1300

North Dakota State Water Commission

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September 15, 2015

Roger Sauer
Renville County Water Resource Board
7635 30th Ave. NW
Glenburn, ND 58740

RE: Renville County Study – Tolley Slough

Enclosed is a written report that summarizes the findings of the Tolley Slough study conducted in Renville County and fulfills the responsibilities of the State Water Commission (SWC), as stated in the agreement between the Renville County Water Resource Board and the SWC, dated June 30th 2013.

As part of this study, the SWC examined the hydrology of the Tolley Slough drainage basin, evaluated potential outlet configurations and other measures to mitigate issues related to elevated slough, natural outlet, and groundwater levels, and completed a written report with findings and cost estimates.

This report includes survey data collected as part of the study and the hydrologic model of the basin.

If you have any questions, or would like to meet to discuss the results please contact me at 701-328-4956.

Sincerely,

James Timothy Fay, P.E.
Investigations Section Chief

Tolley Slough Investigation Report

SWC Project #1300
North Dakota State Water Commission
900 East Boulevard
Bismarck, ND 58505-0850

Prepared for:
Renville County Water Resource Board

June 2015

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1. Introduction

Tolley Slough is located near the city of Tolley in Renville County. The Renville County Water Resource Board (Board) contacted the North Dakota State Water Commission (SWC) about overland flooding on January 24th of 2012. The Board commented that the slough used its natural outlet in July of 2011, damaging county roads and inundating farmland. Northern Plains Railroad is the main connection for Tolley's' grain elevator and has had problems with inundation, ice formation, and saturating the railroad tracks. The Board's investigation request was to examine the hydrology and the possibility of lowering the water surface of the slough to a more manageable level.

The SWC agreed to conduct a study investigating the hydrology of the basin and evaluate mitigation alternatives.

Tolley Slough is much like other pothole regions; it receives inflows from direct precipitation and runoff from snowmelt and rainstorms. The area around the slough has dramatically changed since 2010, when the slough was relatively dry. Figure 1 compares the 2010 National Agricultural Imagery Program (NAIP) with the 2012 NAIP.

Figure 1. Tolley Slough, 2010 on the left compared to 2012 NAIP on the right.

1.1 Site Location

Tolley Slough is located in central Renville County in north central North Dakota, adjacent to the city of Tolley. The slough is located with Sections 19, 20, 29, 30, 31, 32, 33 of Township 161 North, Range 86 West; Sections 6 of Township 160 North, Range 86 West; and Sections 1, 2, 12 of Township 160 North, Range 87 West. Currently the surface area of the slough is approximately 2.9 square miles and is situated within a contributing basin of 58.8 square miles.

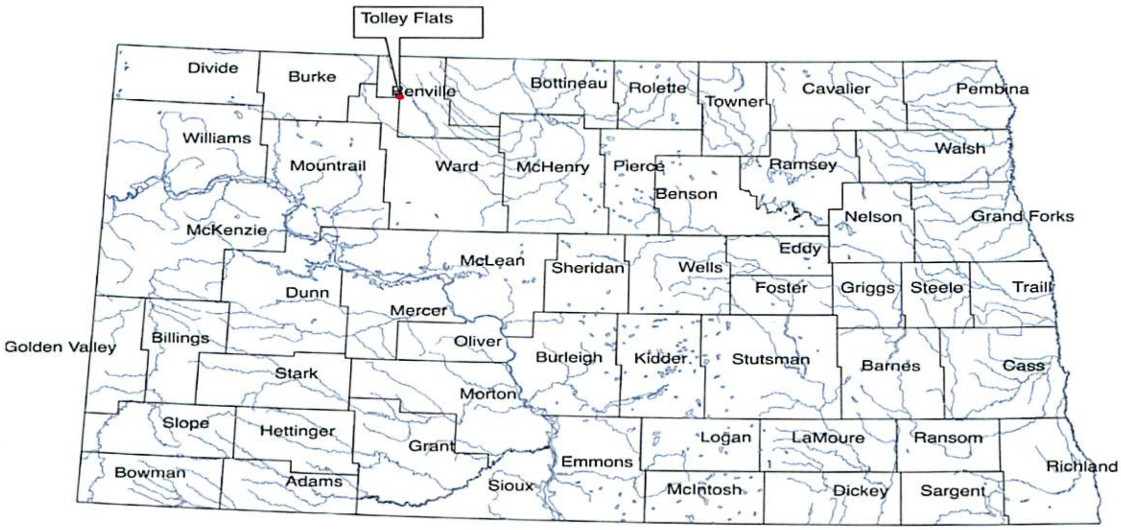

Figure 2. Tolley Slough, Site Location.

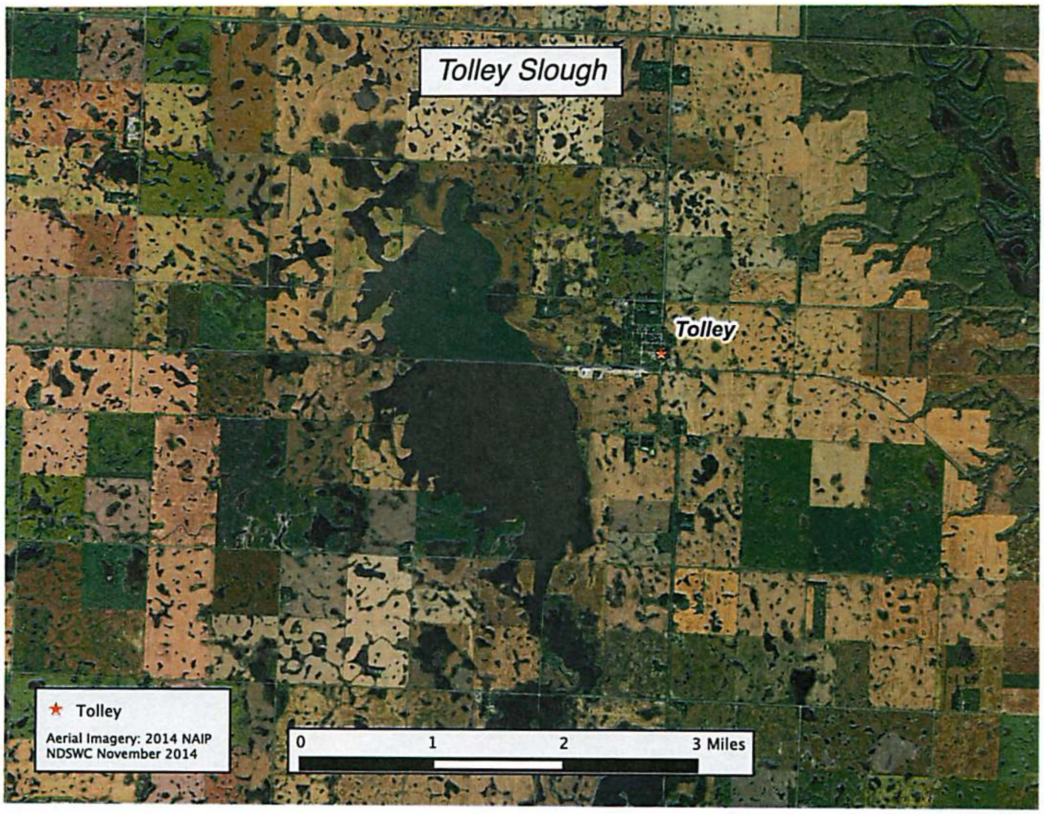

Figure 3. Tolley Slough, 2012 NAIP.

1.2 Problem Background

The city of Tolley experienced overland flooding from the slough every year since the summer of 2010. The flooding from the slough is currently consuming farmland, inundating roadways, and has temporarily inundated the railroad. However, prior to 2010, the slough was typically dry or it only inundated small amounts of farmland, but seldom reaches the level of its natural outlet.

Northern Plains Railroad has also witnessed ice on the slough exerting stress on the railroad track. Ice formation in the fall of 2014 caused delays in the railroad's operation due to the ice bending the rails and moving them out of alignment.

The current water surface, near the natural outlet elevation, is one of the main causes of concern. Once the water surface increases, the slough begins to discharge over its 15-mile long natural outlet, damaging roadways and inundating farmland. Figure 4 shows the natural outlet of the slough drainage through Mackobee Coulee into Lake Darling.

