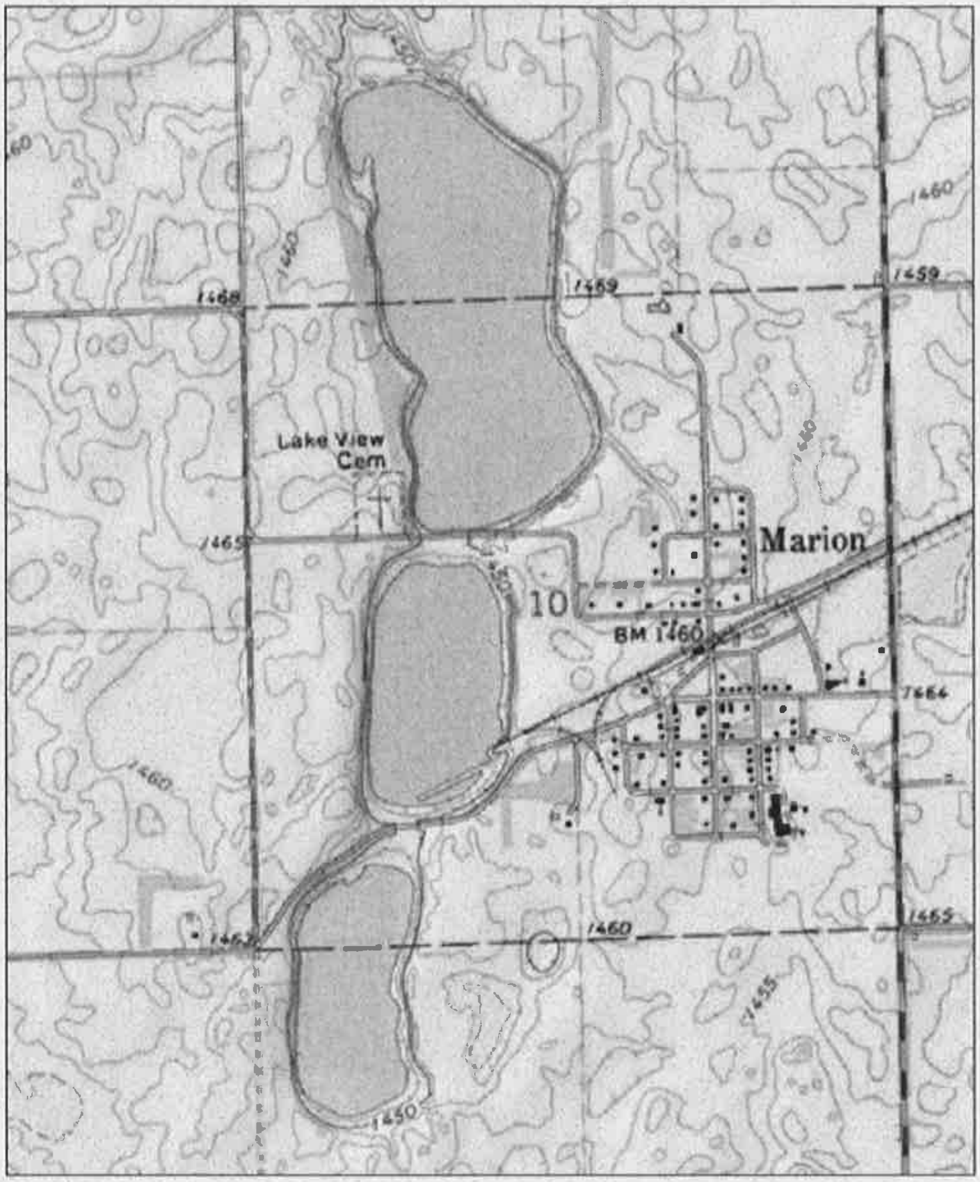
Boom Lake Investigation

Marion, LaMoure County, North Dakota

SWC Project #1285



North Dakota
State Water Commission

March 2012

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SWC Project #1285
North Dakota State Water Commission
900 East Boulevard
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Prepared for:
LaMoure County Water Resource District

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Executive Summary

Boom Lake (also known as Marion Lake) is a pothole lake located near the City of Marion, LaMoure County, North Dakota that currently does not have an outlet. Since the early 1990s, the lake and surrounding groundwater levels have risen in response to precipitation. The rising groundwater and surface water have caused a variety of problems for the residents of Marion including basement flooding and flooding of roads. The peak 2011 lake level rose to within approximately 2.5 feet of overtopping a bank protecting northern Marion from flooding.

Two roads, which formerly crossed Boom Lake, have also flooded. A road that connects Marion to Lake View Cemetery flooded during the mid-1990s. Southwest Road flooded during the spring of 2011 leaving County Road 61 as the only route supplying access and egress to the city. The City is currently evaluating raising Southwest Road.

At the request of the LaMoure County Water Resource District (District), the North Dakota State Water Commission (SWC) agreed to conduct a study investigating the hydrology of the closed basin and evaluate drainage alternatives or other measures that could be implemented to mitigate issues caused by elevated lake and groundwater levels. This report summarizes the findings of the investigation.

Boom Lake is like other pothole lakes and receives inflows from direct precipitation and runoff from snowmelt and rainstorms. Direct rainfall on the surface of the lake and spring melt inflows, which includes the melting of direct snowfall on the surface of the lake and snowmelt runoff, account for the largest inflows. The spring melt event corresponds to a small portion of annual precipitation; however, it can result in disproportionality large inflows into the lake because of runoff along the frozen ground. The spring runoff events of 2010 and 2011 were rare events (approximately less than one percent and two percent annual occurrence events, respectively) that accelerated the rise of lake.

Boom Lake is unique from other lakes in that the uses of sump pumps at residences contribute to rise in lake level. The discharges from sump pumps either infiltrate into the ground or gravity drain through ditches to two pumping stations. The pumping stations use manually controlled trash pumps to discharge the collected water, which includes stormwater, discharges from sump pumps, and groundwater seeps to Boom Lake. During 2010 and 2011, these pumping stations were operated from first thaw to first freeze to prevent the flooding of homes and city infrastructure. The long-term inflows to Boom Lake from these pumping stations are significant.

During November 2011 the lake elevation was surveyed at elevation 1455 feet (ft) above the North American Vertical Datum of 1988. The natural outlet of the lake is on the southeast end of the lake at elevation 1459 ft. At a half foot below the natural outlet elevation, elevation 1458.5 ft, the lake would overtop a bank and flood much of northern Marion.

Constructing an outlet that lowers the lake level would provide several benefits including greatly reducing the risk of flooding in northern Marion, reducing problems associated with an elevated water table, removing the need to raise Southwest Road, and replacing the pumping stations with gravity drainage. The path of the natural outlet southeast of the lake to Bear Creek is the most cost effective alignment. Disadvantages of an outlet include the high cost and downstream impacts. Wetlands and farmland would be impacted and downstream improvements to road crossings would likely be necessary.

Alternatives that address issues related to elevated levels in Boom Lake were developed as options for the City to evaluate and select. Alternatives 1 and 2 include constructing an outlet at elevation 1451 ft to lower the level in Boom Lake and replace the temporary pumping stations with gravity drain systems. Alternative 3 includes constructing a gravity outlet at elevation 1455 ft, replacing the pumping station with a combination of a gravity drain and an automated lift station. Alternative 4 includes building a dike to protect northern Marion and continuing operation of the temporary pumping stations. Estimates of construction costs for each alternative are included in **Table E1**.

Alternative	Description	Capital Costs	20 Year Operational and Maintenance Costs	Total Costs
1	Gravity Outlet at El 1451	$680,000	$30,000	$710,000
2	Pump Outlet at El 1451	$470,000	$210,000	$620,000
3	Gravity Outlet at El 1455	$560,000	$70,000	$640,000*
4	No Outlet	$10,000	$180,000	$190,000*

*Does not include cost of road raise.

Table E1: Summary of Alternative Costs

The cost estimates for each option provided in this report were calculated at a level that provides a degree of accuracy appropriate to compare the costs of each option relative to each other. Actual costs for each option may vary significantly and depend on many factors including but not limited to design requirements, permitting requirements, land values, and the contractor's means and methods.

Regardless of what solution is ultimately selected by the City, it is recommended that lake levels and pumping station operation are measured and documented to gain better understanding of how lake levels react to storm and runoff events and how quickly the lake is rising. It is also recommended that Marion residents living in the northern section of town or other low-lying areas investigate if flood insurance is applicable for their specific situation.

1. Introduction

Boom Lake (also known as Marion Lake) is currently a terminal lake located near the City of Marion, LaMoure County, North Dakota. Since the early 1990s, the lake and surrounding groundwater levels have risen in response to precipitation. The rising groundwater and surface water have caused a variety of problems for the residents of Marion including basement flooding and flooding of roads. The peak 2011 lake level rose within approximately 2.5 feet of overtopping a bank protecting a portion of the city. During 2010 and 2011, Marion has operated pumping stations from spring thaw to first freeze to protect homes and infrastructure from groundwater discharged from the sump pumps, stormwater runoff, and groundwater seepage.

The LaMoure County Water Resource District (District) requested the North Dakota State Water Commission (SWC) to conduct an investigation of the hydrology of the closed basin and evaluate drainage alternatives or other measures that could be implemented to mitigate issues caused by elevated lake and groundwater levels. Initially the District was most concerned with groundwater levels; however, the rising surface water potentially poses a flood threat for northern Marion. The SWC and District entered a Study Agreement during October 2011 (**Appendix A**). This report presents the results of the study and identifies alternatives for the City to implement.

1.1 Site Location

Boom Lake is located in northern LaMoure County in southeast North Dakota, adjacent to Marion and approximately 25 miles southeast of Jamestown (**Figures 1** and **2**). The lake is located within Sections 3, 10, and 15 of Township 136 North, Range 61 West. The lake was divided in to three sections by two roads, presumably when the town was developed during the early 1900s. Currently the surface area of the lake is approximately 240 acres and is situated within a 4.0-square-mile basin of which approximately 2.5 square miles are likely contributing runoff. The surface elevation lake is currently below the natural outlet.

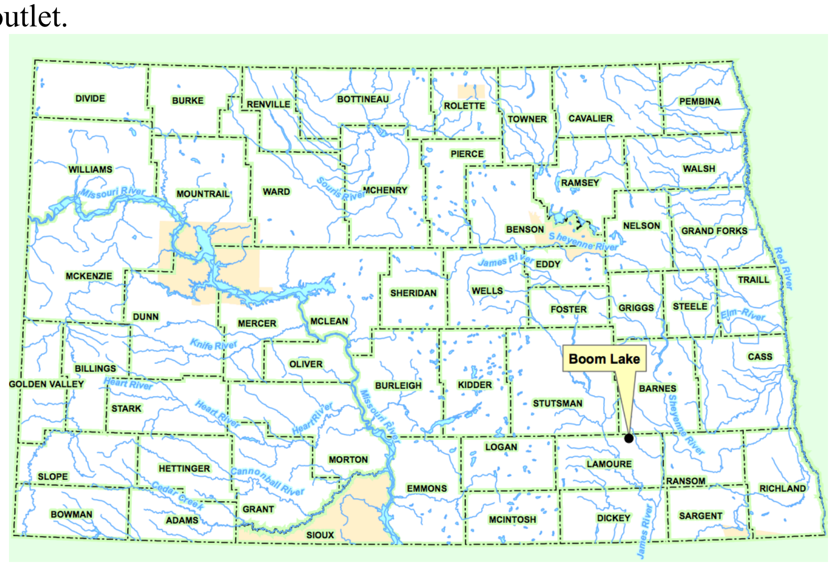

Figure 1: Site Location

Figure 2: Site Layout

1.2 Problem Background

The city of Marion has experienced several problems caused by elevated lake and groundwater levels. As of 2011, the lake has risen to the point that it threatens to flood the northern portion of the city if the recent trend of above average precipitation continues. Other notable issues include basement flooding caused by elevated groundwater levels, road flooding, and the operation of temporary pumping stations to protect sewer infrastructure from groundwater and stormwater.

The lake surface was surveyed on November 1, 2011 at approximately 1455.0 ft above the North American Vertical Datum of 1988 (NAVD88). At approximately elevation 1459.0 ft the lake will overflow and eventually drain to Bear Creek. Before the lake reaches its outlet level, at approximately 1458.5 ft, the lake would begin overflowing into the drainage ditch and flood much of northern Marion as shown on **Figure 3**.

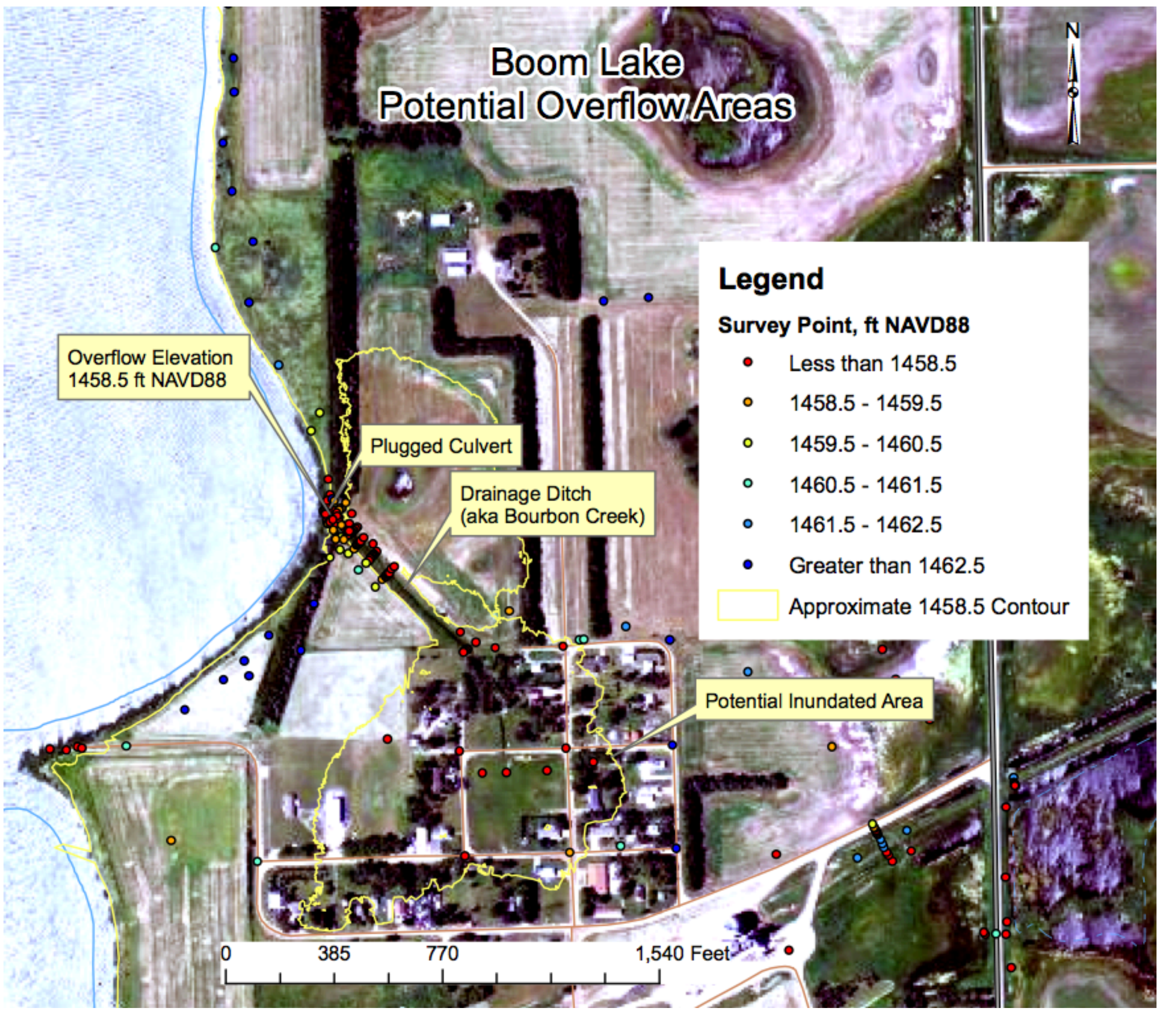

Figure 3: Potential Lake Overflow Location at Nothern Marion

According to the city mayor, Mr. Gene Rode, many, if not most, residences have been removing groundwater that has infiltrated into basements via sump pumps. This groundwater problem initially occurred around the spring of 1997 at the northern section of city and had spread throughout much of the city as of the spring of 2011. Water discharged from the sump pumps either infiltrates back into the ground or drains by gravity to temporary pumping stations, which discharge into Boom Lake. A drainage ditch is used to convey stormwater and the sump pump discharges to Boom Lake via gravity. The drainage ditch is shown in **Figures 2** and **3**. The culvert connecting the drainage ditch to the lake was plugged with clay during the spring of 2010 to prevent the lake from encroaching the town and a 433 gallon per minute (gpm) trash pump has been used to evacuate water from the ditch into the lake (Pumping Station 1). This pump was typically operated approximately 5 hours a day at full throttle for 8 months of the year during 2010 and 2011.

A slough near the eastern edge of town adjacent to County Road 61 receives stormwater and sump pump discharges from the southern section of town (**Figure 2**). The slough has grown to the extent that it threatens to inundate a nearby sewer system lift station. This slough is part of a larger slough complex that is divided by the railroad and highway. Culverts connecting the slough complex do exist, but they have been plugged. In addition to inflows from stormwater and sump pump discharges, the slough also likely receives groundwater seepage from the larger slough to the east across County Highway 61. Since 2006, a 6-inch-diameter, diesel engine-powered trash pump and 1,900 ft of conveyance piping periodically drained this slough into the lake (Pumping Station 2).

The rising waters have inundated the two roads that formerly divided Boom Lake, and County Road 61 remains the only functional access road to the city. A road linking the city with Lake View Cemetery was flooded during the 1990s and is now used as a boat ramp. Southwest Road has been raised at least once and was flooded during March 2011.

Most of Lake View Cemetery is located at an elevation several feet higher than Boom Lake, but there is potential for some shoreline erosion to occur by wave action. Also, groundwater beneath the cemetery is likely elevated and could cause additional problems.

A municipal well located in the southern section of the lake was operated from 1991 until 1997 when it was flooded. The town has since joined a rural water supply.

1.3 Survey Methods

As part of the investigation, the SWC collected survey data during November 2011. Before the investigation, SWC collected survey data on April 20, 2010 to assess the lake level with respect to the surrounding topography. A benchmark was established using a fire hydrant near the center of town. The survey data is included in **Appendix B**.

Vertical data was collected within third-order accuracy. Point coordinates were referenced to the North Dakota State Plane Coordinate System (South Zone, North

American Datum of 1983) as determined by differential Global Positioning System (GPS) observations. All elevations are expressed as heights above NAVD88.

2. Hydrology

Pothole lakes or sloughs, such as Boom Lake, occupy depressions formed by glaciers. Boom Lake 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. Most potholes are disconnected from other surface water bodies and do not have an outlet to drain their waters to larger drainage systems that will eventually lead to the ocean. The potholes gain water from precipitation, runoff, 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).

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 pothole water surface was the greatest inflow to these systems, followed by inflows from spring snowmelt events and runoff from rainstorms (Shjeflo, 1968).

