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MEMORANDUM

FROM: Laura Ackerman, P.E., Investigations Section Chief LCA

SUBJECT: Twin Lakes Analysis Update

DATE: February 12, 2020

On October 18, 2019, the State Water Commission received a request from the LaMoure County Water Resource District (District) regarding the Twin Lakes investigation, which was originally completed in 2017. The District requested additional analysis of the lake inflow data and the storage capacity curve that were used in the 2017 investigation. The District also requested an update to the HEC-HMS and HEC-RAS models to simulate potential damages that would result from the lake naturally overflowing under current conditions.

This additional analysis was completed and results were documented in a memorandum, dated December 18, 2019. This memorandum is appended at the end of the 2017 investigation report for Twin Lakes.

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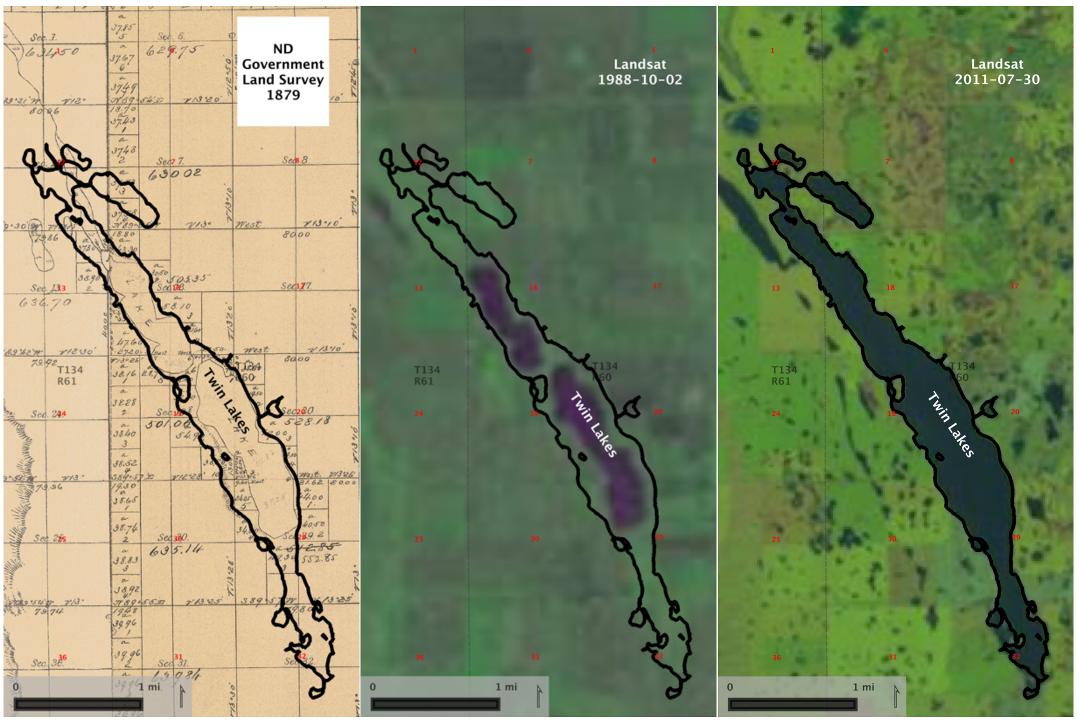
Twin Lakes Investigation Report

LaMoure County, North Dakota



SWC Project #1285
October 2017

North Dakota
State Water Commission

Twin Lakes Investigation Report

LaMoure County, North Dakota

SWC Project #1285
North Dakota State Water Commission
900 East Boulevard
Bismarck, ND 58505-0850

For:
LaMoure County Water Resource District

October 2017

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Introduction

Twin Lakes is a prairie pothole lake system consisting of two large depressions within LaMoure County, North Dakota about 2 miles northeast of the City of LaMoure (City) (**Figures 1** and **2a**). The depressions were nearly dry during the early 1990s, and water levels have since risen approximately 30 feet creating a 2-square mile (mi^2) lake that is the terminus of a 38 mi^2 watershed, most of which does not contribute runoff under average circumstances.

The North Dakota State Water Commission (SWC) was contacted by the LaMoure County Water Resource District (District) and City to investigate the hydrology and hydraulics of Twin Lakes because of the growing concern that the lake will continue to rise and eventually overflow, potentially flooding infrastructure, residences, and agricultural land within the city and surrounding areas (**Figure 2b**). Because there is no defined channel where the outlet coulee meets the floodplain, the impact of the overflow discharge is not intuitive. Additionally, the lake has already affected land owners surrounding the lake, forcing at least one residence to be relocated and has caused agricultural losses.

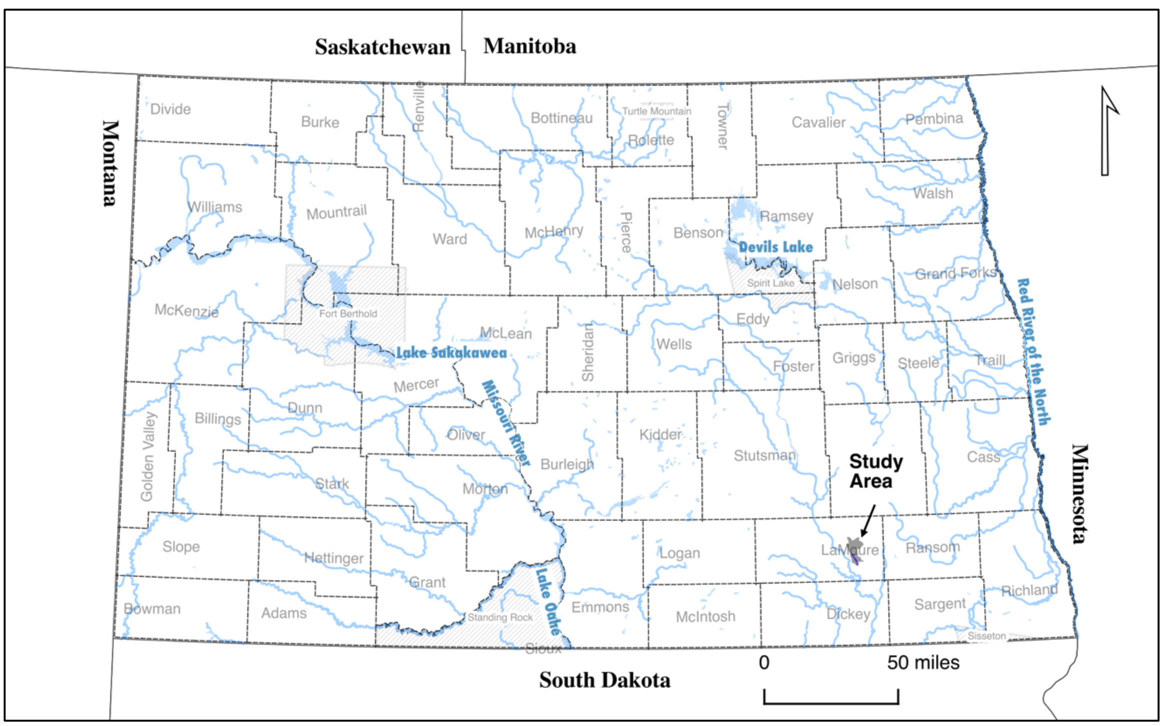

Figure 1: Project location.

The SWC entered an agreement (**Appendix A**) with the District in March 2012 to investigate the hydrology of Twin Lakes, collect survey data, identify the potential implications caused by the lake overflowing, and evaluate options that could mitigate damages. A memorandum summarizing initial results was produced and distributed on January 31, 2014.

This report presents the findings of the hydrologic and hydraulic analysis and potential actions for consideration by the District and City. This study did not evaluate the likelihood of the lake overflowing, as this was beyond the scope of this investigation. Electronic data files and models are included with this report in **Appendix B**.

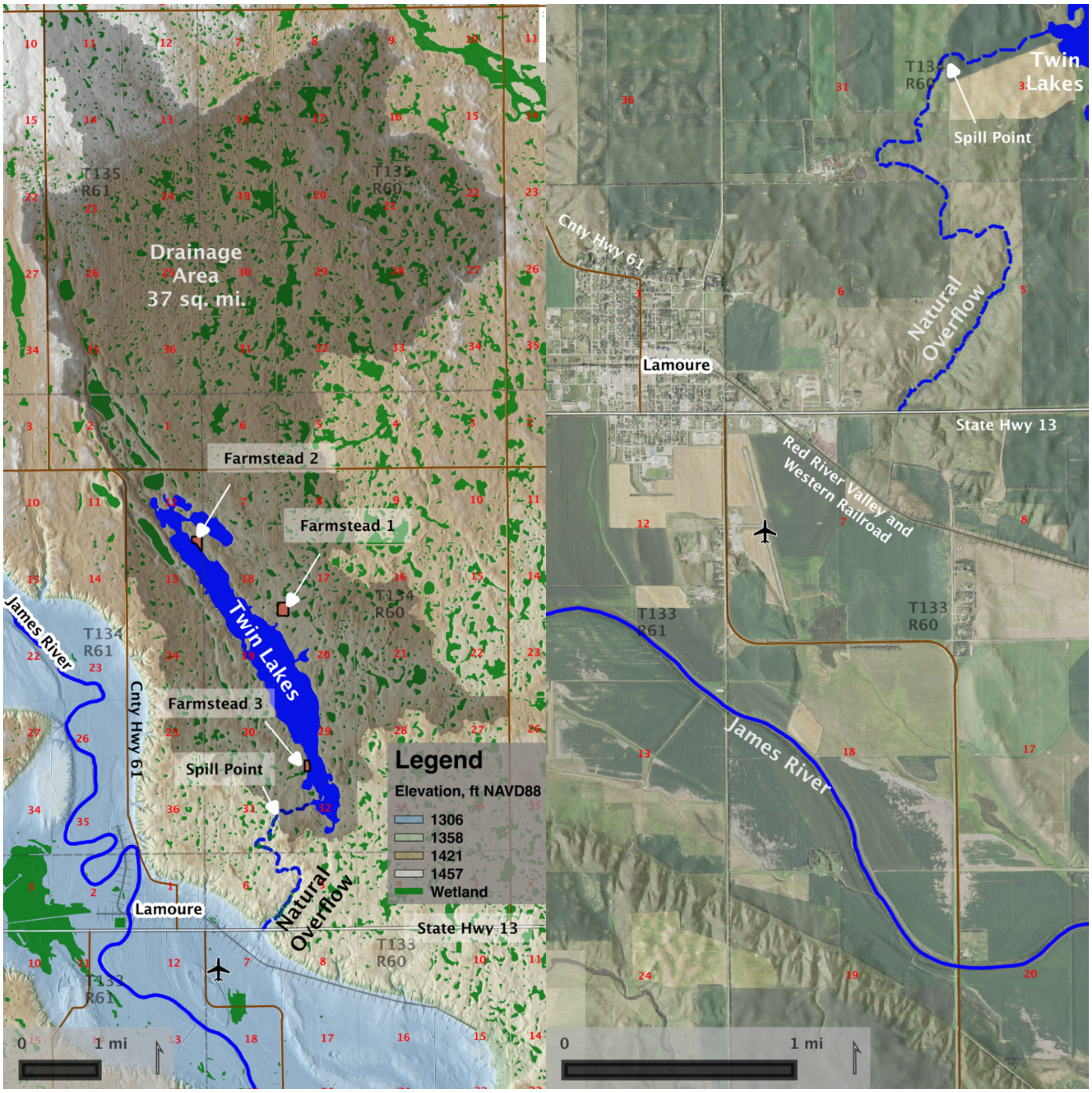

Figure 2a (left): Twin Lakes watershed and lake footprint.
Figure 2b (right): Twin Lakes natural overflow alignment.

Problem Background

The highest lake level on record, 1398.5 ft North American Datum of 1988 (NAVD88), occurred during the summer of 2011 and was within 5 feet of its spill elevation of 1403.5 NAVD88. As of May 2017, the lake has dropped 3.5 feet to 1395 ft NAVD88. The lake is currently impacting three farmsteads (**Figure 2a**) and has inundated acres of agricultural land and township roads. Farmstead 1 has had to employ local protections to prevent inundation when the lake was at its peak. Farmstead 2 has lost many outbuildings to the lake. Farmstead 3 has already been vacated because access has been inundated.

There is a concern that if the lake overflowed, State Highway 13 would divert water westward towards town or washout. Without a hydraulic model, it is unclear exactly what other impacts may occur, but several commercial buildings, the Red River Valley and Western Railroad, and airstrip are located south of the highway and north of the James River. Highway 13 west of the James River has been overtopped during James River flooding, and the District and City are concerned if access to LaMoure would be reduced to one road, County Highway 61. This study validates these concerns, provides a better estimate of the potential impacts from a lake overflow, and presents mitigation options.

Hydrology

Pothole lakes or sloughs, such as Twin Lakes, occupy depressions formed by glaciers. Twin Lakes is located within the Glaciated Plains, which encompasses eastern and northern North Dakota and is located just east of the Missouri Coteau. Potholes wetlands and lakes are common within the Glaciated Plains, and the Twin Lakes watershed contains many, as shown by the number of wetlands in **Figure 2a**. Most potholes are disconnected from other surface water bodies and do not have an outlet to drain their waters to larger drainage systems. The potholes gain water from precipitation, runoff, and groundwater seepage and lose water from evapotranspiration (ET) and groundwater seepage. The climate of North Dakota is characterized by extremes in temperature and precipitation, which has resulted in great variability in water levels within pothole lakes and wetlands (Winter and Rosenberry, 1998).

Lake Inflow

The area that drains into the lake varies as a function of runoff because of the many sloughs and depressions. Given enough runoff, the surface drainage area for the lake would be around 38 mi^2. However, for most runoff events; the drainage area is likely only between 5 and 10 mi^2. **Figure 3** shows the contributing drainage area as a function of the runoff event from an analysis performed as part of the hydrology model (**Appendices B** and **C**). **Figure 4** shows the boundaries of a 10 mi^2 drainage area, a 23 mi^2 drainage area, and the total drainage area.

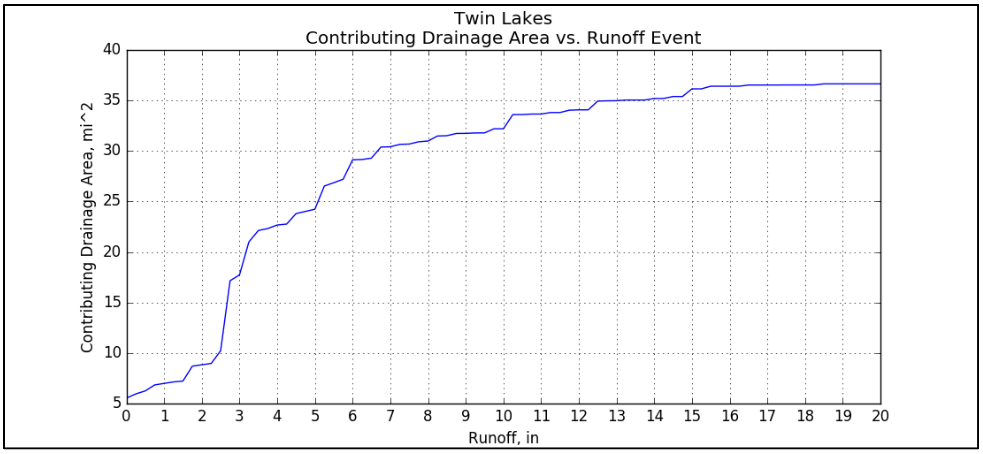

Figure 3: Twin Lakes contributing drainage area vs. runoff event.

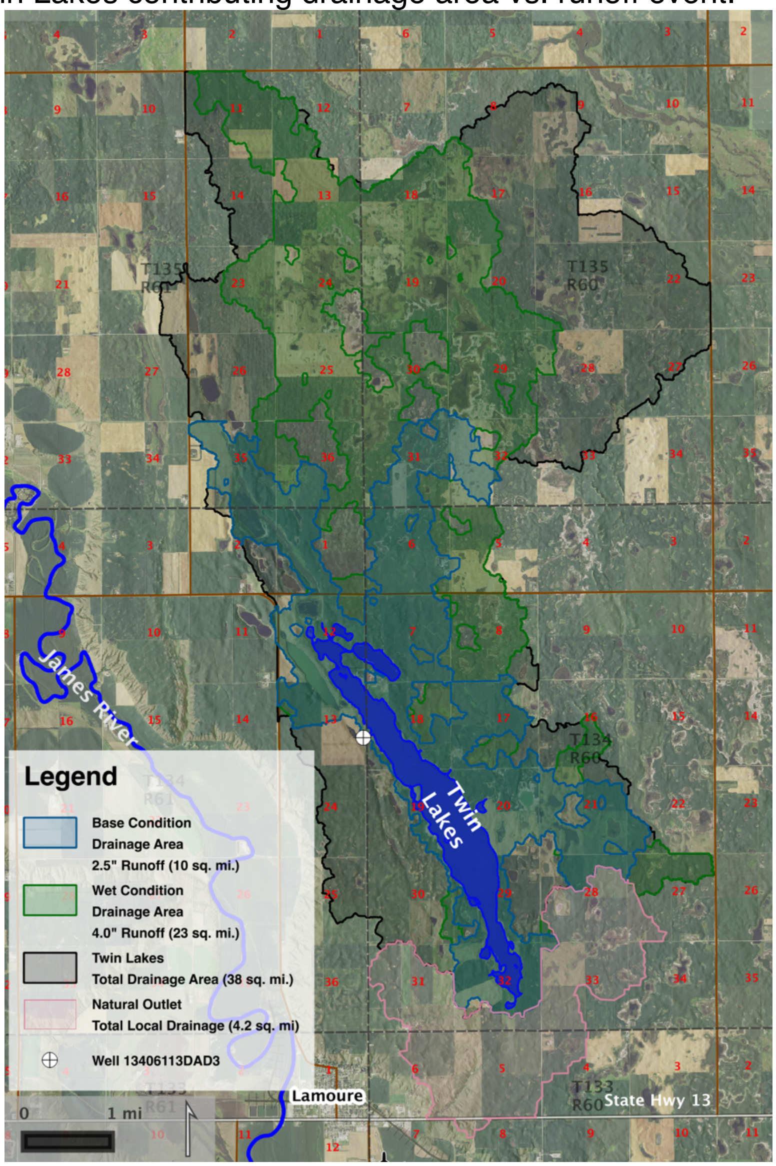

Figure 4: Twin Lakes contributing drainage area for the 2.5” (light blue area) and 4.0” (green) runoff events.

Water levels in pothole wetlands or lakes that are underlain by low permeability soils, such as glacial till, are highly dependent on precipitation and ET since their interaction with groundwater is relatively limited (Shjeflo, 1968; Winter and Rosenberry, 1998). Hydraulic communication between potholes and the shallow water table does occur, but the exchange between groundwater and surface water is typically minor when compared to precipitation gains and ET losses. A study by the United States Geological Survey (USGS) on the hydrology of potholes along the Missouri Coteau in North Dakota concluded that direct rainfall on the pothole water surface was the greatest inflow to these systems, followed by inflows from spring snowmelt events and runoff from rainstorms (Shjeflo, 1968).

The lake overlies the Spirtwood Aquifer; however, the aquifer is roughly 100 feet below the lake and is separated by thick layers of glacial till which prevent any significant connectivity. Based on information gained from the hydrologic model, it is possible that a shallow groundwater table connects surface depressions to the lake. In other words, nearby sloughs and depressions within the drainage area that don't hydraulically connect on the surface may be connected below the ground.

Lake Capacity

A storage capacity curve (**Figure 5**) was constructed by correlating lake depth contours collected by the North Dakota Game and Fish Department during 2008 with elevations obtained from the National Elevation Dataset and the topographic LiDAR survey collected during 2010. Analysis of the LiDAR and ground survey determined that the spill elevation of the lake is 1403.5 feet (ft NAVD88)[1]. The recent peak elevation of 1398.5 ft NAVD88 occurred during the summer of 2011. Ground survey data are available in **Appendix B** and LiDAR can be accessed via the SWC's website at http://lidar.swc.nd.gov.