Culverts along the outlet path are undersized and silted in, increasing flows across county roads. Existing culverts along the natural outlet, when cleaned, would provide insignificant flow during an outlet event.

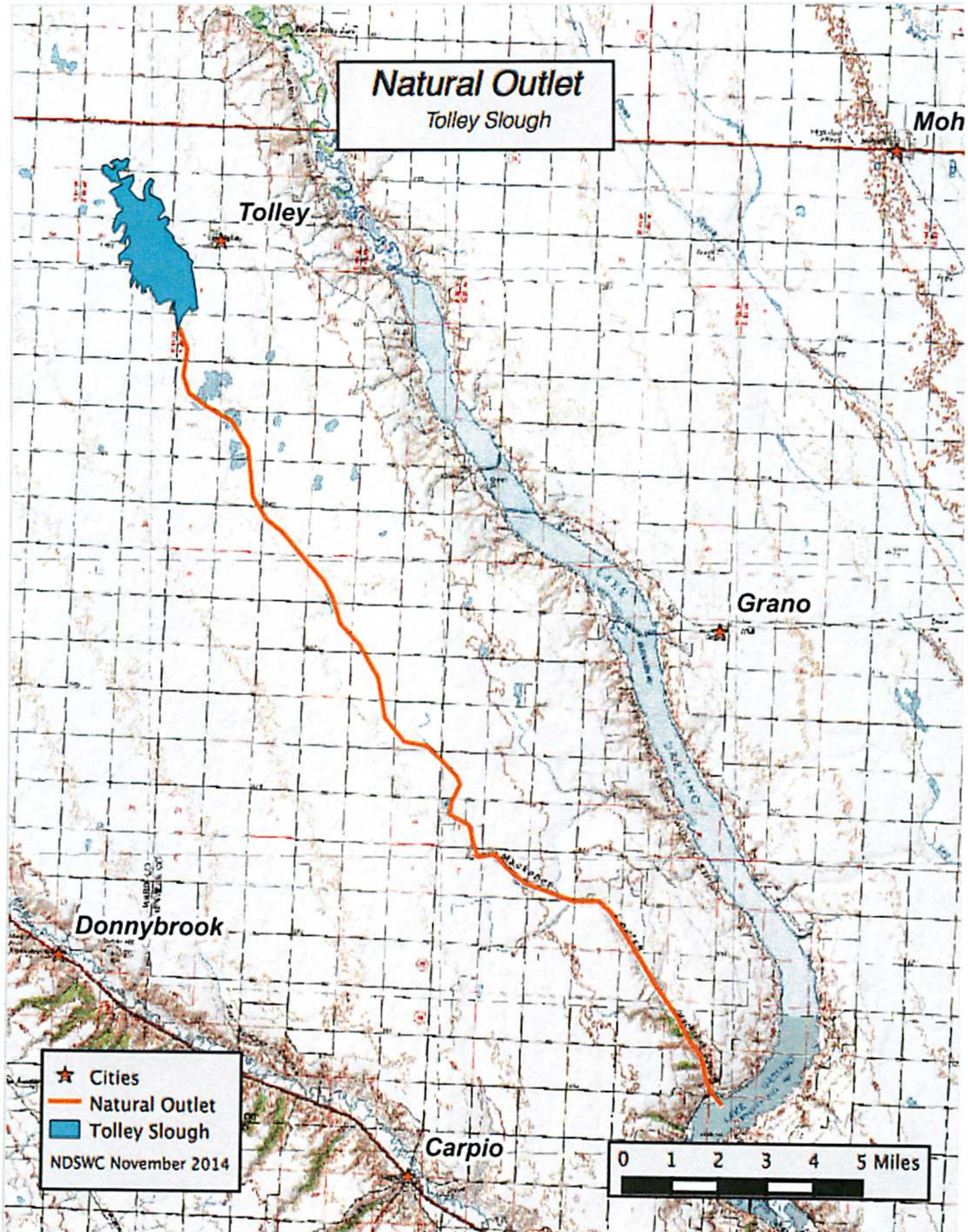

Figure 4. Natural Outlet, Tolley Slough.

An elevation capacity curve is shown in Figure 5. The digital elevation model used to compute the elevation capacity curve came from the National Elevation Dataset (NED) and any data derived from the NED should only be used as an approximation.

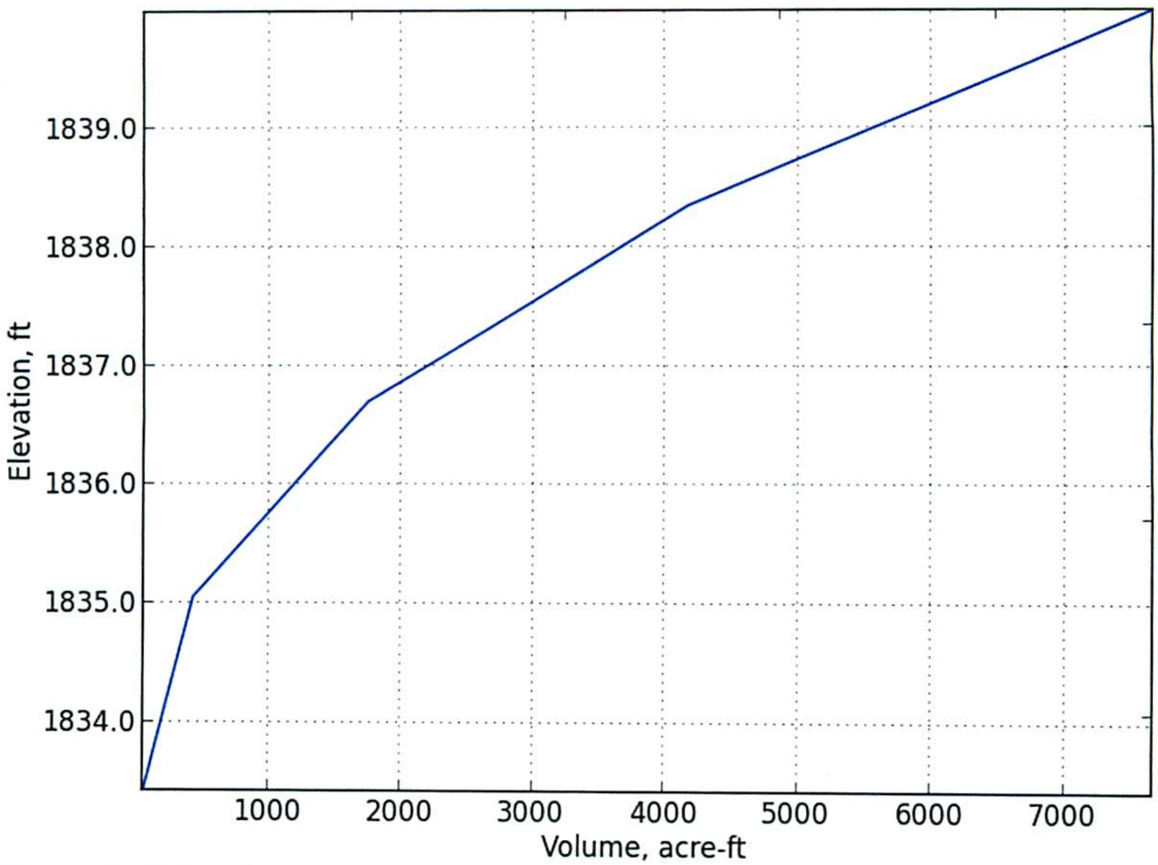

Figure 5. Tolley Slough elevation-capacity curve.

The elevation capacity curve shows the slough's maximum water surface to be nearly 1840 ft before it discharges through its natural outlet. At 1840 ft the slough holds approximately 7500 acre-ft of water. Since it has recently discharged, it is assumed the slough is currently at its maximum capacity, having no additional storage.

2. Survey

A survey of the surrounding water surface elevations, railroad track elevation, and possible drainage route were completed on June 2nd of 2012. The vertical datum for the survey was North American Vertical Datum 1988 (NAVD 88) and the horizontal datum was North American Datum 1983 (NAD 83). Figure 6 shows the water surface elevations from the survey conducted on June 2nd 2012. The survey data collected is available in Appendix A.

Light Detection And Ranging (LiDAR) data was collected for the area east of Tolley, ND. The LiDAR data is a 1-meter collect in horizontal datum NAD83 and vertical datum NAVD88.

