scenarios That Were Considered*

1. The tile drainage study will focus on a pair of monitoring site in Red Lake County. The tile drainage site that will be monitored is a gravity-tiled portion of a Bachand Brothers field in Section 8 of Lambert Township. Both surface and tile flow exit the field at a single point on the north side of State Highway 92. A surface monitoring site was also found on a Keith Swenson field that is basically located across the highway from the Bachand Brothers field. Surface flow from this field can also be measured at a single point (although a pair of flow measurement stations may be needed in order to measure flow without effecting the drainage on Swenson's field. These stations would be located within the township ditch upstream and downstream of the field ditch outlet. The amount of flow coming from the field would equal the flow at the downstream site minus the flow at the upstream site.

    a. The Keith Swenson site did not work for this study, so we decided to go with the Yaggie 2 site instead.

2. Todd and Arnold Stanley of Marshall County are very interested in having the RLWD monitor the quality of water being drained from their tile-drained fields.

    a. None of their sites, however, are ideal for measuring the quantity of water coming from the field. This is because of the volume of water that is carried in the ditch into which their gravity outlet tile drainage flows and the indeterminate watersheds of the individual tile drained fields. None of their sites are located at the top of their respective subwatersheds and are, rather, located toward the bottom. Rating curves for these ditches would be difficult to develop. There is at least one field, however, where all the flow (surface and gravity tile) goes the same direction. Although the flow estimates may be as accurate as desired by certain academics, we should still be able to quantify flow prior to and after drainage from this field. This would require at least a dozen trips to the site for stream gauging. The ditch should be gauged frequently enough to create a rating curve with an $R^2$ value of at least 0.9. This would prove the accuracy of the flow estimates that are based upon the rating curve.

   b. Water quality at the gravity tile drained Stanley field could be compared to a pumped system, surface drainage, or natural background (from state forest area to the East).

3. The wild rice paddy operations basically involve a square watershed with a controlled outlet. There are rice paddies with subsurface tile drainage and there are paddies with surface drainage only. All of the rice paddies have water control structures that are used for flooding the paddies in the spring and draining the paddies in the late summer for harvest.

   a. Compare water quality from a tile drained wild rice paddy to water quality from a surface drained wild rice paddy.

   b. Intensive sampling will be conducted at wild rice paddy outlets during the annual late summer drawdown for harvest. Water level data loggers will be installed at outlets that exhibit weir flow in order to estimate flow based upon weir dimensions and water level. The focus of this monitoring will be on the Red Lake Band of Chippewa wild rice paddies for the first year of monitoring and on the Clearwater Rice paddies for the second year of the project.

4. Compare concentrations of water quality parameters from a gravity tile outlet to concentrations from a pumped tile outlet and, if possible, to water quality from an outlet with a water control structure.

   a. If a water control structure is installed on one of Bachand's fields to get an accurate measurement of flow, then water quality (only) samples can be collected from one of Bachand's other gravity tile outlets and from one of Hilgeman's or Bachand's pumped tile sites.

   b. This could be done with the Marshall/Beltrami County sites as well.

## *Data Acquisition Requirements*

Of course, water quality and flow are the most important types of data that will be collected for the study. However, there are many other types of data that are also important. They will aid in the analysis of data. This data should be collected for each growing season.

1. Watershed Area
2. Land Use
3. Types of crops grown on each field
4. Tile spacing
5. Tile Depth
6. Amounts and types of fertilizer applied to the fields
7. Dates and times that equipment was installed.

Also, notes will be taken in a field notebook dedicated to the project. These notes will provide information that may be valuable when analyzing and interpreting data.

## *Non-Direct Methods*

ArcView, versions 3.1 and 9.1will be used for map creation and spatial analysis of each field that is being monitored. SSURGO soils data, along with the Soil Data Viewer will be used to analyze the soils in each field. Delineations of watershed will be completed digitally in ArcView using USGS topographic quad maps, field observations, and surveys.