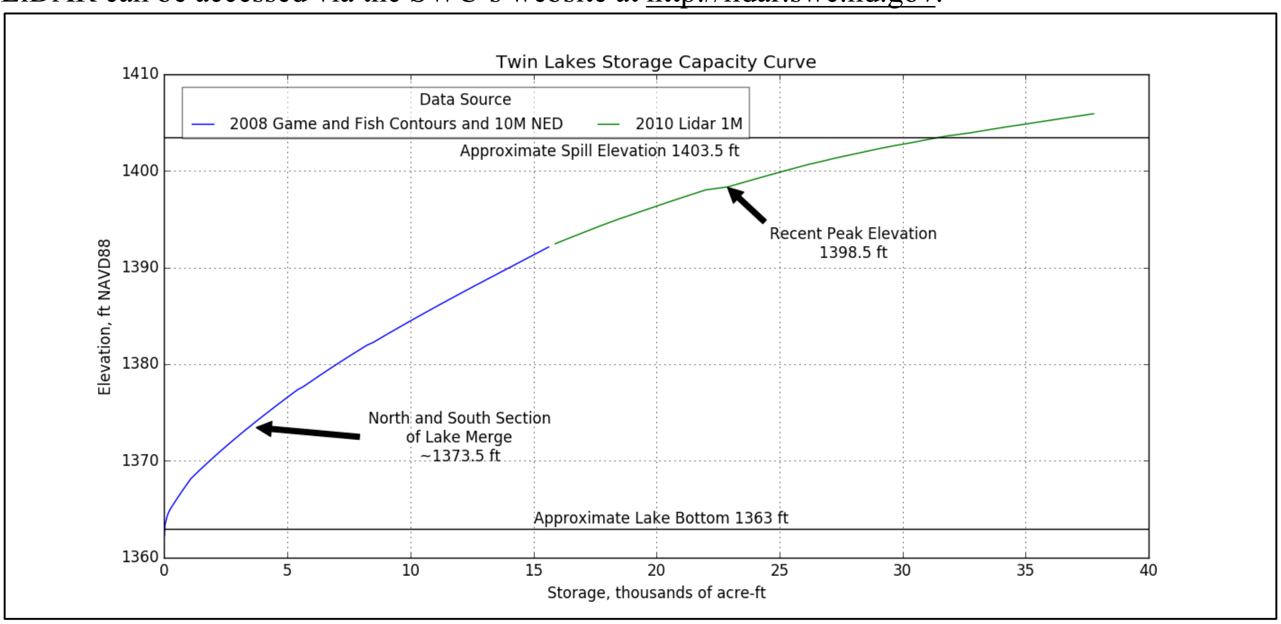

Figure 5: Twin Lakes storage capacity curve.

[1] The ground survey and LiDAR survey spill points were 1403.3 ft and 1403.7 ft, respectively.

Historical Water Levels and Precipitation

The lake water elevation has fluctuated over the years. It is likely that the lake has overflowed at least once prehistorically, but there is no record of it doing so over the past 150 years. A historical hydrograph dating back decades was created by using georeferenced historical maps and aerial and Landsat imagery combined with NED and LiDAR elevation data. **Figure 6** shows the lake's current footprint overlying the lake outline captured by the original General Land Office 1879 survey plat, a lake Landsat image collected on October 10, 1988, and a Landsat image collected near the lake's historical high elevation on July 30, 2011.

Since 2011, lake levels have been surveyed and measured with a staff gage, so there is much greater confidence in the lake elevation data than the data derived from maps, imagery, and topographic data. **Figure 7** shows the lake stage hydrograph.

When the water levels in the lakes were below the merge elevation of 1373.5 ft NAVD88, it was observed that the northern lake elevation was essentially constant at approximately 1370.5 ft whereas the southern lake level was variable. It is assumed either a culvert or porous embankment material allowed the northern lake to discharge into the southern lake. Therefore, the southern lake level was chosen to represent both lakes' elevation prior to merging in the mid 1990s.

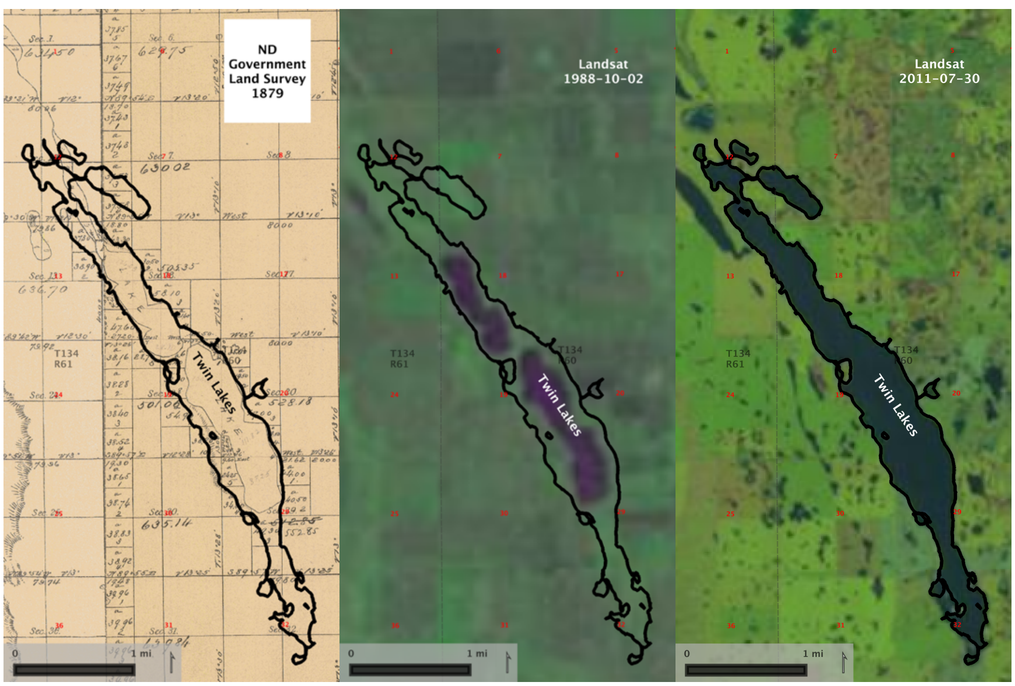

Figure 6: Outline of Twin Lakes footprint at elevation 1395 ft NAVD88 overlying 1879 General Land Office survey plat outline, 1988 Landsat image, and a 2011 Landsat image.

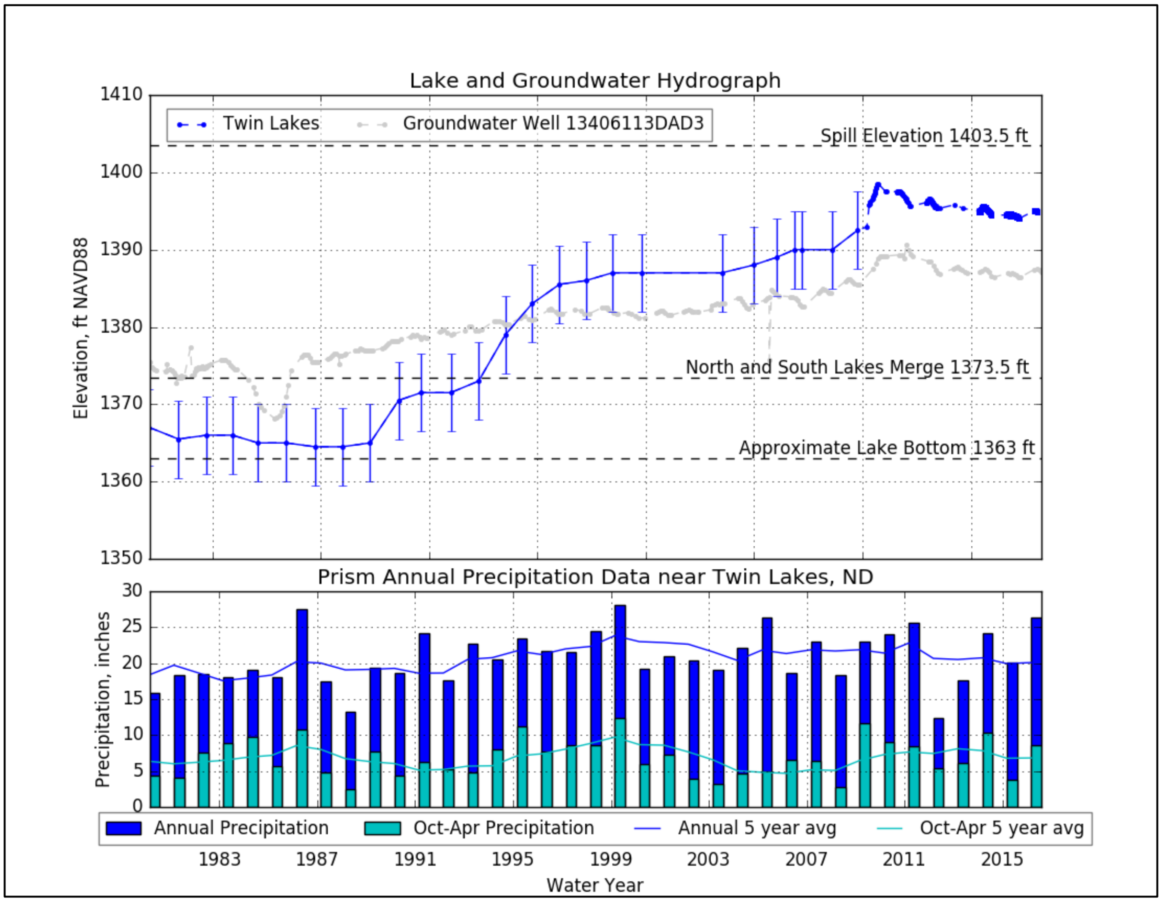

Figure 7: Twin Lakes hydrograph and annual precipitation data.

The lake levels were fairly constant during the 1980s, early 1990s, and early 2000s with rapid increases during the late 1990s and early 2010s. The stepwise growth of the lake is likely from variability in contributing drainage area.

A nest of groundwater wells is also located nearby (**Figure 4**). Well 13406113DAD3 was screened between elevation 1345 and 1350 ft, near the elevation of the lake bottom. It appears that the lake is not well connected with this groundwater system; however, the levels do correlate (**Figure 7)** suggesting that some connection does exist. This is best illustrated in the recent lake elevation measurements that are based on surveyed data.

Historical precipitation data were obtained from the PRISM dataset (PRISM Climate Group, 2017). **Figure 7** also shows the precipitation total for the water year, defined as October 1 through September 30, and winter precipitation totals, defined as precipitation falling from October through April. Precipitation totals during mid to late 1990s and the early 2010s appear to be elevated. The five-year weighted average total precipitation was generally under 20 inches per year during the 1980s and early 1990s and over 20 inches per year from the mid-1990s to present.

Hydrology Model

A hydrology model was developed using GRASS GIS (GRASS Development Team, 2016) and HEC-HMS 4.2 (Hydrologic Engineering Center, 2006). Topographic, soil, and climate data were assimilated and used to model the lake. Because the water level of a closed basin lake is subject to cumulative climatic effects, the Soil Moisture Accounting (SMA) soil loss method was used. This allowed for a continuous historical simulation from 1993, which is when potential evapotranspiration (PET) data became available from the North Dakota Agricultural Weather Network (NDAWN, 2017), through May 2017. The model calibration and methodology is described in detail within **Appendix C**.

Hydrology Model Calibration

The hydrology model was calibrated with lake elevations by running a continuous simulation from September 1993 through May 2017. Observed lake elevation data before 2011 is estimated from georeferenced aerial and Landsat imagery and elevation data; therefore, it has a large error associated with it. Based on Landsat imagery, the two lakes did not merge into one lake until 1997, so the simulated elevations prior to 1997 are not representative of the Landsat-derived elevations. **Figure 8** shows the simulated and observed lake elevations from 1997 through 2016. **Figure 9** shows the simulated and observed lake elevations during the period from 2011 through 2016, when observed lake levels were measured with more precision and more frequently.

The simulated elevation matches the observed elevations very well considering the length of the simulation, the error in the elevations estimated using remote sensing, and the error in the elevation-storage function. The elevation residual is typically within 2 ft from 1997 through 2010 and within 1 foot from 2011 through 2016.

Figure 8: Simulated (blue line) and observed (red symbols) lake elevations from 1997 through early 2017.

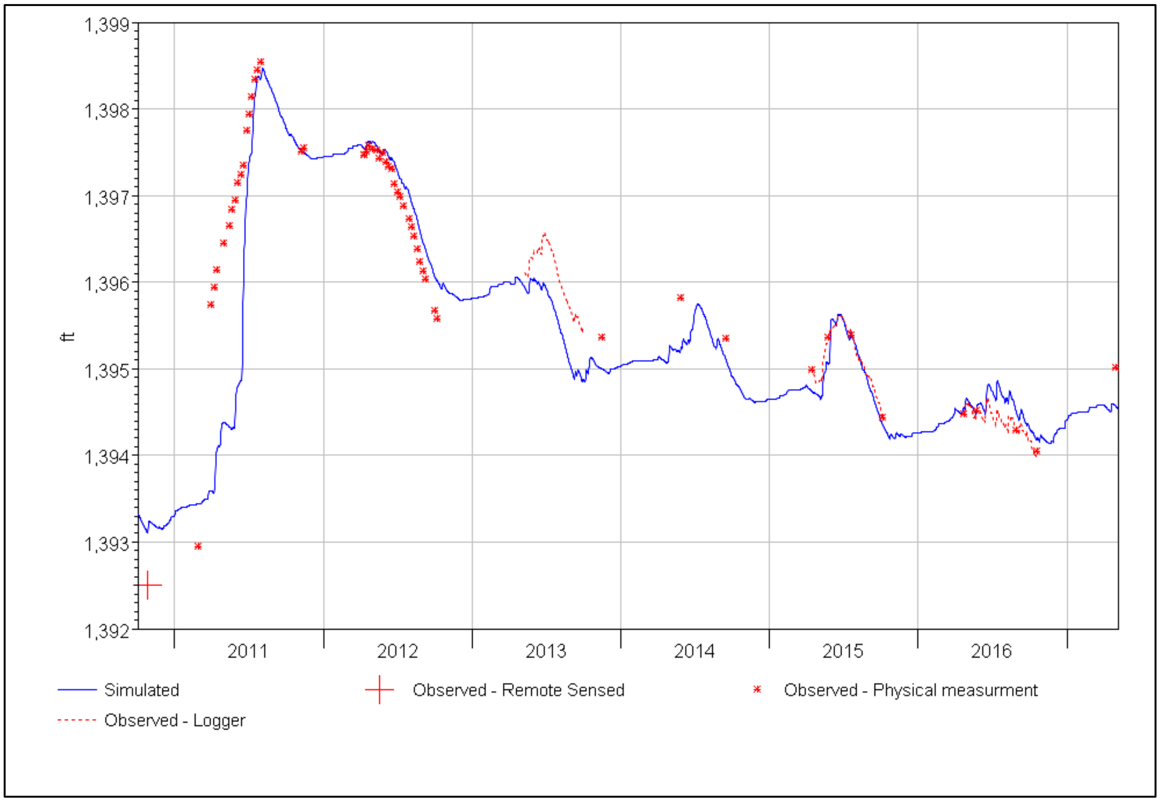

Figure 9: Simulated (blue line) and observed (red symbols) lake elevations during the period of physical observations, late 2010 through early 2017.

Synthetic Hydrology Events

Synthetic hydrology events were developed for two reasons:

1. To estimate how much the lake would rise during extreme precipitation events.
2. To estimate the volume and duration of water that would overflow toward LaMoure if an extreme event occurred with the lake at its overflow elevation.

The synthetic events were created by using NOAA's Atlas 14 precipitation estimates (Perica et. al., 2013) and assumed conservative initial conditions within the model. The modeled values from the historical simulation ending in May 2017 including wet condition drainage area were used as the antecedent conditions. The lake elevation was assumed to be at 1395 ft NAVD88. During the spring of 2017, soil conditions were also fairly wet, and, with the addition of the wet condition drainage area, this represents a fairly conservative initial condition. This approach is realistic because soils are often wet with snowmelt during the spring and early summer, a time when heavy precipitation typically occurs in North Dakota.

Table 1 summarizes the results from the synthetic events. The table includes the Atlas 14 total point precipitation, the precipitation applied to the basin reduced by the area-reduction curve, the rise in lake level assuming a starting elevation of 1395 ft, the increase in lake volume, the total lake volume, and the approximate volume remaining until a spill occurs.

Table 1: Summary of synthetic event hydrologic model results.

Event	Atlas 14 Total Precip., Inches	Area Reduction Precip., Inches	Rise from Elevation 1395 ft NAVD88, ft	Lake Volume Increase, acre-ft	Lake Volume acre-ft	Remaning Storage Until Spill, acre-ft
500 year 10 Day	10.70	10.49	5.90	7,750	25,196	5,904
100 year 10 Day	8.49	8.32	4.50	5,568	23,034	8,066
50 year 10 Day	7.59	7.44	3.90	4,765	22,209	8,891
10 year 10 Day	5.66	5.55	2.60	3,094	20,558	10,542
1 year 10 Day	3.56	3.49	1.20	1,508	18,992	12,108
None	0.00	0.00	0	-	17,665	13,435

The simulation shows that even if a 500-year, 10-day rain event occurred with the lake at 1395 ft NAVD88, there is still significant storage available before the lake spills. As of May 2017, a risk of the lake overflowing from a single event or within a single year is very unlikely. However, the cumulative effects of a wetter than average climate over a period of years may cause the lake to overflow eventually.

Hydraulics

A hydraulic model was developed to simulate the flooding impacts caused by an event where Twin Lakes reaches its spill level and a rare precipitation event occurs. The likelihood of this taking place within a timeframe that warrants concern is small; however, it is possible. The City and District also expressed interest in understanding the implications of such an event occurring while the James River is flooding. The effects of the outlet control eroding were also considered.

A combination 1- dimensional (1D) and 2-dimensional (2D) model was developed to simulate the hydraulics of the James River near LaMoure and Twin Lakes and its potential overflow. The 2D portion model was created with HEC-RAS 5.0.3 and was merged with a portion of the 1D model of the James River completed by the USACE (USACE, 2014). Since there is no record of the lake ever overflowing, the model could not be calibrated. The hydraulic model methodology is described in detail in **Appendix D**.

Potential Impacts from Lake Flooding and Overflow

Using the hydrology and hydraulic models, potential impacts from lake flooding and overflowing were evaluated to provide the District and the City with information on what might happen. The following three scenarios were simulated:

- **Scenario 1 (Lake Flood Event, Current Condition)** – This scenario simulates a 10-day, 100-year rainfall event falling on the Twin Lakes drainage basin with an initial lake level of 1395 ft NAVD88 and wet antecedent conditions.
- **Scenario 2 (Lake Flood Event, Overflow Condition**) – This scenario simulates a 10-day, 100-year rainfall event falling on the Twin Lakes drainage basin with an

initial lake level at the spill elevation and wet antecedent conditions (Scenario 1 but with the lake at the spill level).

- **Scenario 3 (Lake Flood Event, Overflow Condition, Outlet Erosion**) – This scenario simulates a 10-day, 100-year rainfall event falling on the Twin Lakes drainage basin with an initial lake level at the spill elevation, wet antecedent conditions, outlet spill point erosion, and breaching of State Highway 13 (Scenario 2 but with erosion).
- **Scenario 4 (Lake Flood Event, Overflow Condition, Outlet Erosion, James River Flood Event)** This scenario simulates a 10-day, 100-year rainfall event falling on the Twin Lakes drainage basin with an initial lake level at the spill elevation, wet antecedent conditions, outlet spill point erosion, breaching of State Highway 13, and a coincident 100-year flow event occurring on the James River with temporary levees in place (Scenario 3 but with James River flooding).

The 100-year, 10-day rainfall event rather than the 100-year, 1-day event was selected as the storm event to evaluate overflow of Twin Lakes because volume is of greater concern than peak flow. Discharge from the lake attenuates when it reaches State Highway 13 due to the flow spreading out across the James River floodplain, so peak flows downstream of the highway are not as large of concern. In the case of Scenario 4, the river elevation and temporary levees are an additional constraint, so the 100-year peak flow on the river was selected and applied as steady flow, which isn't entirely unreasonable because of the regulation of the river provided by Jamestown Reservoir.

Scenario 1 (100 Lake Flood Event, Current Condition)

If Scenario 1 occurred the effects would be minimal. The hydraulic model simulates the peak lake elevation of 1399 ft NAVD88. Some impacts would occur near the lake; however, these would be fairly manageable since in 2011 the lake has been just below this level. Because this scenario uses the May 2017 lake level, 1395 ft NAVD88, this scenario, albeit rare, could occur within the short-term future.

A list of likely potential damages occurring during Scenario 1 is below:

- Near Lake
    - Max lake elevation 1399 ft NAVD88
    - Access issues to Farmsteads 1 and 3
    - Inundation of agricultural land
- Near Town
    - No impacts

Scenario 2 (100 Lake Flood Event, Overflow Condition)

Since Scenario 2 requires the lake water surface elevation to be at its spill point, it would take some time to reach this condition. As of May 2017, the lake has enough storage for at least two extreme runoff events before it spills.

Scenario 2 would cause problems by inundating infrastructure, personal property, and agricultural land. **Figure 10** shows the maximum inundation simulated by the hydraulic model near the lake and LaMoure, respectively.