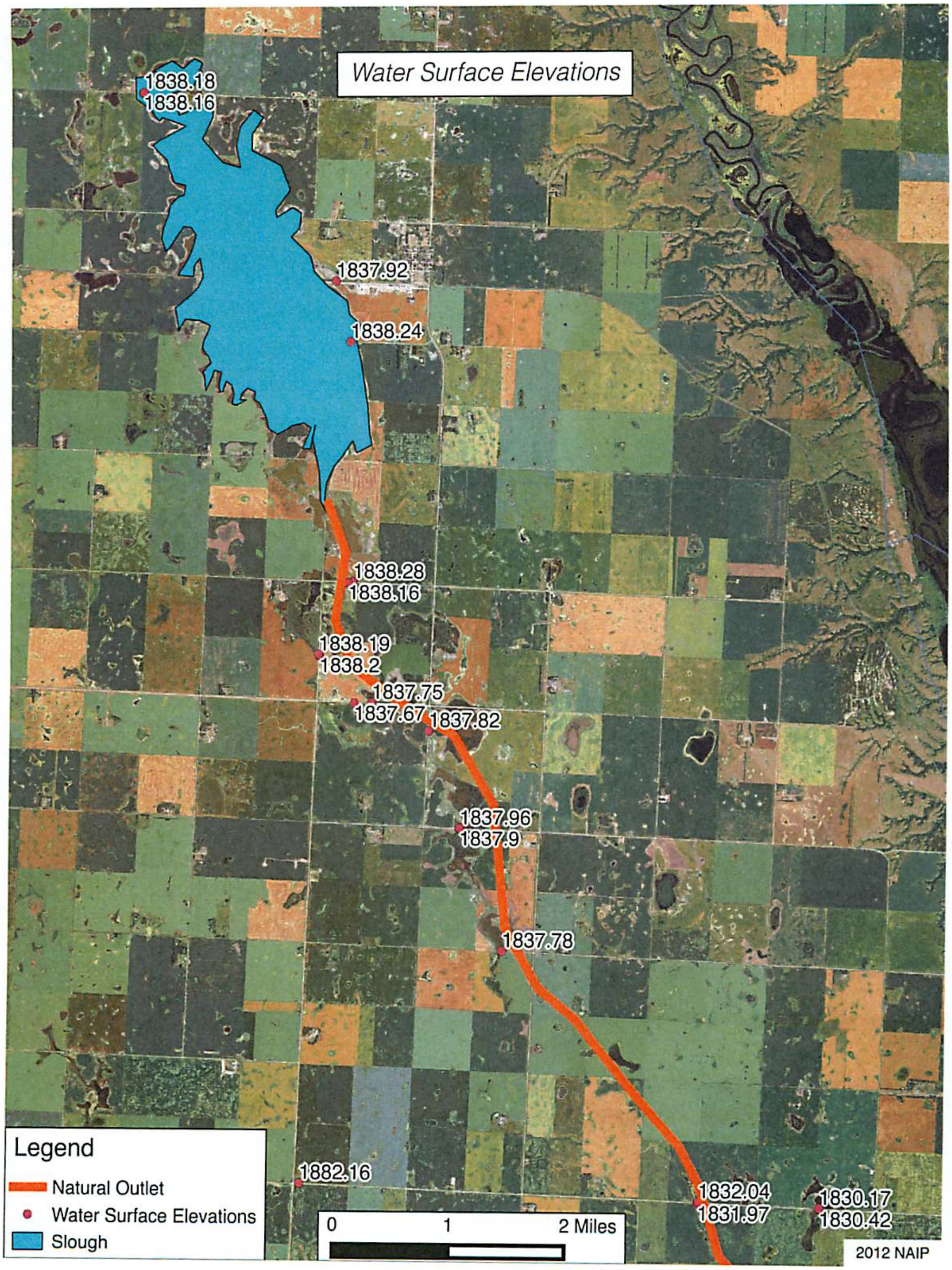

Figure 6. Water Surface Elevations, June 2nd 2012.

3. Geology

Tolley Slough hasn't been known to have strong groundwater connection to other bodies of water. The surface geology suggests that the slough bed is composed of silt surrounded by glacial till. Figure 7 depicts a geologic surface map created from the Soil Survey Geographical Database (SSURGO).

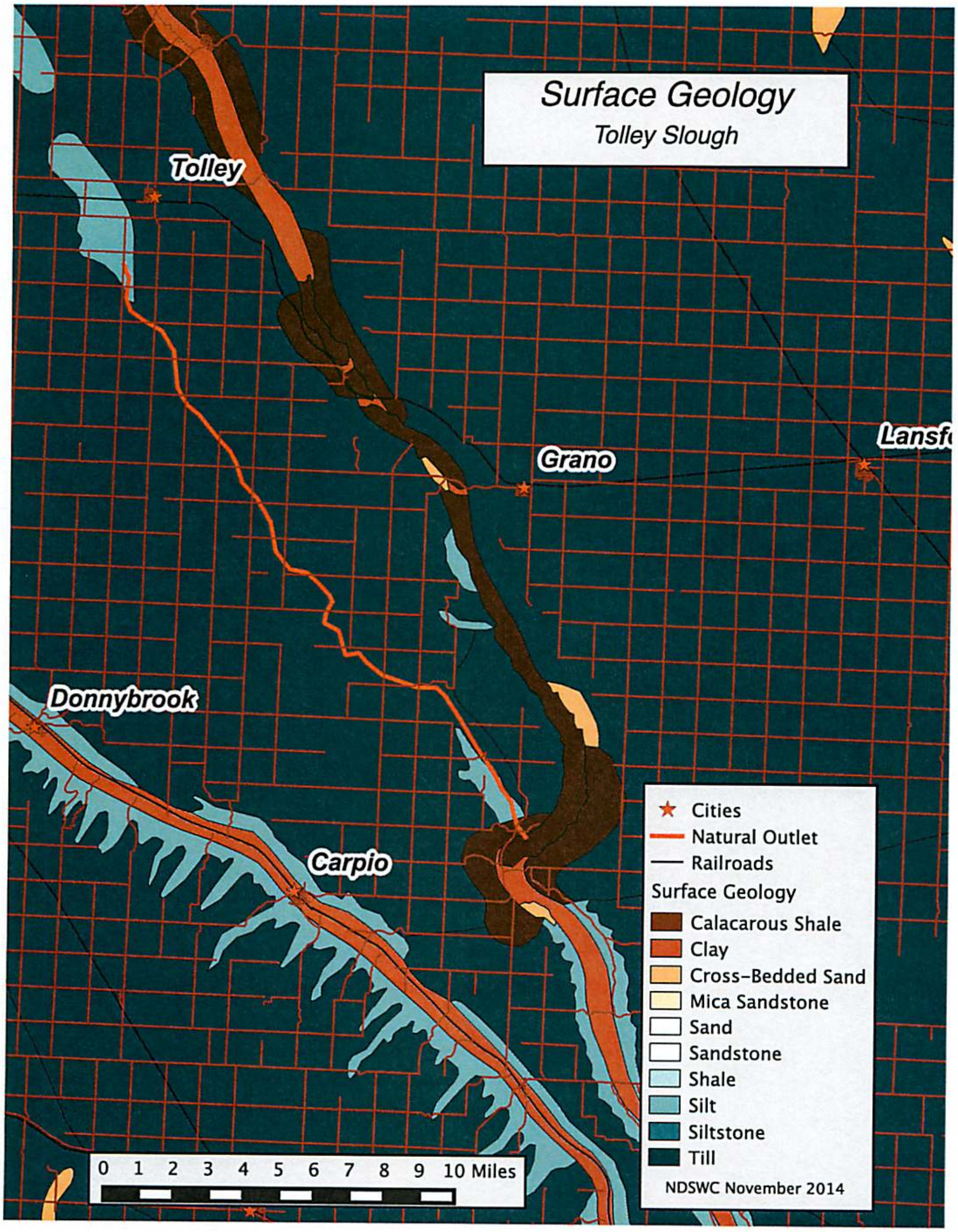

Figure 7. Tolley Flats Geologic Surface Map (SSURGO).

This map suggests silt lining on Tolley Slough, which could be preventing the slough infiltration into the subsoil. The silt lining also makes it unlikely that Tolley Slough would have a strong ground water connection.