Boom Lake gains waters from precipitation, runoff, and pumping station discharges and loses water from ET and seepage. Boom Lake is different from other pothole systems in that the pumping stations that discharge groundwater from sump pumps and stormwater to the lake also provide a significant source of inflow. Based on the November 2011 survey data, it is likely inflows from groundwater seepage to Boom Lake are exceeded by outflows from groundwater seepage, resulting in a net seepage loss.

2.1 Topography and Geology

The landscape of the Glaciated Plains has been characterized as undulating glacial topography with low to moderate relief (Bluemle, 2000). A County Groundwater Study conducted for Dickey and LaMoure counties, reports that the area immediately surrounding Boom Lake is described as a rolling surface with kettles with partial to non-integrated drainage underlain with a moderately thick layer of till (Bluemle, 1979).

Sloughs underlain with till that do not have outlets are common in the area. Many of the sloughs are known as kettles, which are located in depressions left by ice blocks buried in glacial sediment that slowly melted after the glacier retreated (Bluemle, 1979). In the

County Groundwater Study, Boom Lake is described as a larger slough occupying depressions or a "kettle chain" that marks the course of a buried valley (Blumle, 1979).

Drainage Basin

The drainage basin surrounding Boom Lake is a complex network of depressions and sloughs. It is difficult to determine the exact contributing area because of the accuracy of the available data; sloughs have variable storage depending on recent precipitation patterns; and drainage culverts that may or may not be functional.

The watershed draining into Boom Lake was estimated by using the 1/3 arc second scaled Digital Elevation Map (DEM) from the National Elevation Dataset (NED) and terrain processing with the United States Army Corps (USACE) Geospatial Hydrologic Modeling Extension (HEC-GEOHMS) (Gesh et. al., 2002; Gesh, 2007). The basin was refined using aerial photos and USGS 1:24,000 scale quadrangle topographic maps of the area. The watershed area is conservatively estimated at 4.0 square miles, with the lake accounting for approximately 10 percent of the area; although, up to 1.5 square miles to the east likely are currently not contributing for the 10-day 100-year rainfall event because of depressional storage (**Figure 4**). Smaller depressions within the drainage area may result in additional non-contributing areas for most storm events.

Based on survey data, if the lake reached elevation 1459 ft, it would begin draining to a series of sloughs on the southern edge of the lake, which would eventually discharge to Bear Creek to the east (**Figure 4**). The exact outlet location cannot be determined with the available data, and multiple outlet points may exist at the south edge of the lake. Bear Creek eventually discharges to the James River above Oakes, North Dakota in Dickey County.

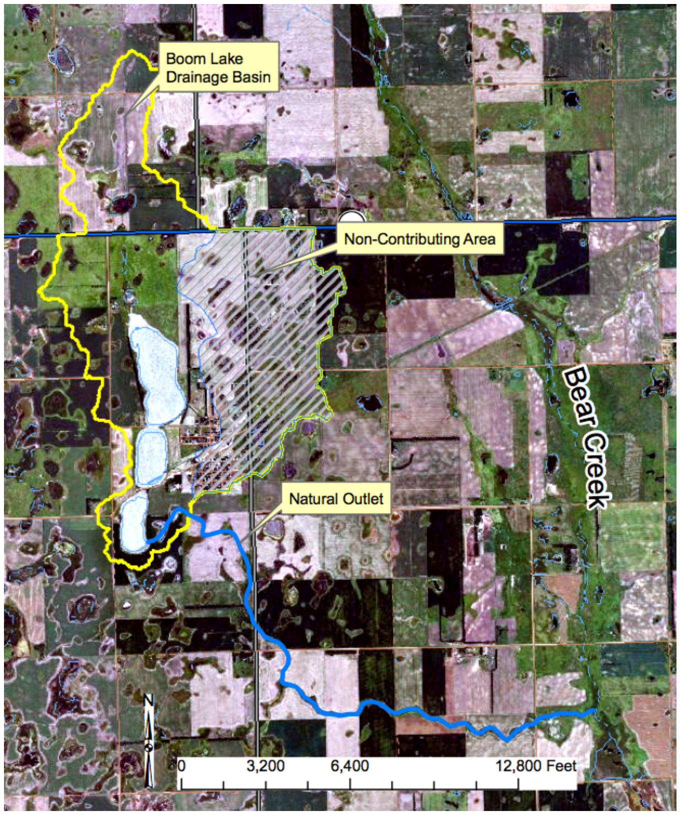

Figure 4: Boom Lake Drainage Basin and Natural Outlet Path

Geology

The County Groundwater Study also identified that although an undifferentiated glacial-drift aquifer does exist beneath the lake and was formerly used for its water supply, a significantly producing aquifer is absent in the area (Armstrong, 1980).

Drilling has occurred in the area for municipal and residential well installation and monitoring well installation. Several monitoring wells were installed to investigate petroleum underground storage tanks (USTs) that were leaking as part of the North Dakota Department of Health's (NDDOH) UST Program. As shown in **Figure 5**, most of the boreholes were installed in central Marion near the former USTs. A borehole was also installed at the southern section of Boom Lake and became the city's municipal well (**Figure 5**). Well drillers' logs for these boreholes were submitted to the SWC and are included in **Appendix C**.

Data from the well drillers' logs reveals that generally beneath Marion and Boom Lake a till layer approximately 10 to 20 ft thick overlies a coarser lens of sand and gravel, which is roughly 10 to 30 ft thick. The sand and gravel is underlain by till and bedrock. Hydraulic connection between lake and groundwater within the coarser lens is likely impeded by the till that separates them; however, it is possible that fractures or sand lenses within the till improve this communication.

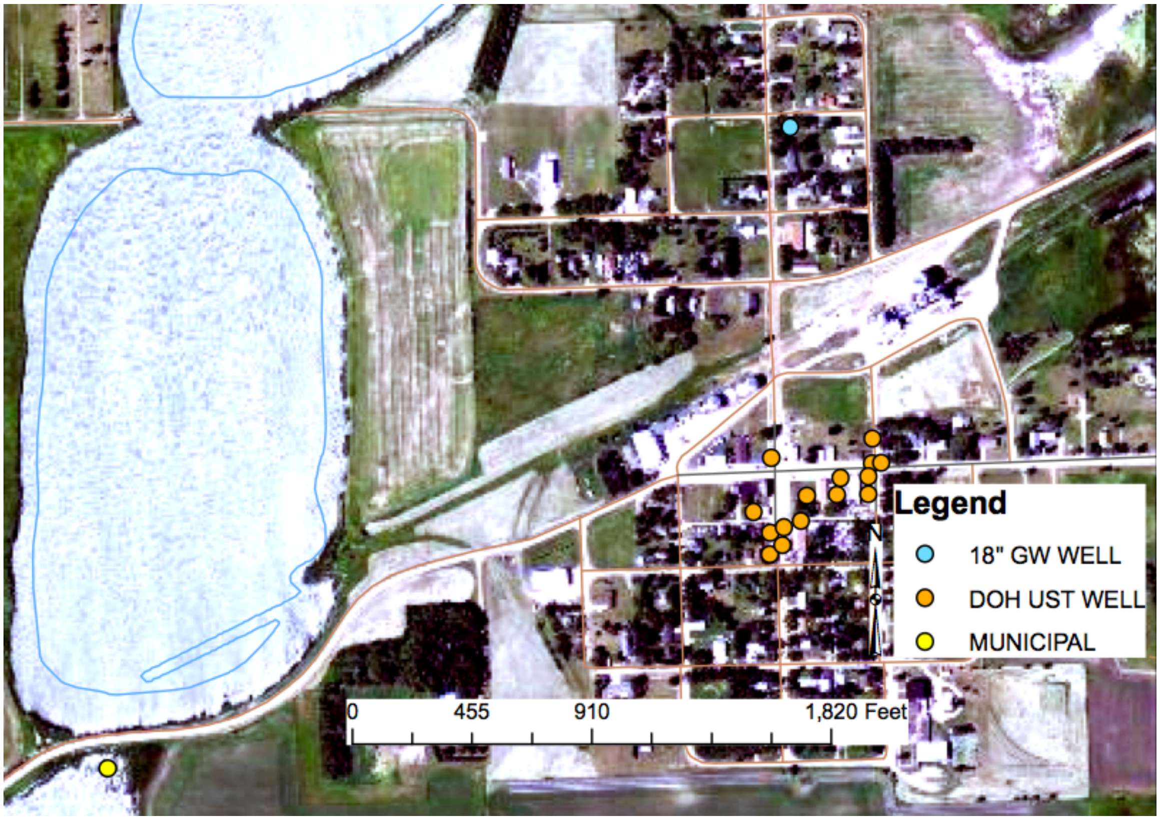

Figure 5: Former Municipal Well and DOH UST Well Locations

2.2 Lake Storage

A relationship between water storage and elevation for Boom Lake was approximated by calculating the volume of the lake at a given stage with the NED data and preliminary LIDAR survey data[1] obtained from the USACE (**Figure 6**). The survey data the NED is based on was obtained between 1960 and 1979, when the lake was at a lower level, and more bank line was exposed (Evans, 2011). The curve assumes that the three portions of the lake are hydraulically connected and balanced regardless of stage. Bathymetry data is not available for the lake, so it was estimated that the lake storage is approximately 1,000 acre feet at elevation 1450 ft based on an assumed average depth of 5 ft.

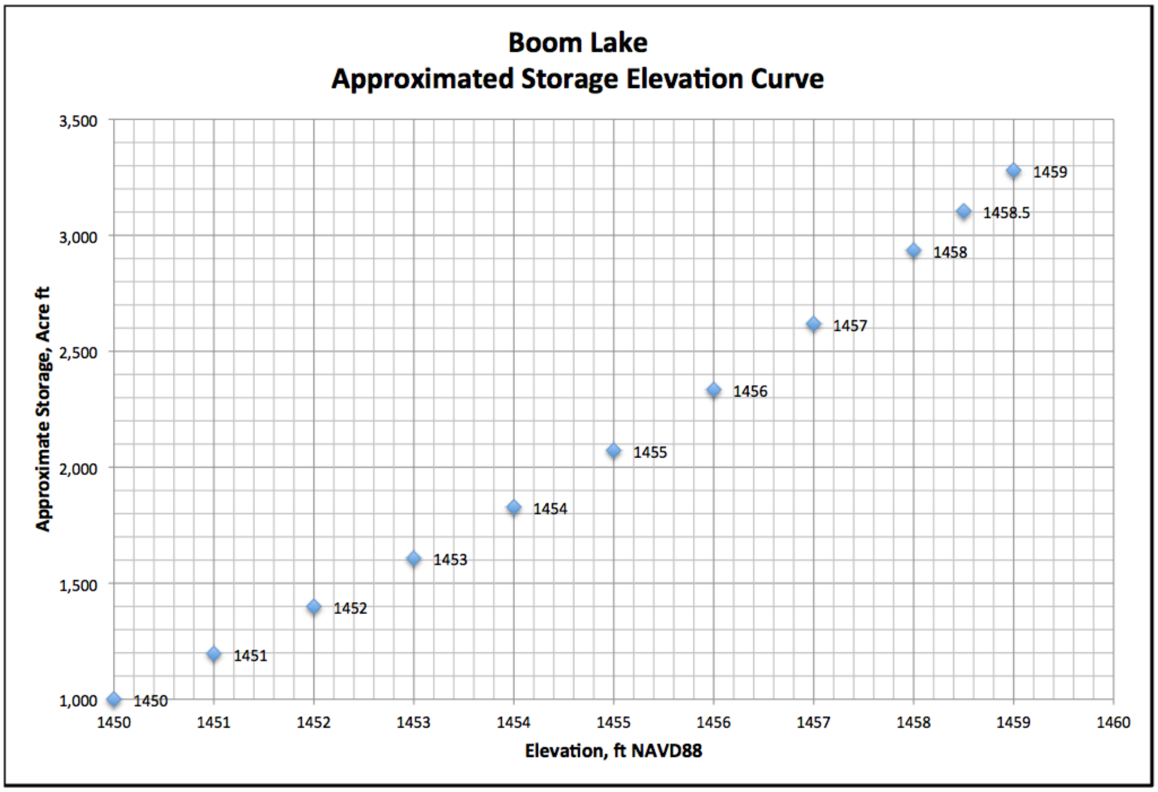

Figure 6: Approximated Storage Elevation Curve for Boom Lake

Figure 7 shows the estimated footprint of the lake at elevations 1455 ft through 1459 ft. At approximately 1456.5 ft, the lake will spill over into two smaller sloughs just east of the southeast edge of the lake that will increase its surface area and storage area.

[1] The LIDAR data are approximately ten times the resolution of the NED data; however, these data are preliminary and a complete quality assurance and quality control check has not been completed. These data were used to supplement the NED data.

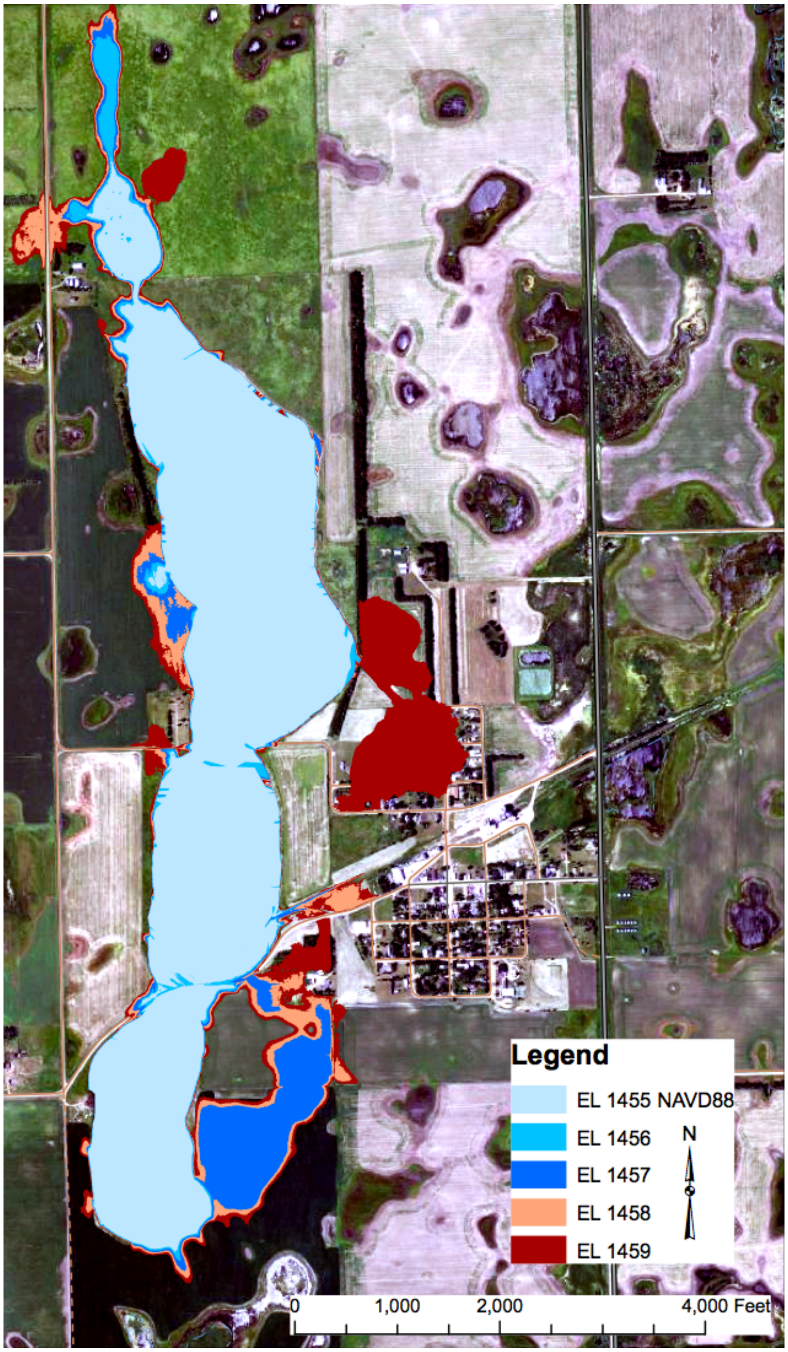

Figure 7: Estimated Lake Footprint at Elevations 1455 Through 1459

2.3 Precipitation

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

Monthly precipitation data obtained from the National Climatic Data Center collected at the Jamestown Regional Airport (located approximately 25 miles northwest of Marion) over the past fifty years is shown in **Figure 8**. The precipitation data is grouped by water year[2]. As shown in **Figure 8**, on average an additional 3.6 inches of precipitation fell from 1993 to 2011 compared to the average annual precipitation that fell from 1962 through 1992.

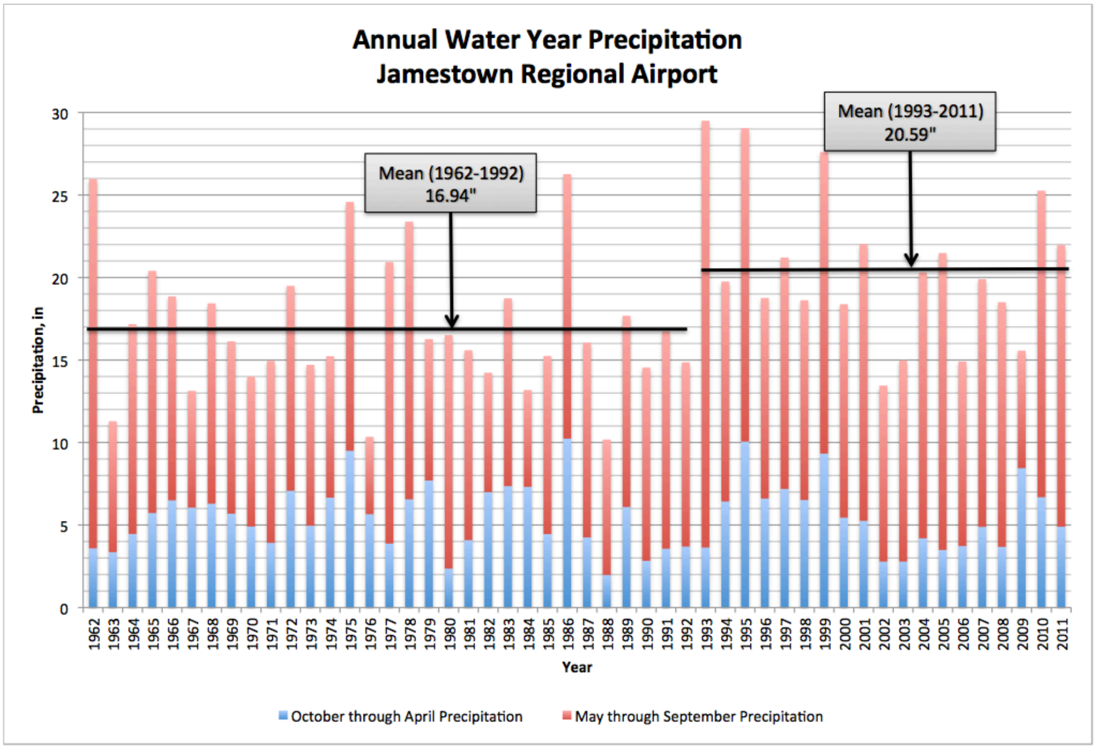

Figure 8: Annual Water Year Precipitation, Jamestown, ND, 1962-2011

As shown in **Figure 9**, the Marion and Lichville area on average receives more precipitation than the gauge at Jamestown according to the North Dakota Agricultural Weather Network (NDAWN). However, precipitation at Marion likely followed the same trends over the past 50 years as seen in the Jamestown data.