## *Red River Watershed Management Board Flow Monitoring Plan*

Development of Agricultural Tile Drainage Design Guidance for the Red River Basin

Draft, 4-12-05

Background

Tile drainage has been present in the Red River Basin for many years, but only to a limited extent. The installation of tile has greatly accelerated in recent years. This is probably influenced by the current wet period in the climatic cycle. It is also likely driven by agricultural economic factors and by the natural progression of agricultural development. It may be a next logical step for many farmers striving to increase agricultural output or improve efficiency.

Current applications range from random tiling of nuisance wet areas, such as low spots, swales, and ditch bottoms, to pattern tiling of entire fields. In most cases, the tile drainage enhances or augments, but does not completely replace, surface drainage. These applications are almost exclusively applied to existing cropland.

Concern

The Red River Basin is notoriously flood prone, including the main stem of the Red River and most of its tributaries. It is a widely held belief that agricultural development in general and drainage improvements in particular are responsible for increased flooding.

A cause and effect relationship between historic drainage improvements and flooding on the Red River has not been proven and may not be true. This is probably due in part to the fact that drainage has mixed effects relative to flood flows. For example, drainage of hydrologically isolated potholes will undoubtedly add to downstream flows. On the other hand, drainage of wet areas tends to reduce antecedent moisture conditions thereby reducing subsequent direct runoff. Furthermore, other features associated with drainage, such as culverts, may tend to reduce downstream peak flow rates.

Despite the fact that a connection between historic drainage and increased Red River flooding has not been proven, it should not be assumed that future drainage improvements will have no effect. That will depend on the type and design of improvements being considered. It may also depend on the location within the basin of the considered improvements.

## Purpose of study

The purpose of this study is to help develop a better understanding of tile drainage and its potential effects on downstream flows in the Red River Basin. The intent is not to determine if tile drainage is good or bad from the standpoint of flooding. Rather, it is to determine how adjusting basic tile design parameters might influence downstream effects.

## Desired outcome

The goal is to develop tile drainage design guidelines specific to the Red River Basin. These guidelines would allow landowners to enjoy most, if not all, of the benefits commonly associated with tile drainage, but with due consideration given to downstream effects.

## Premise

Tile drainage design standards have evolved through years of practice in heavily tiled areas such as southern Minnesota and other areas such as Ohio, Indiana, Illinois and Iowa. Standards developed elsewhere may not be appropriate for the Red River Basin for the following reasons:

1. The climate in the Red River Basin is much drier than in most heavily tiled areas. This is probably the primary reason why tile drainage has been slow to develop in the Basin. Because the amount of excess moisture is less, the required tile drainage capacity in the Red River Basin may also be less.

2. The Red River and most of its tributaries are very prone to flooding. These flood prone streams may be quite remote from the field being tiled. However, they may be impacted by the cumulative effects of tile drainage throughout their watershed area. It is generally accepted that tile drainage in moderate to low permeability soils with a high water table tends to decrease peak outflows from fields, which

would benefit downstream flooding. But there is also some evidence that the volume of flow may increase. This would tend to aggravate downstream flooding particularly on streams with long flood durations such as the Red River where, 30 days of continuous flooding is not uncommon.

## Phase 1 study

The phase 1 study will focus at the field scale. It will explore the effect of varying the primary design parameters associated with pattern tiling which are tile size, depth, and spacing.

It will first attempt to optimize design parameters based on field scale benefits and costs. The predicted effect on the downstream hydrograph of field optimized tile drainage versus surface drainage will be reported.

Next it will explore the effect on the downstream hydrograph of changing design parameters, individually and in combination. The relationship to field level benefits and costs will also be reported.

### Methodology

A field scale model will be developed based on typical conditions in the Red River Basin related to lands likely to be tiled. The model will consider both surface and subsurface drainage. The model should be capable of analyzing both single event design storms and continuous long-term historic climatological data. Use of the continuous model will best account for the semi-arid climate of the Red River Basin. Single event modeling will be used to develop relationships based on specific sets of assumptions.

### Variables

**Given variables** include soil type, climate, and land use.

At least 3 soil types will be considered including typical, lighter, and heavier soils.

Climatic records from at least 2 long-term stations will be used. These will likely include Crookston and Morris.