Boring logs (Appendix B) near Tolley Slough also indicate that the first 30 feet of soil is clay. Thick clay layers do not typically allow strong groundwater connections supporting the geologic surface data showing a poor groundwater connection.

The surveyed water surfaces of neighboring water bodies appear to be similar in elevation to the slough of interest near Tolley. Since the survey was collected after the outlet's discharge, the similar water surfaces are primarily caused by the natural discharge over flat ground and not a strong groundwater connection. This assumption can be justified by the boring logs and geologic surface map.

4. Hydrology

The climatic conditions of the area were examined to determine hydrologic inputs to the study area. These inputs were used in a HEC-HMS model to determine the effect of certain events at Tolley Slough.

4.1 Climate

North Dakota's geographic location lends itself to extreme variability in precipitation. As a result, the state's history includes many drought and flood events. Since 1993 much of the state has received above average precipitation.

Yearly precipitation data was obtained from the National Climate Data Center (NCDC) for North Central North Dakota, also known as North Dakota Climate Region 2. Figure 8 shows the average yearly precipitation data collected since 1990 for North Central North Dakota.

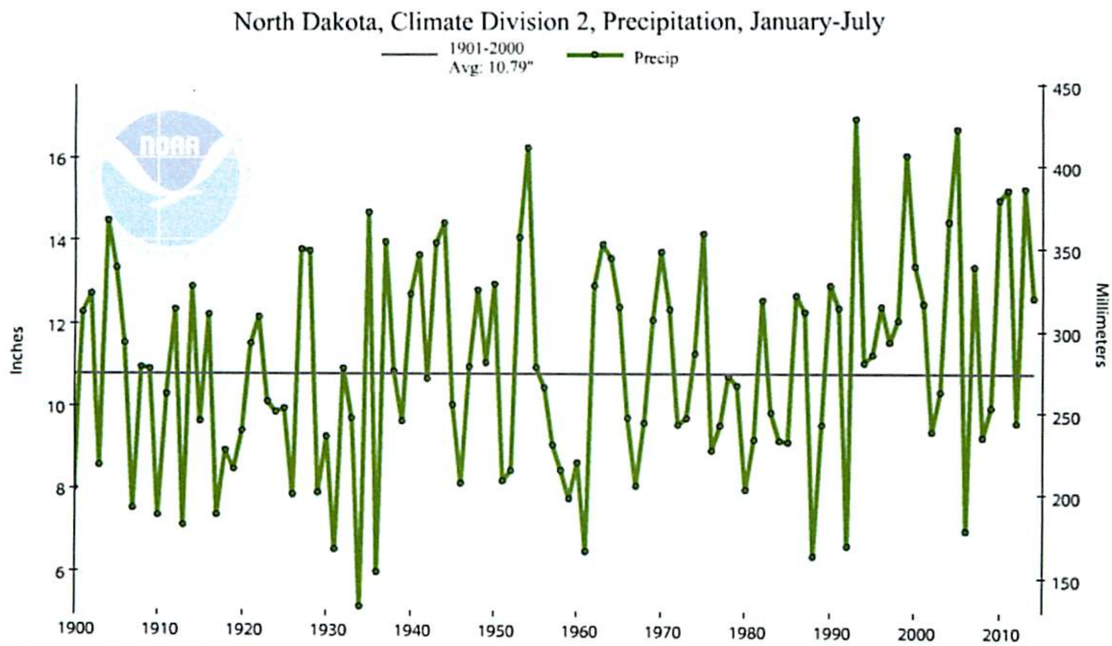

Figure 8. NCDC's annual precipitation plot for North Central North Dakota.

4.2 Hydrology Model

The U.S. Army Corps of Engineers' Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS, version 4.0) was used to model the hydrology of the Tolley Slough Basin. Spatial analysis and the calculation of some hydrology model parameters were performed using ArcMap (versions 9.3 and 10.0) and Quantum GIS (version 2.0.0). Inputs for the HEC-HMS model include basin area, transform parameter, and a loss parameter.

4.2.1 Basin

Terrain preprocessing was performed using the Spatial Analyst tools in ArcMap on a 10-meter resolution DEM from the NED. The basin was kept as one continuous sub-basin, as shown in Figure 9.

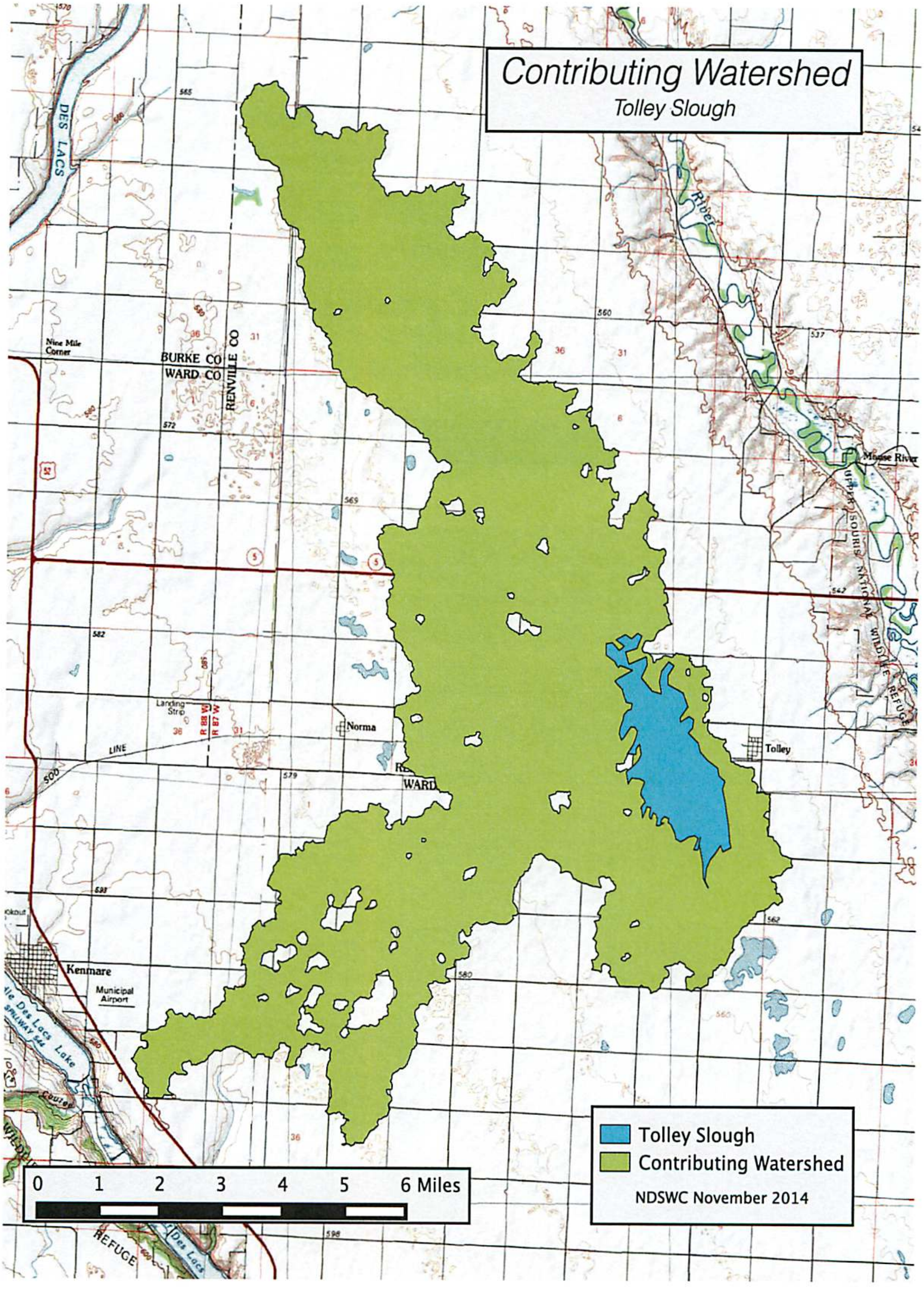

Figure 9. Tolley Slough, Contributing Watershed.

4.2.2 Transform Method

The Soil Conservation Service (SCS) unit hydrograph model was selected as the transform method. The time of concentration (TOC) was calculated using a GIS travel time tool. A more detailed discussion on the travel time tool is provided in Appendix C. Land class and wetland data were required for use of the travel time tool. Land class data was obtained from the National Land Cover Database 2006 (NLCD2006). Wetland data was acquired from U.S. Fish and Wildlife Service's National Wetland Inventory. The calculated TOC value for the basin is provided in Table 1.