[2] A water year begins in October and extends through September of the following year. For example the 2011 water year includes data from October 1, 2010 through September 30, 2011.

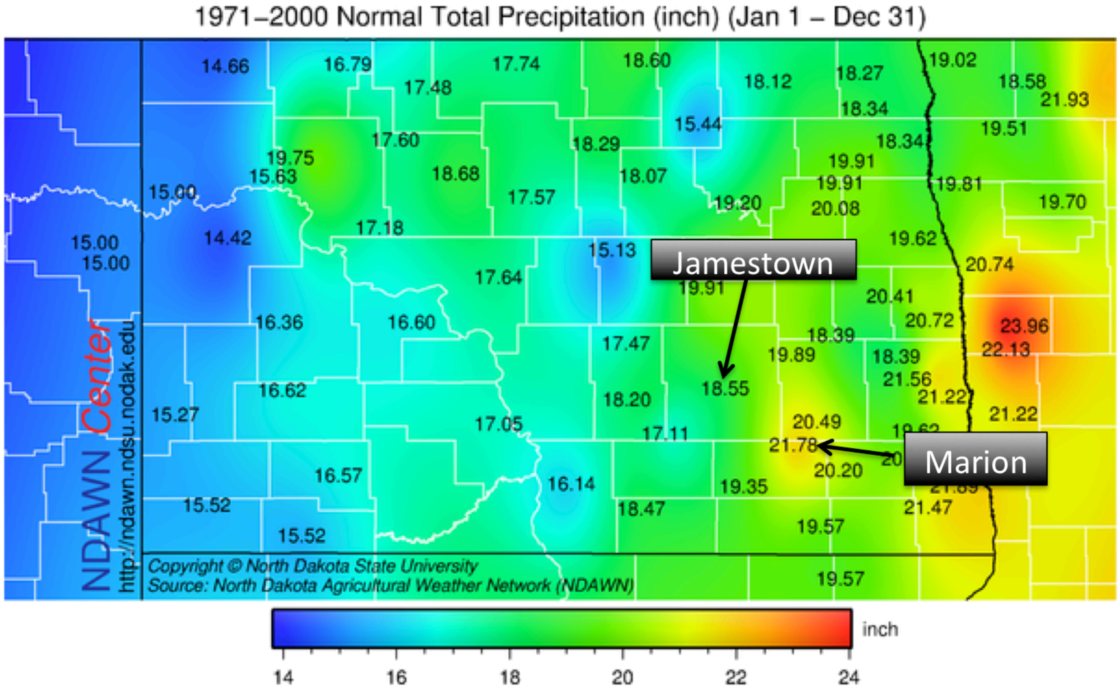

Figure 9: NDAWN Network Average Precipitation (NDAWN NWS Normal Total Precipitation; http://ndawn.ndsu.nodak.edu/get-map.html?mtype=nwsdaily&variable=dnwsnr&begin_date=01-01&end_date=12-31,accessed December 14, 2011)

According to model estimates from the National Operational Hydrologic Remote Sensing Center (NOHRSC), the March 2010 and 2011 snowmelt events for Marion were particularly severe. **Figures 10** and **11** show the snowmelt estimates for 2010 and 2011, respectively. The 2010 snowmelt event appears to have exceeded the 100-year 10-day snowmelt event of 4.4 inches of snow water equivalent (SWE) by 40% with approximately 6.2 inches SWE. The 2011 snowmelt event was roughly equivalent to a 50-year 10-day snowmelt event of 3.7 inches SWE. The 100-year and 50-year events correspond to a 1 percent and 2 percent annual occurrence probability, respectively.

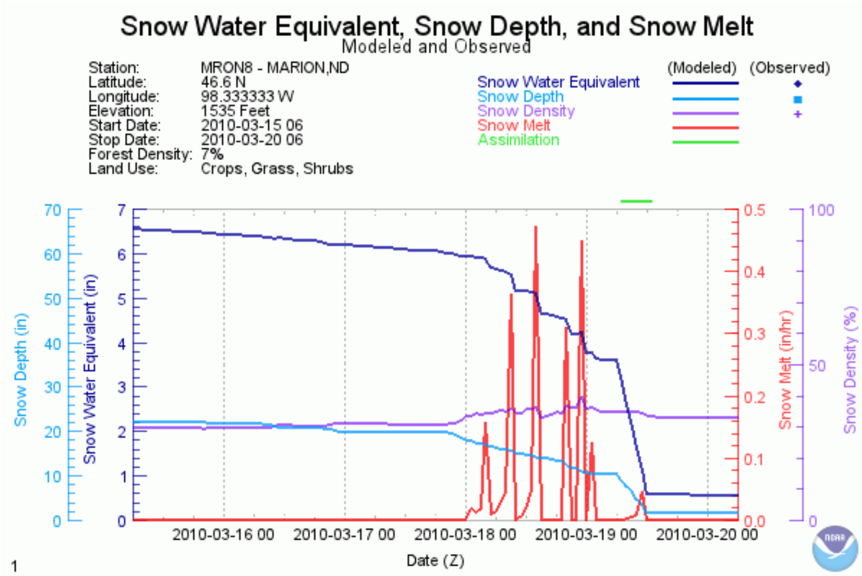

Figure 10: NOHRSC 2010 Snowmelt Estimate at Marion, ND (NOHRSC Interactive Snow Information, http://www.nohrsc.noaa.gov/interactive/html/map.html, accessed December 14, 2011)

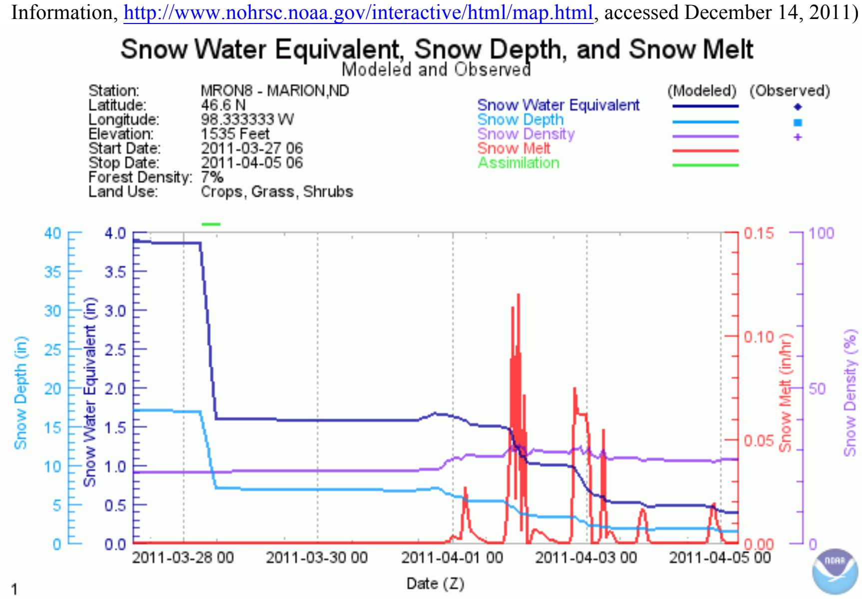

Figure 11: NOHRSC 2011 Snowmelt Estimate at Marion, ND (NOHRSC Interactive Snow Information, http://www.nohrsc.noaa.gov/interactive/html/map.html, accessed December 14, 2011)

2.4 Lake Level Fluctuation

Great variability in the water level of Boom Lake is evident within historical records. The original survey performed by the General Land Office during late summer 1879 shows Boom Lake as mud flat (**Figure 12**). A United States Geological Survey (USGS) map created from survey data collected from 1893 to 1894 shows the outline of a lake roughly corresponding to the present lake footprint (**Figure 13**).

Figure 12: Overlay of the 1879 Survey Plat Showing Boom Lake as a Mud Flat

Figure 13: Overlay of a USGS Quadrangle Showing the Outline of Boom Lake circa 1893-1894

During the past 20 years, lake levels have continued to fluctuate. This is shown in Landsat aerial images in **Figures 14**, **15**, and **16**. The southern section of the lake south of Southwest Road was dry and the middle and northern sections of the lake were fairly low during October 1992 (**Figure 14**). During the spring of 1996 it appears that the northern and middle lake sections merged based on **Figure 15** and in previous Landsat images. **Figure 16**, taken during July 2011 shows all three lake sections fully merged. It is apparent from these images that the surrounding wetland areas have also grown substantially along with the lake.

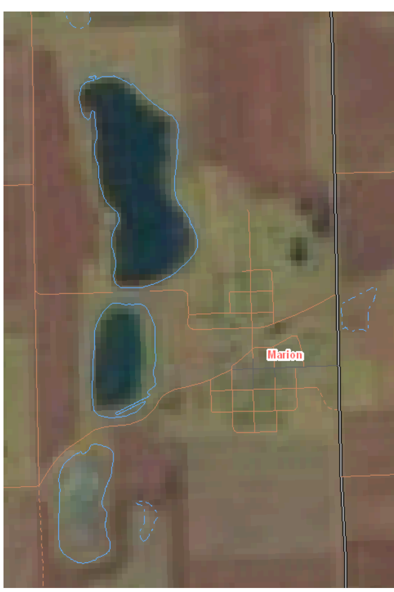

Figure 14: Landsat Image Taken 10/29/92

Figure 15: Landsat Image Taken 06/09/96

Figure 16: Landsat Image Taken 07/05/11

Figure 17 shows a hydrograph of estimated and surveyed lake levels. An estimated water level of 1444 ft is assumed during October 1992 based on the aerial extent shown in **Figure 14** and an estimated lake bottom elevation of 1440 ft. The northern and middle lake sections merged during the spring of 1996 at an elevation that is roughly estimated to be 1449 ft based on surveyed points collected along the submerged road. On April 20, 2010 the level in the northern and middle lake sections were surveyed by the SWC at 1454.2 ft and the level in southern section of the lake was surveyed about three feet lower at 1451.2 ft (or approximately 1453.5 ft if the lake sections were equalized). During March 2011, the northern and middle lake section reached elevation 1454.7 ft and flooded Southwest Road. On November 1, 2011 the lake was surveyed at 1455.0 ft, and it's estimated that the lake elevation peaked in 2011 roughly one foot higher at 1456.0 ft.

The rise of the lake correlates with the above average precipitation that has occurred since 1993. The lake levels will decrease once the wet weather cycle has passed; however, predicting when that will occur is not possible.

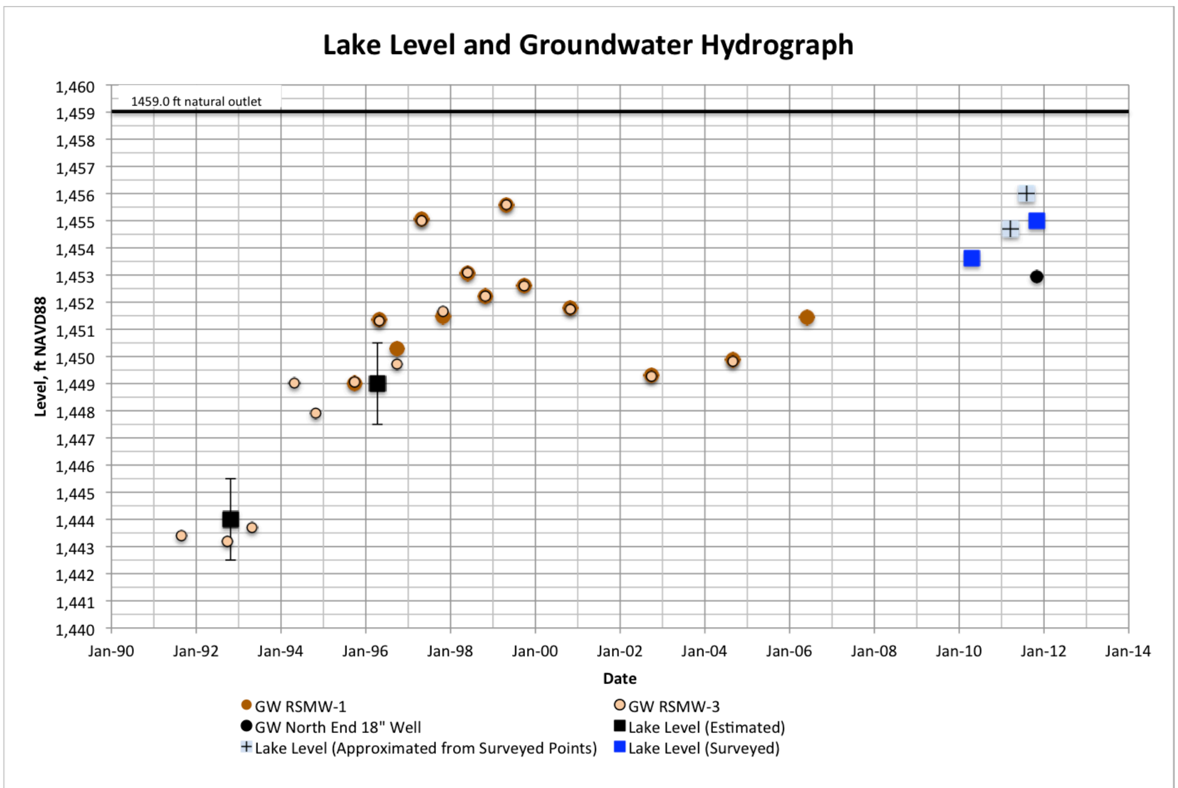

Figure 17: Lake Level and Groundwater Hydrograph Showing Select UST Monitoring Wells (1991-2006)

2.5 Groundwater Level Fluctuation

Groundwater levels have also been rising as evidenced in groundwater measurements and by the increase homes using sump pumps in Marion. **Figure 17** shows a hydrograph of groundwater elevations measured in two representative observation wells installed in central Marion as part of the UST investigation and a groundwater measurement collected during November 2011 by the SWC, as well as lake levels described in the previous section.

The measurements from the UST investigation span from 1991 to 2006 when the wells were abandoned and generally correlate closely to each other (MACTEC, 2006). Groundwater levels have varied from roughly elevation 1443 ft to 1455.5 ft and show a marked increase from 1993 to 1994. The hydrograph also shows groundwater levels vary by as much as 3.5 feet from spring to fall. Large groundwater level fluctuations are likely due to the relatively low specific storage associated with till soils. In tight soils like till, there is relatively little pore space for groundwater to occupy so a large change in groundwater level can occur with a small change in volume of water stored in the aquifer.

On November 1, 2011 the SWC measured a groundwater elevation of about 1453.0 ft in an 18-inch-diameter well located north of the UST wells shown on **Figure 5**. A driller's log of this well is not on file with SWC, so construction details and stratigraphy are not available. Based on higher slough water surface elevations surveyed east of the well near County Highway 61, it is likely that that the November 2011 measurement is lower than the natural condition because of the operation of sump pumps. The water surface elevations of the sloughs near County Highway 61 ranged from 1453.5 ft to 1456.7 ft during November 2011 (**Figure 18**).

2.6 Groundwater – Surface Water Interaction

Pothole and wetland interaction with shallow groundwater is a complex system. Wetlands can receive inflow from groundwater or discharge to groundwater (**Figure 19**) (LaBaugh, et. al 1998). Additionally, the studies have shown that most times groundwater seepage into a wetland and groundwater discharge from a wetland, or through flow, occur concurrently (**Figure 19**) (LaBough, et. al, 1998; Sloan, 1972).

Based on the hydrograph of surface water and groundwater levels, it appears that groundwater levels in Marion roughly correlate with lake levels. It is difficult to define the exact relationship between Boom Lake and shallow aquifer system based on the limited data available. The hydrograph (**Figure 17**) suggests that during the 1990s the lake was likely a discharge point for groundwater most of the time resulting in a net gain from groundwater, and in recently years, an outflow condition or through flow condition resulting in net loss to groundwater.

Water surface levels of the lake and surrounding sloughs and the groundwater level data collected during November 2011 suggest a through flow condition exists with slough water levels higher than the lake level in the east and slough water levels lower than the lake levels to the southeast (**Figure 18**).

Figure 18: Surface Water and Groundwater Elevations - November 2011

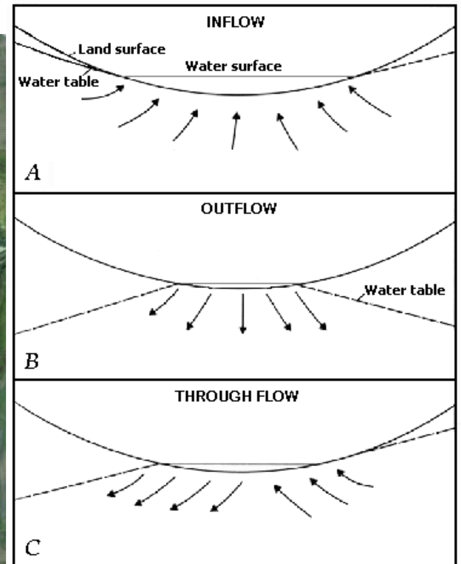

Figure 19: Surface Water and Groundwater Interactions of Potholes (Adapted from Ground-water hydrology of prairie potholes in North Dakota, Figure 8. (Sloan, 1972). http://library.ndsu.edu/exhibits/text/potholes/585c.html, accessed January 19, 2012)

Regardless of the exact relationship between Boom Lake and the shallow groundwater, the lake level likely controls the groundwater level at Marion to some degree, particularly the northern section of Marion, because of its size and proximity.

2.7 Water Balance

A water balance was calculated to approximate the inflow distribution between survey events, April 20, 2010 and November 1, 2011. This calculation is included in **Appendix D**. Assuming the northern and southern sections of the lake were equalized on April 20, 2010, the lake rose roughly 1.5 feet over the 18 months, which include a major snowmelt event. Between April 20, 2010 and the peak water elevation during the summer of 2011, the lake rose roughly 2.5 feet.

Figures 20 and **21** shows the approximated annual inflow and outflow distributions estimated by the water balance, respectively. Inflows from direct rainfall were measured from the NDAWN station in Marion. Runoff and snowmelt inputs and losses from seepage and ET were estimated from the 1968 USGS study on pothole hydrology by Shjeflo. Pumping station discharges were estimated in **Appendix E** using pump and operation information provided by the City of Marion.