The simulation predicts the lake overflows at its spill point and flows down a draw to State Highway 13 with a peak flow of roughly 270 cfs. The total volume discharged is over 3,000 acre-ft. The 42-inch diameter reinforced concrete pipe (RCP) culvert at State Highway 13 cannot pass all of the flow coming down the draw. The flow is divided; some goes through the culvert, some is diverted west along the highway toward town, and some overtops the highway west of the culvert near an approach. The flow diverted west along the highway fills open gravel pits that eventually spill across the railroad tracks into LaMoure. Water flowing through the highway culvert or over the highway overtops the Red River Valley and Western Rail Line, fills up the area around the airstrip, and eventually flows across 103rd Ave SE toward the James River. Tailwater will back up west into town via an 18" corrugated metal culvert through 102nd Ave SE. It is also possible that State Highway 13 could wash out and more water would be routed through the airstrip property.

A list of likely potential damages occurring during Scenario 2 is below:

- Near Lake
  - Max lake elevation 1405 ft NAVD88
  - Inundation of Farmsteads 1 and 3 with over 2 feet of water. Wave action may cause some inundation and access will be problematic at Farmstead 2.
  - Inundation of local road 104 Ave SE
  - Breaching of local road 72 St SE
  - Inundation of agricultural land
- Near Town
  - Shallow inundation (less than 2 feet) of multiple residences and businesses
  - Inundation and possible breaching of State Highway 13
  - Inundation of railroad
  - Inundation of airstrip and buildings
  - Inundation of local road 103rd Ave SE
  - Inundation of agricultural land
  - Mud and debris from erosion could be significant near State Highway 13

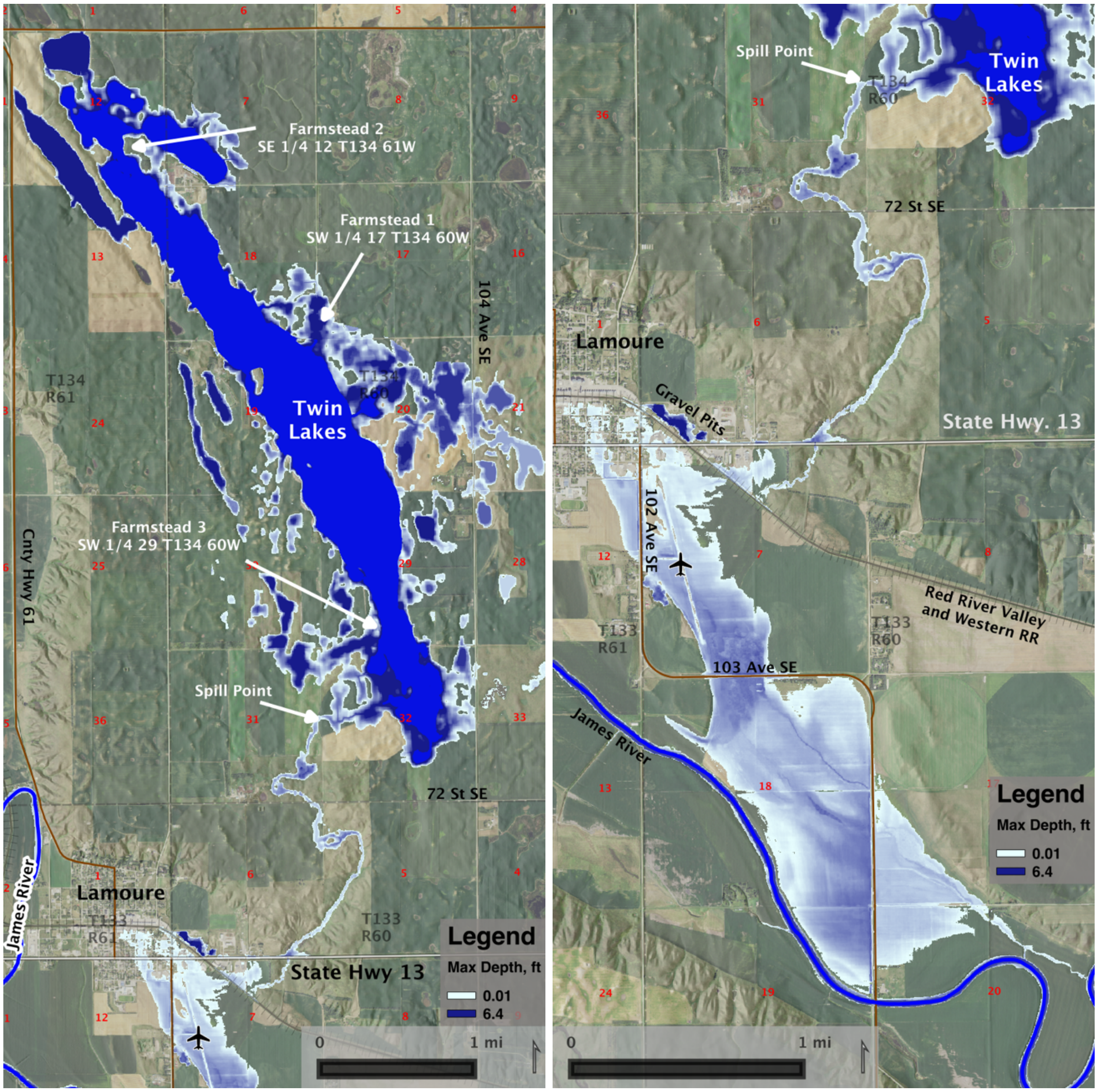

Figure 10: Scenario 2 inundation caused by a 100-year, 10-day rainfall event over Twin Lakes with the starting elevation of the lake at its spill point.

Scenario 3 (100 Lake Flood Event, Overflow Condition, Outlet Erosion)

Scenario 3 is very similar to Scenario 2, with the difference being that the Twin Lakes outlet is eroded 3 feet lower than the original spill elevation and State Highway 13 is breached. A section line trail currently controls the spill elevation of Twin Lakes. It is likely that this trail would be easily erodible, and once the erosion begins it may continue for some time. Fortunately, the slope in this area is very gradual toward the lake, so the erosion would be governed by the amount and type of material it would have to remove to lower the lake. **Figure 11** shows a cross-section of the Twin Lakes control point.

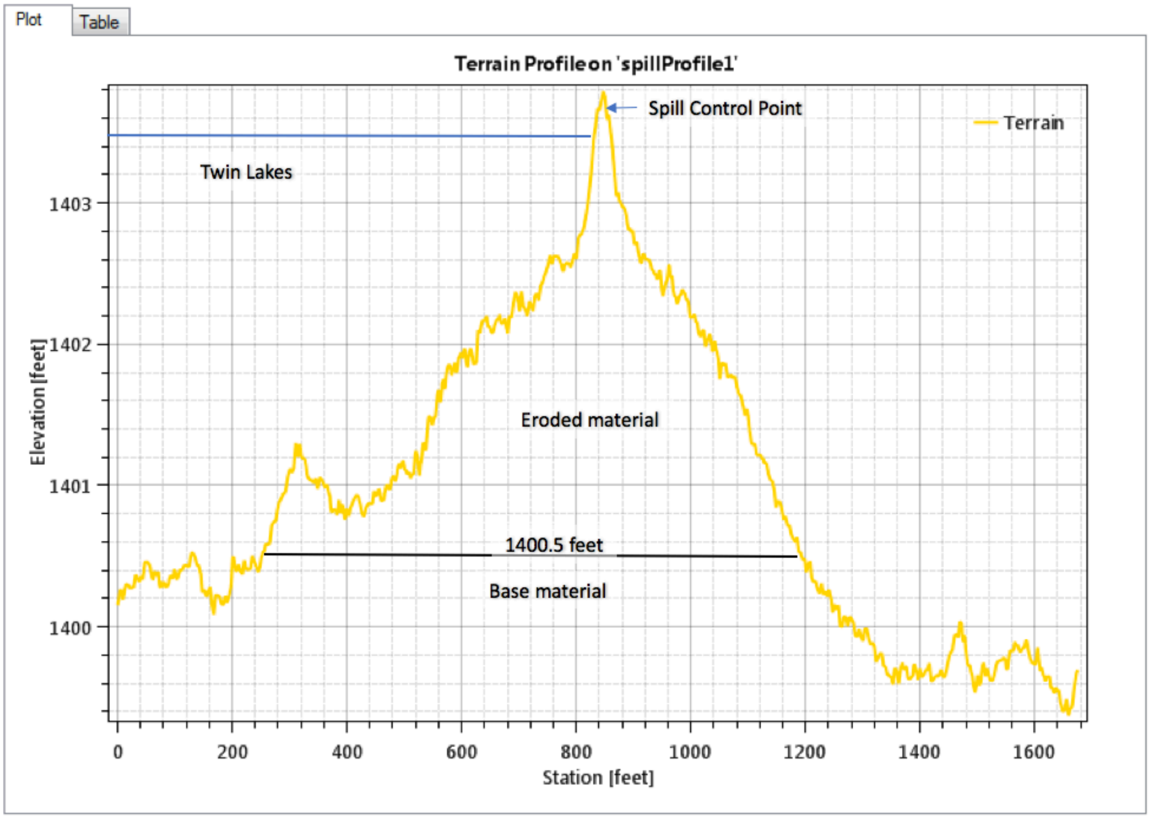

Figure 11: Cross section of outlet control topography and breach elevation (Note: Vertical scale is greatly exaggerated).

Using available data, it is assumed that the erosion would stabilize around elevation 1400.5 feet NAVD88 because the slope becomes more gradual, and at that point the eroded area would be approximately 1,000 feet long by roughly 50 feet wide at the top and approximately 1.5 feet deep over the length of erosion. The amount of erosion is an important unknown variable and further investigation may be warranted. State Highway 13 is assumed to breach shortly after the overflow reaches it. The breach is assumed to be 100 feet wide at the base with 1:1 side slopes. Further detail on how the breaches were modeled can be found in **Appendix D**.

Figure 12 shows the maximum depth of inundation for Scenario 3. Generally, the inundation pattern and depth is similar to Scenario 2, except with the highway breached, floodwaters are no longer diverted along the highway into LaMoure. Simulated peak flow rates were much higher than Scenario 2, with a flow of 850 cfs just upstream of the highway. Overall volume is over 7,400 acre-ft, over twice the volume produced in Scenario 2, because the lake outlet has eroded lower.

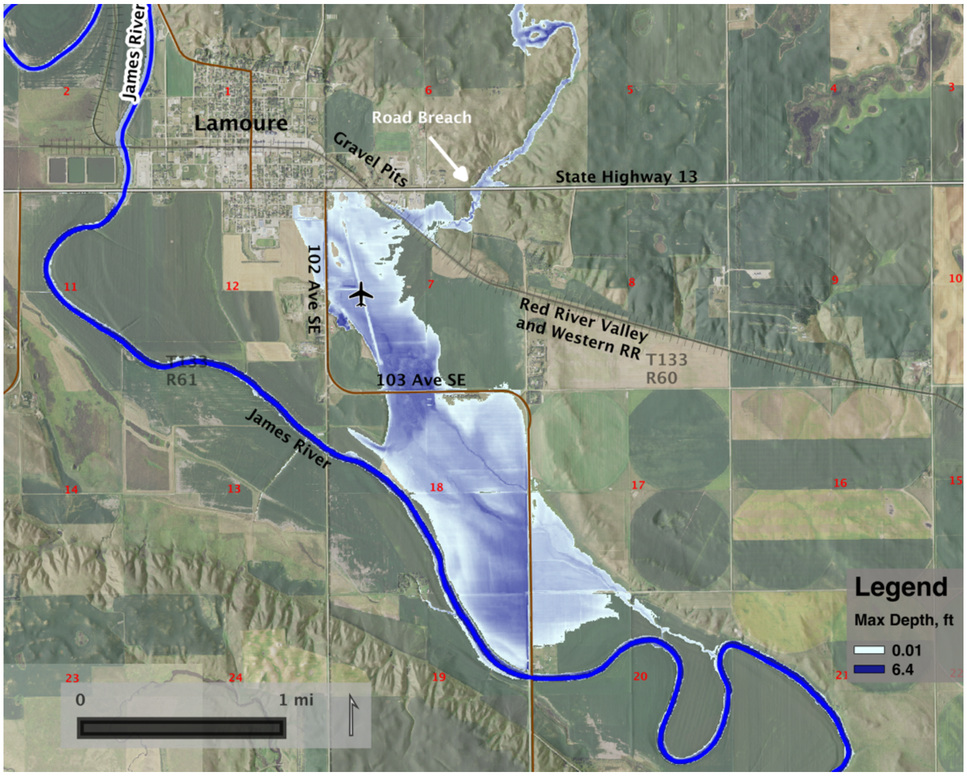

Figure 12: Scenario 3 inundation caused by a 100-year, 10-day rainfall event over Twin Lakes with the starting elevation of the lake at its spill point and assuming the lake outlet and State Highway 13 have breached.

Generally, the impacts caused by Scenario 3 are very similar to Scenario 2 with the exception of more damages caused by higher velocities and debris and the footprint of inundation would be a little smaller. A list of likely potential damages occurring during Scenario 3 is below:

- Near Lake
  - Inundation of Farmsteads 1 and 3 with over 2 feet of water. Wave action may cause some inundation and access will be problematic at Farmstead 2.
  - Inundation of local road 104 Ave SE
  - Breaching of local road 72 St SE
  - Inundation of agricultural land
  - Erosion damage at lake outlet
- Near Town
  - Shallow inundation (less than 2 feet) of multiple businesses and residences
  - Breaching of State Highway 13
  - Inundation and damage to railroad
  - Inundation of airstrip and buildings
  - Inundation of local road 103rd Ave SE
  - Inundation of agricultural land
  - Erosion from high flow rates, deposition of sediment and debris

Scenario 4 (Lake Flood Event, Overflow Condition, Outlet and Highway Breach, James River Flood Event)

Scenario 4 includes the 100-year, 10-day rainfall event on Twin Lakes with the lake spilling, erosion at the lake outlet, and breaching of the highway (Scenario 3) with a coincident 100-year flood event on the James River and associated temporary levees. The USACE derived 100-year flow of 11,620 cfs on the James River was used.

Figure 13 shows the maximum inundation depth simulated for Scenario 4. The potential damages associated with Scenario 3 occur, but the temporary levee south of the airstrip protecting LaMoure from James River flooding traps the floodwaters from Twin Lakes near the airstrip. In the simulation, no levees were overtopped. This causes floodwaters from the lake to back up into town. The temporary levee on 103 Ave SE was assumed to be 1310.5 ft NAVD88 which would allow for 3 feet of freeboard for the 100-year flood elevation on the James River. This increases the depth of flooding from Twin Lakes because it does not allow the water from the lake to exit to the James River unless the levee south of the airstrip is overtopped.

Damages caused by Scenario 4 are worse than Scenario 3 because the temporary emergency levee in place along 103 Ave SE south of the airstrip protecting the airstrip from river flooding doesn't allow the flood waters from Twin Lakes to drain to the river. A list of likely potential damages occurring during Scenario 4 is below:

- Near Lake
    - Inundation of Farmsteads 1 and 3 with over 2 feet of water. Wave action may cause some inundation and access will be problematic at Farmstead 2.
    - Inundation of local road 104 Ave SE
    - Breaching of local road 72 St SE
    - Inundation of agricultural land
    - Erosion damage at lake outlet
- Near Town
    - Shallow inundation (less than 2 feet) of many residences and businesses
    - Breaching of State Highway 13
    - Inundation and damage to railroad
    - Inundation of airstrip and buildings
    - Inundation of local road 103rd Ave SE
    - Inundation of agricultural land
    - Erosion from high flow rates, deposition of sediment and debris

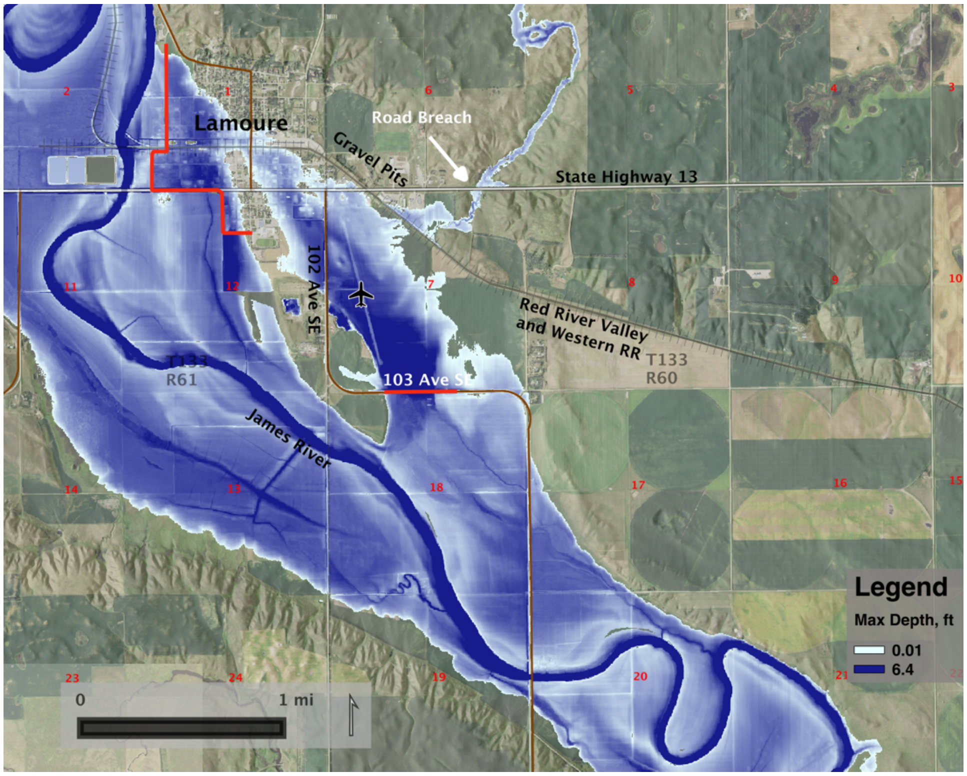

Figure 13: Scenario 4 inundation caused by Scenario 3 along with a 100-year flood event on the James River. Inundation within the town and airport is from the lake.

Mitigative Actions

Although Twin Lakes is still much higher than it was during the 1990s; as of May 2017, the lake has dropped roughly 3.5 feet from its historical high in 2011. Landowners surrounding the lake and those below the lake's natural outlet likely have in interest in lowering or maintaining the lake level; however, the cost of doing so is significant. Some actions that maintain the lake elevation at elevation 1395 ft NAVD88 are evaluated along with actions that mitigate damages in the event of a natural overflow.

Maintain Lake Elevation at 1395 ft NAVD88

Several gravity outlet configurations were considered, and the most viable configurations are shown in **Figure 14**. Two excavated, open channels were evaluated along with two gravity draining pipe options. All options assume that some type of control structure would be installed at the inlet to control outflows into the channel or pipe. The maximum design flow for the open channels is 100 cfs and the maximum design flow for the 60" diameter pipe outlets is roughly 50 cfs with the lake at its maximum recorded pool elevation of 1398.5 ft. These flow rates should be sufficient to control the lake level to prevent an overflow based on historical trends. However, these options are costly, and land easements will likely be difficult to obtain. For the southern outlet options, crossing the railroad will present a significant challenge.

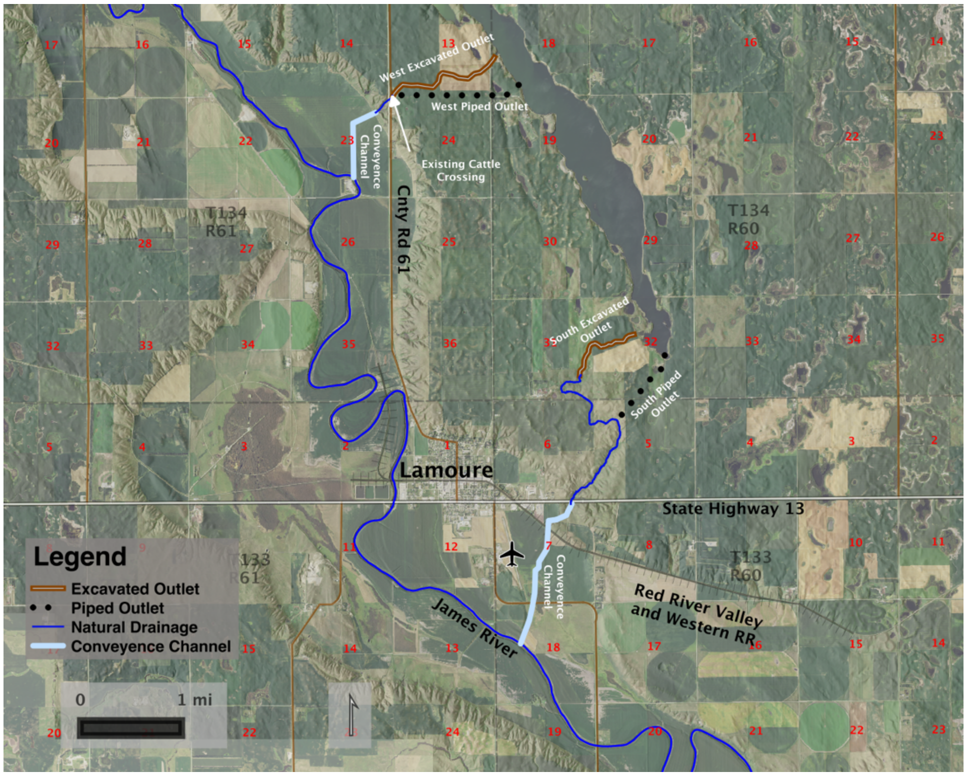

Figure 14: Evaluated gravity drain options.