Land use will be what is considered typical of the Red River Basin. However, if tiling is anticipated to change future land use, the effect of anticipated land use changes should also be considered.

**Independent variables** include the primary design parameters of tile size, depth, and spacing.

Tile size determines the maximum outflow rate from the subsurface drain system. A commonly recommended design capacity is based on a 3/8" design coefficient. This would be equivalent to a flow rate of about 10 cfs per square mile of area drained. Tile size corresponding to this flow rate will be considered along with other, primarily lower, design flow rates.

Tile depth contributes, along with spacing, to the gathering capacity of the tile. It also determines how low the water table can be artificially drained by the tile. This will directly influence the amount of soil water storage capacity available at the beginning of precipitation and flood events. Common tile depths are 3 to 4 feet. These will be considered along with other, primarily deeper, tile depths.

Tile spacing contributes, along with depth, to the gathering capacity of the tile. Usually, depth is determined first based on other considerations and then the required tile spacing is determined based on desired gathering capacity. Gathering capacity is the ability to move water laterally through the soil to the tile when the water level at the highest point between the tiles is slightly below the ground surface. It is customary to design gathering capacity to the same drainage coefficient as the tile capacity is designed to. As discussed above, a commonly recommended design coefficient is 3/8". This will be considered along with other, primarily lower, coefficients. Tile spacing will be evaluated independent of the tile size variable.

**Dependent variables** are the results of the design alternatives considered. Those of primary interest are related to agricultural benefits, costs, and downstream flows.

Agricultural benefits will be evaluated using the continuous model. Specific outputs may include the number of times the water table would be above the ground surface and the duration of high water table conditions preventing field work or retarding plant development.

Cost of installation will be determined based on typical contract prices.

Downstream flows, at the field outlet, will be evaluated using both the continuous and single event models. The variables considered will be peak flow, total volume, and volume released during a flood window (8 days, more or less), and volume released after the flood window. Outflow hydrographs will be reported in addition to numerical output.

**Additional studies**

The need for additional phases of study will depend on the outcome of the initial phase. The most logical following step would be a determination of watershed scale flood effects associated with different design alternatives. There may also need to be additional study to evaluate effects specific to random tiling. These, along with the results of the phase 1 study, would lead to recommended design criteria for the Red River Basin. Consideration would also be given to modifying criteria based on location within the basin to account for timing or other factors.

# Data Quality Objectives for Measurement Data

## *Sample handling and Custody Methods*

Samples will be handled, preserved, and logged according to the methods described in Sections 4 and 7 of the *Standard Operating Procedures for Water Quality Monitoring in the Red River Basin*.

## *Quality Control*

Red Lake Watershed District water quality staff (and anyone collecting samples in conjunction with the RLWD) use the guidelines presented in Section 3 of the *Standard Operating Procedures for Water Quality Monitoring in the Red River Basin*.

### Accuracy

Water quality samples will be collected using the methods outlined in the *Standard Operating Procedures for Water Quality Monitoring in the Red River Basin*. The methods described in this manual are designed to minimize the possibility of sample contamination and therefore maximize accuracy. Any equipment used for collecting water quality data should be kept clean and properly calibrated.

## *Instrument Calibration, Frequency, and Record-Keeping*

The RLWD keeps a log of every multiparameter sonde calibration. Sondes are calibrated before each sampling day for dissolved oxygen and approximately monthly for pH and conductivity. Turbidimeters should be calibrated with Formazin standards once every three months and calibration checks should be conducted monthly using Gelex standards. See Section 8.1.B of the *Standard Operating Procedures for Water Quality Monitoring in the Red River Basin* for more details and calibration check instructions. Consult the HACH 2100P manual for Formazin calibration methods.