Table 1. Tolley Slough time of concentration.

	Drainage Area (Square Miles)	TOC (hr)	Lag Time (min)
Tolley Slough Basin	58.8554	120	7200

4.2.3 Loss Method

The Green-Ampt loss model was used as the loss method in the hydrology model. A more detailed discussion on the Green-Ampt algorithm is provided in Appendix C. The calculated Green-Ampt parameters are provided in Table 2.

Table 2. Tolley Slough HEC-HMS loss parameters.

	Porosity	Hydraulic Conductivity (in/hr)	Suction (in)	% Impervious
Tolley Slough Basin	0.47436	0.16776	19.58058	4

4.3 Frequency Storms

The frequency storms used in the Tolley Slough Basin HEC-HMS model were created using Atlas 14 point precipitation data. The data collected was partial duration series data.

Table 3. Runoff generated from frequency storms.

Frequency Event (Year)	Percent Chance of Reoccurrence	Runoff (acre-ft)
10	10	2,286
25	4	3,241
50	2	3,927
100	1	4,738
500	0.2	6,840

5. Flood Mitigation Design

A stable outlet from Tolley Slough will reduce damages to Renville County roads and Northern Plains Railroad, while also lowering the water surface to allow access to currently inundated farmland. The county roads along the natural outlet could be affected depending on the severity of the event. Figure 10 is a map of the roads that could be affected when the outlet is discharging. The list of the county roads that could be affected during outlet discharge is located in appendix C.

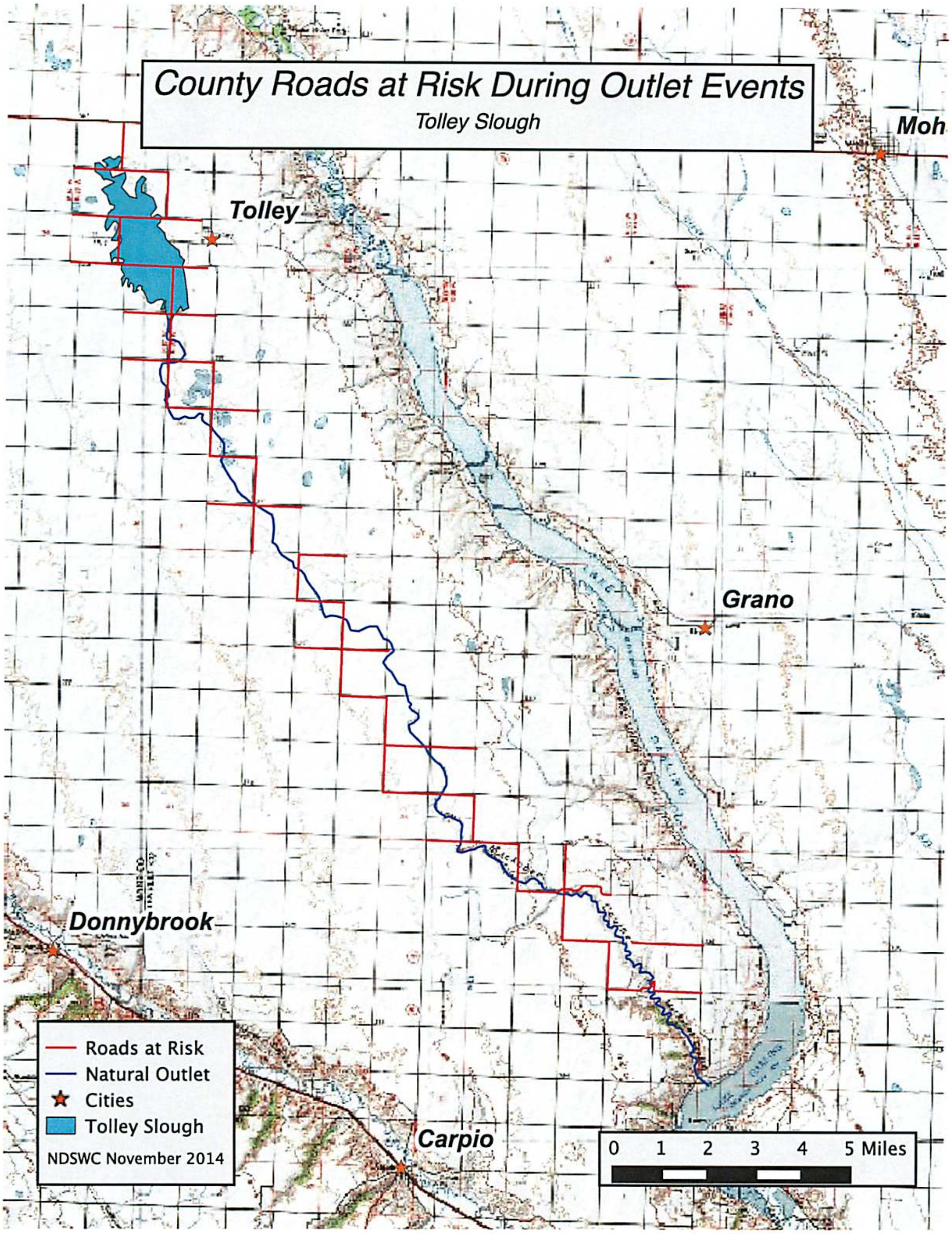

Figure 10: Roads that could be affected by Tolley Slough's natural discharge.

A water surface elevation of 1835.5 ft would alleviate damages to roads, railroads, and decrease the inundation area of the surrounding farmland. Reducing the slough to this level would leave nearly 800 acre-feet of water in the wetlands, conditions similar to those prior to 2010.

Reducing water levels to 1835.5 ft. requires that the outlet would be able to remove nearly 6700 acre-feet of water. Designing an outlet to remove 10 cfs would be equivalent to removing 20 acre-feet per day, taking roughly 335 days. Since the average open water season in North Dakota is between April and November it would take nearly two years to reduce the water surface in the slough, providing no new inflows would enter. If however, the allowable rate for the outlet increased to 20 cfs, or 40 acre-feet per day, the outlet would be able to handle inflows and reduce the time needed to lower the water surface elevation of the slough. Increasing the flow to 20 cfs would decrease the slough elevation to desired levels in 188 days, providing no new inflows enter Tolley Slough. An outlet with a discharge capacity of 20 cfs was then created in the HEC-HMS model. The reservoir representing Tolley Slough in the HEC-HMS model's water surface was then lowered to an elevation of 1835.5. These modifications to the HEC-HMS model can show the affects of creating the proposed outlet structures. Each of the frequency events were then re-run with the modifications in place to view the outcomes of each event. Figure 11 shows the behavior of Tolley Slough equipped with a 20 cfs outlet during a 10, 25, 50, and 100 year event.