With all four options, water is drained via gravity to a natural drainage channel. The natural channel would transport it to the James River floodplain where a constructed channel would be used to convey the water to the river and prevent it from spreading out. **Table 2**, summarizes important parameters for each configuration and cost estimates. **Appendix E** contains the cost estimate and assumptions for the drains.

Table 2: Summary of evaluated gravity drain options.

Outlet Alignment	Length of Excavated Outlet Channel, mi	Length of Pipe, mi	Length of Natural Channel, mi	Length of Conveyence Channel, mi	Total Excvation Volume, cy	Cost
South Excavated Channel Outlet	0.8	-	2.1	1.6	76,000	$ 2,000,000
West Excavated Channel Outlet	1.2	-	0.2	0.8	487,000	$ 7,300,000
South Piped Outlet	-	0.8	2.1	1.6	62,000	$ 3,000,000
West Piped Outlet	-	1.3	0.2	0.8	60,000	$ 2,600,000

Pumped outlets would likely not be a viable option. Pumping would be costlier than the cheapest option, South Excavated Channel, because of associated electric costs. Furthermore, a channel would still need to be built to confine the water once it reaches the James River floodplain.

Emergency Protection Measures

Because of the cost associated with constructing an outlet and the possibility that the lake may not overflow within a timeframe near enough to warrant planning, the City and District may want to consider continued monitoring of the lake and emergency protection measures.

As discussed previously, the impacts of Twin Lakes overflow would be significant to the City and surrounding area. Because the existing control at the spill point is a prairie trail, it is likely that the trail would erode and some type of small breach would occur at the outlet. Model Scenario 3 includes erosion of the outlet and breaching of State Highway 13 (**Figure 12**). In this case, flooding in the City of LaMoure would be minimal and could be easily prevented by plugging the culvert in 102 Ave. SE. However, State Highway 13 would be washed out restricting access, the railroad would be inundated and likely damaged, and commercial buildings on the south side of State Highway 13 and the airstrip would be inundated. Protecting buildings along State Highway 13 with sandbags could be easily done, but buildings near the airstrip and the airstrip itself would be more challenging to protect.

In the case of Scenario 4, Twin Lakes overflow with outlet erosion, highway breaching, and James River flooding with temporary levees, the temporary levee protection south of the airstrip, along 103 Ave. SE, would trap water from the lake and LaMoure would be inundated via backwater (**Figure 13**). This could be mitigated by breaching the levee, south of the airstrip, along 103 Ave. SE, and plugging the culvert west of the airstrip, within 102 Ave. SE (**Figure 15**). Although the commercial buildings south of State Highway 13 would be inundated, those close to the highway could be protected. It would be very important to maintain access to town via County Road 61 because Highway 13 would be blocked in both directions and the airstrip and railroad would be inundated.

If the 42" RCP culvert at Highway 13 was upgraded to a box culvert that could handle peak flows of 850 cfs (the estimated peak flow occurring in model Scenario 4), there is a chance that this portion of the highway could remain open. However, it is possible that the mud and debris (e.g. cattails and dead trees) generated from the outlet erosion would block the culvert, resulting in the washing out of the highway anyway. It may not be worth the investment in upgrading the crossing that may or may not perform as designed for an event that likely won't happen.

Farmsteads 1 and 3 would be inundated with flooding less than two feet; however, the duration would be fairly long and wave action would make ring dike protection challenging. Farmstead 2 is located on higher ground, but access would be flooded, and wave action may cause inundation and damage. It is recommended that the owners of these properties consider purchasing flood insurance which would provide some financial protection if the residence were to flood.

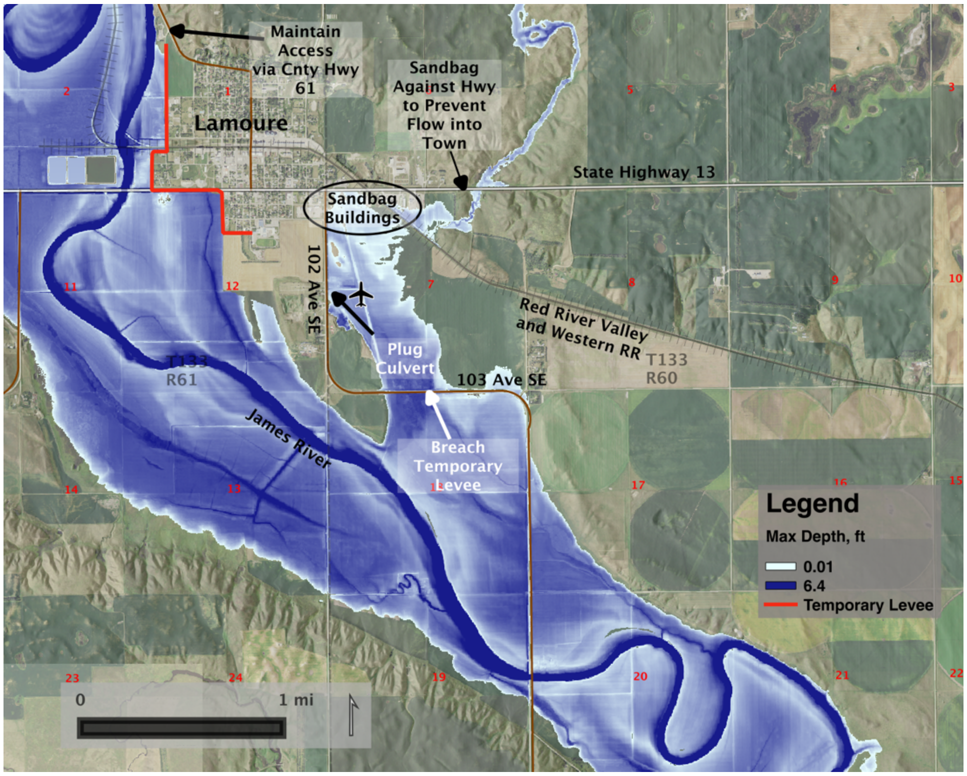

Figure 15: Simulated inundation for Scenario 4 with Emergency Protection Measures in place.

Summary

Twin Lakes, a large, closed basin lake, has risen nearly 30 ft since the early 1990s and restricted access to one farmstead, flooded township roads, and has caused agricultural damages. Prehistorically, the lake likely overflowed at least once during its formation and melting of glaciers. The lake elevation was at a historical high of 1398.5 ft NAVD88 during the summer of 2011, and as of May 2017 has receded to elevation 1395 ft NAVD88. This study could not evaluate the likelihood of the lake overflowing, as this was beyond its scope.

If the lake overflows at elevation 1403.5 ft NAVD88, it would cause flooding and infrastructure damage to LaMoure and the commercial area southeast of town. It would also impact three farmsteads. Generally speaking, lake overflow flooding could be easily prevented from entering the residential area of LaMoure, but the breaching of State Highway 13 and the railroad and inundation of local airstrip and nearby commercial buildings would be difficult to prevent. Since the overflow control point is an old prairie trail, it is likely that some erosion would occur allowing the lake to lower, releasing more water. It's unclear how much lower the outlet would erode, but based on the topography surrounding the outlet, the study assumed 3 ft.

Several options to maintain the lake at elevation 1395 ft NAVD88 and control outflows from the lake via gravity were evaluated. These options are costly, millions of dollars, including the cheapest option of excavating the natural outlet to a lower level. The volume of water required to be released to effectively manage the lake level would likely make pumping options even less desirable. The engineered outlets would have to cross irrigated farmland to reach the James River, and land easements may be challenging to obtain.

Emergency Protection Measures were identified to minimize impacts from the lake overflowing and also considered the constraints posed by temporary levees in place to combat flooding from the James River. The measures include the following:

- Maintain access to LaMoure via County Highway 61, as this may be the only access to the city,
- Do not install temporary levee protection south of the airstrip along 103 Ave. SE or breach the protection if already in place,
- Block culvert west of the airstrip along 102 Ave. SE,
- Sandbag along State Highway 13 to prevent water from diverting westward towards town, and
- Sandbag commercial buildings along State Highway 13 and airstrip, if possible.

The culvert crossing at State Highway 13 could be upgraded to accommodate a high flow from outlet erosion, but debris from erosion may end up blocking the crossing anyway. It may not be worth the investment given the uncertainties.

Continued monitoring of the lake elevation is recommended. The SWC routinely monitored levels over the past few years, and these data can be accessed via our website. The community may also want to use Scenario 4 as a planning tool to be prepared if the lake continues to rise. Investment in an outlet works is also an option, albeit costly, and it's not certain if it will be needed within its design life.

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Appendix A
Agreement

SWC Project #1285
Project Manager: MWeier
March 2012

Investigation Agreement

1. **PARTIES.** This agreement is between the State of North Dakota (State), acting through the State Water Commission (Commission), and the LaMoure County Water Resource District (District).

2. **PROJECT DESCRIPTION.** Commission shall: conduct a study of the hydrology of the currently closed basin system surrounding Twin Lakes, located in LaMoure County; identify potential implications of the lake naturally overflowing; and evaluate options that could be implemented to mitigate current damages caused by the lake flooding and potential future damages resulting from a possible natural overflow (Project).

3. **COMMISSION'S RESPONSIBILITIES.** Commission shall:

   a. Examine hydrology of the Twin Lakes drainage basin.

   b. Conduct topographic surveys and field observations to collect necessary data.

   c. Identify potential implications of a natural overflow of the lake.

   d. Evaluate options that could be implemented to mitigate current damages caused by the lake flooding and potential future damages resulting from a possible natural overflow.

   e. Complete a written report with findings, including cost estimates.

4. **DISTRICT'S RESPONSIBILITIES.** District shall:

   a. Acquire written permission from landowners for access and modification to property related to Project.

   b. Pay a deposit of $2,250 to Commission.

5. **TERM.** This agreement terminates on June 30, 2013.

6. **INSURANCE.** State and District each shall secure and keep in force during the term of this agreement, from an insurance company, government self-insurance pool, or government self-retention fund authorized to do business in North Dakota, commercial general liability with minimum limits of liability of $250,000 per person and $500,000 per occurrence.

7. **Breach.** Violation of any provision of this agreement by District constitutes breach of this agreement. A breach obligates District to reimburse Commission for all funds paid to District and relieves Commission of all obligations under this agreement.

8. **Agreement Becomes Void.** This agreement is void if not signed and returned by District within 60 days of Commission's signature.

9. **Termination.**

a. Commission may terminate this agreement effective upon delivery of written notice to District, or a later date as may be stated in the notice, under any of the following conditions:

(1) If Commission determines an emergency exists.

(2) If funding from federal, state, or other sources is not obtained and continued at levels sufficient to provide the funds necessary to comply with this agreement. The parties may modify this agreement to accommodate a reduction in funds.

(3) If federal or state laws or rules are modified or interpreted in a way that the services are no longer allowable or appropriate for purchase under this agreement or are no longer eligible for the funding proposed for payments authorized by this agreement.

(4) If any license, permit, or certificate required by law, rule, or this agreement is denied, revoked, suspended, or not renewed.

(5) If Commission determines that continuing the agreement is no longer necessary or would not produce beneficial results commensurate with the further expenditure of public funds.

b. Any termination of this agreement shall be without prejudice to any obligations or liabilities of either party already accrued prior to termination.

c. The rights and remedies of any party provided in this agreement are not exclusive.

10. **Applicable Law and Venue.** This agreement is governed by and construed in accordance with the laws of the State of North Dakota. Any action to enforce this agreement must be brought in the District Court of Burleigh County, North Dakota.

11. **Severability.** If any term of this agreement is declared by a court having jurisdiction to be illegal or unenforceable, the validity of the remaining terms must not be affected, and if possible, the rights and obligations of the parties are to be construed and enforced as if the agreement did not contain that term.

12. Spoliation – Notice of Potential Claims. District agrees to promptly notify Commission of all potential claims that arise or result from this agreement. District shall also take all reasonable steps to preserve all physical evidence and information that may be relevant to the circumstances surrounding a potential claim, while maintaining public safety, and grants to Commission the opportunity to review and inspect the evidence, including the scene of an accident.

13. Merger. This agreement constitutes the entire agreement between the parties. There are no understandings, agreements, or representations, oral or written, not specified within this agreement. This agreement may not be modified, supplemented, or amended in any manner except by written agreement signed by both parties.

NORTH DAKOTA STATE WATER COMMISSION
By: Todd Sando
TODD SANDO, P.E.
Chief Engineer and Secretary

Date: 3/26/12

LAMOURE COUNTY WATER RESOURCE DISTRICT
By: Kerry Ketterling
KERRY KETTERLING
Chairman

Date: 4-12-12

SWC Project #1285
Project Manager: MWeier
May 2013

AMENDMENT I to the Investigation Agreement

1. **Background.** In March 2012, the State of North Dakota (State), by and through the State Water Commission (Commission), and the LaMoure County Water Resource District (District) entered into an agreement to conduct a study of the hydrology of the currently closed basin system surrounding Twin Lakes, located in LaMoure County; identify potential implications of the lake naturally overflowing; and evaluate options that could be implemented to mitigate current damages caused by the lake flooding and potential future damages resulting from a possible natural overflow ("2012 Agreement").

2. **Intent.** The intent of the parties here is to amend the 2012 Agreement to extend the term.

3. **Agreement.** Commission and District agree to amend the 2012 Agreement by replacing the language in paragraph 5 with the following language:

> 5. TERM. This agreement terminates on June 30, 2015, unless extended in writing and signed by both parties.

NORTH DAKOTA STATE WATER COMMISSION
By: Todd Sando
TODD SANDO, P.E.
Chief Engineer and Secretary

Date: 5/17/13

LAMOURE COUNTY WATER RESOURCE DISTRICT
By: Kerry Ketterling
KERRY KETTERLING
Chairman

Date: ____________________

SWC Project #1285
Project Manager: MWeier
June 2015

AMENDMENT II to the Investigation Agreement

1. **Background.** In March 2012, the State of North Dakota (State), by and through the State Water Commission (Commission), and the LaMoure County Water Resource District (District) entered into an agreement to conduct a study of the hydrology of the currently closed basin system surrounding Twin Lakes, located in LaMoure County; identify potential implications of the lake naturally overflowing; and evaluate options that could be implemented to mitigate current damages caused by the lake flooding and potential future damages resulting from a possible natural overflow ("2012 Agreement").

2. **Intent.** The intent of the parties here is to amend the 2012 Agreement to extend the term.

3. **Agreement.** Commission and District agree to amend the 2012 Agreement by replacing the language in paragraph 5 with the following language:

> 5. **TERM.** This agreement terminates on June 30, 2017, unless extended in writing and signed by both parties.

NORTH DAKOTA STATE WATER COMMISSION
By: Todd Sando

TODD SANDO, P.E.
Chief Engineer and Secretary

Date: 6/25/15

LAMOURE COUNTY WATER RESOURCE DISTRICT
By: Marvin Schultz

MARVIN SCHULTZ
Chairman

Date: 7-16-15

Appendix C
Hydrology Model Description

A hydrology model was developed using GRASS GIS (GRASS Development Team, 2016) and HEC-HMS 4.2 (Hydrologic Engineering Center, 2006). Topographic, soil, and climate data were assimilated and used to model the lake. Because the water level of a closed basin lake is subject to cumulative climatic effects, the Soil Moisture Accounting (SMA) soil loss method was used. This allowed for a continuous historical simulation from 1993, which is when potential evapotranspiration (PET) data became available from the North Dakota Agricultural Weather Network (NDAWN, 2017), through May 2017. The model was calibrated by adjusting loss parameters and drainage area.

Drainage Area Calculation

The drainage area for the lake was estimated to be 38 mi^2; however, it is mostly non-contributing because of the many depressions and potholes within the watershed. The drainage boundary was estimated using LiDAR data collected during October and November 2010 with the r.stream.extract algorithm within GRASS GIS (Jasiewicz and Metz, 2011; GRASS Development Team, 2012).

A “fill-and-spill” method was used to estimate how much of the drainage basin typically contributes. LiDAR cannot collect data below the water surface, so the LiDAR collected during October and November 2010 shows the depressions filled to the water level that was observed at the time of the collect. So, a key assumption is the antecedent water levels in the depressions are those observed during the fall of 2010. The available storage in each depression before it spills was calculated and compared to the volume of runoff. The runoff volume is calculated by multiplying a set runoff depth with the drainage area of each depression. If the volume of runoff draining to a depression exceeds the available storage volume within the depression, the excess runoff would then be routed downstream. This process is iterated to until the storage and runoff calculations are stable.

The “fill-and-spill” method was used for 0.25” runoff depth increments ranging from 0.25” to 2”. **Figure C1** shows how the contributing drainage area of Twin Lakes increases with runoff depth. For most runoff events the drainage area is less than 10 mi^2, but there is a steep break in the curve around a depth of 2.5” and a flattening of the curve around 4.0”.

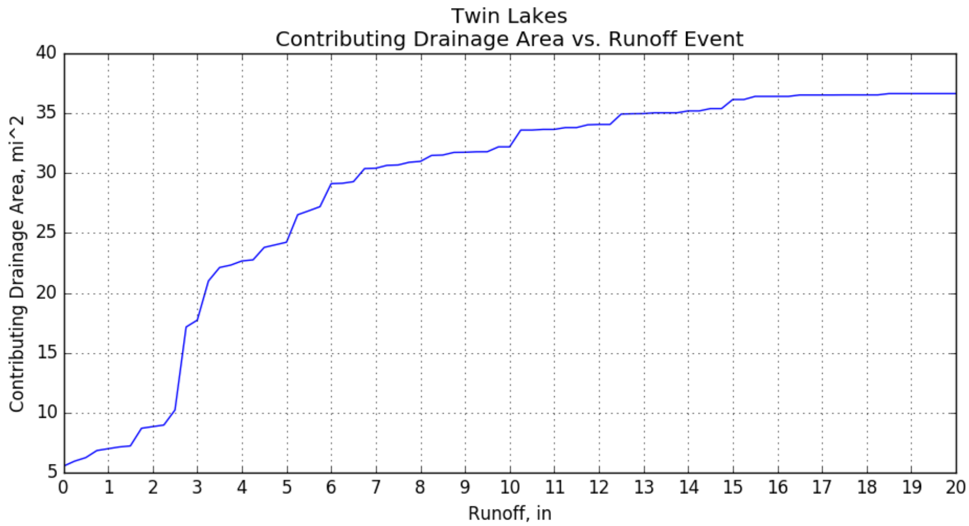

Figure C1: Twin Lakes contributing drainage area vs. runoff event.

Figure C2 shows how the aerial extent of drainage area varies with runoff event. The total 38 mi^2 drainage area is shaded gray, the 23 mi^2 drainage area for a 4.0” runoff event is shaded green (wet condition area), and the 10 mi^2 drainage area for a 2.5” runoff event is shaded light blue (base condition area). A background aerial photograph collected during the summer of 2016 shows numerous depressions within the wet condition area that prevent it from contributing during more frequent runoff events.

Because of the variability of drainage area, it was used as a calibration parameter in the hydrology model. HEC-HMS does not allow for drainage area to vary with time or precipitation; however, this was addressed by separating the base condition area and wet condition area into separate subbasins. The wet condition area only receives precipitation from fall of 2009 through the fall of 2012 during the continuous historical simulation. The additional drainage area was needed to correctly simulate 2011, a year that the lake level rose 5.5 feet over five months.

The HEC-HMS model also includes a separate subbasin for the surface of Twin Lakes to allow direct input of precipitation into the lake with minimal travel time loss and a local drainage basin (a.k.a. Outlet Local Basin) to estimate local drainage that would contribute at the State Highway 13 crossing. **Table C1** summarizes the drainage areas used in the HEC-HMS model.