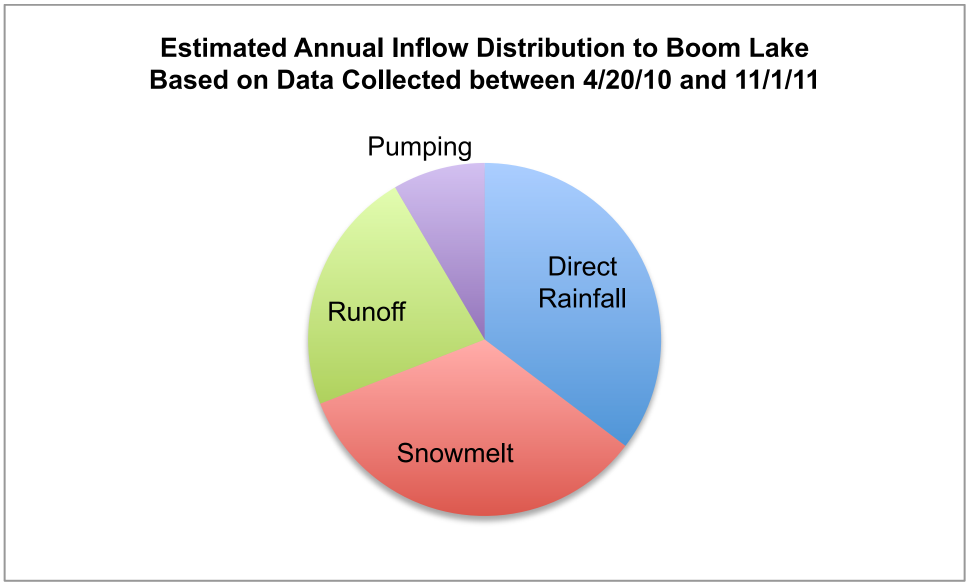

Figure 20: Estimated Annual Inflow Distribution to Boom Lake

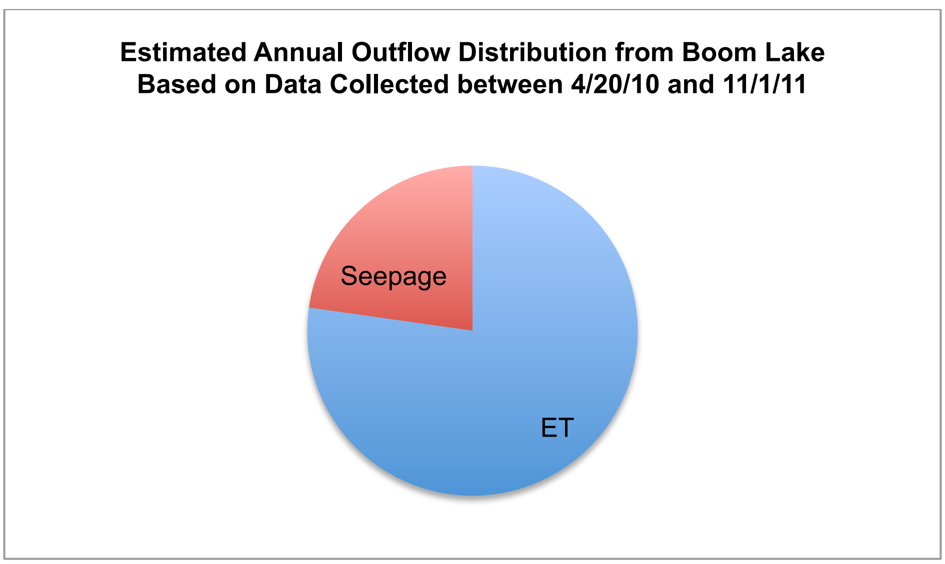

Figure 21: Estimated Annual Outflow Distribution from Boom Lake

The precision of water balance estimate is by no means exact but gives a rough idea of the relative magnitude of inflows and outflows. Direct rainfall and snowmelt account for over two thirds of the inflow to the lake, while runoff after rain events and pumping discharges make up a small portion of the total inflow. Without additional data, it is not possible to determine exact inflows from snowmelt, runoff, and pumping and outflows from seepage. Also it is not possible to determine the effect of inflows from pumping;

however, it appears from this initial estimate that pumping is significantly contributing to the rise in lake levels.

2.8 Hydrologic Model

A hydrologic model of the Boom Lake drainage basin was created with the USACE Hydrologic Engineering Center (HEC) Hydrologic Modeling System (HMS) Version 3.5. The model and documentation is included in **Appendix F**.

The drainage basin was determined as described in Section 2.1. However, two basin areas (2.5 square miles and 4 square miles) were modeled to represent smaller or larger contributing areas depending on the modeled scenario. The model uses the Soil Conservation Service (SCS) curve number method described in the Hydrology Manual for North Dakota to estimate losses and runoff (U.S. Dept. of Agriculture, n.d.). The curve number was calculated using land use data obtained from the 2006 National Land Cover Dataset (NLCD) from the USGS (Fry et. al., 2011) and soil classification data from the Soil Survey Geographic (SSURGO) Database maintained by the Natural Resources Conservation Service (NRCS) (U.S. Dept. of Agriculture, 2011) . Time of concentration was calculated using the methods described in Technical Release 55 (TR-55) (U.S. Dept. of Agriculture, 1986). The Clark unit hydrograph was used as a transform method to perform the runoff calculations and the hydrograph storage parameter was estimated based on regression analysis performed by the USACE during their Phase I Hydrologic Modeling Red River of the North Tributaries (USACE, 2011).

Since the lake has not been gauged, calibrating the HMS model for a given or known storm event was not possible. However, the water balance inflow estimate was compared to HMS predicted inflows from the snowmelt event and the sum of summer storm events that occurred from April 20, 2010 through November 1, 2011. This comparison is included in **Appendix F**. **Table 1** summarizes the inflow volume and rise in lake level predicted by the hydrologic model for selected storm events for the existing condition.

The results predict that the lake is not currently in danger flooding northern Marion for storm events with a 1 percent annual frequency. The model also predicts the lake will remain below flood level if a snowmelt event similar to the 2010 snowmelt event occurs, which exceeded the 100-year 10-day snowmelt event. However, the model predicts significant losses in available storage that would increase the risk of flooding for future storm events.

Existing Condition - Initial Stage 1455 ft		2.5 mi Basin	
Event	**Total Precipitation, in**	**Inflow Volume, ac-ft**	**Peak Lake Stage, ft**
Rainfall			
2 Year 24 Hr Rainfall	2.3	94	1455.4
5 Year 24 Hr Rainfall	3.0	154	1455.6
100 Year 24 Hr Rainfall	5.1	385	1456.4
100 Year 10 Day Rainfall	8.8	583	1457.1
PMP 48 Hr - 10 sq mi basin	30.7	3694	1460.5*
Snowmelt			
50 Year 10 Day Snow Melt - 80% Impervious	3.7	418	1456.6
100 Year 10 Day Snow Melt - 80% Impervious	4.4	498	1456.8
2010 10 Day Snow Melt - 80% Impervious	6.2	721	1457.6

*Assumes discharge from 150 ft wide broad crested spillway outlet at 1459 ft and no tailwater effect

Table 1: Summary of HMS Results for Existing Condition (Elevation 1455 ft)

A Probable Maximum Precipitation (PMP) event is the theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage area at a certain time of year. A 48 hr PMP event over 10 square miles, which covers the entire drainage basin, is predicted to currently cause flooding in northern Marion and cause the lake to outlet naturally. However, the predicted inflow for a PMP event is larger than the estimated storage available if the lake were dry. The PMP event is so severe and rare nothing can be done to prevent flooding if it ever occurred.

3. Alternative Analysis

A number of options that may alleviate some of the issues caused by the elevated lake and groundwater levels were evaluated in this section. The cost estimates for each option provided in this report were calculated at a level that provides a degree of accuracy appropriate to compare the costs of each option relative to each other. Actual costs for each option may vary significantly and depend on many factors including but not limited to design requirements, permitting requirements, land values, and the contractor's means and methods.

Lowering the water level in Boom Lake provides the most benefit; however, it is relatively costly. Other options that do not involve lowering the lake level would be less costly, but provide less benefit.

3.1 Benefit of Lowering Lake Levels

Constructing an outlet that lowers the lake level would provide several benefits, including greatly reducing the risk of flooding in northern Marion. As previously stated the lake would overtop an embankment protecting northern Marion before it would outlet to the south. Although the risk of flooding from a single storm or snowmelt event is currently remote, the risk may increase if the wet weather cycle continues. Lowering the lake would minimize risk of flooding northern Marion even if the wet weather cycle continues.

Reducing lake levels would also aid in reducing some of the problems occurring with an elevated water table. Lowering the lake level would reduce the groundwater table by allowing groundwater to discharge into the lake. Although, nearby sloughs losing water to groundwater through infiltration and low-permeability till soils that limit groundwater conveyance could keep the groundwater table elevated, so it is expected that sump pumps would still be required to keep basements dry. Lowering the lake below the depth of many basements would result in a lake surface elevation below approximately 1447 ft, which would present technical challenges (e.g. hydraulically connecting the lakes once they had lowered and lost their connection) and higher costs. Therefore, many basements would remain below the groundwater table. However, over time it is likely that the sump pumps at many residences would cycle less frequently, since the groundwater table will be depressed by the lower lake level.

Lowering the lake level would also expose Southwest Road and restore a second access route for residents and emergency services. Southwest Road would likely require regrading and potentially additional fill if subsidence has occurred. Large culverts would also need to be installed to keep the lake equalized. It is expected that the road dividing the northern and middle sections of the lake would still be submerged if the lake elevation was maintained above 1451 ft.

The culvert and drainage ditch in northern Marion could be unplugged and Pumping Station 1 would no longer be needed since gravity drainage could be restored.

3.2 Outlet Alignment Screening

Several outlet alignments that drain to Bear Creek to the east and Dry Coulee to the west were evaluated (**Figure 22**). As a screening tool, an open channel, gravity outlet draining the lake at elevation 1451 ft was assumed to evaluate the required depth and distance. Evaluating gravity drainage emphasizes selecting the most practical conveyance route regardless if a gravity drainage outlet option or pumped outlet option is selected. United States Fish and Wildlife Service (USFWS) easements and wetlands included under the USFWS National Wetland Inventory were also considered in screening.

Table 2 summarizes excavation volume, depth, and length for each alignment, assuming a 10-ft-wide trapezoidal channel with 3-to-1 side slopes is used and would allow the lake to outlet at elevation 1451 ft for several alignments. Most of the alignments follow the low-lying areas to minimize excavation, which also puts them in the path of wetlands. For longer channel lengths, excavation volumes are greatly influenced by changes in elevation of one or two feet, which is within the accuracy of the NED data in this area. Therefore, these excavation estimates are best used to roughly gauge alignment excavation volumes relative to each other. Excavation volumes for some alignments were adjusted using USGS topographical maps and survey data.

Bear Creek and Dry Coulee both drain to the James River; however, Dry Coulee is a much more direct route. The confluence of Dry Coulee and the James River is approximately 8 miles southwest of Boom Lake at the City of Dickey. Bear Creek discharges into the James River further south just above Oakes located in Dickey County. Dry Coulee is a more mature drainage system and has larger existing culverts than Bear Creek, which are desirable features for an outlet discharge point. However, as shown by the excavation volumes **Table 2**, the depth of cut required and distance separating Dry Coulee from Boom Lake makes it a much more challenging option. Furthermore, crossing multiple USFWS easements and larger sloughs would likely add additional requirements that would result in higher costs.

Marion and the LaMoure County Water Resource Board expressed interest in an alignment that would drain water to Bear Creek northeast of the lake (NE Alignment) because of potential landowner cooperation along a portion of the route. This alignment is roughly 2.7 miles long, requires considerable excavation and passes through several USFWS easements, wetlands, and large sloughs.

An outlet alignment that is similar to the natural outlet path (SE Alignment) is the shortest route to a drainage that flows into Bear Creek. This alignment takes advantage of the natural drainage to shorten the length requiring construction and major improvements. Major construction of this alignment also avoids USFWS easements and the shorter length reduces the area of wetlands potentially affected. The outlet alternatives described later in this section assume this alignment.

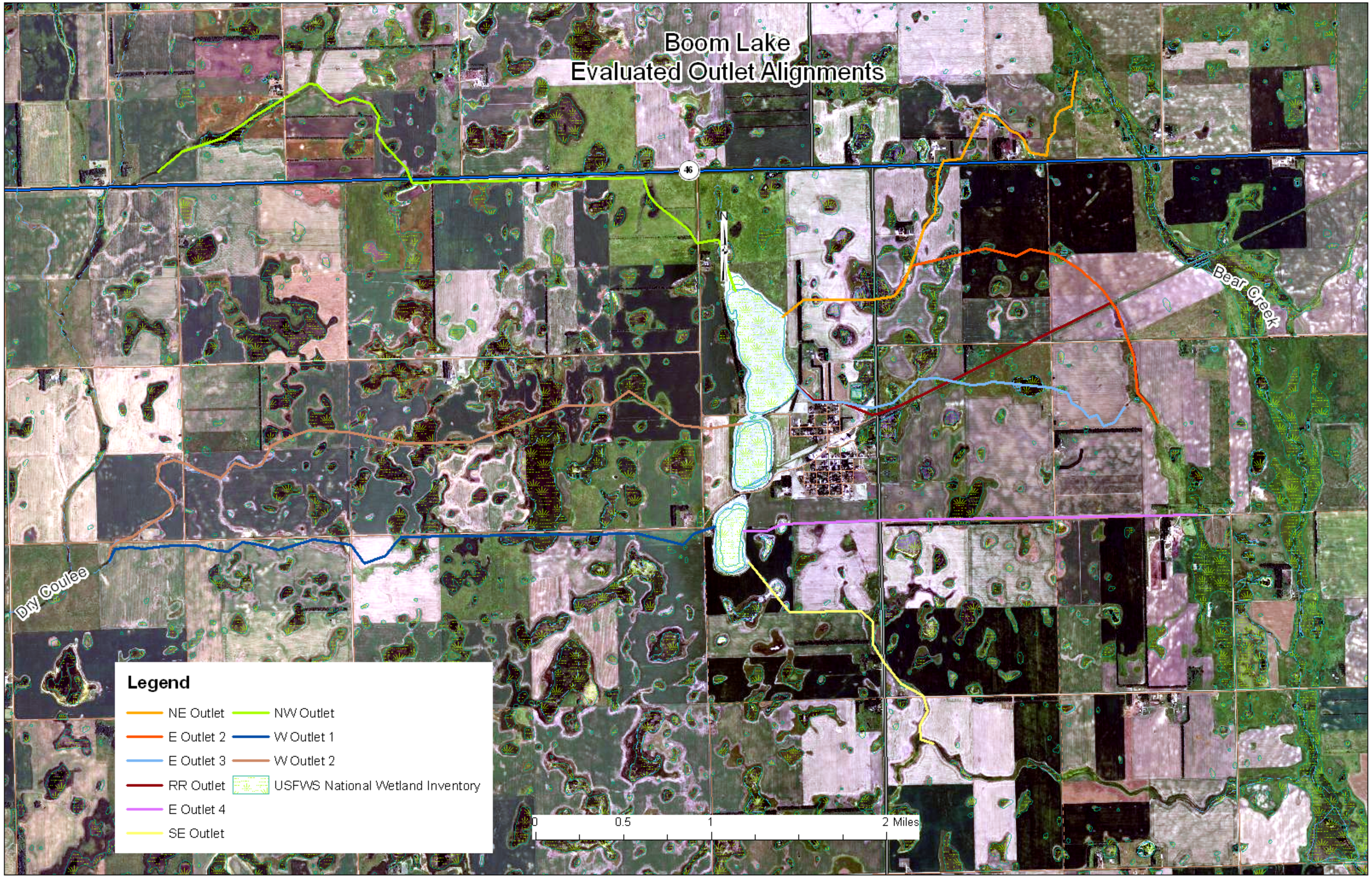

Figure 22: Evaluated Outlet Alignments

Route ID	Drainage Basin	Length, mi	Cut Volume, cy	Max Top Width, ft	Max Depth, ft	USFWS Easement	Railroad Easement
		Outlet Draining Lake at El 1451					
SE	Bear Creek	1.4	60,000	105	17	No	No
NE	Bear Creek	2.7	110,000	97	14.5	Yes	No
W2	Dry Coulee	3.6	150,000	92	14	Yes	No
E3	Bear Creek	2.1	150,000	90	13.5	Yes	Yes
E2	Bear Creek	2.7	160,000	116	17.5	Yes	No
E4	Bear Creek	2.3	190,000	120	18	No	No
RR	Dry Coulee	2.5	200,000	143	22	No	Yes
W1	Dry Coulee	3.6	210,000	105	16	Yes	No
NW	Dry Coulee	3.9	250,000	108	16.5	Yes	No

Table 2: Summary of Evaluated Outlet Alignments

3.3 Downstream Impacts from an Outlet

An outlet constructed along the SE Alignment would pass through farmland. If an open channel conveyance option that discharges from the lake at elevation 1451 ft is selected, up to 125 ft of right-of-way for a 1.4 mile distance would be needed for the channel to be constructed. Over the remaining 2.5 miles to Bear Creek only minor improvements to the natural drainage channel would likely be required. It is expected that the width of the existing, natural drainage channel would be sufficient and additional farmland would not be impacted. Nevertheless, a hydraulic analysis would be required for design.

Ultimately, the Boom Lake drainage basin will add flow to Bear Creek if an outlet is constructed. However, it should be reiterated that the Boom Lake basin would drain to Bear Creek naturally if the lake rises to its natural spill level. Not accounting for potential non-contributing drainage areas, Boom Lake would increase the total area drained by Bear Creek by approximately 10 percent at the confluence of the Boom Lake drainage channel and Bear Creek. The impacts the additional drainage would need to be investigated further as some of the culverts at Bear Creek road crossings downstream of the confluence appear to be undersized for current conditions.

One way to reduce the impact of additional inflow into Bear Creek is to control the outflow from Boom Lake. There are a number of control structures that can do this, but the simplest structure would be a weir outlet. Based on the flow estimates from the hydrologic model, weir discharges for nearly all runoff events could be kept under 50 cubic feet per second (cfs).

Alternatively, an operated outlet could be used to limit or stop discharges from Boom Lake based on flows in Bear Creek. It may be difficult to define downstream conditions that should limit Boom Lake discharges since the only stream gauge on Bear Creek is located near its confluence with the James River in Dickey County. It's likely most spring runoff events could be held in the lake until the summer. However, some rare runoff events may exceed the available storage depending on the design.

If the wet weather cycle and pump station operation continue as they have during 2010 and 2011, the lake will eventually reach a level where it will outlet and discharge into Bear Creek naturally. This would have the most impact to downstream users because the discharges would be uncontrolled. Flooding would greatly impact farmland immediately south and east of the lake along the natural outlet(s).

3.4 Description of Alternatives

Alternative 1 – Lowering Lake Level to El 1451 ft via Gravity Outlet

Alternative 1 consists of a gravity outlet that would allow water to exit Boom Lake at elevation 1451 ft (**Figure 23**). The alternative would replace the existing pumping stations with gravity drain systems.

This alternative assumes a 10-foot-wide trapezoidal ditch with 3-to-1 side slopes. The 1.4-mile-long ditch would follow a 0.02% slope from the lake to a drainage that discharges into Bear Creek. The ditch would span approximately 105 ft at its widest point, require a maximum cut of 17 ft and generate approximately 60,000 cubic yards of excavated material.

A manually operated outlet could be implemented to release flows based on flow rates downstream. However, a 6-ft-long broad crested weir outlet is assumed to estimate peak flow rates. A weir outlet minimizes operation and maintenance costs.