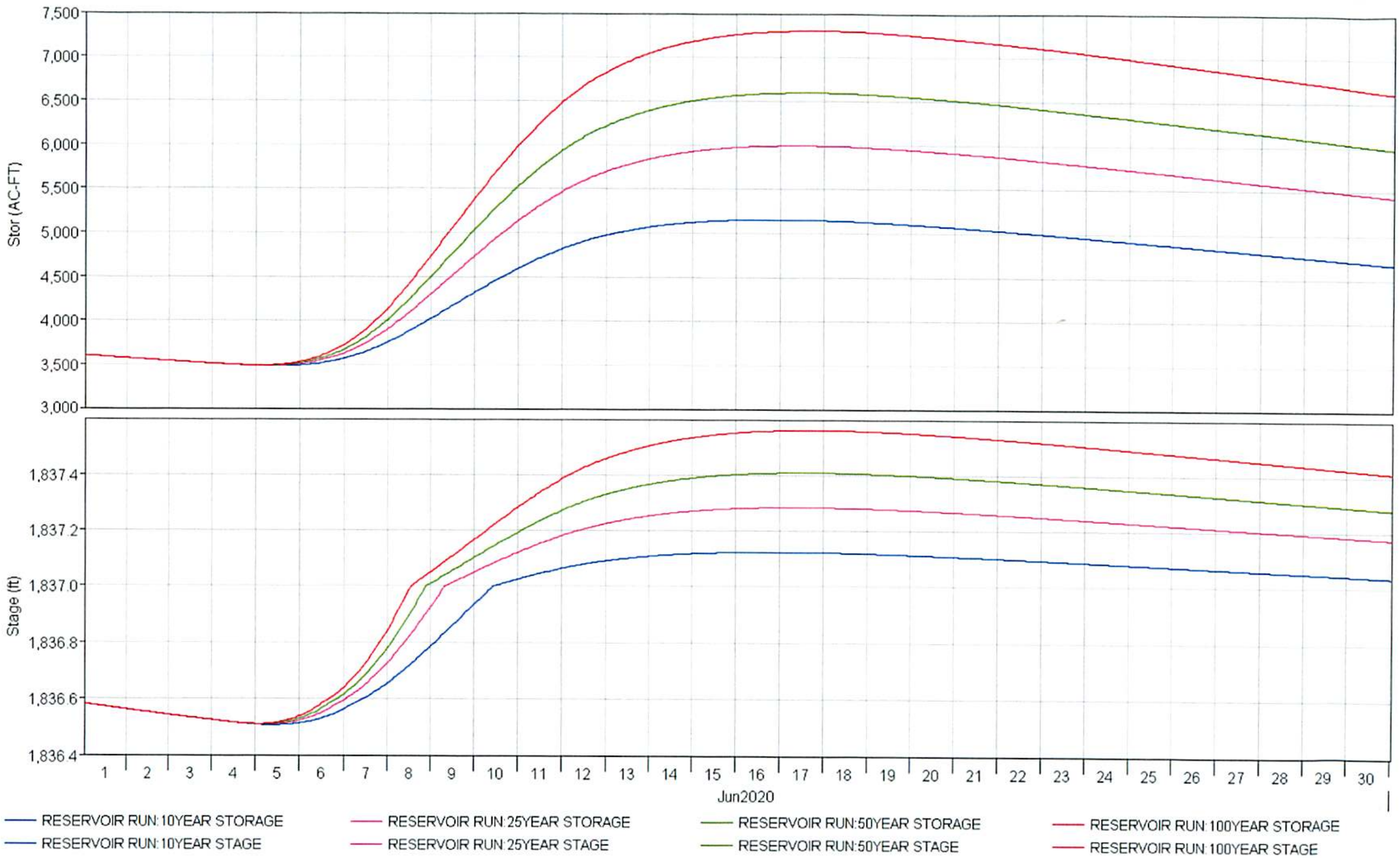

Figure 11: Modeled frequency events for Tolley Slough with proposed outlet modifications.

5.1 Alternative Route Screening

The alternative alignments for possible outlets were evaluated to determine the optimum route. As a screening tool, an open channel gravity outlet was evaluated to reduce the water surface elevation to 1835.5 ft. Evaluating routes with gravity outlets emphasizes selecting the most optimum route for conveyance regardless of what outlet system is put into place.

5.2 Alternative 1

After determining the flows needed to reduce the water surface elevation of the slough, routes for possible outlets were examined. During initial talks with area residents, it was suggested to build an outlet along the right of way of the railroad tracks. Thus, defining Alternative 1. In the city of Tolley, the right of way is 100 ft on each side of the track; out of Tolley the right of way is only 50 ft on each side of the tracks. The width of the right of way would require land acquisition along this route, depending on which type of outlet is designed. Alternative 1 was examined due to local input. It extends from the slough through the city of Tolley, ultimately flowing into Lake Darling. Figure 10 is the plan view of Alternative 1.

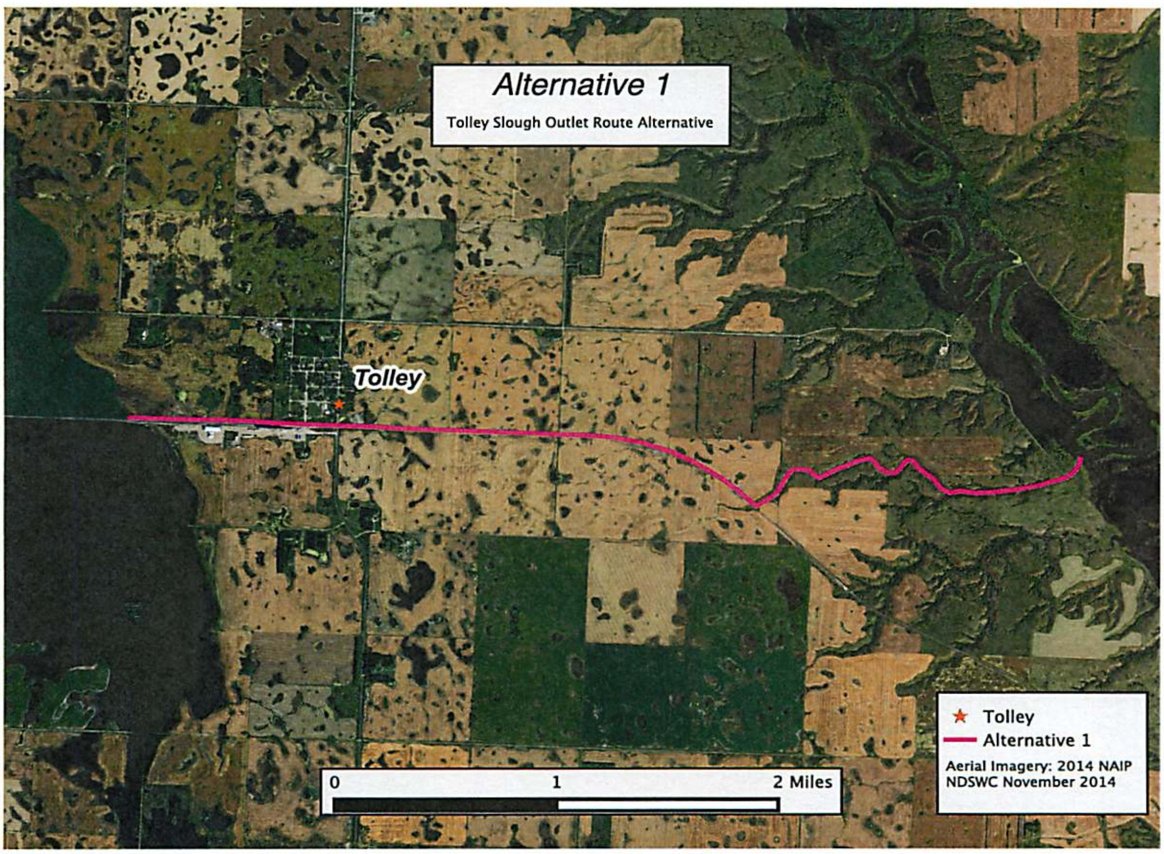

Figure 10. Tolley Slough, Outlet Alternative Route 1.

Alternative 1 was the preferred route by local residents due to the perceived minimal land acquisition needed to complete the project. The city of Tolley occupies one of the highest points between Tolley Slough and Lake Darling. This requires extensive excavation for many outlet systems and increases the amount of land acquisition required to complete the project, however, this is only one of the several challenges facing Alternative 1. Figure 11 is the ground profile view for Alternative 1 extracted from the LiDAR collect.