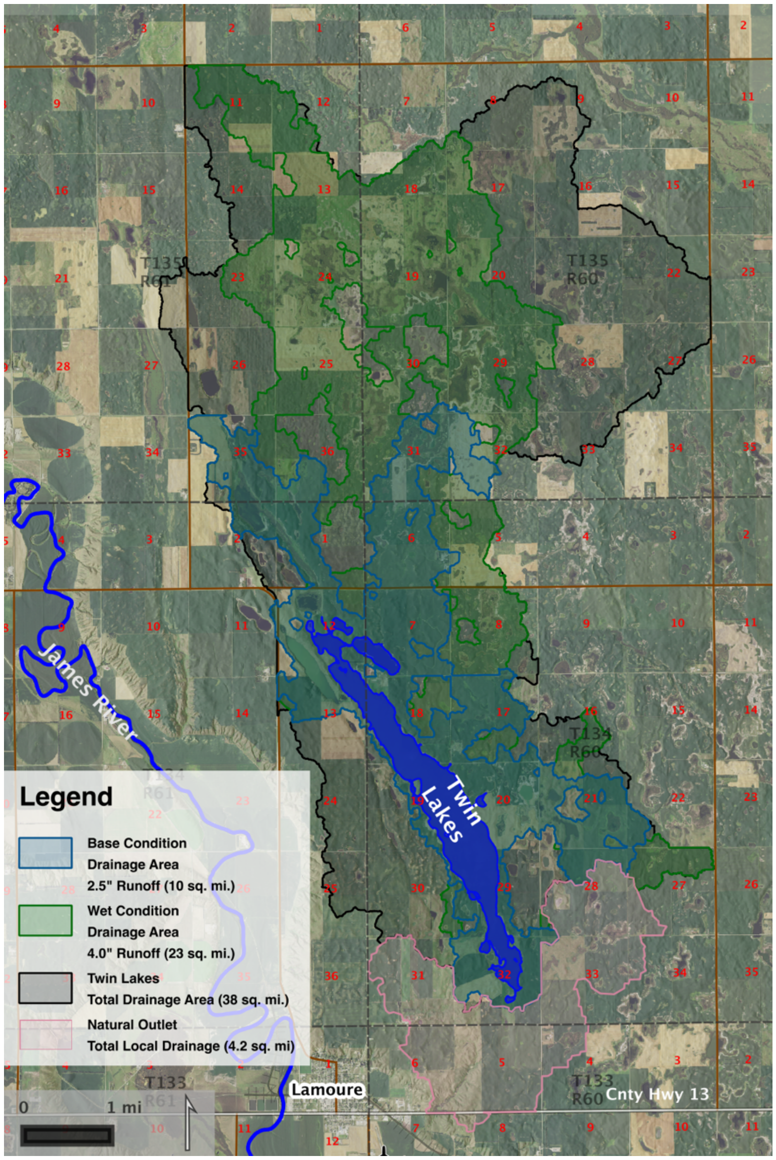

Figure C2: Twin Lakes contributing drainage area for the 2.5" (light blue area) and 4.0" (green) runoff events.

Table C1: Twin Lakes contributing drainage area for the 2.5" (light blue area) and 4.0" (green) runoff events.

Subbasin	Drainage Area, sq. mi.	Notes
Wet Condition	13	Additional wet condition area, only used during synthetic events and late 2009 through 2012 during historical simulation
Base Condition	8	Base condition area
Lake	1.8	Surface area of lake
OutletLocalBasin	1.4	Likely contributing local drainage area along natural overflow alignment (total drainage area 4.2 mi^2)

Infiltration Loss Method

The SMA loss method was used to allow for continuous, multi-year simulation of the lake. **Figure C3** shows how the watershed is represented with different storage layers. The Twin Lakes model uses canopy interception, tension zone storage, and one groundwater layer. The groundwater layer was added by trial and error, and allows the water to eventually reach the lake through baseflow. Conceptually, this layer implicitly accounts for the physical reality of runoff making its way through the chain of numerous depressions to the lowest point in the system, Twin Lakes. Although it has not been physically verified in the watershed, there could be some type of groundwater connection between the chain of depressions that ultimately leads to the lake.

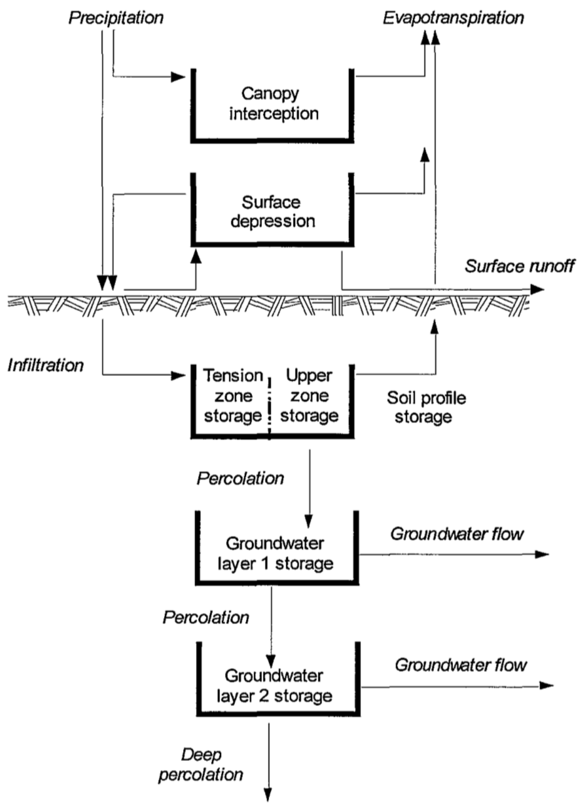

Figure C3: Soil Moisture Accounting Method (SMA) diagram (Hydrologic Engineering Center, 2000).

Table C2 summarizes the parameters used in the SMA method. Soil parameters were obtain by using initial estimates and adjusting during the long-term historical calibration. The initial estimates were calculated by using the Soil Survey Geographic (SSURGO) Database maintained by the U.S. Natural Resources Conservation for LaMoure County (Soil Survey Staff, 2015) and. Impervious area was estimated from the 2011 National Land Cover Data set (Fry et. al, 2011). The model is most sensitive to soil percolation, which was initially estimated from the SSURGO vertical hydraulic conductivity and the constant loss method guidance found in the HEC-HMS Technical Reference Manual (Hydrologic Engineering Center, 2000).

Table C2: Soil Moisture Accounting Method (SMA) parameters.

Basin	Maximum Infiltration, In/hr	Impervious, %	Soil Storage, In	Tension Storage, In	Soil Percolation, In/Hr	Groundwater Storage, In	Groundwater Percolation, In/Hr	Grounwater Coefficient, Hr
WetCondition	0.05	0.2	20.64	14.544	0.05	0	0	120
BaseCondition	0.15	0.2	20.64	14.544	0.1	5	0	120
Lake	0.01	100	0	0	0.05	0	0	120
OutletLocalBasin	0.15	0.08	20.64	14.544	0.05	5	0	120

The groundwater percolation parameter was set to zero, meaning that there is no loss to a deeper groundwater system. All precipitation losses result from evapotranspiration. Conceptually, this is reasonable because the surface geology is glacial till and there is minimal conductivity with the underling Spirtwood Aquifer. The linear reservoir baseflow method was used to enable groundwater from the Base Condition subbasin to exit into Twin Lakes.

The simple canopy method was used to allow evapotranspiration. The canopy maximum storage was assumed to be 0.1" and a crop coefficient of 1.1 was used with the tension reduction uptake method for all subbasins except the lake subbasin.

Travel time is not a crucial parameter in this model because the lake flooding is a cumulative issue. However, the Clark transformation method was used and the parameters were estimated with GIS tools and engineering judgment. Travel time parameters are shown in **Table C3**.

Table C3: Travel time parameters.

Subbasin	Time of Concentration, hrs	Storage Coefficient, hr
WetCondition	20	41.3
BaseCondition	10	30.5
Lake	0.1	0.1
OutletLocalBasin	7.7	11.6

Metrological Model

Meteorological data was obtained from the PRISM dataset (PRISM Climate Group, 2017), North Dakota Agricultural Weather Network (NDAWN, 2017), and the NOAA National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC) SNOw Data Assimilation System (SNODAS) model (NOHRSC, 2004). The daily PRISM data set was downloaded for a 4 kilometer by 4-kilometer area located near the centroid of the base condition drainage area and used as the precipitation input with the exception of the spring of 2011. The SNODAS snowmelt model was used as a precipitation input during the spring of 2011 as an attempt to better capture the hydrograph timing. A daily specified hyetograph was created for each subbasin.

Jensen-Haise potential evapotranspiration (PET) data was downloaded from the Edgeley, Marion, and Lisbon NDAWN stations and averaged. The averaged PET was used with the canopy and SMA method to calculate ET.

The average PET data was also used to calculate monthly average ET that occurred from Twin Lakes from the early 1990s through 2016. These data were converted to lake ET by using the adjustment factors determined by the USGS and SWC water balance method for Devils Lake, ND (Weier, 2015). The daily lake ET values where then aggregated and averaged into monthly average values. **Table C4** shows the average monthly lake ET values used.

Table C4: Twin Lakes monthly average lake ET values.

Month	Lake ET, in	Month	Lake ET, in
January	0	July	6.1
February	0	August	6.8
March	0	September	5.4
April	1.9	October	3.4
May	3	November	1.4
June	4.5	December	0

Hydrology Model Calibration

The hydrology model was calibrated by running a continuous simulation from September 1993 through May 2017. Observed lake elevation data before 2011 is estimated from Landsat imagery and elevation data; therefore, it has a large error (± 5 feet) associated with it. During 2011 the SWC and a private observer began collecting data which is much more accurate, typically within 0.1 feet. Based on Landsat aerial imagery, the two lakes did not merge into one lake until 1997, so the simulated lake elevations before 1997 are not representative of the remote sensed elevations. **Figure C4** shows the simulated and observed lake elevations from 1997 through 2016. **Figure C5** shows the simulated and observed lake elevations during the period from 2011 through 2016, when the higher precision elevation observations occurred.

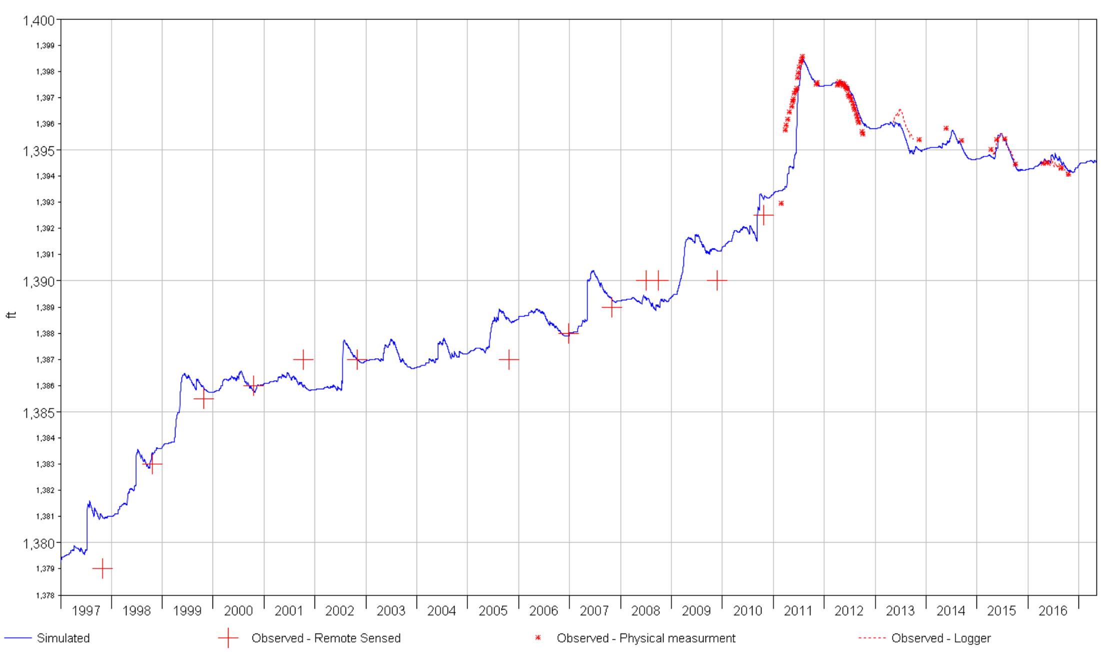

Figure C4: Simulated (blue line) and observed (red symbols) lake elevations from 1997 through early 2017.

The simulated elevation matches the observed elevations very well considering the length of the simulation; the error in the elevations estimated using remote sensing; and the error in the elevation-storage function. The elevation residual is typically within 2 ft from 1997 through 2010 and within 1 foot from 2011 through 2016.

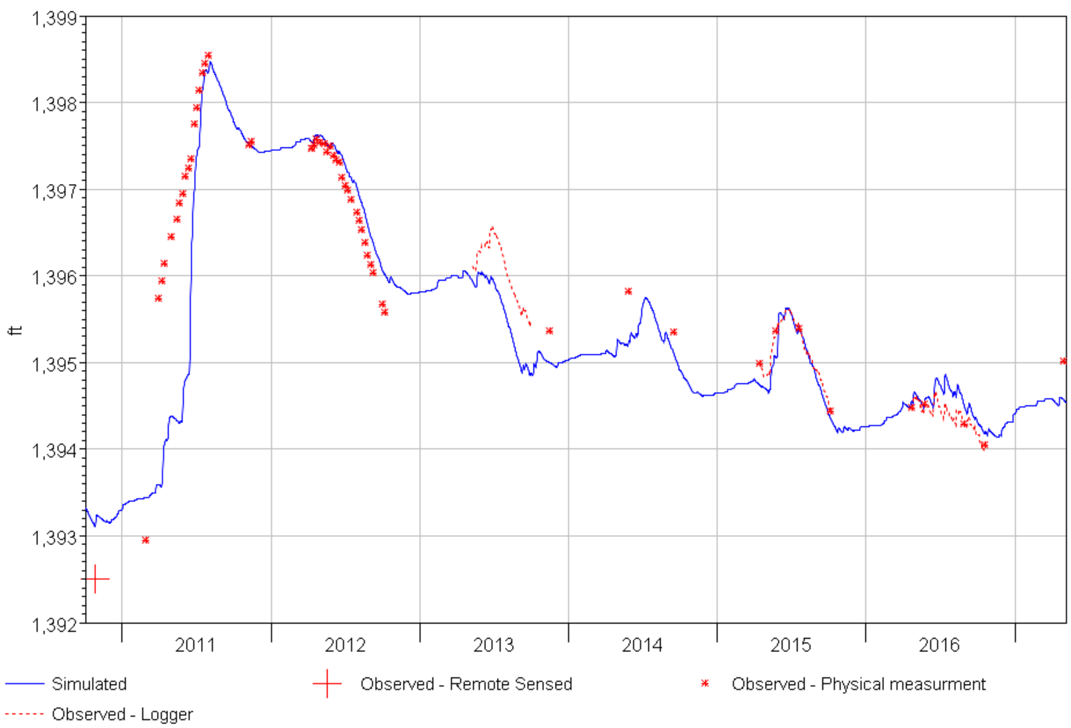

Figure C5: Simulated (blue line) and observed (red symbols) lake elevations during the period of physical observations, late 2010 through early 2017.

The simulation included a four year warm up period from 1993 to 1997 to allow the model to equilibrate from the unknown initial conditions. The warm up period is not shown because the model cannot predict lake levels when the lake is split in two, below elevation 1373.5 ft NAVD88. The initial lake level used in 1993 was 1370 NAVD88, and 30% of the soil and groundwater storage was considered occupied.

Figure C5 illustrates the rapid rise in lake levels of 5 feet that occurred over 6 months during 2011. The wet condition drainage area was modeled during this time to account for the contribution of this area, which typically is non–contributing. Landsat imagery collected on May 2, 2011 (**Figure C6**) suggests that a large, downstream depression within the wet condition drainage area was draining into the base condition area supporting the use of the expanded drainage area.

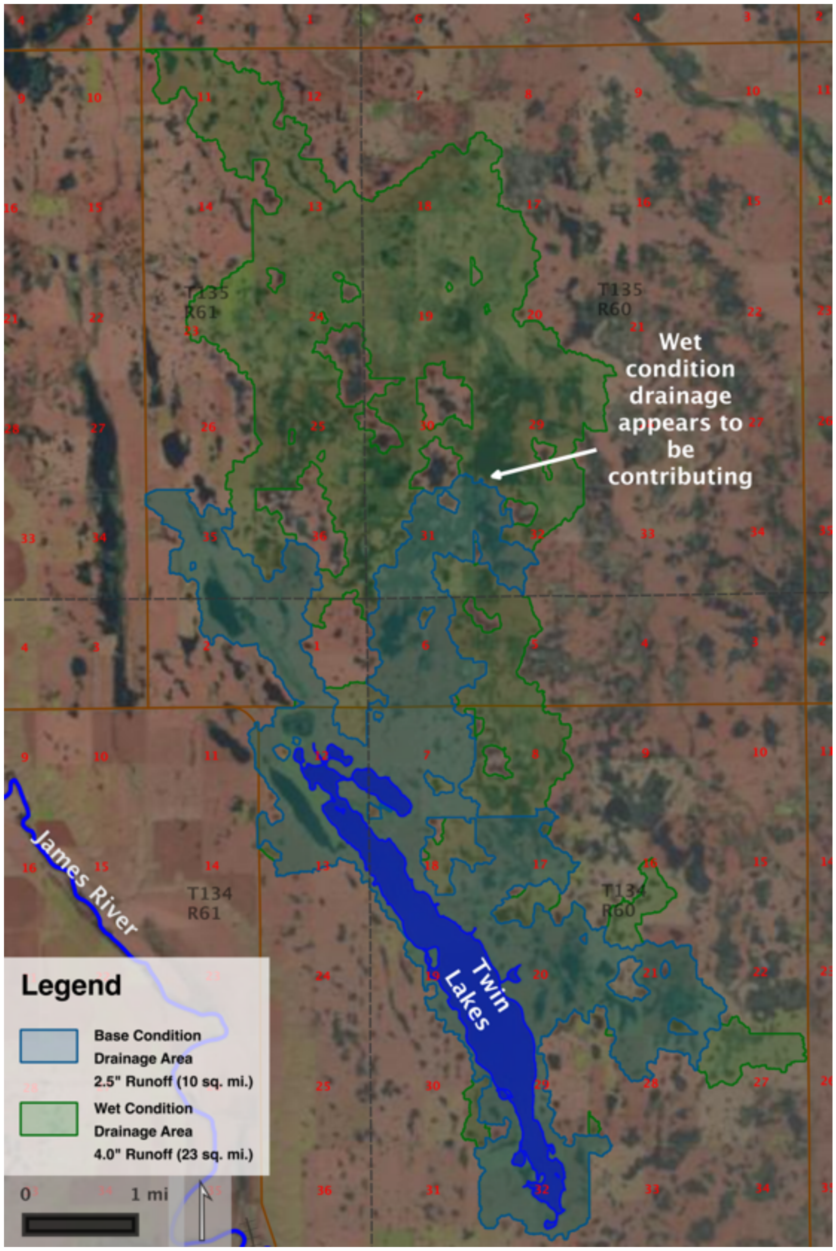

Figure C6: Landsat image collected on May 2, 2011 showing the wet condition drainage area connected to the base condition area.

Synthetic Hydrology Events

Synthetic hydrology events were developed for two reasons:

1. To estimate how much the lake would rise during extreme precipitation events
2. and to estimate the volume and duration of water that would overflow toward LaMoure if an extreme event occurred with the lake at its overflow elevation.

The synthetic events were created by using NOAA's Atlas 14 precipitation estimates (Perica et. al., 2013) and assumed conservative initial conditions within the model. The modeled values from the historical simulation ending in May 2017 including wet condition drainage area were used as the antecedent conditions. The lake elevation was assumed to be at 1395 ft NAVD88. During the spring of 2017, soil conditions were also fairly wet and with the addition of the wet condition drainage area, this represents a fairly conservative initial condition. This approach is realistic because soils are often wet with snowmelt during the spring and early summer, a time when heavy precipitation typically occurs in North Dakota.

Table C5 summarizes the results from the synthetic events. The table includes the Atlas 14 total point precipitation, the precipitation applied to the basin reduced by the area-reduction curve, the rise in lake level assuming a starting elevation of 1395 ft, the increase in lake volume, the total lake volume, and the approximate volume remaining until a spill occurs.

Table C5: Summary of synthetic event hydrologic model results.

Event	Atlas 14 Total Precip., Inches	Area Reduction Precip., Inches	Rise from Elevation 1395 ft NAVD88, ft	Lake Volume Increase, acre-ft	Lake Volume acre-ft	Remaning Storage Until Spill, acre-ft
500 year 10 Day	10.70	10.49	5.90	7,750	25,196	5,904
100 year 10 Day	8.49	8.32	4.50	5,568	23,034	8,066
50 year 10 Day	7.59	7.44	3.90	4,765	22,209	8,891
10 year 10 Day	5.66	5.55	2.60	3,094	20,558	10,542
1 year 10 Day	3.56	3.49	1.20	1,508	18,992	12,108
None	0.00	0.00	0	-	17,665	13,435

The simulation shows that even if a 500-year, 10-day rain event occurred with the lake at 1395 ft NAVD88, there is still significant storage available before the lake spills. As of May 2017, a risk of the lake overflowing from a single event or within a single year is very unlikely. However, the cumulative effects of a wetter than average climate over a period of years may cause the lake to overflow eventually.