Clean Water Act (CWA) Section 404 regulates the discharge of dredged and fill material into waters of the United States, including wetlands, and any fill brought into the lake to construct the outlet may be subject to regulation. Therefore, obtaining a permit from the USACE to bring in fill during the outlet construction may be required. Additionally, wetlands impacted along the outlet alignment may be under the jurisdiction of the USACE or NRCS and may require mitigation.

As discussed in the previous section, this alternative would also likely require improvements at all road crossings along the alignment to Bear Creek and potentially road crossings downstream on Bear Creek. Minor maintenance or improvements to the existing, natural drainage channel would also likely be required for about 2.5 miles from the end of the constructed channel to Bear Creek. Using an operated outlet could minimize these improvements.

This alternative also would replace the current pumping stations with gravity drain systems. As stated previously, Pumping Station 1 would no longer be needed since the lake would be lowered to a point where the drainage ditch would gravity drain if the culvert was unplugged.

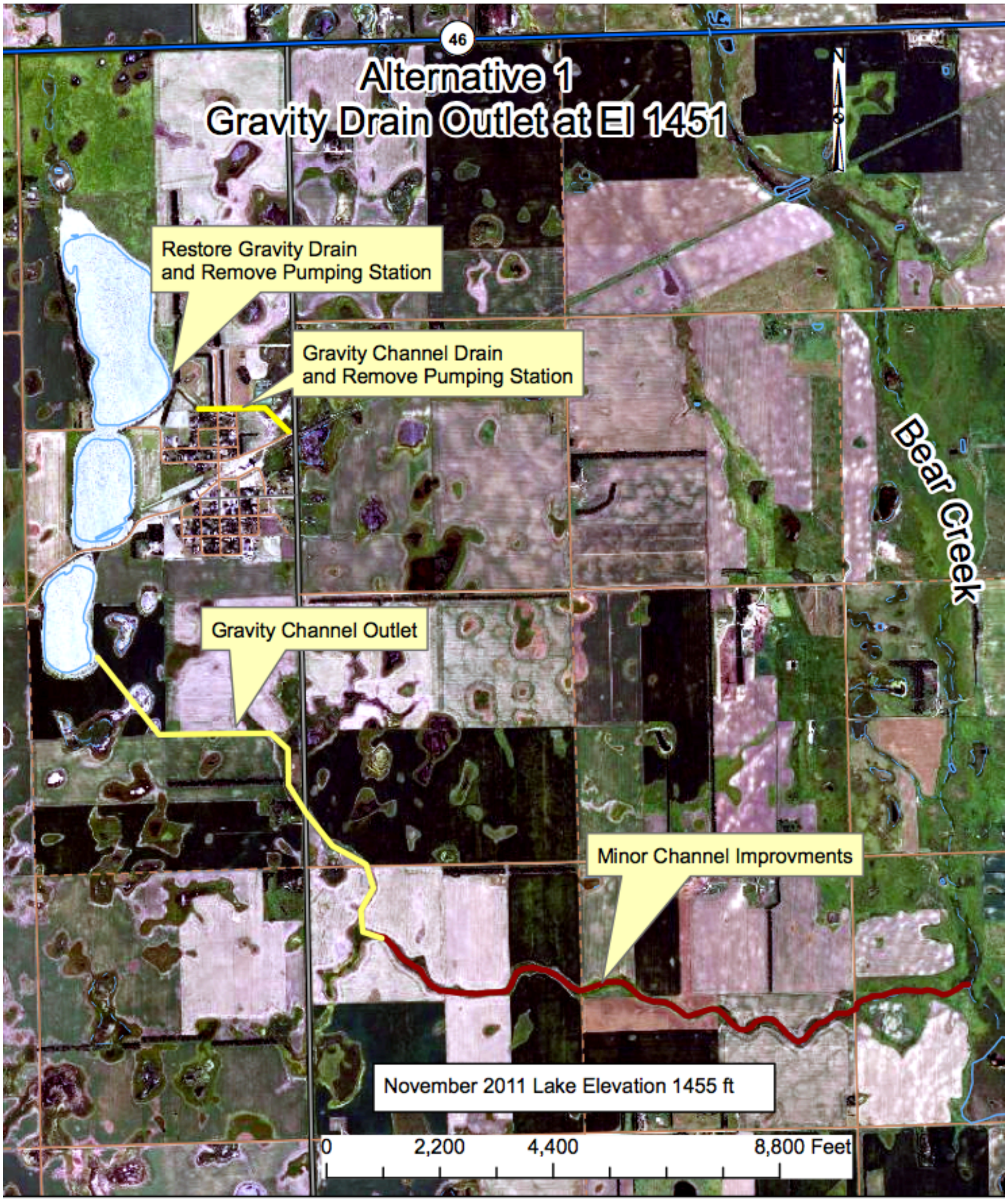

Figure 23: Alternative 1 – Gravity Drain Outlet at Elevation 1451 ft

The culverts near Pumping Station 2 would be repaired or replaced and a drainage ditch would be installed that would drain water from the slough complex to the lake. The drainage ditch is shown on **Figure 23** and would extend approximately 2,000 feet from Pumping Station 2 to the existing drainage ditch that drains northern Marion. The ditch invert would be constructed at elevation 1456 ft and extend at a 0.02% slope to the existing drainage ditch. The ditch would drain water from the slough complex before it reached elevation 1457 ft at which point it would flood the sewage lift station. A 4-ft-wide trapezoidal ditch with 3-to-1 side slopes would span approximately 60 ft at its widest point, require a maximum cut of 9 ft, and generate approximately 8,700 cubic yards of excavated material.

The HMS model was used to estimate stage and discharge results for this alternative for storm events assuming the weir outlet. The installation of a gravity drain to replace Pumping Station 2 would integrate the drainage area that is likely currently non-contributing so a 4-square-mile basin is assumed. **Table 3** summarizes the model results.

Gravity Outlet Condition - Initial Stage 1451		4 sq mi Basin		
Event	Total Precipitation, in	Total Inflow Volume, ac-ft	Peak Discharge, cfs	Peak Lake Stage, ft
Rainfall				
5 Year 24 Hr Rainfall	3.0	246	14	1451.9
100 Year 24 Hr Rainfall	5.1	616	49	1453.1
100 Year 10 Day Rainfall	8.8	932	62	1453.4
Snowmelt				
50 Year 10 Day Snow Melt - 80% Impervious	3.7	669	42	1452.9
100 Year 10 Day Snow Melt - 80% Impervious	4.4	797	53	1453.2
2010 10 Day Snow Melt - 80% Impervious	6.2	1,153	83	1453.9

Assumes discharge from 6 ft wide broad crested spillway outlet at 1451 ft and no tailwater effect

Table 3: Summary of HMS Results for Gravity Outlet Condition (Elevation 1451 ft)

The drainage ditch at the north end of Marion has a bank full elevation of approximately 1454 ft, and the lake begins flooding Southwest Road at elevation 1454.7 ft. As shown in **Table 3**, for the 100-year frequency events, the outlet peak discharge of the outlet would be on the order of 50 cfs, Southwest Road would not flood, and the drainage ditch would not overtop.

Table G1 in **Appendix G** summarizes the estimated costs for this alternative. This alternative is estimated to cost approximately $710,000 including $30,000 for maintenance over the next 20 years.

Alternative 2 – Lowering Lake Level to El 1451 via Pump Outlet

Alternative 2 consists of a pump outlet that would drawdown Boom Lake to a minimum elevation of 1451 ft (**Figure 24**). This alternative also assumes that the temporary pumping stations would be replaced with gravity drain systems. The alternative assumes a conveyance channel would be constructed from the pump outlet to the natural drainage that discharges into Bear Creek. It also assumes the pump would be automated and capable of discharging at least 50 cfs.

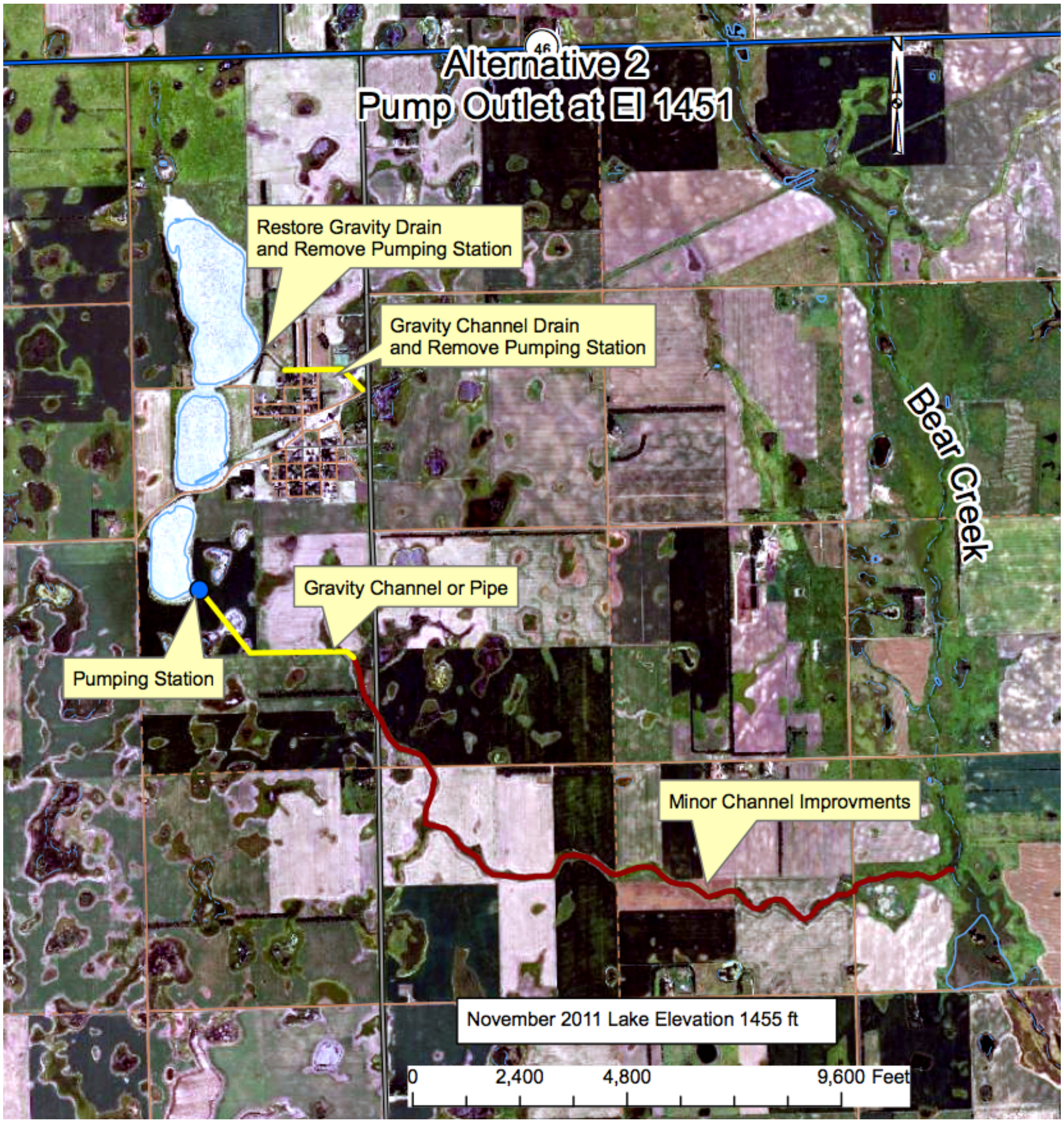

Figure 24: Alternative 2 – Pump Outlet at Elevation 1451 ft

Similar to Alternative 1, this alternative would likely require improvements at all road crossings along the alignment to Bear Creek and potentially some road crossings downstream on Bear Creek. Minor maintenance or improvements to the existing, natural drainage channel would also likely be required for about 3.3 miles from the end of the constructed channel to Bear Creek.

As with Alternative 1, Pumping Station 1 would no longer be needed as the current drainage ditch could drain via gravity. This alternative also would replace Pumping Station 2 by restoring the culverts and installing drainage ditch that would drain water from the slough complex to the lake (**Figure 24**).

An advantage of this alternative is that lake levels could be lowered below elevation 1451 for minimal additional cost and would be controlled by an operating plan. A disadvantage is higher operation and maintenance costs would be required.

Additionally a Section 404 permit may be required from the USACE, because fill may be imported into the lake as part of the outlet construction. Wetlands impacted along the outlet alignment may be under the jurisdiction of the NRCS or the USACE and may require mitigation.

Table **G2** in **Appendix G** summarizes the estimated costs for this alternative, which is estimated to cost approximately $620,000 including $210,000 for maintenance over the next 20 years.

Alternative 3 –Outlet at El 1455 ft

Alternative 3 is similar to Alternative 1 except the lake outlet is constructed at elevation 1455 ft, the November 2011 lake elevation (**Figure 25**). This alternative would prevent the lake from rising to the point where it could flood portions of Marion for most storm events, but does not provide the benefits of lowering the lake level. This alternative also assumes that Pumping Station 1 is replaced with an automated lift station and Pumping Station 2 is replaced with a gravity drain system.

The outlet assumes a 10-ft-wide trapezoidal ditch with 3-to-1 side slopes. The 0.8-mile-long ditch would follow a 0.02% slope from the lake to a drainage that discharges into Bear Creek. The ditch would span approximately 80 ft at its widest point, require a maximum cut of 12 ft and generate approximately 20,000 cubic yards of excavated material.

As with Alternative 1, a 6-ft-long broad crested weir outlet is assumed to estimate peak flow rates, although a manually operated control structure could also be used.

Similar to Alternatives 1 and 2, road crossings to Bear Creek and potentially downstream on Bear Creek would need to be improved in the event of the lake discharging.

A Section 404 permit may not be required for the outlet construction because the outlet structure can be constructed without importing fill into the lake. However, wetlands impacted along the outlet alignment may be under the jurisdiction of the USACE or NRCS and may require mitigation.

Since the lake level would not be lowered, Southwest Road would need to be raised approximately 4 ft. Adequately sized culverts that would maintain balance between the northern and southern portions of the lake would need to be installed. These costs are not included in the cost estimate.

The lake level would not be lowered enough to allow the drainage ditch in northern Marion to gravity drain so an automated lift station would need to be installed. An automated lift station with a pump operating at 1,500 gallon per minute (gpm) is assumed.

As with Alternatives 1 and 2, this alternative also includes replacing Pumping Station 2 with a gravity drain system by restoring the culverts and installing a drainage ditch that would drain water from the slough complex to the lake (**Figure 25**).

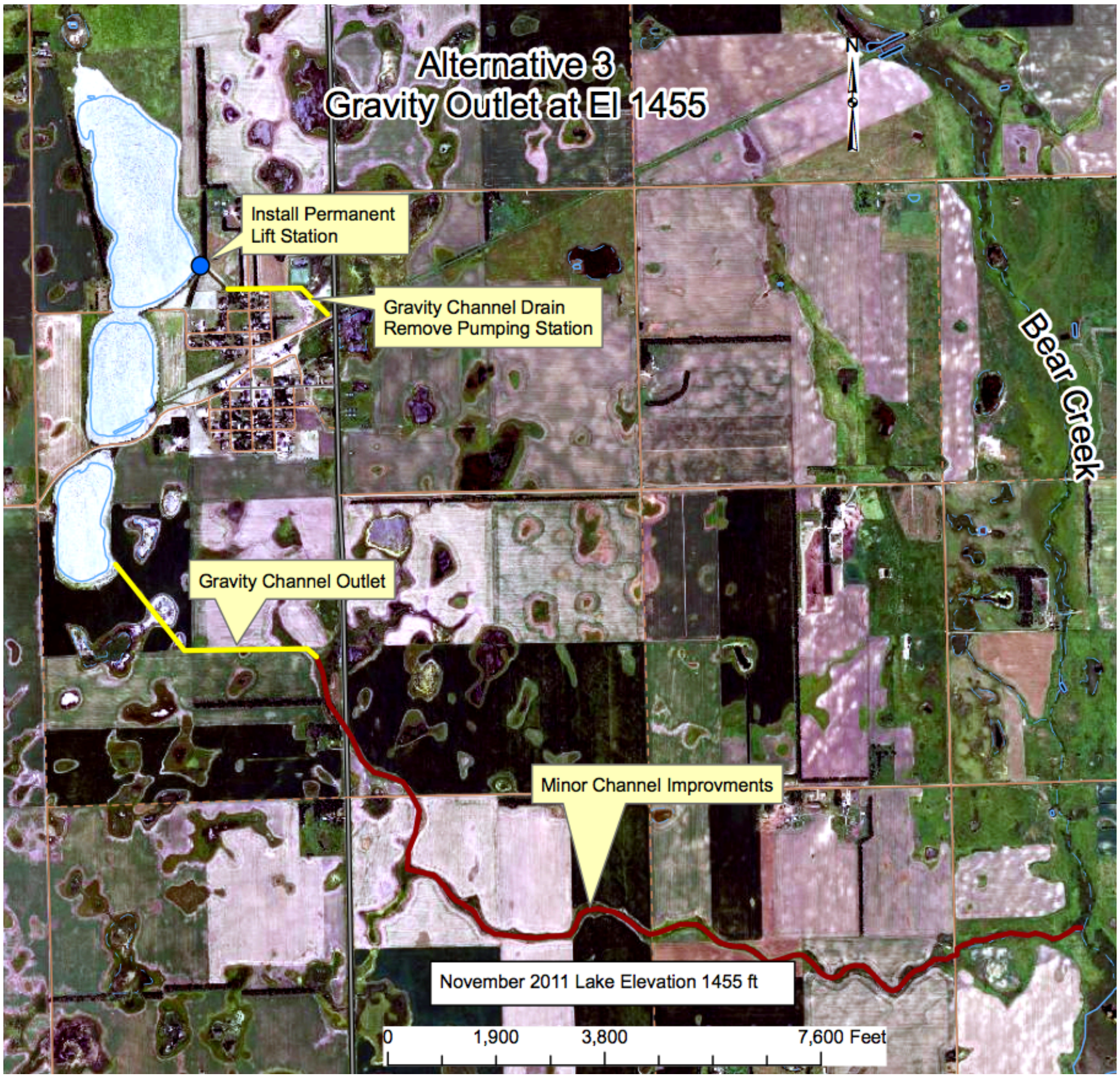

Figure 25: Alternative 3 – Gravity Outlet at Elevation 1455 ft

A control structure and contributing drainage area similar to Alternative 1 is assumed; therefore, peak flow rates would be similar as well as shown in **Table 4**. Peak lake stages from storm events, also shown in **Table 4**, would be 4 feet higher than those predicted for Alternative 1.