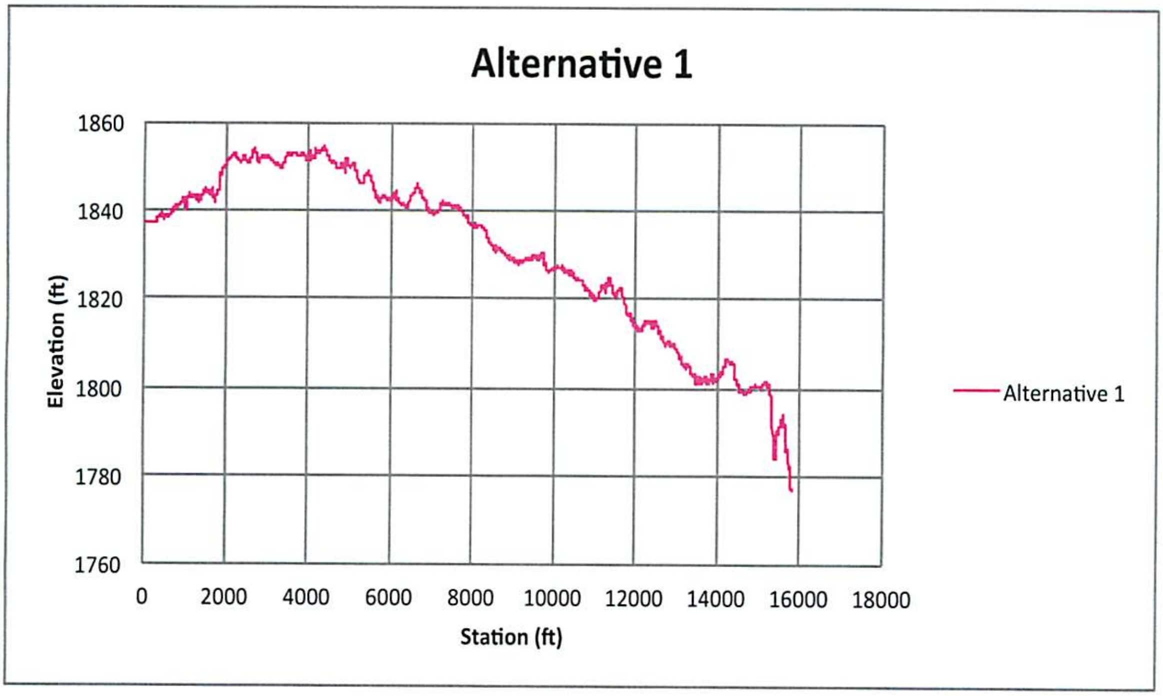

Figure 11. Alternative 1's ground profile plot.

Challenges facing Alternative 1:

- Topography (high ground near Tolley requiring increased excavation/land acquisition)
- Proximity to the railroad and elevator (soil stability during and after construction requires specialized construction techniques and safety concerns)
- Proximity to Tolley (open channel accessibility is unacceptable inside city limits due to safety concerns)
- Possibility of post-construction leakage (could cause soil instability, which combined with continued dynamic loadings, could have catastrophic consequences)

5.3 Alternative 2

After considering the topography, proximity to the railroad, elevator, and city of Tolley, and the possibility of leakage along Alternative 1, other outlet paths were investigated. Alternative 2 is an outlet path to the north of Tolley that follows the lowest points between the slough and the Mouse River. By following the lowest points the route takes advantage of the natural grade. This reduces the amount of earthwork required to move water out of the slough. Figure 12 is the plan view of Alternative 2.

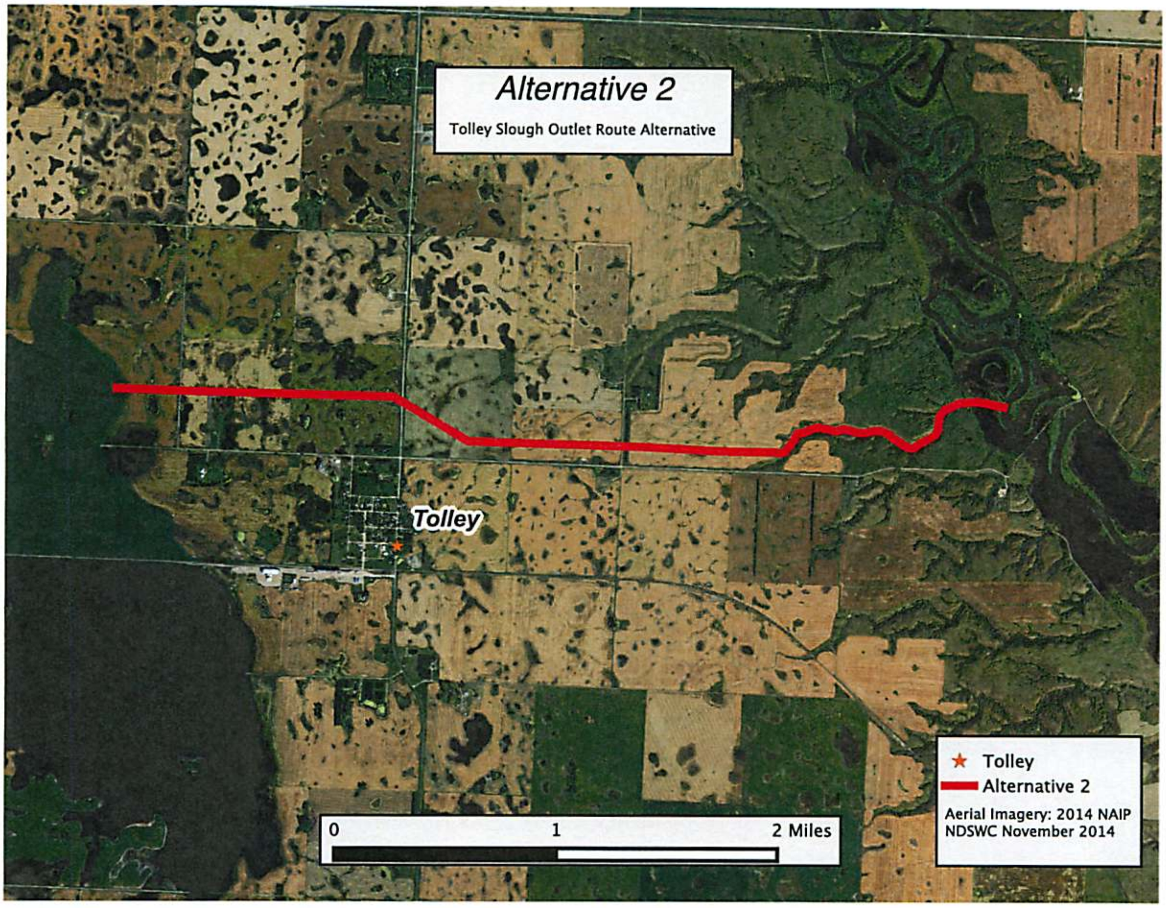

Figure 12. Tolley Slough outlet alternative route 2.

The benefit of Alternative 2 is that it requires the least amount of earthwork to remove water out of the slough. This means that any outlet option that is considered on Alternative 1 would also work on Alternative 2. The route would require land acquisition along most of the route depending on what type of outlet is put into place. Figure 13 is the ground profile view for Alternative 2 extracted from the LIDAR collect. The ground profile plots for both Alternative 1 and Alternative 2 are compared in Figure 14.

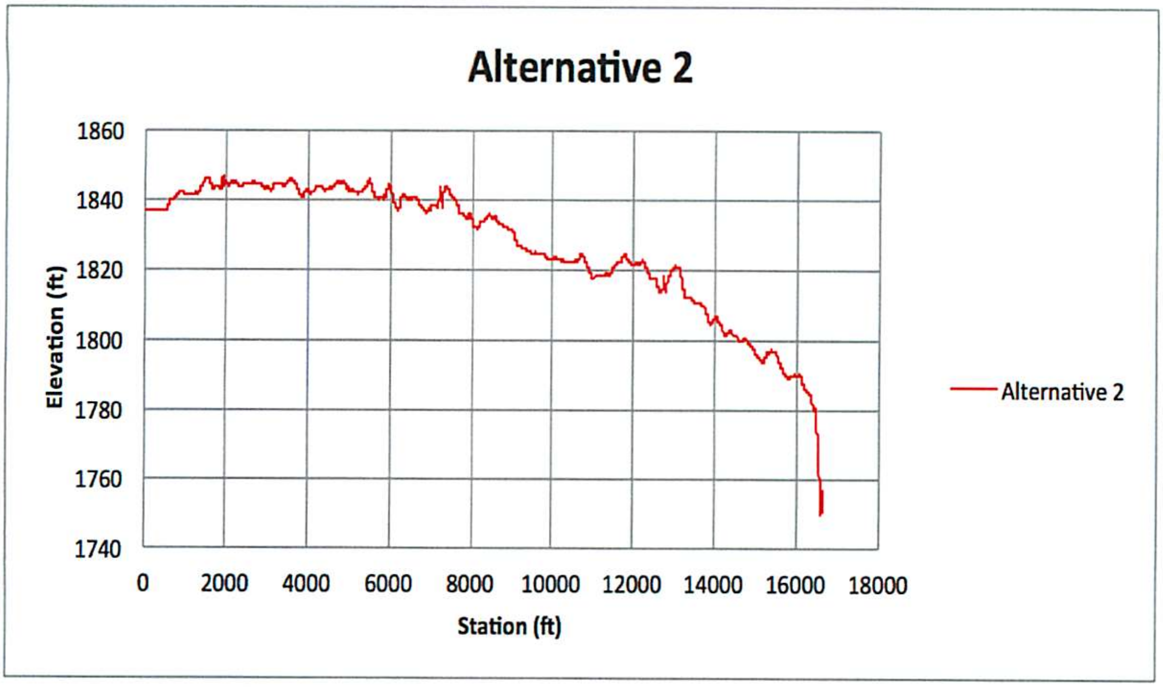

Figure 13: Alternative 2's ground profile plot.