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Appendix D
Hydraulic Model Description

A hydraulic model was developed to simulate the flooding impacts caused by an event where Twin Lakes reaches its spill level and a rare precipitation event occurs. The likelihood of this taking place within a timeframe that warrants concern is small; however, it is possible. The City and District also expressed interest in understanding the implications of such an event occurring while the James River is flooding. The effects of the outlet control eroding were also considered.

A combination 1- dimensional (1D) and 2-dimensional (2D) model was developed to simulate the hydraulics of the James River near Lamoure and Twin Lakes and its potential overflow (**Figure D1**). The 2D portion model was created with HEC-RAS 5.0.3 (HEC, 2016) and was merged with a portion of the 1D model of the James River completed by the USACE (USACE, 2014). The 1D model was mostly unchanged with the exception of truncating the length of the original James River model, shortening the length of some cross-sections near Lamoure, and connecting to the 2D areas with a lateral structure. The 2D model was created based on 1-meter resolution LiDAR data collected during the fall of 2010.

Multiple scenarios were modeled including lake overflow events, lake spill point breach events, and a combination of lake spill point breach event and James River flooding event. A localized model was developed to help understand the hydraulics of the spill point.

2D Computational Mesh

Two separate 2D areas were generated to represent the lake and its natural outlet. The lake was represented as the Twin Lakes 2D area to best capture the attenuation of the inflows provided by the lake and the hydraulics of the spill point. A very course grid roughly 1,000 ft by 1,000 ft was used for the Twin Lakes 2D area.

A much finer 200 ft by 200 ft grid was used to represent the natural outlet 2D area (Overflow 2D area) (**Figure D2**). Additionally, several breaklines were used to capture roadways that act as control points.

A simple, localized model focused on the lake spill point was also created with a fine 30 ft by 30 ft grid to better assess the hydraulics of the spill point (**Figure D3**).

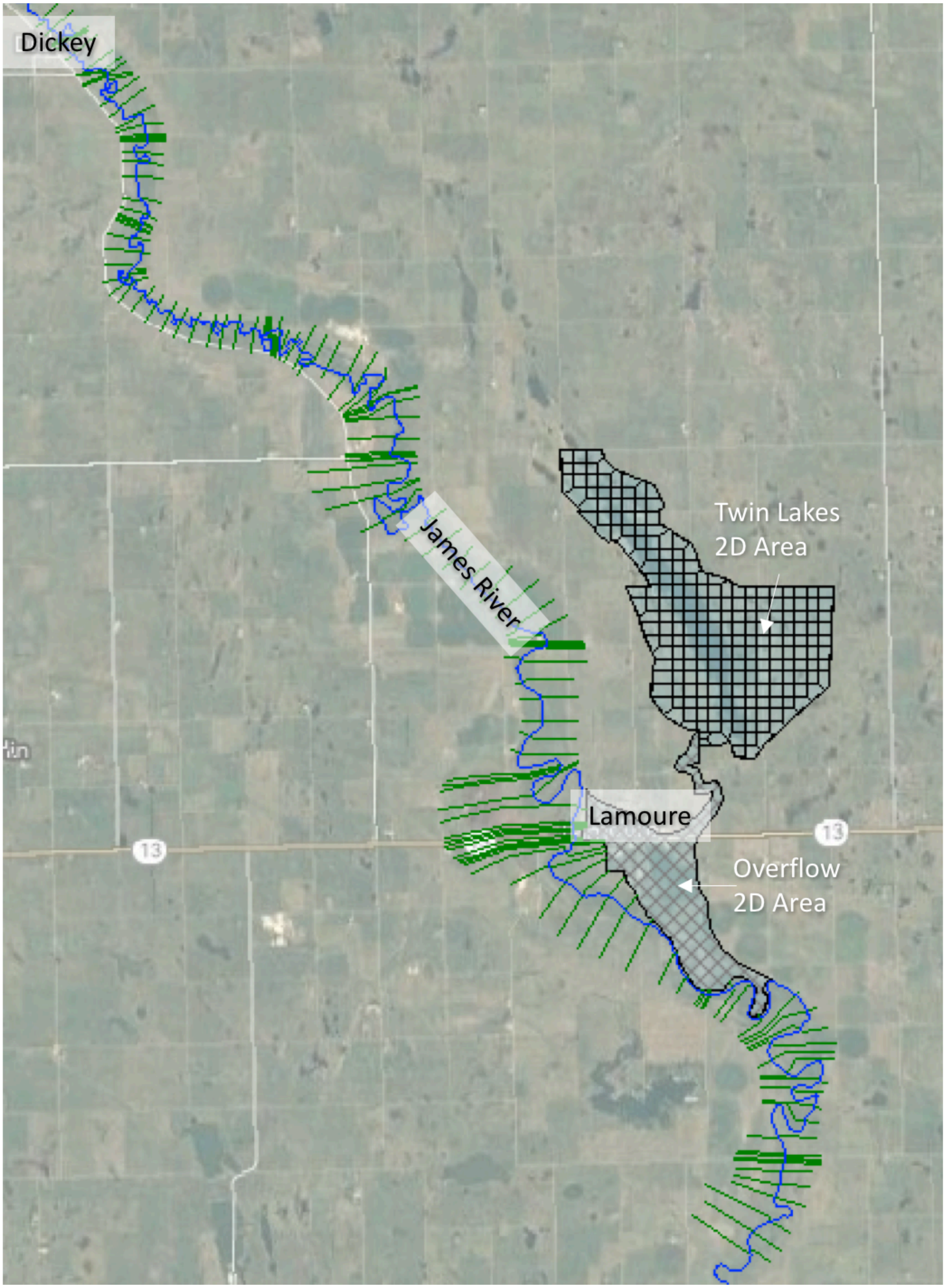

Figure D1: Hydraulic model domain.

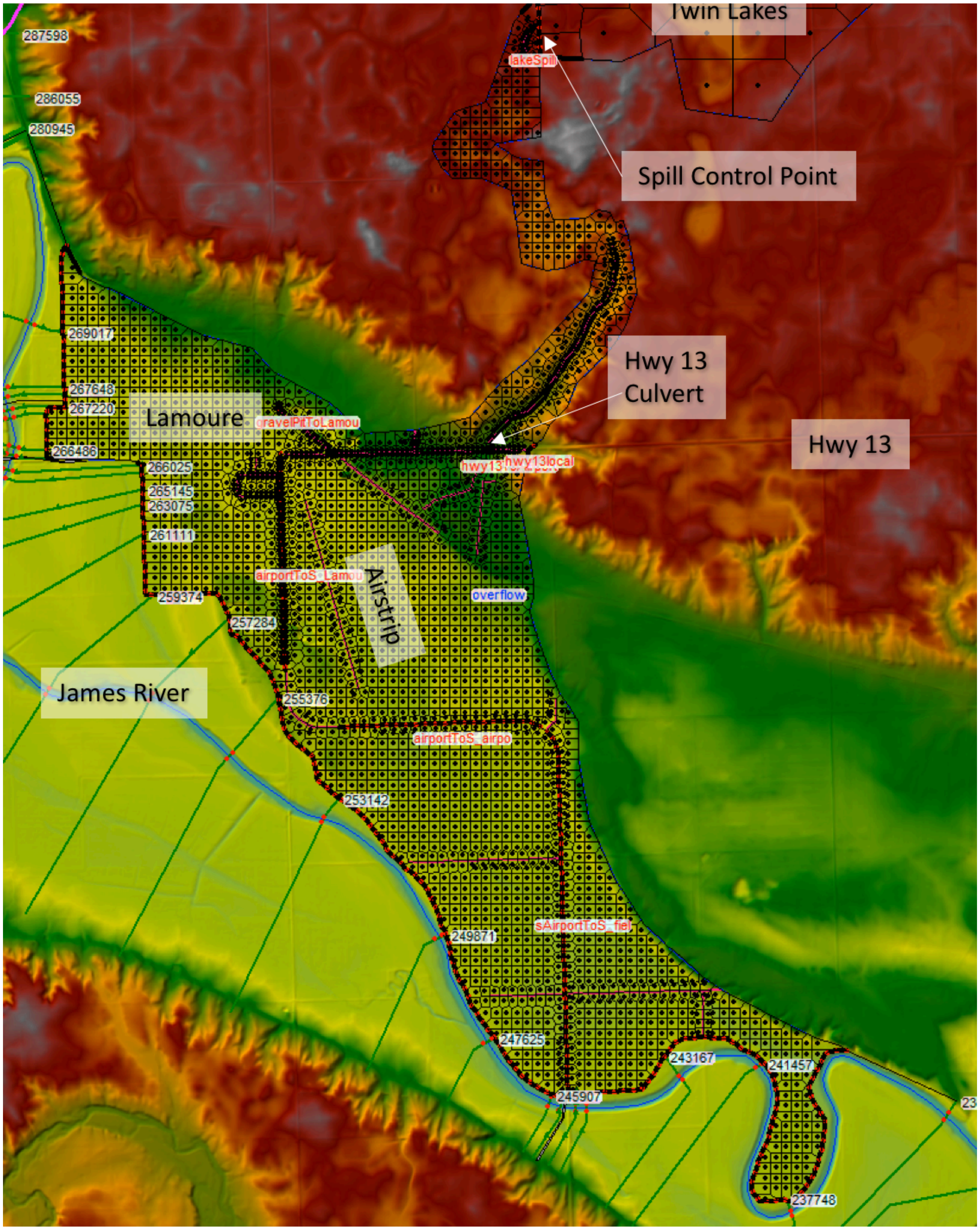

Figure D2: Overflow 2D area, Hwy 13 culvert, and lake overflow control point with LiDAR terrain as a background.

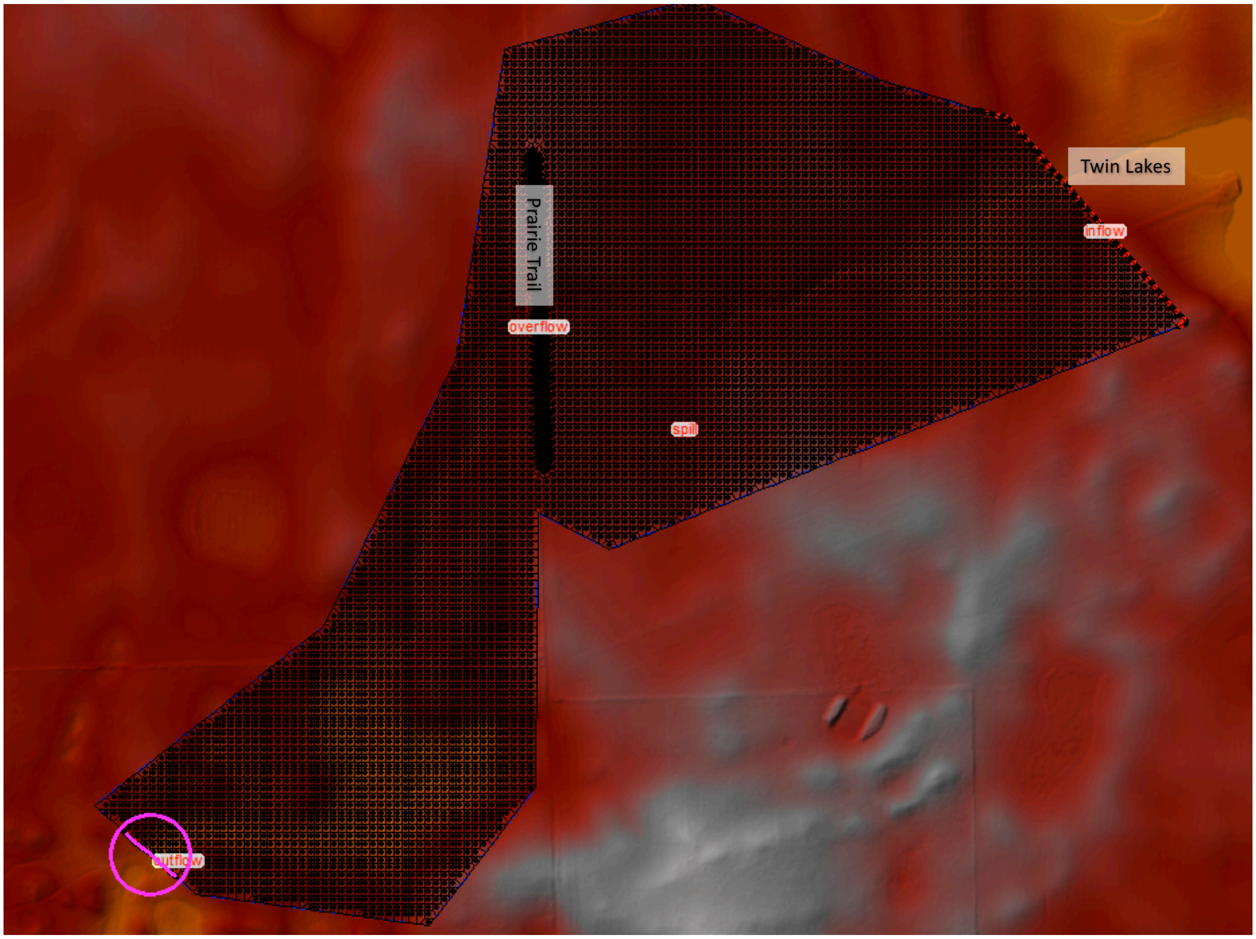

Figure D3: Localized lake spill point model domain.

Culverts, 2D Connections, and Lateral Structures

Few culverts were modeled in the 2D area, with the most significant culvert being a 42" reinforced concrete culvert located below State Highway 13 where the natural outlet meets the floodplain of the James River (**Figure D2**). This culvert was modeled within an internal 2D connection and was surveyed by the SWC during 2012 (**Appendix B**).

A 2D area connection was used to model the lake spill point. The spill point was modeled as a weir with a coefficient of 4.0. An effort was made to estimate the spill efficiency as well as possible because this has implications on how high the lake would rise and impacts to farmsteads and roads. A separate, small 2D model was made of the spill point to get an estimate of an appropriate weir coefficient to use. In this smaller model, a 30 ft by 30 ft grid was used with a roughness coefficient of 0.045 to build a spill rating curve for a range of flows. Although the weir coefficient of 4.0 is higher than one may expect, a rating curve built from an older, iRIC model used earlier in the project (Weier, 2014), corresponded to a weir coefficient of 3.0, and the curves varied by only 33% at an elevation of 1405 ft NAVD88. **Figure D4** shows the rating curves generated by the smaller, full 2D model with 0.045 roughness coefficient, the weir coefficient of 4.0, the weir coefficient of 3.0, and the iRIC model.

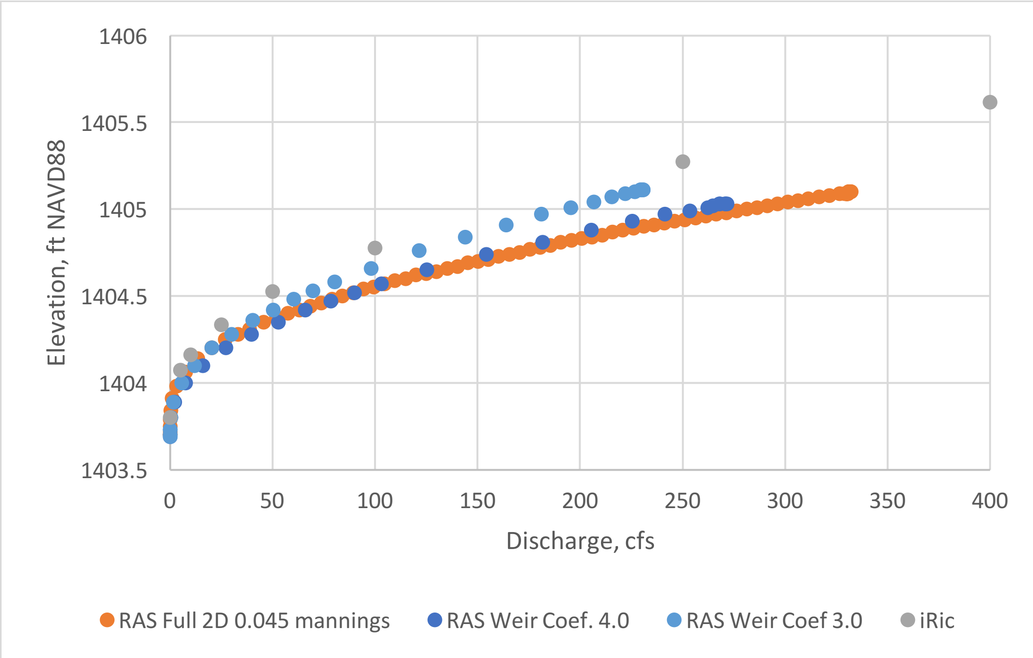

Figure D4: Evaluated spill point rating curves.

Lateral structures were used to connect the 1D portion of the model to the 2D portion of the model. These were digitized at a local topographic high to best mimic weir flow. The weir coefficient ranged from 0.5 to 1.5 depending on the relative height of the weir.

Roughness

The 2011 National Land Use Classification System (Fry, 2011) grid was used to spatially vary the Manning's Roughness coefficient for the 2D portion of the model. Roughness values in the 1D portion of the model were unchanged. **Table D1** shows the default roughness values used in each land classification.

Land Cover Layer		
	Name	Default Mann n
1	barren land rock/sand/clay	0.04
2	cultivated crops	0.06
3	deciduous forest	0.1
4	developed, high intensity	0.15
5	developed, low intensity	0.1
6	developed, medium intensity	0.13
7	developed, open space	0.04
8	emergent herbaceous wetlands	0.08
9	evergreen forest	0.12
10	grassland/herbaceous	0.045
11	open water	0.035
12	pasture/hay	0.06
13	shrub/scrub	0.08
14	woody wetlands	0.12

Table D1: Roughness values used within the 2D domain.

Boundary Conditions

Inflow hydrographs were applied to the upstream cross-section of the James River and in the northern portion of the Twin Lakes 2D area. A normal depth friction slope boundary condition of 0.00004 was used at the downstream cross-section of the James River which is similar to the 100-year energy grade line.

The localized spill model used a step inflow hydrograph for the upstream boundary condition and a normal depth with a friction slope of the natural topography (0.003) for the downstream boundary condition.

Erosion and Breaching Parameters

For certain scenarios, the lake spill point and State Highway 13 crossing were modeled as eroding and breaching. This was evaluated because the spill point control is a prairie trail and would likely begin to erode if the lake overflowed. **Figure D5** shows a profile of the natural outlet along the spill control point and the breach elevation.

Using available data, it is assumed that the erosion would stabilize around elevation 1400.5 feet NAVD88 because the slope becomes more gradual, and at that point the eroded area would be approximately 1,000 feet long by roughly 50 feet wide at the top and approximately 1.5 feet deep over the length of erosion. The amount of erosion is an important unknown variable and further investigation may be warranted. State Highway 13 is assumed to breach shortly after the overflow reaches it. The breach is assumed to be 100 feet wide at the base with 1:1 side slopes.

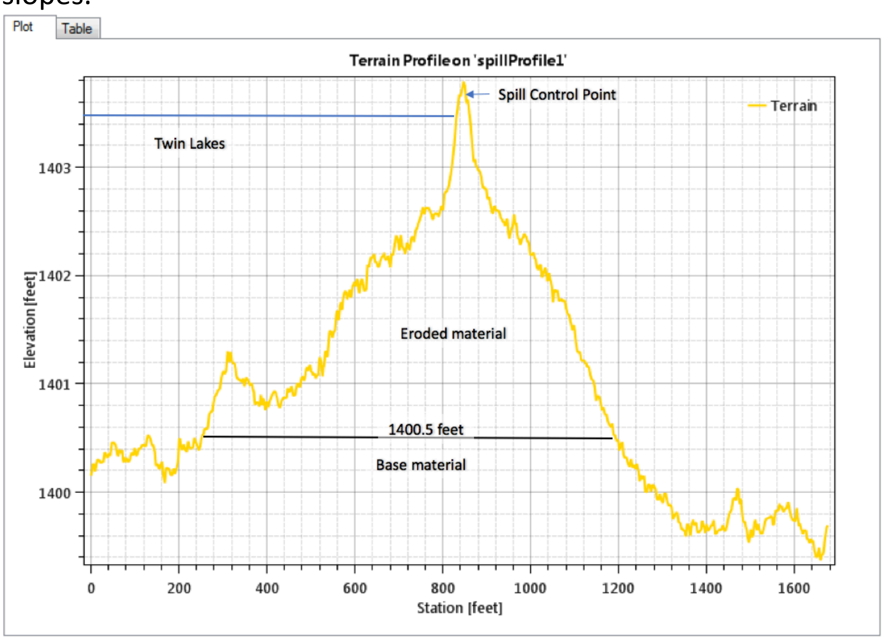

Figure D5: Cross section of outlet control topography and breach elevation (Note: Vertical scale is greatly exaggerated).