## *Inspection/Acceptance Requirements for Supplies*

Certain supplies will be needed for the project these include:

1. Distilled Water for rinsing turbidity vials, rinsing transparency tubes, and for blank samples
2. Coolers for shipping samples
3. Sample bottles
    a. Approx 750 ml TSS bottles

    b. 500 ml phosphorus bottles
    c. 250 ml phosphorus sample bottle
4. Sulfuric acid, in 1 ml and 2 ml vials, for preserving samples
5. Chain of Custody Forms
6. Standard solutions for calibration of multiparameter sondes

Distilled water can be purchased at grocery stores by anyone that is conducting monitoring. Two coolers have been provided to the Marshall-Beltrami SWCD along with at least four sets of sample bottles, sulfuric acid bottles, and at least two chain of custody forms. After the lab receives the coolers, they are shipped back to the agency from which they were shipped, so it is important to place a shipping label with the Marshall-Beltrami SWCD's return address on the coolers containing samples they have collected. This ensures that RMB Environmental Laboratories will send coolers back to the SWCD so they will have them for the next round of sampling. When coolers are received back from the lab, they should be checked to make sure that the correct numbers of bottles and sulfuric acid vials have been returned.

The RLWD keeps a supply of pH and conductivity standard solutions for multiparameter sonde calibration and regularly calibrates its sondes according to the methods and frequency recommended in the *Standard Operating Procedures for Water Quality Monitoring in the Red River Basin*.

## Special Training Requirements/Assessment

No further water quality sampling training should be necessary for Red Lake Watershed District Staff. They currently conduct a long-term water quality monitoring program and did the majority of the writing for the *Standard Operating Procedures fro Water Quality Monitoring in the Red River Watershed.* If SWCDs are going to collect samples, the RLWD should make sure they are using the same methods. All project partners will be provided with a copy of the *Standard Operating Procedures for Water Quality Monitoring in the Red River Watershed*. RLWD staff will accompany SWCD samplers for at least two sampling runs at the beginning of the project to make sure they are using correct methods.

## Documentation and Records

### *Data Management*

Data will be recorded on data sheets in the field by the Red Lake Watershed District and the Marshall-Beltrami SWCD. Data will then be stored and analyzed using Microsoft Excel spreadsheets. Data will be maintained by the Red Lake Watershed District. Field measurements will be recorded on field data sheets. These field data sheets will be kept in a file at the RLWD. Chain of custody forms will also be kept in a file. When results are received from RMB Environmental Laboratories, they will be entered into spreadsheets as soon as possible.

Data should be checked for errors. After entering set of sampling results, the numbers in the paper copy should be checked against the spreadsheet to make sure they match before the paper copy is filed. Outlying results should be checked against field data sheets and lab results.

The original paper copies of the results will be placed in a fire-proof file at the RLWD office. Data is backup is performed monthly at the RLWD and is stored on an external hard drive that is stored in a safe deposit box.

## Assessment and Oversight

Assessment and oversight of this project will be conducted by the RLWD project manager (Water Quality Coordinator), Red River Watershed Management Board, HDR Engineering, Northwest Minnesota Foundation (funding), University of Minnesota staff, and others.

As part of the grant agreement, the RLWD agrees to:

1. Use the funds as specified in the approved grant proposal.
2. Maintain your records to show and account for the uses of grant funds.
3. Allow NMF access to records to show and account for the uses of grant funds.
4. Participate in any future evaluation conducted by the NMF, including providing information and statistics as requested.
5. Repay any portion of the funds not used for the specified purpose.
6. Refrain from use of any funds for purposes prohibited by law.
7. Cooperate with any efforts of NMF to publicize the grant award.
8. Comply with reasonable requests for information about program activities.
9. Meet any additional terms and conditions specified by the NMF.

### *Assessment and Response Actions*

At the end of the first year of monitoring, data will be reviewed. It will be assessed for completeness. The data will be examined to determine whether or not changes in the monitoring program are necessary. A critical eye should be focused on the project, for many may be focused upon its results. Several questions should be asked. Is the sampling frequency sufficient? Are we sampling the right number of parameters? Is the accuracy of our monitoring program sufficient to satisfy the critical reviewer? What sorts of hypotheses are developing? Is our data reliable to prove or disprove these hypotheses? A presentation featuring preliminary results may be requested by one or more organization.