Figure 14: Tolley alternatives ground profile plot.

Although Alternative 2 is the most efficient route hydraulically, each alternative has high velocities through the coulees into Lake Darling. HEC-RAS models were created for each alternative route (Appendix D) to calculate channel velocities. The velocities calculated for each alternative were reasonable in most of the channel, but became significantly higher when moving through the coulees to Lake Darling. Energy dissipation structures or other techniques must be applied to both alternatives. Energy dissipation structures were not included in cost estimates due to the large variability in price.

Each of the alternatives would require modifications to several roadways. The modifications examined for the open channels for each alternative route were culverts at each crossing. The standard culvert size determined to be adequate was a 42-inch or 3.5-foot diameter culvert. This size allows an open channel gravity flow of nearly 33 cfs, more than enough flow to account for natural runoff into the open channel. Each alternative would have a control structure on the most upstream crossing to control the discharge through the channel.

Construction of either alternative may require a Section 404 permit. The Clean Water Act (CWA) Section 404 regulates the discharge of dredged and fill material into waters of the United States, including wetlands, and any fill brought into the slough to construct the outlet may be subject to regulation. Therefore, obtaining a permit from the United States Army Corps of Engineers (USACE) to place fill during the outlet construction may be required. Additionally, wetlands impacted along the outlet alignment may be under the jurisdiction of the USFWS easements and may require mitigation.

5.5 Gravity Flow Pipe Design

Alternative 1 and 2 were also examined as closed gravity flows pipe systems. These pipe systems would follow the same grade as the open channel design, but would restore the surface after construction.

Alternative 1 would be more desirable as a piped system due to minimum land acquisition costs and the shorter route. Due to the load on the pipe system from the railroad track, reinforced concrete pipe was examined for this alternative. Reinforced concrete pipe is a rigid pipe that only carries the load of the soil directly above the pipe. This means that the rigid pipe could be placed within the right of way of the railroad track without taking the load from trains and the railroad. Placing the rigid pipe within the right of way of the railroad would still require special safety equipment, increasing the cost of the pipeline.

Alternative 2 is a slightly longer route, requiring around 2,000 feet of extra pipe. The benefit to Alternative 2 is that the pipe system be made of high strength HDPE or reinforced concrete pipe. HDPE is a slightly less expensive pipe system that would reduce some costs. HDPE is also extremely variable in cost, which can change drastically over short periods of time.

Alternative 1 and 2 would both require control structures on the upstream end of the system to ensure a maximum discharge capacity of 20 cfs.

5.6 Pump Design:

Traditionally, pumping is viewed as a drainage method with one of the smallest finished footprints. Even though pumping initially sounds like a suitable method of water removal, it is typically one of the most expensive options. Pumping systems have higher operation and maintenance costs than other outlet options, along with having higher construction costs.

Power costs alone can be large enough to remove pumping as an acceptable outlet option. Based on area power cost averages, running a pump of this size typically costs between $15 and $17 (values based off of the Devils Lake Outlet operations, 2014) dollars per acre-ft removed in power costs. This means that without any new inflows into Tolley Slough, it would cost nearly $114,000 in power to drop the water surface to its desired level. Based on the area's hydrology, millions of dollars could be spent just in power costs trying to maintain the slough's elevation. With operating, maintenance, and power costs creating this expense; a pumping option is not suggested as an outlet method for Tolley Slough.

5.7 Siphon Design:

Residents inquired about the use of a siphon to remove water from the Tolley Slough. Siphons work by creating a suction head that lifts water out of a reservoir to a point of lower elevation. The suction head is created by priming the siphon with a pump, priming the siphon displaces the air in the system creating the suction head.

Siphons are an efficient way to move water out of a reservoir. However, construction and operation of a large siphon can be difficult. The system must be air tight, any air leaks will cause the siphon to fail. Siphons are limited in the amount of total lift required. If the forces of gravity and friction losses are greater than the suction head required, the siphon will fail and need to be primed. Maximum siphon lift equation can be used to determine if a siphon is hydraulically possible at a site. It was determined, through initial calculations that a siphon would fail due to friction losses within such a large structure. The siphon could however become hydraulically possible by notching through the high ground in order to reduce the maximum lift. Creating a notch that would effectively reduce the maximum siphon lift would have similar cost implications as creating an open channel with the added cost of pumps to prime the siphon and pipe. Calculations used to determine if a siphon operation would be hydraulically feasible are located in Appendix D.

6.0 Summary and Recommendations:

It is recommended that a permanent outlet be placed along Alternative 2, preferably a gravity flow open channel outlet with 3.5 ft culverts at each of the four crossings. The route along Alternative 1 should be avoided if possible due to the close proximity to the elevator and railroad, proximity city of Tolley, topography, and possibility of leakage, but if an outlet is most desirable through the city, it is recommended that the outlet be open channel with a piped section through Tolley. The section through Tolley would have to be piped due to the space restrictions. Table 4 & 5 are cost estimates for the two recommended alternatives described above. The cost estimates in Tables 4 & 5 do not include land acquisition for the project or energy dissipation controls through the coulee into Lake Darling.

The recommended alternatives would reduce the risk of further damages caused by the natural outlet flows and would control the water surface elevation of Tolley Slough. If nothing is done to reduce the water surface elevation of Tolley Slough, the slough could continue to use its natural outlet if the current wet cycle continues. If the wet cycle ends, the sloughs water surface elevation could decrease by infiltration and evaporation.

Tolley Slough Outlet: Alternative 1 Open Channel With Piped Section Through Tolley	Unit	Unit Price	Quantity	Total Cost
Construction Costs *				
1) Channel Excavation	YD3	$3.00	87,171	$261,513
2) 42" Concrete Pipe	LF	$278	3,876	$1,077,528
			Subtotal	$1,339,041
Design Costs				
1) Design and Oversight	10% of const. cost	10%	$1,339,041	$133,904
Cost Summary				
Total Capital costs without contingency				$1,472,945
Contingency (25%)		25%	$1,472,945	$368,236
Total Cost Estimate				**$1,841,181.38**
Tolley Slough Outlet: Alternative 2 Open Channel With Crossings	**Unit**	**Unit Price**	**Quantity**	**Total Cost**
Construction Costs				
1) Channel Excavation	YD3	$3.00	141,071	$423,213
2) 42" Concrete Pipe	LF	$278	360	$100,080
			Subtotal	$523,293
Design Costs				
1) Design and Oversight	10% of const. cost	10%	$523,293	$52,329
Cost Summary				
Total Capital costs without contingency				$575,622
Contingency (25%)		25%	$575,622	$143,906
Total Cost Estimate				**$719,528**

***Does not include additional costs for special construction techniques.**
Table 4: Cost estimates for recommended alternative outlets.

Tolley Slough Outlet: Alternative 1 Gravity Flow Pipe Option	Unit	Unit Price	Quantity	Total Cost
Construction Costs				
1) 42" Concrete Pipe	LF	$278	14,185	$3,943,430
				$0
			Subtotal	$3,943,430
Design Costs				
1) Design and Oversight	10% of const. cost	10%	$3,943,430	$394,343.00
Cost Summary				
Total Capital costs without contingency				$4,337,773
Contingency (25%)		25%	$4,337,773	$1,084,443
Total Cost Estimate				**$5,422,216**

Tolley Slough Outlet: Alternative 2 Gravity Flow Pipe Option	Unit	Unit Price	Quantity	Total Cost
Construction Costs				
1) 42" Concrete Pipe	LF	$278	16,652	$4,629,252
				$0
			Subtotal	$4,629,252
Design Costs				
1) Design and Oversight	10% of const. cost	10%	$4,629,252	$462,925.24
Cost Summary				
Total Capital costs without contingency				$5,092,178
Contingency (25%)		25%	$5,092,178	$1,273,044
Total Cost Estimate				**$6,365,222**

Table 5: Cost estimates for gravity flow pipe options.

7.0 References:

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