Figure D6 shows parameters used for the breach formation. The Xu & Zhang method within HEC-RAS was selected to calculate the breaching parameters. This method appeared to be the most realistic for this type of breach because the grade near the spill point is much flatter than dam spillways. More material must erode to lower the water surface than a typical dam.

Highway 13 was modeled as breaching very quickly with a final bottom width of 100 ft and 1:1 side slopes; however, some scenarios modeled the section of the highway as already breached for increased model stability.

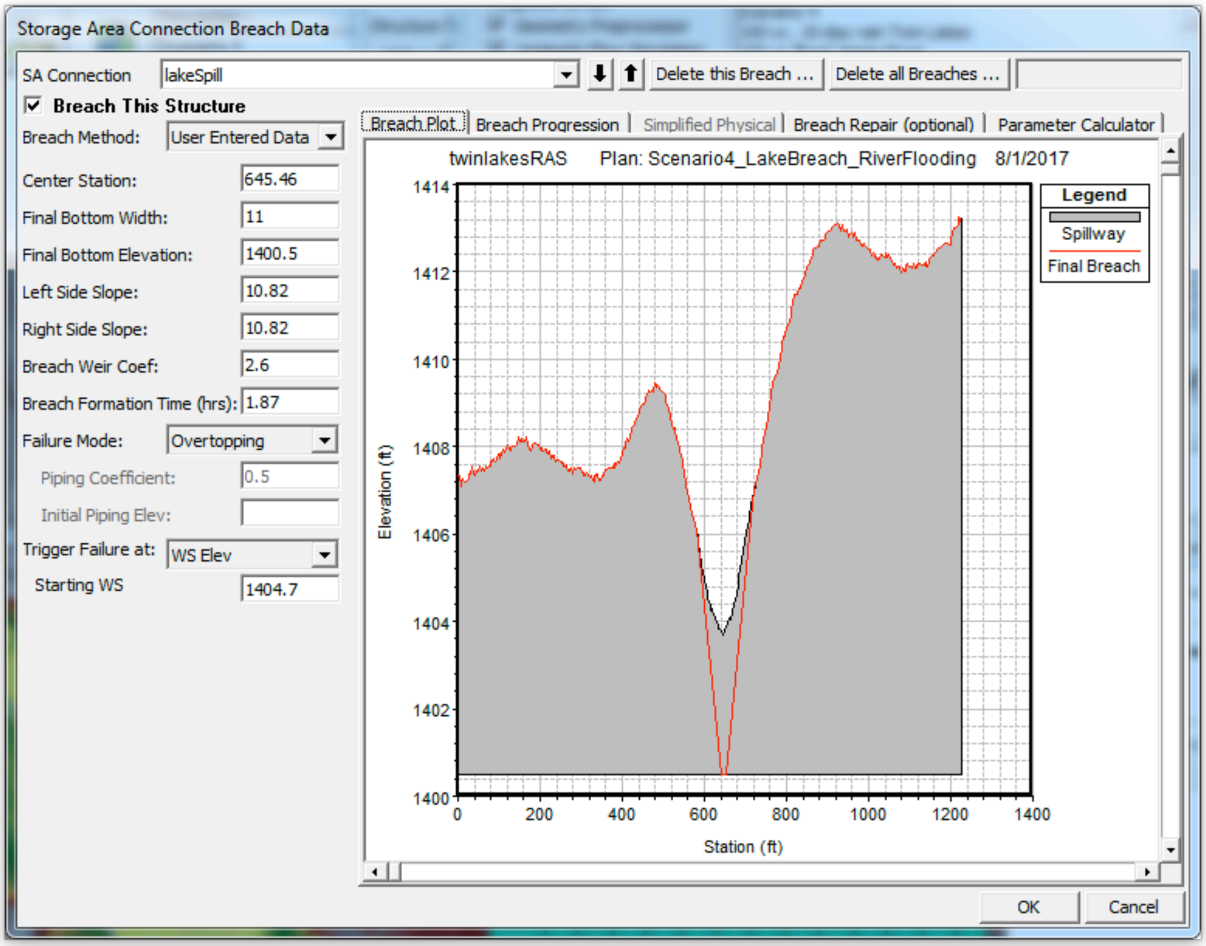

Figure D6: Lake spill point breaching parameters

Model Solver and Time Step

The Full Saint Venant equations were used because the diffusion wave solver cannot accurately describe the spilling of the lake and spill point breach scenarios. The Overflow 2D area was the limiting factor in runtimes because of the dynamic flooding. Time steps used for the Overflow 2D area ranged from 12 seconds to 1 second depending on the scenario.

Calibration

The model could not be calibrated because there is no record of the lake overflowing. Confidence is high that this model is simulating the overflow realistically because the results match those of the earlier iRic model. Quality control and calibration for the James River portion of the model is discussed in the USACE James River Preliminary Feasibility Investigation (USACE, 2014).

References

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Appendix E
Engineered Outlet Assessment

Although Twin Lakes is still much higher than it was during the 1990s; as of May 2017, the lake has dropped roughly 3.5 feet from its historical high in 2011. Landowners surrounding the lake and those below the lake's natural outlet likely have in interest in lowering or maintaining the lake level; however, the cost of doing so is significant. Some actions that maintain the lake elevation at 1395 ft NAVD88 were evaluated and are presented below.

Several gravity outlet configurations were considered, and the most viable configurations are shown in **Figures E1** through **E4**. Two excavated, open channels were evaluated along with two gravity draining pipe options. All options assume that some type of control structure would be installed at the inlet to control outflows into the channel or pipe. The maximum design flow for the open channels is 100 cubic feet per second (cfs) and the maximum design flow for the 60" diameter pipe outlets is roughly 50 cfs with the lake at its maximum recorded pool elevation of 1398.5 ft. These flow rates should be sufficient to control the lake level to prevent an overflow based on historical trends. However, these options are costly and land easements will likely be difficult to obtain. For the southern outlet options, crossing the railroad will present a significant challenge.

South Excavated Outlet Option

Figure E1 shows an excavated outlet alignment along the natural outlet (South Excavated Outlet). Although only 25,000 cubic yards (cy) would be needed to excavate a channel with a bottom width of 10 feet and 3:1 side slopes through the existing outlet control, construction of a conveyance channel within the James River floodplain would require about 50,000 cy of excavation. The natural drainage would be used in the middle portion of the alignment, but would require improvements to prevent erosion. This alignment would require multiple crossings, including State Highway 13 and railroad crossing. A closure structure would be installed near the James River to allow the conveyance channel to be closed during times when the James River is flooding.

South Piped Outlet Option

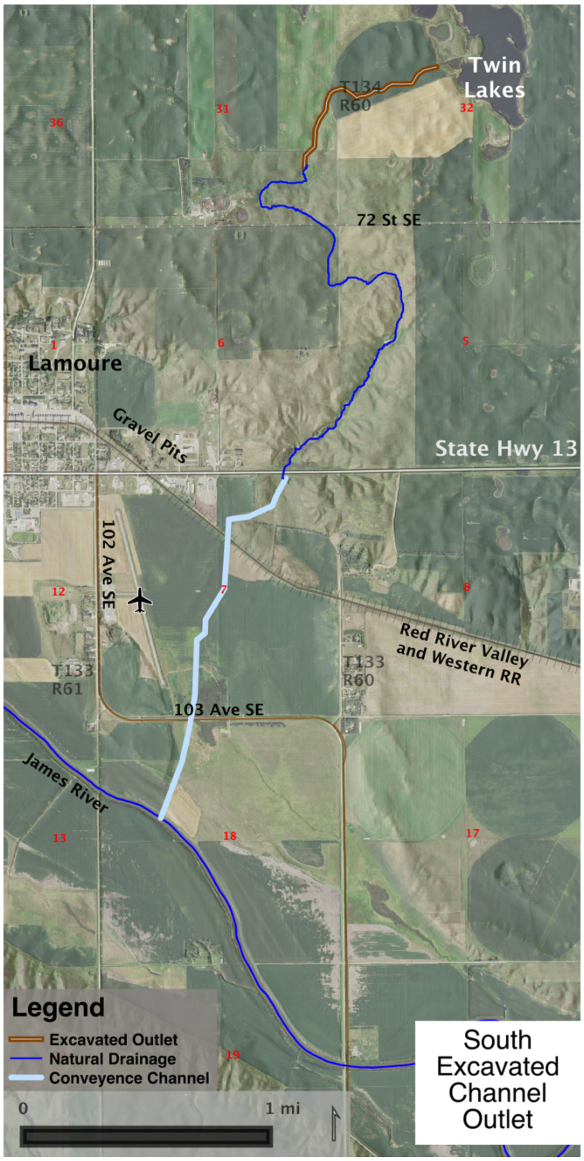
Figure E2 shows a gravity drain pipe outlet alignment near the natural outlet (South Piped Outlet Option). This option uses a 60" diameter concrete pipe to drain from the lake to the natural drainage and the same constructed conveyance channel within the James River described above. This option has requirements similar to the South Excavated Outlet Option because they share a good portion of the natural drainage channel and the constructed conveyance channel.

West Excavated Outlet Option

Figure E3 shows an excavated outlet alignment to the west of Twin Lakes. Overall the alignment is a fairly short distance to the James River, and there is an existing cattle crossing below County Highway 61. However, this alignment requires over 500,000 cy of excavation making it very costly. Again, this option calls for the use of an excavated outlet channel, improvements to the natural drainage channel, and a constructed conveyance channel within the James River floodplain along with a closure structure near the James River.

West Piped Outlet Option

Figure E4 shows a piped outlet alignment to the west of Twin Lakes. This is similar to the West Excavated Outlet Option, except a 60" concrete drainage pipe is used.



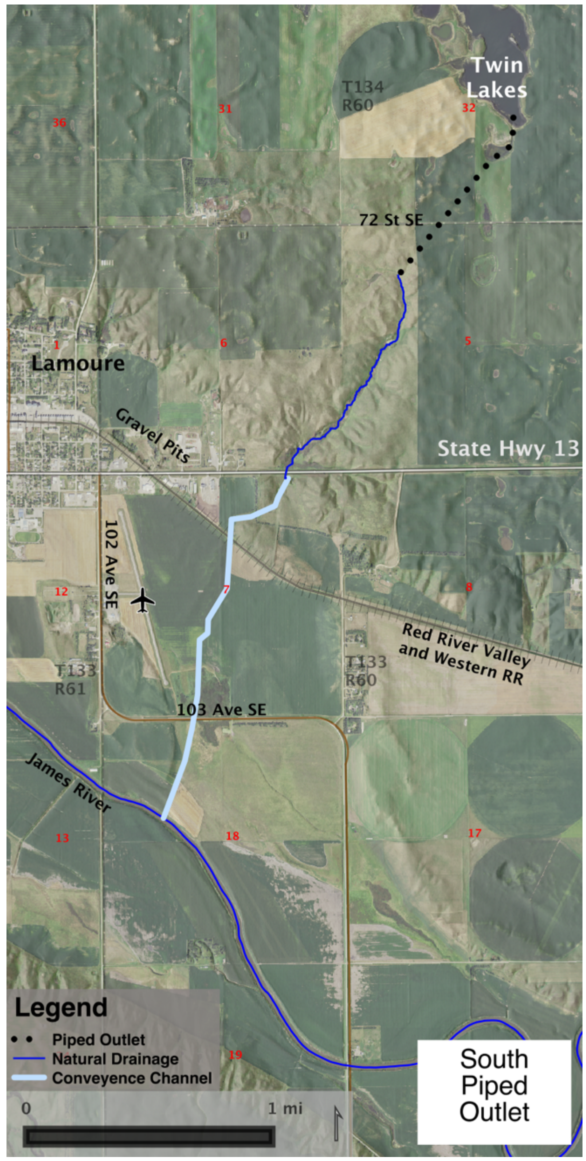
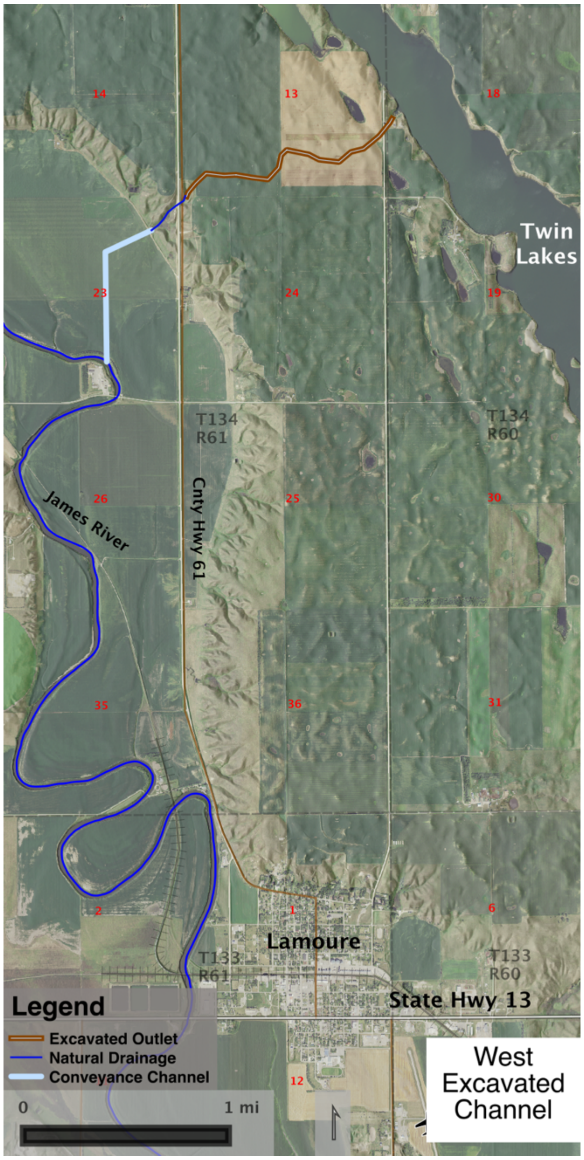


Figure E1 (left): South Excavated Channel Outlet Option.
Figure E2 (right): South Piped Outlet Option.



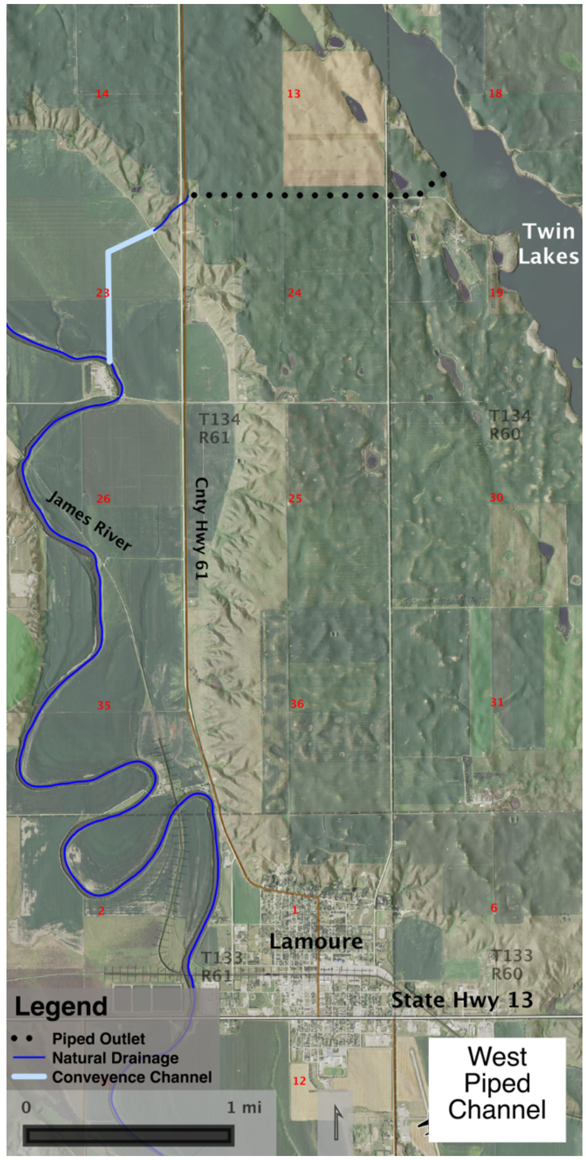


Figure E3 (left): West Excavated Channel Outlet Option.
Figure E4 (right): West Piped Outlet Option.

Cost Estimate

Costs for the outlets are summarized in **Table E1**. The cost estimate was performed at a high level to provide context of the financial commitment that would be needed to undertake constructing an outlet. These costs were developed using the 2014 RSMeans Heavy Construction Cost Data reference along with engineering judgment and assumptions. The costs do not include permitting or land easements which may be significant obstacles preventing construction.

Table E1. Cost Estimate

Cost Estimate	Source	Unit Cost	units	South Excavated Outlet	West Excavated	South Piped Outlet	West Piped Outlet
Outlet Channel Excavation			CY	25,316	472,956	11,000	45,600
Outlet Pipe Length			LF	-	-	4,307	6,765
Conveyence Channel Construction			CY	51,000	14,000	51,000	14,000
Excavating, Trench	RS MEANS 31 23						
4' to 6' deep 1/2 CY excavtor	0090	$ 7.45	BCY	$ 625,414	$ 3,990,608	$ 417,945	$ 114,730
Concrete Pipe	33 41 13.60						
Reinforced culvert, class 3, assume gaskets	2090 (assume w/ gaskets	$ 275.00	LF	-	-	$ 1,184,510	$ 1,860,348
General Fill	RS MEANS 31 23						
Spread fill, from stockpile	0190	$ 4.70	LCY	$ 430,425	$ 2,746,434	$ 287,640	$ 78,960
Road Crossings							
Hwy 13 Box Culverts	asumption	$ 50,000	each	$ 50,000	-	$ 50,000	-
Railroad	asumption	$ 200,000	each	$ 200,000	-	$ 200,000	-
Other Crossings	asumption	$ 25,000	each	$ 25,000	$ 25,000	$ 25,000	$ 25,000
Control Structures							
Inlet for outlet channel or pipe	asumption	$ 150,000	each	$ 150,000	$ 150,000	$ 150,000	$ 150,000
Closure structure at James	asumption	$ 125,000	each	$ 125,000	$ 125,000	$ 125,000	$ 125,000
Natural Channel Erosion							
Energy dissipation for natural	asumption	Varies	each	$ 200,000	$ 100,000	$ 200,000	$ 100,000
Location Factor	RS MEANS						
Jamestown, ND	587	77%	percent of total cost	$ 1,385,078	$ 5,474,112	$ 2,024,953	$ 1,882,247
Adjustment to present cost	RS MEANS						
2014 to 2017 cost	https://www.rsmeansonline.com/references/unit/refpdf/hci.p	102%	percent of total cost	$ 1,412,780	$ 5,583,594	$ 2,065,452	$ 1,919,892
Survey & Engineering	asumption	varies	percent of total cost	$ 211,917	$ 279,180	$ 309,818	$ 191,989
Subtotal				$ 1,624,697	$ 5,862,774	$ 2,375,270	$ 2,111,881
25% contingency		25%	percent of	$ 406,174	$ 1,465,693	$ 593,817	$ 527,970
Total				$ 2,030,871	$ 7,328,467	$ 2,969,087	$ 2,639,852

From RS Means 2014 Heavy Construction Cost Data

Assumptions

- 10 ft wide channel with 3:1 side slopes for the excvated channels
- Excavated materail can be disposed of locally by spreading
- For pipe options excavation costs remain the same, but with less volume
- Natural channel portion can be improved
- Does not include permiting or land easements

TO: Kerry Ketterling, Chair, LaMoure County Water Resource District
FROM: Alexis Faber, E.I.T., Water Resource Engineer, ND State Water Commission
DATE: December 18, 2019

RE: Twin Lakes Data Analysis

On October 18, 2019, the State Water Commission (Commission) received a request from the LaMoure County Water Resource District (District) pertaining to the closed basin system surrounding Twin Lakes, located in LaMoure County. The Commission completed a Twin Lakes investigation in October 2017. The District requested additional analysis of the lake inflow data and the storage capacity curve that were used in the 2017 investigation. The District also requested an update to the HEC-HMS and HEC-RAS models to simulate potential damages that would result from the lake naturally overflowing under current conditions.

As requested, the lake inflow data from the 2017 Twin Lakes Investigations Report (Report) was reanalyzed. It was determined that the 2017 HEC-HMS model (Model) contains the most relevant and up-to-date parameter data. The hydrology model was originally calibrated by running a continuous simulation from September 1993 through May 2017, which is a considerably long simulation that includes the peak elevation at Twin Lakes from August 2011, 1395.80 feet (NAVD88). The Model was not updated with the 2018 and 2019 gage data due to our confidence in the current calibration to the observed data for the period of record for which it was ran. The Model was conservatively constructed with the assumption that the ground is saturated, which reasonably reflects the current conditions. The Model was used to simulate the synthetic events and obtain their resulting volume increase to Twin Lakes.