### *Reports*

Semi-annual reports will be produced for the Northwest Minnesota Foundation. After the completion of the second year of monitoring, a scientific report will be written and distributed. Also, a pamphlet summarizing the results will be produced. All of these materials will be made publicly available on the RLWD website: www.redlakewatershed.org.

The RLWD will include mention of NMF sponsorship of the project in press releases, news conferences, and other media contacts concerning the project. Material developed or published by the project, including brochures, announcements, flyers, manuals, reports, etc. shall mention NMF sponsorship. Copies of NMF's logo suitable for reproduction are available upon request.

| | |
|---|---|
| Interim Activity and Financial Reports Due: | June 15, 2005<br>December 15, 2005<br>June 15, 2006 |
| Final Activity and Financial Report Due | March 1, 2007 |

Presentations on the project goals and methods will be given whenever there is an opportunity. After completion of the project, an abstract will be submitted to one or more water-related conference so that the results can be presented to other scientists and decision makers.

## Data Validation and Usability

### *Data Review, Validation, and Verification Requirements*

Data spreadsheets, field data sheets, and field notebooks will be examined to make sure all data used for analysis is acceptable. If there is reason to suspect the accuracy of a set of results (potential contamination, etc.), the data may not be used.

### *Validation and Verification Methods*

In stage data, outliers that are the result of disturbance will be removed from the record. Samples collected during periods of no flow, if collected, will be noted, but not included in statistical analysis. Sites that were abandoned or for which there are only a few samples may be considered for reinforcing project findings, but won't be used in statistical analysis. If field notes mention a possibility that a sample may have been contaminated, the results for sample will be excluded from statistical analysis.

### *Reconciliation with Data Quality Objectives*

Data will be examined for completeness. Results from blank and duplicate samples will be noted and analyzed.

## References


Brown, Larry C. and Jay W. Johnson. "Nitrogen and the Hydrologic Cycle." Ohio State University Extension Fact Sheet. http://ohioline.osu.edu/aex-fact/0463.html. Accessed on October 19, 2004.

Busman, Lowell and Gary Sands. *Agricultural Drainage Publication Series: Issues and Answers*. Regents of the University of Minnesota. 2002.

Craig, Bill. "Field Drain Economics" Microsoft PowerPoint Presentation. 2005 Agricultural Tile Drainage Design & Soil Water Management Workshop. February 23, 2005.

Fraser, Heather and Ron Fleming. "Environmental Benefits of Tile Drainage – Literature Review. " Land Improvement Contractors of Ontario. October, 2001.

Kandel, Hans. "Tile Drainage Research in Northwestern Minnesota" Microsoft PowerPoint Presentation. 2005 Agricultural Tile Drainage Design & Soil Water Management Workshop. February 23, 2005.

Kean, Al and Gary Sands. "Subsurface Drainage, Hydrology and WQ Considerations Microsoft PowerPoint Presentation. " 22nd Annual Red River Basin Land and Water International Summit. January 12-14, 2005.

Land Improvement Contractors of Ontario. LICO Fact Sheets. Active Web Corporation. 1998.

Red Lake Watershed District. *Protocols for Water Quality Data Management and Analysis (*draft). January 2005.

Red Lake Watershed District. *Standard Operating Procedures for Water Quality Monitoring in the Red River Watershed Revision 6.* October 24, 2003.

Red Lake Watershed District. "Red Lake Watershed Farm to Stream Project Proposal to the Northwest Minnesota Foundation". September 23, 2004.

Sands, Dr. Gary, "Agricultural Drainage 101" Microsoft PowerPoint Presentation.

Sands, Dr. Gary. "Feasibility of Controlled Drainage for Mitigating Nutrient Loss From Tile Drainage Systems in South Central Minnesota." WRC Research. 2001.

Sands, Dr. Gary. "Frequently-Asked Questions About Subsurface (Tile) Drainage." 2005 Agricultural Tile Drainage Design & Soil Water Management Workshop. February 23, 2005.

Sands, Dr. Gary. "Tile Drainage in the Red River Valley" Microsoft PowerPoint Presentation. Red River Basin Water Quality Team Meeting. April 28, 2003.