Gravity Outlet Condition - Initial Stage 1455		4 sq mi Basin		
Event	**Total Precipitation, in**	**Total Inflow Volume, ac-ft**	**Peak Discharge, cfs**	**Peak Lake Stage, ft**
Rainfall				
5 Year 24 Hr Rainfall	3.0	246	14	1455.9
100 Year 24 Hr Rainfall	5.1	616	49	1457.1
100 Year 10 Day Rainfall	8.8	932	62	1457.4
Snowmelt				
50 Year 10 Day Snow Melt - 80% Impervious	3.7	669	42	1456.9
100 Year 10 Day Snow Melt - 80% Impervious	4.4	797	53	1457.2
2010 10 Day Snow Melt - 80% Impervious	6.2	1,153	83	1457.9

Assumes discharge from 6 ft wide broad crested spillway outlet at 1455 ft and no tailwater effect

Table 4: Summary of HMS Results for Gravity Outlet Condition (Elevation 1455 ft)

Table G3 in **Appendix G** summarizes the estimated costs for this alternative. This alternative is estimated to cost approximately $640,000 including $70,000 for maintenance over the next 20 years. These costs do not include road raise costs.

Alternative 4 – No Outlet

Alternative 4 assumes that no outlet is constructed and a small dike is constructed to protect northern Marion, which is at greatest risk of flooding. This alternative does not lower lake or groundwater levels and does not control outflows from the lake; therefore, it provides minimal benefit.

A dike approximately 800 ft long would be constructed to protect northern Marion. This dike is identified as a primary dike in **Figure 26**. The dike would be constructed to at least elevation 1461 ft, which would make the dike roughly 2.5 ft high at its highest point and roughly require 500 cy of fill. Based on the survey data, this dike would protect the area most vulnerable to flooding. This would provide approximately 2 ft of freeboard above the lake outlet.

According to estimates from the hydrologic model, 0.6 ft of freeboard would be sufficient to contain the lake for 100-year snowmelt and rain events (**Appendix F**). However, the model does not account for tailwater effects caused by flow restrictions downstream and the 1.4 ft additional freeboard would likely be desired to protect against wave overtopping during the spring and summer.

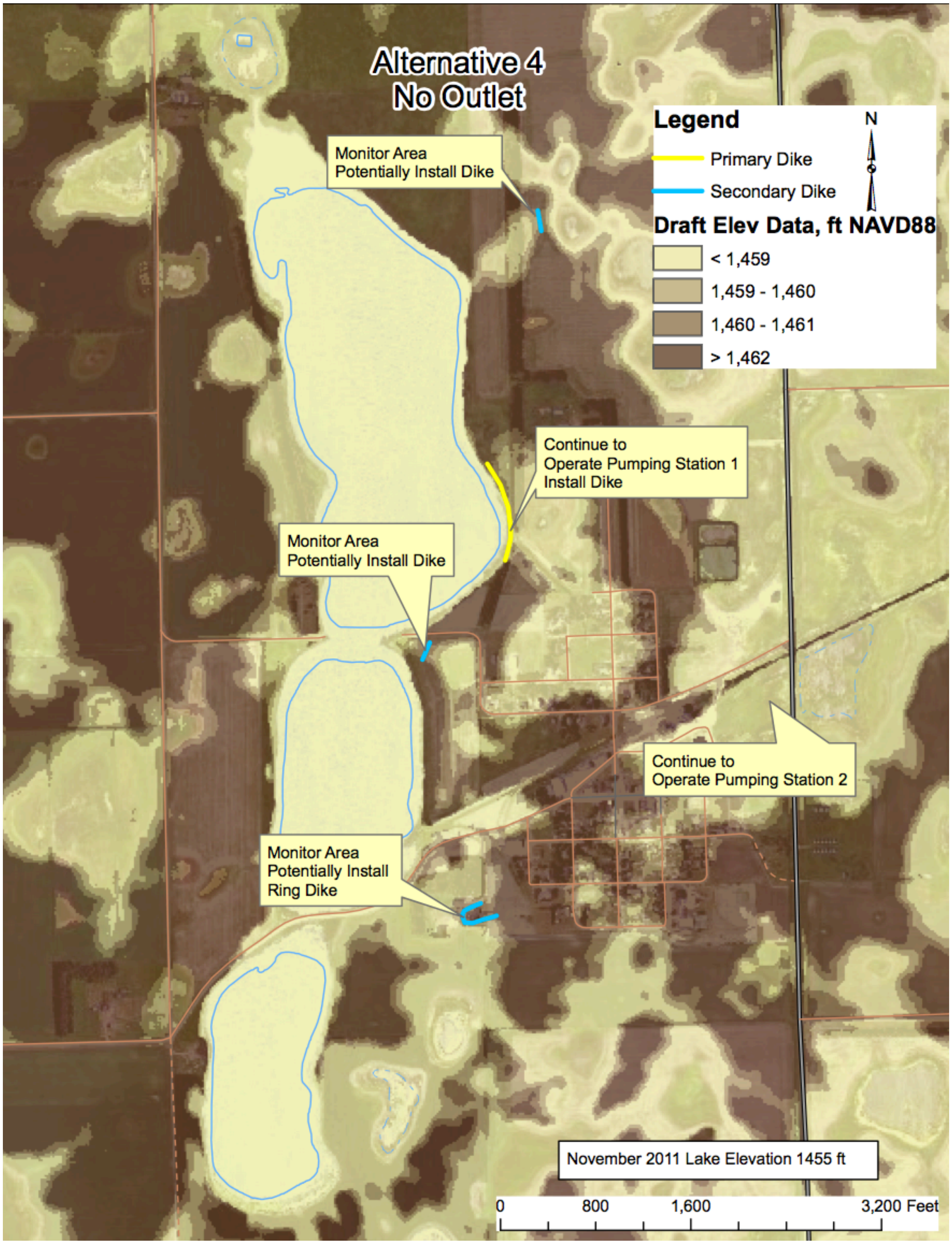

Figure 26: Alternative 4 – No Outlet

Other areas may need protection against flooding as well. With the current elevation data it is not completely clear where these areas are, but it is anticipated that small sandbag dikes likely could protect these areas if necessary. As the lake overflows naturally, the outlet will erode and slightly lower the outlet elevation, which could allow for removal of the temporary flood protection. **Figure 26** shows preliminary elevation data from a LIDAR survey collected by the USACE. Secondary dike areas which may be required if the lake begins to outlet naturally are identified on **Figure 26**. The costs associated with these secondary dikes were not included in the cost estimate.

Since the lake level would not be lowered, Southwest Road would need to be raised to provide an alternative route to access Marion. Adequately sized culverts that would maintain balance between the northern and southern portions of the lake would need to be installed. This is necessary to prevent uneven pooling at the northern portion of the lake from inflows. These cost are not included in this estimate.

It also appears that portions of Lake View Cemetery may flood at elevation 1459 ft (**Figures 7** and **26**). Mitigative measures to protect or relocate the cemetery may need to be implemented if the lake reaches this elevation. These costs are not included in this cost estimate.

This alternative assumes that Pumping Stations 1 and 2 continue to be operated manually and are not upgraded. Discharging the water from Pump Stations 1 and 2 somewhere other than Boom Lake would help limit the rise of the lake. Unfortunately, a simple or cost effective alternative does not exist.

Table G4 in **Appendix G** summarizes the estimated costs for this alternative. This alternative is estimated to cost approximately $190,000 including $180,000 for operation and maintenance over the next 20 years not including road raise and temporary flood protection costs.

3.5 Summary and Recommendations

As shown in **Table 5**, lowering the lake level by constructing an outlet would resolve some of the current and potential future problems caused the elevated levels of Boom Lake; however, it is a costly solution. Alternative 3, which would construct an outlet to prevent future flooding and automate the existing pumping stations, is also costly, and would likely be the most expensive option if the cost of raising Southwest Road were considered. Alternative 4 would protect Marion from flooding if the lake continues to rise and is comparatively cheaper, but does not provide resolution to the issues caused by a high water table and lake levels. However, if the wet weather cycle ends these issues may be resolved naturally. The SWC does not recommend one alternative over another as these options are presented for local government pursue or investigate further.

Alternative	Description	Capital Costs	20 Year Operational and Maintenance Costs	Total Costs
1	Gravity Outlet at El 1451	$680,000	$30,000	$710,000
2	Pump Outlet at El 1451	$470,000	$210,000	$620,000
3	Gravity Outlet at El 1455	$560,000	$70,000	$640,000*
4	No Outlet	$10,000	$180,000	$190,000*

*Does not include cost of raising Southwest Road.

Table 5: Summary of Alternative Costs

It is recommended that local government develop a contingency plan to protect residents from inundation in the event the lake rises before a solution is implemented. This contingency plan would identify resources that would construct the protective dike(s). How quickly the lake is rising is still unknown since the lake has not been gauged. It is recommended that the City begin monitoring lake levels and pumping station discharges to gain a better understanding on how the lake responds to rain and snowmelt events as well as seepage and ET losses. These measurements will help assess how quickly the lake is rising, aid in the decision-making process, and design of a solution.

It is also recommended that Marion residents living in the northern section of town or other low-lying areas investigate if flood insurance is applicable for their specific situation. Flood insurance could provide financial protection if lake levels continue to rise and flooding eventually occurs.

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Appendix A – Agreement

SWC Project #1285
Project Manager: MWeier
September 2011

Agreement for Cost Participation
to Conduct Study in LaMoure County

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 closed basin system surrounding Boom Lake, also known as Marion Lake, located in LaMoure County, and identify potential outlets that could be constructed to mitigate issues related to high lake levels (Project).

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

   a. Examine hydrology of the closed basin.

   b. Evaluate potential outlet configurations or other measures that could be implemented to mitigate issues related to high lake and groundwater levels.

   c. 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 $830 to Commission.

5. **TERM.** This agreement becomes effective upon signing by both parties and shall terminate on June 30, 2013.

6. **INDEMNIFICATION.** Commission and District each agree to assume their own liability for any and all claims of any nature, including all costs, expenses, and attorneys' fees that may in any manner result from or arise out of this agreement.

7. **INSURANCE.** District 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 $1,000,000 per occurrence.

8. 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 expended by Commission to District for Project and relieves Commission of all obligations under this agreement.

9. AGREEMENT BECOMES VOID. This agreement is void if not signed and returned by District within 60 dates of Commission's signature

10. FORCE MAJEURE. Commission will not be held responsible for delay or default caused by fire, riot, acts of God, or war.

11. 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.

12. 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.

13. 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.

14. 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.

15. 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: 9/22/11

LAMOURE COUNTY WATER RESOURCE DISTRICT
By: Kerry Ketterling

KERRY KETTERLING
Chairman

Date: Oct 3 /11

Appendix B – Survey Data (electronic only)

Appendix C – Drillers Logs (electronic only)

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

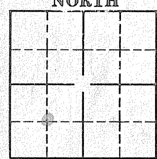
Name: City of Marion

Address: Marion, N. Dak.

2. WELL LOCATION

Sketch map location must agree with written location.

NORTH



1 Mile

County: LaMoure

___ ¼ ___ ¼ ___ ¼ Sec. 10 Twp. 136 N. Rg. 61 W.

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Industrial
☐ Stock ☒ Municipal ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Other

If other, specify ___

5. WATER QUALITY

Was a water sample collected for chemical analysis?
☒ Yes ☐ No

If so, to what laboratory was it sent: State Lab.

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 50 feet.

Casing: ☒ Steel ☐ Plastic ☐ Concrete
☒ Threaded ☐ Welded ☐ Other

If other, specify ___

Pipe Weight: Diameter: From: 0 To: 40

Pipe Weight	Diameter	From	To
25 lb/ft.	8 inches	0 feet	40 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No

Length of pipe perforated ___ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material: Stainless Diameter 8 PS inches
(stainless steel, bronze, etc.)

Slot size	set from	feet to	feet
35	40	50	

Was a packer or seal used? ☐ Yes ☒ No

If so, what material ___

Type of well: Straight screen ☒ Gravel packed ☐

Was the well grouted? Yes ☒ No ☐

To what depth? 18 + feet

Material used in grouting: Cement

Well head completion: Pitless adapter ___

12" above grade ___ Other ___

If other, specify ___

Was well disinfected upon completion? ☒ Yes ☐ No

7. WATER LEVEL

Static water level 6 feet below land surface

If flowing: closed-in pressure ___ psi

GPM flow ___ through ___ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ___

8. WELL TEST DATA

☒ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

18 ft. after 19 hrs. pumping 155 gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
Buff till	0	16
grey till	16	19
coarse sand + gravel	19	52
till	52	60

(Use separate sheet if necessary.)

10. DATE COMPLETED 4-7-73

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ___

12. REMARKS:

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Mann Drilling Co. — 3
Driller's or Firm's Name — Certificate No.

Garrison, N. Dak.
Address

Larry Mann — 4-7-73
Signed by — Date

DUPLICATE — BOARD'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name: City of Marion

Address: Marion, N.D.

2. WELL LOCATION

Sketch map location must agree with written location.

NORTH

1 Mile

Sec. [1 Mile] ______

County: Lamoure

___ ¼ ___ ¼ ___ ¼ Sec. 10 Twp. 136 N. Rg. 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☒ Municipal ☐ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☒ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☐ Auger

If other, specify ______

5. WATER QUALITY

Was a water sample collected for:

Chemical Analysis? ☒ Yes ☐ No

Bacteriological Analysis? ☒ Yes ☐ No

If so, to what laboratory was it sent: N.D. LAB

6. WELL CONSTRUCTION

Diameter of hole 10 inches. Depth 50 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☒ Welded ☐ Other

If other, specify ______

Pipe Weight:	Diameter:	From:	To:
___ lb/ft.	6 inches	0 feet	33 feet
___ lb/ft.	___ inches	___ feet	___ feet
___ lb/ft.	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ___ ft to ___ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 5 inches (stainless steel, bronze, etc.)

Slot size #40 set from 33 feet to 48 feet

Slot size ___ set from ___ feet to ___ feet

Was a packer or seal used? ☐ Yes ☒ No

If so, what material ______ Depth ______ Ft.

Type of well: Straight screen ☒ Gravel packed ☐

Depth grouted: From 30 To 10

Grouting Material: Cement ✓ Other ______

If other explain: Cement / volclay grout

Well head completion: Pitless unit ✓

12" above grade ✓ Other ______

If other, specify ______

Was pump installed: ☒ Yes ☐ No

Was well disinfected upon completion? ☒ Yes ☐ No

7. WATER LEVEL

Static water level 8 feet below land surface

If flowing: closed-in pressure ___ psi

GPM flow ___ through ___ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ______

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

12 ft. after 8 hrs. pumping 75 gpm

___ ft. after ___ hrs. pumping ___ gpm

___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Topsoil-2'-Till to		
stiff clay	0	17½
gray till - stiff	17½	21
Silty - sand clay mix	21	25
fine to med sand -	25	49
mixed gravel -		

(Use separate sheet if necessary.)

10. DATE COMPLETED 1 FEB 1991

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ______

12. REMARKS:

replacement well - old well is collapsing - City will keep for emergency stand by - / BACK-up

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Smith Inc — 109

Driller's or Firm's Name — Certificate No.

1740 E Main Ave W F90

Address

Stu Scandel — 1-FEB-91

Signed by — Date

WHITE—DRILLER'S COPY YELLOW—BOARD'S COPY PINK—CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

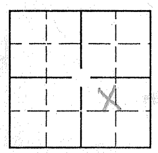
WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER
Name ND State Dept. of Health & Consolidated labs
Address Bismark, ND

2. WELL LOCATION
Sketch map location must agree with written location.

NORTH



1 MILE
Sec. (1 mile)

County Lamoure
SE 1/4 NW 1/4 SE 1/4 Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE
☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal [✓ Monitoring] ☐ Industrial ☐ Test Hole

4. METHOD DRILLED
☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored [✓ Auger]
If other, specify HSA

5. WATER QUALITY
Was a water sample collected for:
Chemcial Analysis? [✓ Yes] ☐ No
Bacteriological Analysis? ☐ Yes [✓ No]
If so, to what laboratory was it sent? ECS, Inc.

6. WELL CONSTRUCTION
Diameter of hole 7 5/8 inches. Depth 30 feet.
Casing: ☐ Steel [✓ Plastic] ☐ Concrete ☐ Threaded ☐ Welded ☐ Other
If other, specify

Pipe Weight:	Diameter:	From:	To:
___ lb/ft	2 inches	0 feet	-15 feet
___ lb/ft	___ inches	___ feet	___ feet
___ lb/ft	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes [✓ No]
Perforated pipe set from ___ ft to ___ feet
Was casing left open end? ☐ Yes [✓ No]
Was a well screened installed? [✓ Yes] ☐ No
Material PVC Diameter 2 inches
Slot Size #10 set from -15 feet to -30 feet
Slot Size ___ set from ___ feet to ___ feet
Was packer or seal used? ☐ Yes [✓ No]
If so, what material ___ Depth ___ ft.
(stainless steel, bronze, etc.)
Type of well: Straight screen [✓] Gravel packed [✓]
Depth grouted: From 0 To 12'
Grouting Material: Cement X Other
If other explain:
Well head completion: Pitless unit
12" above grade ___ Other 8" flush mount
If other, specify
Was pump installed: ☐ Yes [✓ No]
Was well disinfected upon completion? ☐ Yes [✓ No]

7. WATER LEVEL
Static water level 15.0 feet below surface
If flowing: closed-in pressure ___ psi
GPM flow ___ through ___ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify

8. WELL TEST DATA
☐ Pump ☐ Bailer ☐ Other N/A
Pumping level below land surface:
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
asphalt	0	0.3
lean clay	0.3	11
Sand	11	30

(Use separate sheet if necessary)

10. DATE COMPLETED 6-2-93

11. WAS WELL PLUGGED OR ABANDONED?
☐ Yes [✓ No]
If so, how

12. REMARKS:
Well ID MW-1
TCT #5300 93-124

13. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.
Twin City Testing Corp. 404
Driller's or Firm's Name Certificate No
2105 7th Ave N, Fargo, ND
Address
[illegible] 6-24-93
Signed by Date

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

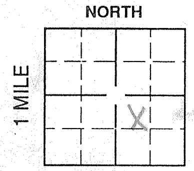
WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER
Name: ND State Dept. of Health & Consolidated labs
Address: Bismarck, ND

2. WELL LOCATION
Sketch map location must agree with written location.

NORTH



Sec. (1 mile)
County: Lamoure
SE 1/4 NW 1/4 SE 1/4 Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE
☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED
☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger
If other, specify: HSA

5. WATER QUALITY
Was a water sample collected for:
Chemcial Analysis? ☒ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☒ No
If so, to what laboratory was it sent? ECS, Inc.

6. WELL CONSTRUCTION
Diameter of hole 7 5/8 inches. Depth 30 feet.
Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☐ Other
If other, specify ____

Pipe Weight:	Diameter:	From:	To:
____ lb/ft	2 inches	0 feet	12 feet
____ lb/ft	____ inches	____ feet	____ feet
____ lb/ft	____ inches	____ feet	____ feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ____ ft to ____ feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
Slot Size #10 set from 15 feet to 30 feet
Slot Size ____ set from ____ feet to ____ feet
Was packer or seal used? ☐ Yes ☒ No
If so, what material ____ Depth ____ ft.
(stainless steel, bronze, etc.)
Type of well: Straight screen ☒ Gravel packed ☒
Depth grouted: From 0 To 12
Grouting Material: Cement X Other ____
If other explain: ____
Well head completion: Pitless unit ____
12" above grade ____ Other 8" flush mount
If other, specify ____
Was pump installed: ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL
Static water level 16.0 feet below surface
If flowing: closed-in pressure ____ psi
GPM flow ____ through ____ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify ____

8. WELL TEST DATA
☐ Pump ☐ Bailer ☐ Other N/A
Pumping level below land surface:
____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
lean clay	0	15
Sand	15	30

(Use separate sheet if necessary)

10. DATE COMPLETED 6-2-93

11. WAS WELL PLUGGED OR ABANDONED?
☐ Yes ☒ No
If so, how ____

12. REMARKS:
Well ID MW-2
TCT # 5300 93-124

13. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Twin City Testing Corp. — 404
Driller's or Firm's Name — Certificate No
2105 7th Ave N, Fargo, ND
Address
Terry John — 6-24-93
Signed by — Date

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name: ND State Dept of Health & consolidated labs

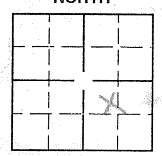
Address: Bismarck, ND

2. WELL LOCATION

Sketch map location must agree with written location.