The most current water surface elevation of Twin Lakes is 1400.18 feet (NAVD88). This elevation was obtained by the LaMoure County Highway Superintendent on November 5, 2019. The Model was updated with this elevation in order to obtain the rise in lake elevation and total lake volume.

The following table summarizes the Model synthetic event results. This table includes the Atlas 14 total point precipitation, the precipitation applied to the basin reduced by the area-reduction curve, the rise in lake level assuming a starting elevation of 1400.18 feet (NAVD88), the increase in lake volume, the total lake volume, and the approximate volume remaining until the lake overflows.

EVENT	ATLAS 14 TOTAL PRECIPITATION *inch*	AREA REDUCTION PRECIPITATION *inch*	VOLUME INCREASE *acre-ft*	TOTAL LAKE VOLUME *acre-ft*	RESULTING LAKE ELEVATION *ft*	REMAINING STORAGE UNTIL SPILL *acre-ft*
500 year - 10 day	10.7	10.49	7750	31412	1404.2	-312 to 398
100 year - 10 day	8.49	8.32	5568	29355	1403.3	1745 to 2456
50 year - 10 day	7.59	7.44	4765	28520	1402.9	2580 to 3291
25 year - 10 day	6.73	6.6	3997	27763	1402.4	3337 to 4047
10 year - 10 day	5.66	5.55	3094	26877	1402.0	4223 to 4934
5 year - 10 day	4.92	4.82	2505	26300	1401.6	4800 to 5511
2 year - 10 day	4.07	3.99	1863	25671	1401.2	5429 to 6139
1 year - 10 day	3.56	3.49	1508	25325	1401.0	5775 to 6486
100 year - 24 hour	6	5.99	5513	29333	1403.3	1767 to 2477
50 year - 24 hour	5.24	5.23	4683	28515	1402.8	2585 to 3296

The storage capacity curve that was constructed for the Report correlated contours collected by the North Dakota Game and Fish Department during 2008 with elevations obtained from the National Elevation Dataset and the topographic LiDAR survey collect during 2010. These data are still the most up-to-date data, so the curve was not updated. Linear interpolation of the storage capacity curve was used to determine that the volume of Twin Lakes at the most current water surface elevation of 1400.18 feet is approximately 25,468 acre-feet. A range of total capacity available in the lake was calculated using the ground survey and LiDAR survey spill points, 1403.3 feet and 1403.7 feet, respectively. Using both spill point elevations, it was determined that Twin Lakes has a total capacity of approximately 31,100 to 31,810 acre-feet. Therefore, there is approximately 5,632 to 6,342 acre-feet of storage remaining in Twin Lakes.

The 100-year, 10-day event would result in an inflow of 5568 acre-feet, putting the lake at or near the spill elevation. This event would result from approximately 8.32 inches of uniform rainfall over the entire basin that is delineated in the Report. A combination of smaller events could also cause the lake to overflow.

It was verified that the HEC-RAS model is composed of the most relevant available data. Scenario 2 in the Report models the 100-year 10-Day event occurring when Twin Lakes is at the spill elevation. The simulation predicts the lake overflows at its spill point and flows down a draw to State Highway 13 with a peak flow of roughly 270 cfs at the spill point. The total volume discharged at the spill point location is over 3,000 acre-ft. Page 12 of the Report, attached with this memo, contains more details on the inundation and potential damages occurring if this event were to occur.

Due to the current conditions of the James River, it is recommended to take conservative precaution and use the worst-case scenario for Spring 2020 planning. If an outlet design is desired, the water board will need to hire a private consulting firm. Proper permitting with the State Engineer would also need to be obtained. The surface drain application has been included with this memo. Please note that this application can be used for both emergency drains and permanent drains.

In terms of applying for cost-share assistance, in summary, each biennium, the Commission completes a Water Development Plan (WDP) that includes an inventory of projects that water project sponsors are planning to bring to the Commission for cost-share during each budget cycle. Projects identified in the WDP are given priority for cost-share funding over those that are not included in the WDP.

The current 2019 WDP for the 2019-2021 biennial funding cycle is available at http://www.swc.nd.gov/pdfs/2019_water_development_report.pdf.

In January 2020, the Commission will send letters of inquiry to every water board, joint board, city, etc. in the state, asking if they have projects they are trying to move forward that might require Commission cost-share. The deadline for projects to be submitted to the Commission to be included as part of the project inventory in the 2021 WDP is April 2020. It is recommended to submit the Planning Information and Planning Form as soon as possible to ensure its inclusion on the 2021 biennium agenda. The form is to be filled out online at http://www.swc.nd.gov/reclink/4dcgi/projectPlanningForm.

Please note, the inventory of projects included in WDPs is for planning and budgeting purposes only. Projects included in the plans are not guaranteed funding. They each still need to make a formal request to the Commission for cost-share to be considered for actual funding.

Having said that, *applications for cost-share can be submitted to the Commission at any time.* However, applications received less than 45 days before a Commission meeting will not be considered at that meeting, and will be held for consideration at a future meeting. The next Commission meeting is in February, so the cost share application would need to be submitted by December 30th to be considered for the agenda. The meeting after that would be in April. If you would like to request cost-share assistance for engineering services or construction of your project, the application has been included with this memo.

In terms of potential cost-share, if an entity submits a request for a flood control project, existing policy allows for up to 60% of the total eligible costs – without federal participation. With federal participation/cost-share, the state can cover up to 50% of the non-federal share.

Attachments (3)

AMF/1285

North Dakota | Water Commission

Be Legendary.™

Attachment 1

Scenario 2 would cause problems by inundating infrastructure, personal property, and agricultural land. **Figure 10** shows the maximum inundation simulated by the hydraulic model near the lake and LaMoure, respectively.

The simulation predicts the lake overflows at its spill point and flows down a draw to State Highway 13 with a peak flow of roughly 270 cfs. The total volume discharged is over 3,000 acre-ft. The 42-inch diameter reinforced concrete pipe (RCP) culvert at State Highway 13 cannot pass all of the flow coming down the draw. The flow is divided; some goes through the culvert, some is diverted west along the highway toward town, and some overtops the highway west of the culvert near an approach. The flow diverted west along the highway fills open gravel pits that eventually spill across the railroad tracks into LaMoure. Water flowing through the highway culvert or over the highway overtops the Red River Valley and Western Rail Line, fills up the area around the airstrip, and eventually flows across 103rd Ave SE toward the James River. Tailwater will back up west into town via an 18" corrugated metal culvert through 102nd Ave SE. It is also possible that State Highway 13 could wash out and more water would be routed through the airstrip property.

A list of likely potential damages occurring during Scenario 2 is below:

- Near Lake
    - Max lake elevation 1405 ft NAVD88
    - Inundation of Farmsteads 1 and 3 with over 2 feet of water. Wave action may cause some inundation and access will be problematic at Farmstead 2.
    - Inundation of local road 104 Ave SE
    - Breaching of local road 72 St SE
    - Inundation of agricultural land
- Near Town
    - Shallow inundation (less than 2 feet) of multiple residences and businesses
    - Inundation and possible breaching of State Highway 13
    - Inundation of railroad
    - Inundation of airstrip and buildings
    - Inundation of local road 103rd Ave SE
    - Inundation of agricultural land
    - Mud and debris from erosion could be significant near State Highway 13

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Attachment 2

APPLICATION FOR SURFACE DRAIN

OFFICE OF THE STATE ENGINEER
REGULATORY DIVISION
SFN 2830 (10/2019)

Number	Number
(OSE USE ONLY)	**(WRD USE ONLY)**

OFFICE OF THE STATE ENGINEER USE ONLY

DATE RECEIVED

This application must be submitted to the North Dakota Office of the State Engineer by **mail to 900 E Boulevard Ave, Dept. 770, Bismarck, ND 58505-0850, by fax to (701) 328-3696, or by email to swcregpermits@nd.gov.** To be complete, this application must include the additional information listed in the instructions on page 3. For emergency drain permit applications, see instructions on page 4.

If you need any assistance, please contact the Regulatory Division at (701) 328-2752.

**** **Additional Sheets May Be Attached If Necessary.** ****

Water Resource District In Which Majority Of Project Watershed Is Located

Location Of Drain (drain center line) (use separate sheet(s) if necessary)

¼	Section	Township	Range	County
¼	Section	Township	Range	County
¼	Section	Township	Range	County

Drain Outlet Location And Information

¼	Section	Township	Range	County

Where Does The Drain Outlet Discharge?

☐ Road Ditch ☐ Stream, River, Coulee, etc. ☐ Assessment Drain

☐ Private Drain ☐ Pond, Slough, Or Lake ☐ Other (please explain) ______

Name Of Drain Or Water Body Where Drain Outlets (If applicable)

Purpose Of Drainage (mark all that apply)

☐ Agricultural Drainage ☐ Flood Relief ☐ Emergency ☐ Other (please explain) ______

Feature To Be Drained (mark all that apply)

☐ Pond, Slough, Lake, Or Any Series Thereof ☐ Sheetwater/Overland Flow

☐ Other (please explain) ______

If Draining A Pond, Slough, Lake Or Any Series Thereof, How Far Down Will You Drain Them?
☐ Completely ☐ Partially

Design Data

☐ New Drain Construction ☐ Modification Of Existing Drain

Approximate Watershed Area Contributing To Drain, if known (acres)

Is This An Assessment Drain?
☐ Yes ☐ No

If Yes, Please List Name Of Drain

Type Of Modification To Existing Drain (If applicable)
☐ Deepening ☐ Widening ☐ Extending ☐ Rerouting ☐ Other (please explain) ______

Who Designed The Drain?
☐ Self ☐ Engineering Firm/Agency ______ ☐ Other (please explain) ______

(continued on page 2)

Additional Project Details, Design Information, and Comments

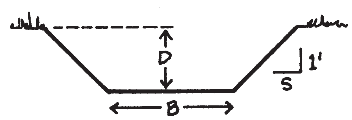
Drainage Method

☐ Gravity (See Section A) ☐ Pumping (See Section B) ☐ Placement Of Fill (See Section C)

(A) Gravity (if checked above)

Gravity Type (please fill appropriate fields below)
☐ Ditch ☐ Pipe

Ditch



Length Of Drain (feet)	Maximum Cut (D) (feet)
Bottom Width (B) (feet)	Side Slopes (S:1 foot)
Pipe Diameter (feet)	Pipe Slope (feet per foot)

(B) Pumping (if checked above)

Pumping Rate (gallons per minute)	Pumping Rate (cubic feet per second)
Pump Style ☐ Movable ☐ Fixed or Stationary	Pump Type ☐ Submersible ☐ Other ____________

(C) Placement Of Fill (if checked above)

Fill Volume (cubic yards)

Other Information

Will The Drain Incorporate A Control Structure? ☐ Yes ☐ No

If Yes, Please Explain

Anticipated Construction Start Date	Anticipated Construction Completion Date

Applicant's Certification

I, the undersigned, am applying for a permit as required under North Dakota Century Code (N.D.C.C.) § 61-32-03. I understand that I must comply with N.D.C.C. § 61-32-03 and North Dakota Administrative Code art. 89-02, and that I must adhere to any conditions required by the Water Resource District and State Engineer as part of an approved permit for this application. Additionally, I acknowledge that my project is accurately described and depicted in this application as I intend to construct it. My signature below acknowledges that I have read and agree to these statements.

Affiliation To Proposed Drain
☐ Landowner ☐ Renter/Tenant ☐ Water Resource District/Agency ☐ Other ____________

Applicant Name (if not an individual, please list organization name)

Address	City	State	ZIP Code

Telephone Number	Cell Phone Number	Email Address

Applicant Signature	Date

Landowner Name (print) (if not the applicant)

Landowner Signature (if not the applicant)	Date

INSTRUCTIONS FOR FILING A SURFACE DRAIN APPLICATION UNDER NORTH DAKOTA CENTURY CODE § 61-32-03

A person seeking to construct a surface drain having a watershed area of 80 acres or more (see "Is a Permit Required" below) must submit a completed permit application to the Office of the State Engineer. To be complete, the application must include all information listed below. If the purpose of the drainage is for an emergency, please see instructions on page 4 of this application.

1. A completed "Application For Surface Drain" form.
2. A detailed drawing depicting the surface drain's location on an aerial photo. The drawing must include the drain's:
    a. Location description in Section-Township-Range format.
    b. Physical footprint of the drain layout including the locations of any, if applicable:
        i. Ditch and pipe locations,
        ii. Pump location(s),
        iii. Placement of fill,
        iv. Other appurtenant works, including weirs, dikes, control structures, etc.,
        v. Identification of existing road culverts utilized and descriptions of any proposed culvert additions or modifications.
    c. A depiction of the flow direction from the outlet location.
3. Any additional information, such as a downstream impact analysis, requested by the Water Resource District or State Engineer from the applicant to make an informed decision on the application.

Is a Permit Required?

North Dakota Century Code § 61-32-03 - Draining a pond, slough, lake, or sheetwater, or any series thereof, which has a watershed area comprising eighty acres or more, requires a permit from the state engineer and water resource district within which is found a majority of the watershed or drainage area. The determination of the watershed or drainage area must be made using the best available maps or surveys.

For more information on drainage permitting,
please visit http://www.swc.nd.gov/reg_approp/drainagepermits/.

INSTRUCTIONS FOR FILING AN EMERGENCY DRAIN APPLICATION UNDER NORTH DAKOTA CENTURY CODE § 61-32-03

A person draining for emergency purposes must send a completed permit application to the State Engineer and Water Resource District of jurisdiction. According to North Dakota Administrative Code § 89-02-05.1-05, an emergency drain permit application must include:

1. Landowner's name and address.
2. Legal description of land where the emergency drain will be located.
3. A map showing the drain location.
4. An estimate of the surface acreage of the pond, slough, lake, sheetwater, or any series thereof and the volume of water to be drained by the emergency drain.
5. A list of all downstream adjacent landowners for a distance of one mile [1.6 kilometers] from the discharge point, along with the addresses and telephone numbers of these landowners.
6. Copies of any written permission received from downstream landowners.
7. A compilation of any written or oral permission and refusals from downstream landowners.
8. A description of the emergency.
9. Written permission allowing the state engineer and board to inspect the drain.

Upon receipt of an emergency drain permit application, the State Engineer will review the application and make a preliminary determination as to the existence of an emergency.

What is the process for an emergency drain permit application?

See North Dakota Administrative Code ch. 89-02-05.1 -
To view this Administrative Code Section in it's entirety, please visit:
https://www.legis.nd.gov/information/acdata/pdf/89-02-05.1.pdf

Attachment 3

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WATER COMMISSION COST-SHARE APPLICATION CHECKLIST

(This checklist must be attached to all applications for Water Commission cost-share assistance.)

Project sponsors requesting cost-share assistance from the North Dakota Water Commission are required to submit completed applications, including all supplemental materials, at least 45 days in advance of meetings. Incomplete applications or those submitted after the 45 day deadline will not appear on the next meeting agenda. Project sponsors, or their authorized representative, must verify that the following information is included as part of their application package for cost-share assistance.

Project Sponsor (Please Initial)	Required SWC Cost-Share Application Materials
	Cost-Share Application Form (SFN 60439)
	Approved Drainage Permit (Rural Flood Control Only)
	Results Of Positive Assessment Vote (Rural Flood Control Only)*
	Sediment Analysis (Drain Reconstructions Only)
	Acquisition Plan (Flood Recovery Property Acquisition Program Only)
	Proof of HMGP Funding Ineligibility (Flood Recovery Property Acquisition Program Only)
	Life Cycle Cost Analysis Worksheet (Water Supply Projects Only)
	Economic Analysis Worksheet (Flood Control & Water Conveyance Projects Only)
	Capital Improvement Plan (Water Supply Projects Only)
	Map Of Project Location
	Detailed Project Costs

** A pre-application process is allowed for assessment projects. (See Project Funding Policy, Procedure, and General Requirements)*

I hereby certify that the information contained in this application for cost-share assistance is true and accurate, and all required materials have been provided with this application. I have read and understand the Water Commission's requirements for a completed application, and further understand that the submission of an incomplete application package will not be considered by the Water Commission for cost-share assistance.

Project Sponsor (Printed Name)	Project Sponsor (Signature)	Date

PLEASE NOTE

The cost-share application (SFN 60439); Life Cycle Cost Analysis Worksheet; Economic Analysis Worksheet; Project Funding Policy, Procedure, and General Requirements; and future meeting dates are available via the Water Commission website at swc.nd.gov. If you have questions, please call 701-328-4989 or email swccostshare@nd.gov.

COST-SHARE REQUEST
NORTH DAKOTA WATER COMMISSION
PLANNING DIVISION
SFN 60439 (10/2019)

This form is to be filled out by the project or program sponsor with Water Commission staff assistance as needed. Applications for cost-share are accepted at any time. However, applications received less than 45 days before a Water Commission meeting will be held for consideration at the next scheduled meeting.

Please answer the following questions as completely as possible. Supporting documents such as maps, detailed cost estimates, and engineering reports should be attached to this form. If additional space is required, please use extra sheets as necessary.

For information regarding cost-share program eligibility see the *Water Commission Cost-Share Policy, Procedure, and General Requirements* – available upon request or at www.swc.nd.gov.

Project, Program, Or Study Name

Sponsor(s)

County	City	Township/Range/Section

Description Of Request ☐ New ☐ Updated (previously submitted)

Specific Needs Addressed By The Project, Program, Or Study And Level Of Study Review Completed

If Study, What Type ☐ Water Supply ☐ Hydrologic ☐ Floodplain Mgmt. ☐ Feasibility ☐ Other

If Project/Program

☐ Bank Stabilization
☐ Dam Safety/EAP
☐ FEMA Levee Program
☐ Flood Protection Program
☐ Irrigation
☐ Multi-Purpose
☐ Municipal Water Supply
☐ Property Acquisition Program
☐ Recreation
☐ Ring Dike Program
☐ Rural Flood Control
☐ Rural Water Supply
☐ Snagging & Clearing
☐ Water Retention

Description Of Problem Or Need And How Project Addresses That Problem Or Need

Funding Timeline (carefully consider when SWC cost-share will be needed)

Source	Total Cost	2019-2021 7/1/19-6/30/21	2021-2023 7/1/21-6/30/23	Beyond 7/1/23
Federal	$0	$	$	$
Water Commission	$0	$	$	$
Other State	$0	$	$	$
Local	$0	$	$	$
Total	$0	$0	$0	$0

Funding Detail (provide names and amounts from all potential funding sources from the table above.)				
Source	Amount	Grant Or Loan	Term	Interest
	$			%
	$			%
	$			%
	$			%

What Are The Potential Obstacles To Implementation (i.e., problems with land acquisition, permits, funding, local opposition, environmental concerns, etc.)?

Explain Timelines For All Phases And Their Current Status (Study, Design, Bid, Construction, Completion, Etc.)

Are Connections For New Rural Customers Located Within The Extra-Territorial Jurisdiction Of A Municipality? ☐ Yes ☐ No

Jurisdictions/Stakeholders Involved In This Project

Has Economic Analysis Been Completed?	☐ Yes	☐ No	☐ Ongoing	☐ Not Applicable
Has Life Cycle Cost Analysis Been Completed?	☐ Yes	☐ No	☐ Ongoing	☐ Not Applicable
Has Feasibility Study Been Completed?	☐ Yes	☐ No	☐ Ongoing	☐ Not Applicable
Has Engineering Design Been Completed?	☐ Yes	☐ No	☐ Ongoing	☐ Not Applicable
Have Land Or Easements Been Acquired?	☐ Yes	☐ No	☐ Ongoing	☐ Not Applicable

Have Assessment Districts Been Formed? ☐ Yes ☐ No ☐ Ongoing ☐ Not Applicable | If Yes, (Date)?

Has Sediment Analysis For Reconstruction Of An Existing Drain Been Completed? ☐ Yes ☐ No

Have You Applied For Any State Permits? ☐ Yes ☐ No ☐ Not Applicable	Type/Number	
Have You Been Approved For Any State Permits? ☐ Yes ☐ No ☐ Not Applicable	Type/Number	
If Yes, Please Explain		
Have You Applied For Any Local Permits? ☐ Yes ☐ No ☐ Not Applicable	Type/Number	
Have You Been Approved For Any Local Permits? ☐ Yes ☐ No ☐ Not Applicable	Type/Number	
If Yes, Please Explain		

Submitted By			Date
Address	City	State	ZIP Code
Sponsor's Telephone Number		Sponsor's Email Address	
Engineer's Name		Engineer's Telephone Number	
Engineer's Company		Engineer's Email Address	
I Certify That, To The Best Of My Knowledge, The Provided Information Is True And Accurate.			
Signature			Date

E-MAIL TO:
swccostshare@nd.gov

MAIL TO:
ND Water Commission ● ATTN: Cost-Share Program
900 E Boulevard Ave. ● Bismarck, ND 58505-0850