NORTH

1 MILE



Sec. (1 mile)

County: Lamoure

SE 1/4 NW 1/4 SE 1/4 Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE

- ☐ Domestic
- ☐ Stock
- ☐ Geothermal
- ☐ Irrigation
- ☐ Municipal
- ☒ Monitoring
- ☐ Industrial
- ☐ Test Hole

4. METHOD DRILLED

- ☐ Cable
- ☐ Forward Rotary
- ☐ Reverse Rotary
- ☐ Jetted
- ☐ Bored
- ☒ Auger

If other, specify: HSA

5. WATER QUALITY

Was a water sample collected for:

Chemcial Analysis? ☒ Yes ☐ No

Bacteriological Analysis? ☐ Yes ☒ No

If so, to what laboratory was it sent? ECS, Inc.

6. WELL CONSTRUCTION

Diameter of hole 7 5/8 inches. Depth 30 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☐ Other

If other, specify ______

Pipe Weight:	Diameter:	From:	To:
____ lb/ft	~~2~~ inches	~~-15~~ feet	~~-30~~ feet
____ lb/ft	2 inches	0 feet	-15 feet
____ lb/ft	____ inches	____ feet	____ feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ______ ft to ______ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material: PVC Diameter: 2 inches

Slot Size ~~#10~~ set from ~~-50~~ feet to ~~-15~~ feet

Slot Size #10 set from -15 feet to -30 feet

Was packer or seal used? ☐ Yes ☒ No

If so, what material ______ Depth ______ ft.

(stainless steel, bronze, etc.)

Type of well: Straight screen ☒ Gravel packed ☒

Depth grouted: From 0 To 12

Grouting Material: Cement X Other ~~8" flush mount~~

If other explain: ______

Well head completion: Pitless unit ______

12" above grade ______ Other 8" flush mount

If other, specify ______

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level 16.0 feet below surface

If flowing: closed-in pressure ______ psi

GPM flow ______ through ______ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ______

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other N/A

Pumping level below land surface:

____ ft. after ____ hrs. pumping ____ gpm

____ ft. after ____ hrs. pumping ____ gpm

____ ft. after ____ hrs. pumping ____ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
asphalt	0	0.3
Fill - gravel	0.3	2
lean clay	2	15
sand	15	30

(Use separate sheet if necessary)

10. DATE COMPLETED 6-2-93

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ______

12. REMARKS:

Well ID MW-3

TCT# 5300 93-124

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Twin City Testing Corp — 404

Driller's or Firm's Name — Certificate No

2105 7th Ave N, Fargo, ND

Address

[signature] — 6-24-93

Signed by — Date

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

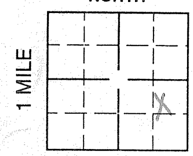
WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER
Name: ND State Dept. of Health & Consolidated labs
Address: Bismarck, ND

2. WELL LOCATION
Sketch map location must agree with written location.

NORTH



Sec. (1 mile)

County: Lamoure

SW 1/4 NE 1/4 SE 1/4 Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE
☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED
☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger
If other, specify: HSA

5. WATER QUALITY
Was a water sample collected for:
Chemcial Analysis? ☒ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☒ No
If so, to what laboratory was it sent? ECS, Inc.

6. WELL CONSTRUCTION
Diameter of hole 7 5/8 inches. Depth 30 feet.
Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☐ Other
If other, specify

Pipe Weight:	Diameter:	From:	To:
___ lb/ft	2 inches	0 feet	15 feet
___ lb/ft	___ inches	___ feet	___ feet
___ lb/ft	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ___ ft to ___ feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
Slot Size #10 set from 15 feet to 30 feet
Slot Size ___ set from ___ feet to ___ feet
Was packer or seal used? ☐ Yes ☒ No
If so, what material ___ Depth ___ ft.
(stainless steel, bronze, etc.)
Type of well: Straight screen ☒ Gravel packed ☒
Depth grouted: From 0 To 12'
Grouting Material: Cement X Other
If other explain:
Well head completion: Pitless unit
12" above grade ___ Other 8" flush mount
If other, specify
Was pump installed: ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL
Static water level 14.0 feet below surface
If flowing: closed-in pressure ___ psi
GPM flow ___ through ___ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify

8. WELL TEST DATA
☐ Pump ☐ Bailer ☐ Other N/A
Pumping level below land surface:
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
asphalt	0	0.3
Sand	0.3	10.0
sandy lean clay	10.0	20.0
Fat clay	20.0	30.0

(Use separate sheet if necessary)

10. DATE COMPLETED 6-2-93

11. WAS WELL PLUGGED OR ABANDONED?
☐ Yes ☒ No
If so, how

12. REMARKS:
Well ID MW-4
TCT #5300 93-104

13. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.
Twin City Testing Corp — 404
Driller's or Firm's Name — Certificate No.
2105 7th Ave N, Fargo, ND
Address
[signature] — 6-24-93
Signed by — Date

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

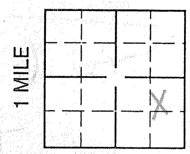
State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER
Name: ND State Dept. of Health & Consolidated labs

Address: Bismarck ND

2. WELL LOCATION
Sketch map location must agree with written location.

NORTH



Sec. (1 mile)

County: Lamoure

SW 1/4 NE 1/4 SE 1/4 Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE
- ☐ Domestic
- ☐ Stock
- ☐ Geothermal
- ☐ Irrigation
- ☐ Municipal
- ☒ Monitoring
- ☐ Industrial
- ☐ Test Hole

4. METHOD DRILLED
- ☐ Cable
- ☐ Forward Rotary
- ☐ Reverse Rotary
- ☐ Jetted
- ☐ Bored
- ☒ Auger

If other, specify: HSA

5. WATER QUALITY
Was a water sample collected for:
Chemcial Analysis? ☒ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☒ No
If so, to what laboratory was it sent? ECS, Inc.

6. WELL CONSTRUCTION
Diameter of hole 7 5/8 inches. Depth 30 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☐ Other

If other, specify ______

Pipe Weight:	Diameter:	From:	To:
___ lb/ft	2 inches	0 feet	-15 feet
___ lb/ft	___ inches	___ feet	___ feet
___ lb/ft	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ______ ft to ______ feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
Slot Size #10 set from -15 feet to -30 feet
Slot Size ______ set from ______ feet to ______ feet
Was packer or seal used? ☐ Yes ☒ No
If so, what material ______ Depth ______ ft.
(stainless steel, bronze, etc.)
Type of well: Straight screen ☒ Gravel packed ☒
Depth grouted: From 0 To 12
Grouting Material: Cement X Other ______
If other explain: ______
Well head completion: Pitless unit ______
12" above grade ______ Other 8" flush mount
If other, specify ______
Was pump installed: ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL
Static water level 13.5 feet below surface
If flowing: closed-in pressure ______ psi
GPM flow ______ through ______ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify ______

8. WELL TEST DATA
☐ Pump ☐ Bailer ☐ Other N/A
Pumping level below land surface:
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
asphalt	0	0.3
Sand	0.3	10.0
Sandy lean clay	10.0	15.0
fat clay	15.0	30.0

(Use separate sheet if necessary)

10. DATE COMPLETED 6-2-93

11. WAS WELL PLUGGED OR ABANDONED?
☐ Yes ☒ No
If so, how ______

12. REMARKS:
Well ID MW-5
TCT #5300 93-104

13. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Twin City Testing Corp 404
Driller's or Firm's Name Certificate No.

2105 7th Ave N, Fargo, ND
Address

[signature] 6-24-93
Signed by Date

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

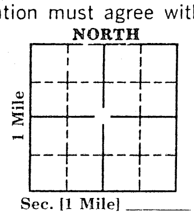
Name: ESE @ Randy's Repair

Address: Marion, ND

2. WELL LOCATION

Sketch map location must agree with written location.

SB-2A, MW-1,
136-61-10DAC



County: Lamoure

SW ¼ NE ¼ SE ¼ Sec 10 Twp. 136 N. Rg. 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify ______

5. WATER QUALITY

Was a water sample collected for:

Chemical Analysis? ☐ Yes ☐ No

Bacteriological Analysis? ☐ Yes ☐ No

If so, to what laboratory was it sent ______

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 30 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify stainless steel screws, no solvent

Pipe Weight:	Diameter:	From:	To:
SDR-21 ~~lb/ft.~~	2 inches	-0.2 feet	15 feet
___ lb/ft.	___ inches	___ feet	___ feet
___ lb/ft.	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ______ ft to ______ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)

Slot size 10 set from 15 feet to 30 feet

Slot size ______ set from ______ feet to ______ feet

Was a packer or seal used? ☐ Yes ☒ No

If so, what material ______ Depth ______ Ft.

Type of well: Straight screen ☒ Gravel packed ☒

Depth grouted: From 12 To 2

Grouting Material: Cement ______ Other X

If other explain: bentonite chips

Well head completion: Pitless unit ______

12" above grade ______ Other X

If other, specify flushmount 12" enclosure

Was pump installed? ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level 16.6 feet below land surface

If flowing: closed-in pressure ______ psi

GPM flow ______ through ______ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ______

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

______ ft. after ______ hrs. pumping ______ gpm

______ ft. after ______ hrs. pumping ______ gpm

______ ft. after ______ hrs. pumping ______ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Gravel, silty to sandy, medium brown, Fill	0	1
Silt, clayey to sandy, dark brown, abt 20% clay, topsoil	1	3
Clay, silty to pebbly, medium brown, Till	3	5
Clay, silty to pebbly, brownish grey, Till, slight odor	5	11.5
Clay, silty to cobbly, brownish gray, Till, slight odor	11.5	19
Sand, fine to coarse, silty w/ gravel, bluish gray, wet, odor	19	22
Clay, silty to gravely, bluish grey, Till, slight odor	22	24
Sand, fine to coarse, abt 40% gravel, medium brown	24	26
Sand, fine to coarse, silty w/abt 10% gravel, bluish gray	26	28
Sand, fine to coarse, abt 40% gravel, bluish gray	28	30

(Use separate sheet if necessary.)

10. DATE COMPLETED 8/7/91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ______

12. REMARKS:

Natural pack to 17.5 feet
320# of #20-40 silica sand to 12 feet
240# of medium bentonite chips to 2 feet
80# quikrete & 12" flushmount to surface

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply Inc. — Certificate No. 96
Driller's or Firm's Name

Address: Box 1191 - Bismarck, ND 58502

Signed by Paul E. Reed — Date 8/7/91

WHITE—DRILLER'S COPY YELLOW—BOARD'S COPY PINK—CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

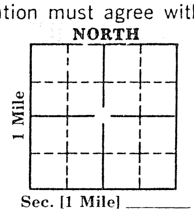
Name: ESE @ Randy's Repair

Address: Marion, ND

2. WELL LOCATION

Sketch map location must agree with written location.

SB-6, MW-2,
136-61-10DAC



County: Lamoure

SW ¼ NE ¼ SE ¼ Sec. 10 Twp. 136 N. Rg. 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify ______

5. WATER QUALITY

Was a water sample collected for:
Chemical Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent ______

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 33 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify: stainless steel screws, no solvent

Pipe Weight	Diameter	From	To
SDR-21 lb/ft.	2 inches	-0.1 feet	15 feet
___ lb/ft.	___ inches	___ feet	___ feet
___ lb/ft.	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ______ ft to ______ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)

Slot size 10 set from 13 feet to 33 feet

Slot size ______ set from ______ feet to ______ feet

Was a packer or seal used? ☐ Yes ☒ No

If so, what material ______ Depth ______ Ft.

Type of well: Straight screen ☒ Gravel packed ☒

Depth grouted: From 11 To 1.5

Grouting Material: Cement ______ Other X

If other explain: bentonite chips

Well head completion: Pitless unit ______

12" above grade ______ Other X

If other, specify: flushmount 12" enclosure

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level ______ feet below land surface

If flowing: closed-in pressure ______ psi

GPM flow ______ through ______ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ______

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Gravel & asphalt	0	0.5
Silt, sandy w/pebbles, dark brown, Topsoil	0.5	1
Clay, silty to cobbly, w/ concrete, medium brownish gray, Fill	1	7
Clay, silty to pebbly, medium brown, Till	7	11.5
Same as above w/slight odor	11.5	18
Rocks	18	18.5
Sand, fine to medium gravel, bluish gray	18.5	26
Clay, silty to pebbly, bluish grey, Till	26	27
Sand, silty to gravely	27	29
Silt, about 10% clay to medium gravel, bluish gray	29	31.5
Clay, silty to gravely, bluish gray, Till	31.5	33
Splitspoon samples: 5 to 5.2 feet		
10 to 11.5 feet		
15 to 16.5 feet		

(Use separate sheet if necessary.)

10. DATE COMPLETED 8/8/91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ______

12. REMARKS:

Natural pack to 18 feet
320# of #20-40 silica sand to 11 feet
240# of medium bentonite chips to 1.5 feet
80# quikrete & 12" flushmount to surface

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply Inc. — Certificate No. 96
Driller's or Firm's Name

Address: Box 1191 - Bismarck, ND 58502

Signed by Paul E. Reed — Date 8/8/91

WHITE—DRILLER'S COPY YELLOW—BOARD'S COPY PINK—CUSTOMER'S COPY

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

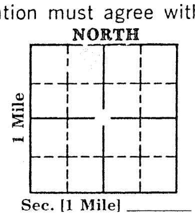
Name: ESE @ Randy's Repair

Address: Marion, ND

2. WELL LOCATION

Sketch map location must agree with written location.

SB-7, MW-3,
136-61-10DAC



County: Lamoure

SW ¼ NE ¼ SE ¼ Sec. 10 Twp. 136 N. Rg. 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify ____

5. WATER QUALITY

Was a water sample collected for:

Chemical Analysis? ☐ Yes ☐ No

Bacteriological Analysis? ☐ Yes ☐ No

If so, to what laboratory was it sent ____

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 33 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify stainless steel screws, no solvent

Pipe Weight:	Diameter:	From:	To:
SDR-21 ~~lbs~~/ft.	2 inches	-0.1 feet	13 feet
____ lb/ft.	____ inches	____ feet	____ feet
____ lb/ft.	____ inches	____ feet	____ feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ____ ft to ____ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)

Slot size 10 set from 13 feet to 33 feet

Slot size ____ set from ____ feet to ____ feet

Was a packer or seal used? ☐ Yes ☒ No

If so, what material ____ Depth ____ Ft.

Type of well: Straight screen ☒ Gravel packed ☒

Depth grouted: From 10.5 To 1.5

Grouting Material: Cement ____ Other X

If other explain: bentonite chips

Well head completion: Pitless unit ____

12" above grade ____ Other X

If other, specify flushmount 12" enclosure

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level ____ feet below land surface

If flowing: closed-in pressure ____ psi

GPM flow ____ through ____ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ____

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

____ ft. after ____ hrs. pumping ____ gpm

____ ft. after ____ hrs. pumping ____ gpm

____ ft. after ____ hrs. pumping ____ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
Asphalt & gravel	0	0.5
Sand, fine to coarse, reddish brown, Fill	0.5	1.5
Silt, sandy, abt 10% clay, w/ pebbles, dark brown, Topsoil/ Till, odor	1.5	2.5
Silt, sandy, abt 30% clay, medium brown, Till	2.5	4
Clay, silty to pebbly, medium brown, Till	4	11.5
Same as above w/cobbles	11.5	18
Sand, silty, w/silt stringers, medium brown	18	22
Sand, fine to coarse, w/40% fine to medium gravel, bluish gray	22	25
Sand, fine to coarse, w/40% fine to coarse gravel & cobbles	25	28
Clay, silty, abt 20% sand, blue	28	30
Clay, silty to sandy w/pebbles bluish gray, Till	30	33
Splitspoon samples: 5 to 6.5 feet		
10 to 11.5 feet		
15 to 16.5 feet		

(Use separate sheet if necessary.)

10. DATE COMPLETED 8/8/91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ____

12. REMARKS:

Natural pack to 20 feet
340# of #20-40 silica sand to 10.5 feet
225# of medium bentonite chips to 1.5 feet
80# quikrete & 12" flushmount to surface

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply Inc. — Certificate No. 96
Driller's or Firm's Name

Address: Box 1191 - Bismarck, ND 58502

Signed by Paul E. Reed (signature) — Date 8/8/91

WHITE—DRILLER'S COPY YELLOW—BOARD'S COPY PINK—CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER
Name: ESE @ LARRY'S AUTO SERVICE
Address: MARION, ND

2. WELL LOCATION
Sketch map location must agree with written location.

MW-4,
136-61-10DBD

NORTH
1 MILE
Sec. (1 mile)

County: LAMOURE

SE 1/4 NW 1/4 SE 1/4 Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE
☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED
☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify ____

5. WATER QUALITY
Was a water sample collected for:
Chemcial Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent? ____

6. WELL CONSTRUCTION
Diameter of hole 8 inches. Depth 25 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify: STAINLESS STEEL SCREWS, NO SOLVENT

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft	2 inches	-0.3 feet	9 feet
___ lb/ft	___ inches	___ feet	___ feet
___ lb/ft	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ____ ft to ____ feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
Slot Size 10 set from 9 feet to 22 feet
Slot Size ____ set from ____ feet to ____ feet
Was packer or seal used? ☐ Yes ☒ No
If so, what material ____ Depth ____ ft.
(stainless steel, bronze, etc.)
Type of well: Straight screen ☒ Gravel packed ☒
Depth grouted: From 7.5 To 1.5
Grouting Material: Cement ____ Other X
If other explain: BENTONITE CHIPS
Well head completion: Pitless unit ____
12" above grade ____ Other X
If other, specify FLUSHMOUNT 12" ENCLOSURE
Was pump installed: ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL
Static water level ____ feet below surface
If flowing: closed-in pressure ____ psi
GPM flow ____ through ____ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify ____

8. WELL TEST DATA
☐ Pump ☐ Bailer ☐ Other
Pumping level below land surface:
____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
ASPHALT	0	0.3
CLAY, SILTY TO SANDY W/COBBLES, MEDIUM BROWN	0.3	1
CLAY, SILTY TO SANDY, DARK BROWN	1	3
CLAY, SILTY TO SANDY W/PEBBLES, DARK BROWN	3	4
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN	4	5.5
COBBLES	5.5	5.8
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN, STRONG ODOR AND FREE PRODUCT, FROM 14 TO 14.5	5.8	15
SAND, SILTY, BLUISH GREY, W/ODOR	15	16
SAND, FINE TO COARSE, ABT 40% FINE GRAVEL	16	22
CLAY, SILTY TO SANDY W/PEBBLES, BLUISH GREY	22	25

(Use separate sheet if necessary)
SPLITSPOON SAMPLES 3 TO 4.5 FEET
8 TO 9.5 FEET
13 TO 14.5

10. DATE COMPLETED 5/17/94

11. WAS WELL PLUGGED OR ABANDONED?
☐ Yes ☒ No
If so, how ____

12. REMARKS:
NATURAL PACK TO 12', 80# OF #20-40 SILICA SAND TO 7.5', 150# OF MEDIUM BENTONITE CHIPS TO 1.5', AND QUIKRETE WITH 8" FLUSHMOUNT PC TO SURFACE.

13. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. — 96
Driller's or Firm's Name — Certificate No

Box 1191 - Bismarck, ND 58502
Address

[signature] 5/17/94
Signed by PAUL E. REED — Date

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER
Name ESE @ LARRY'S AUTO SERVICE
Address MARION, ND

2. WELL LOCATION
Sketch map location must agree with written location.
MW-5,
136-61-10DBD

NORTH
1 MILE
Sec. (1 mile) ____
County LAMOURE

SE ¼ NW ¼ SE ¼ Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE
☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED
☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger
If other, specify ____

5. WATER QUALITY
Was a water sample collected for:
Chemcial Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent? ____

6. WELL CONSTRUCTION
Diameter of hole 8 inches. Depth 25 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify STAINLESS STEEL SCREWS, NO SOLVENT

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft	2 inches	-0.3 feet	9.6 feet
____ lb/ft	____ inches	____ feet	____ feet
____ lb/ft	____ inches	____ feet	____ feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ____ ft to ____ feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
Slot Size 10 set from 9.6 feet to 22.6 feet
Slot Size ____ set from ____ feet to ____ feet
Was packer or seal used? ☐ Yes ☒ No
If so, what material ____ Depth ____ ft.
(stainless steel, bronze, etc.)
Type of well: Straight screen ☒ Gravel packed ☒
Depth grouted: From 7 To 1
Grouting Material: Cement ____ Other X
If other explain: BENTONITE CHIPS
Well head completion: Pitless unit ____
12" above grade ____ Other X
If other, specify FLUSHMOUTN 12" ENCLOSURE
Was pump installed? ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL
Static water level ____ feet below surface
If flowing: closed-in pressure ____ psi
GPM flow ____ through ____ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify ____

8. WELL TEST DATA
☐ Pump ☐ Bailer ☐ Other
Pumping level below land surface:
____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
ASPHALT	0	0.3
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN	0.3	1
CLAY, SILTY TO SANDY W/PEBBLES, DARK BROWN	1	4.5
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN	4.5	14.5
SAND, TO COARSE, ABT 40% FINE GRAVEO, REDDISH BROWN	14.5	22.5
CLAY, SILTY TO SANDY W/PEBBLES, BLUISH GREY	22.5	25
SPLITSPOON SAMPLES 3 TO 4.5 FEET		
8 TO 9.5 FEET		
13 TO 14.5 FEET		

(Use separate sheet if necessary)

10. DATE COMPLETED 5/16/94

11. WAS WELL PLUGGED OR ABANDONED?
☐ Yes ☒ No
If so, how ____

12. REMARKS:
NATURAL PACK TO 12', 160# OF #20-40 SILICA SAND TO 7', 150# OF MEDIUM BENTONITE CHIPS TO 1', AND QUIKRETE WITH 8" FLUSHMOUNT PC TO SURFACE.

13. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. — 96
Driller's or Firm's Name — Certificate No
Box 1191 - Bismarck, ND 58502
Address
[signature] 5/16/94
Signed by PAUL E. REED — Date

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name: ESE @ RANDY'S REPAIR

Address: MARION, ND

2. WELL LOCATION

Sketch map location must agree with written location.

MW-6,
136-61-10DAC

NORTH

1 MILE

Sec. (1 mile)

County: LAMOURE

SW ¼ NE ¼ SE ¼ Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify ______

5. WATER QUALITY

Was a water sample collected for:
Chemcial Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent? ______

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 26.5 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify STAINLESS STEEL SCREWS, NO SOLVENT

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft	2 inches	-0.3 feet	8.5 feet
___ lb/ft	___ inches	___ feet	___ feet
___ lb/ft	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ______ ft to ______ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches

Slot Size 10 set from 8.5 feet to 24.5 feet

Slot Size ______ set from ______ feet to ______ feet

Was packer or seal used? ☐ Yes ☒ No

If so, what material ______ Depth ______ ft.
(stainless steel, bronze, etc.)

Type of well: Straight screen ☒ Gravel packed ☒

Depth grouted: From 7 To 1.5

Grouting Material: Cement ______ Other X

If other explain: BENTONITE CHIPS

Well head completion: Pitless unit ______

12" above grade ______ Other X

If other, specify FLUSHMOUNT 12" ENCLOSURE

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level ______ feet below surface

If flowing: closed-in pressure ______ psi

GPM flow ______ through ______ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ______

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
SILT, CLAYEY TO SANDY, DARK BROWN, TOPSOIL	0	0.5
SAND, SILTY, W/PEBBLES, MEDIUM BROWN	0.5	1.5
CLAY, SILTY TO SANDY W/PEBBLES, DARK BROWN	1.5	4.5
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN	4.5	15.5
SAND, FINE, SILTY W/PEBBLES, MEDIUM BROWN	15.5	16
CLAY, SILTY TO SANDY W/ PEBBLES	16	17
ROCK, SANDSTONE?	17	18
SAND, FINE TO COARSE, ABT 30% FINE GRAVEL	18	23
SAND, FINE TO COARSE, ABT 40% GRAVEL TO COARSE	23	25.5
CLAY, SILTY TO SANDY W/PEBBLES, BLUISH GREY	25.5	26.5

(Use separate sheet if necessary)

SPLITSPOON SAMPLES: 3 TO 4.5 FEET
8 TO 9.5 FEET
13 TO 14.5 FEET

10. DATE COMPLETED 5/17/94

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ______

12. REMARKS:

NATURAL PACK TO 14.5', 240# OF #20-40 SILICA SAND TO 7', 150# OF MEDIUM BENTONITE CHIPS TO 1.5', AND QUIKRETE WITH 8" FLUSHMOUNT PC TO SURFACE.

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. — Driller's or Firm's Name
96 — Certificate No

Box 1191 - Bismarck, ND 58502 — Address

Paul E. Reed — Signed by PAUL E. REED
5/17/94 — Date

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name ESE @ RANDY'S REPAIR

Address MARION, ND

2. WELL LOCATION

Sketch map location must agree with written location.

MW-7
136-61-10DAB

NORTH / 1 MILE / Sec. (1 mile)

County LAMOURE

NW 1/4 NE 1/4 SE 1/4 Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemcial Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent?

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 23 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify STAINLESS STEEL SCREWS

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft	2 inches	-0.2 feet	5 feet
lb/ft	inches	feet	feet
lb/ft	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ___ ft to ___ feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
Slot Size 10 set from 5 feet to 20 feet
Slot Size ___ set from ___ feet to ___ feet
Was packer or seal used? ☐ Yes ☒ No
If so, what material ___ Depth ___ ft.
(stainless steel, bronze, etc.)
Type of well: Straight screen ☒ Gravel packed ☒
Depth grouted: From 3 To 1
Grouting Material: Cement ___ Other X
If other explain: BENTONITE CHIPS
Well head completion: Pitless unit ___
12" above grade ___ Other X
If other, specify FLUSHMOUNT 8" ENCLOSURE
Was pump installed: ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level ___ feet below surface
If flowing: closed-in pressure ___ psi
GPM flow ___ through ___ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
SAND & GRAVEL, MEDIUM BROWN, FILL	0	0.5
SILT, SANDY, DARK BROWN	0.5	1.5
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN, TILL	1.5	15
SANDSTONE?	15	15.2
SAND, TO COARSE, ABT 10% FINE GRAVEL, MEDIUM BROWN	15.2	19
SAND, SILTY, MEDIUM GRAY	19	20
SAND, TO COARSE, ABT 10% FINE GRAVEL, REDDISH BROWN	20	21
CLAY, SILTY TO SANDY, BLUISH GRAY	21	23
SPLITSPOON SAMPLES 9 TO	10.5 FEET	
10.5	TO 12 FEET	
12 TO	13.5 FEET	

(Use separate sheet if necessary)

10. DATE COMPLETED 11/11/94

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how

12. REMARKS:

NATURAL PACK TO 15', 400# OF #20-40 SILICA SAND TO 3', 50# OF MEDIUM BENTONITE CHIPS TO 1', AND QUIKRETE WITH 8" FLUSHMOUNT PC TO SURFACE.

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. — 96
Driller's or Firm's Name — Certificate No

Box 1191 - Bismarck, ND 58502
Address

Signed by PAUL E. REED — Date 11/11/94

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name: ESE @ LARRY'S AUTO SERVICE

Address: MARION, ND

2. WELL LOCATION

Sketch map location must agree with written location.

MW-8,
136-61-10DBD

NORTH / 1 MILE / Sec. (1 mile)

County: LAMOURE

SE 1/4 NW 1/4 SE 1/4 Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemcial Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent?

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 23 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify: STAINLESS STEEL SCREWS

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft	2 inches	-0.4 feet	5 feet
lb/ft	inches	feet	feet
lb/ft	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ___ ft to ___ feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
Slot Size 10 set from 5 feet to 15 feet
Slot Size ___ set from ___ feet to ___ feet
Was packer or seal used? ☐ Yes ☒ No
If so, what material ___ Depth ___ ft.
(stainless steel, bronze, etc.)
Type of well: Straight screen ☒ Gravel packed ☒
Depth grouted: From 3 To 1
Grouting Material: Cement ___ Other X
If other explain: BENTONITE CHIPS
Well head completion: Pitless unit ___
12" above grade ___ Other X
If other, specify: FLUSHMOUNT 8" ENCLOSURE
Was pump installed: ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level ___ feet below surface
If flowing: closed-in pressure ___ psi
GPM flow ___ through ___ inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	Depth (ft.) To
SAND & GRAVEL, MEDIUM BROWN	0	0.5
SILT, SANDY, DARK BROWN	0.5	1.5
SILT, SANDY, LIGHT GRAY	1.5	2
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN	2	9
CLAY, SILTY TO SANDY W/PEBBLES AND SAND STRINGERS, MEDIUM BROWN	9	16
SAND, TO COARSE, ABT 10% FINE GRAVEL, RED BROWN	16	23
SPLITSPOON SAMPLES 9 TO 10.5 FEET		

(Use separate sheet if necessary)

10. DATE COMPLETED 11/11/94

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how

12. REMARKS:

NATURAL PACK TO 15', 400# OF #20-40 SILICA SAND TO 3', 50# OF MEDIUM BENTONITE CHIPS TO 1', AND QUIKRETE WITH 8" FLUSHMOUNT PC TO SURFACE.

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. — Driller's or Firm's Name
96 — Certificate No.

Box 1191 - Bismarck, ND 58502 — Address

Signed by PAUL E. REED Date 11/11/94

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA
BOARD OF WATER WELL CONTRACTORS
900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name ESE @ LARRY'S AUTO SERVICE

Address MARION, ND

2. WELL LOCATION

Sketch map location must agree with written location.

MW-9,
136-61-10DBA

NORTH / 1 MILE / Sec. (1 mile)

County LAMOURE

NE ¼ NW ¼ SE ¼ Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemcial Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent?

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 23 feet.

Casing: ☐ Steel ☐ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify STAINLESS STEEL SCREWS

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft	2 inches	-0.4 feet	5 feet
lb/ft	inches	feet	feet
lb/ft	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ____ ft to ____ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches

Slot Size 10 set from 4 feet to 20 feet

Slot Size ____ set from ____ feet to ____ feet

Was packer or seal used? ☐ Yes ☒ No

If so, what material ____ Depth ____ ft.
(stainless steel, bronze, etc.)

Type of well: Straight screen ☒ Gravel packed ☒

Depth grouted: From 4 To 1

Grouting Material: Cement ____ Other X

If other explain: BENTONITE CHIPS

Well head completion: Pitless unit ____

12" above grade ____ Other X

If other, specify FLUSHMOUNT 8" ENCLOSURE

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level ____ feet below surface

If flowing: closed-in pressure ____ psi

GPM flow ____ through ____ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
ASPHALT	0	0.5
SAND TO COARSE W/GRAVEL, FILL	0.5	1
SILT, SANDY W/PEBBLES, DARK BROWN	1	2.5
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN, TILL	2.5	16.5
SAND, TO COARSE, ABT 10% GRAVEL TO MEDIUM, REDDISH BROWN	16.5	23
SPLITSPOON SAMPLES 9 TO 10.5 FEET		

(Use separate sheet if necessary)

10. DATE COMPLETED 11/11/94

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how

12. REMARKS:

NATURAL PACK TO 16.5;, 520# OF #20-40 SILICA SAND TO 4', 75# OF MEDIUM BENTONITE CHIPS TO 1', AND QUIKRETE WITH 8" FLUSHMOUNT PC TO SURFACE.

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply, Inc. — Driller's or Firm's Name
96 — Certificate No

Box 1191 -- Bismarck, ND 58502 — Address

Signed by PAUL E. REED (signature) Date 11/11/94

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name: ESE @ RANDY'S REPAIR

Address: MARION, ND

2. WELL LOCATION

Sketch map location must agree with written location.

MW-10,
136-61-10DBD

NORTH — 1 MILE — Sec. (1 mile)

County: LAMOURE

SE ¼ NW ¼ SE ¼ Sec. 10 Twp. 136 N.Rg 61 W.

3. PROPOSED USE

☐ Domestic ☐ Stock ☐ Geothermal ☐ Irrigation ☐ Municipal ☒ Monitoring ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ Auger

If other, specify ____

5. WATER QUALITY

Was a water sample collected for:
Chemcial Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent? ____

6. WELL CONSTRUCTION

Diameter of hole 8 inches. Depth 23 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete ☐ Threaded ☐ Welded ☒ Other

If other, specify STAINLESS STEEL SCREWS

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft	2 inches	-0.5 feet	5 feet
____ lb/ft	____ inches	____ feet	____ feet
____ lb/ft	____ inches	____ feet	____ feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ____ ft to ____ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches

Slot Size 10 set from 5 feet to 20 feet

Slot Size ____ set from ____ feet to ____ feet

Was packer or seal used? ☐ Yes ☒ No

If so, what material ____ Depth ____ ft.

(stainless steel, bronze, etc.)

Type of well: Straight screen ☐ Gravel packed ☒

Depth grouted: From 3 To 1

Grouting Material: Cement ____ Other X

If other explain: BENTONITE CHIPS

Well head completion: Pitless unit ____

12" above grade ____ Other X

If other, specify FLUSHMOUNT 8" ENCLOSURE

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level ____ feet below surface

If flowing: closed-in pressure ____ psi

GPM flow ____ through ____ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ____

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm
____ ft. after ____ hrs. pumping ____ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
SILT, SANDY W/PEBBLES, DARK BROWN	0	2
CLAY, SILTY TO SANDY W/PEBBLES, MEDIUM BROWN	2	15
SAND, TO COARSE, ABT 10% GRAVEL, RED BROWN	15	17
SAND, SILTY, MEDIUM BROWN	17	18
SAND, TO COARSE, ABT 10% GRAVEL, RED BROWN	18	23
SPLITSPOON SAMPLES 9 TO 10.5 FEET		

(Use separate sheet if necessary)

10. DATE COMPLETED 11/11/94

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ____

12. REMARKS:

NATURAL PACK TO 15.5', 440# OF #20-40 SILICA SAND TO 3', 50# OF MEDIUM BENTONITE CHIPS TO 1', AND QUIKRETE WITH 8" FLUSHMOUNT PC TO SURFACE.

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Driller's or Firm's Name: Water Supply, Inc. Certificate No: 96

Address: Box 1191 - Bismarck, ND 58502

Signed by: PAUL E REED Date: 11/11/94

WHITE-DRILLER'S COPY YELLOW-BOARD'S COPY PINK-CUSTOMER'S COPY

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

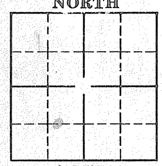
Name: City of Marion

Address: Marion, N. Dak.

2. WELL LOCATION

Sketch map location must agree with written location.

NORTH



1 Mile

County: LAMOURE

___ ¼ ___ ¼ ___ ¼ Sec. 10 Twp. 136 N. Rg. 61 W.

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Industrial
☐ Stock ☐ Municipal ☒ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Other

If other, specify ___

5. WATER QUALITY

Was a water sample collected for chemical analysis?
☐ Yes ☐ No

If so, to what laboratory was it sent ___

6. WELL CONSTRUCTION

Diameter of hole 5 inches. Depth ___ feet.

Casing: ☐ Steel ☐ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☐ Other

If other, specify NONE

Pipe Weight:	Diameter:	From:	To:
___ lb/ft.	___ inches	___ feet	___ feet
___ lb/ft.	___ inches	___ feet	___ feet
___ lb/ft.	___ inches	___ feet	___ feet
___ lb/ft.	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☐ No

Length of pipe perforated ___ feet

Was casing left open end? ☐ Yes ☐ No

Was a well screened installed? ☐ Yes ☐ No

Material ___ Diameter ___ inches
(stainless steel, bronze, etc.)

Slot size ___ set from ___ feet to ___ feet

Slot size ___ set from ___ feet to ___ feet

Slot size ___ set from ___ feet to ___ feet

Slot size ___ set from ___ feet to ___ feet

Was a packer or seal used? ☐ Yes ☐ No

If so, what material ___

Type of well: Straight screen ☐ Gravel packed ☐

Was the well grouted? Yes ☐ No ☐

To what depth? ___ feet

Material used in grouting ___

Well head completion: Pitless adapter ___

12" above grade ___ Other ___

If other, specify ___

Was well disinfected upon completion? ☐ Yes ☐ No

7. WATER LEVEL

Static water level ___ feet below land surface

If flowing: closed-in pressure ___ psi

GPM flow ___ through ___ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ___

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

___ ft. after ___ hrs. pumping ___ gpm

___ ft. after ___ hrs. pumping ___ gpm

___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
till	0	20
sand	20	22
till	22	46
shale	46	60

(Use separate sheet if necessary.)

10. DATE COMPLETED 3-29-73

11. WAS WELL PLUGGED OR ABANDONED?

☒ Yes ☐ No

If so, how ___

12. REMARKS:

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Mann Drilling Co. — Driller's or Firm's Name; 3 — Certificate No.

Lamoure, N. Dak. — Address

Signed by: Henry Mann — Date: 4-29-73

DUPLICATE — BOARD'S COPY

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

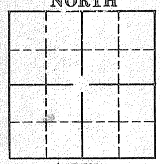
Name City of Marion

Address Marion, N. Dak.

2. WELL LOCATION

Sketch map location must agree with written location.

NORTH



1 Mile

100 ft. East of Well

County Ransom

___ ¼ ___ ¼ ___ ¼ Sec. 10 Twp. 136 N. Rg. 61 W.

3. PROPOSED USE obs. well

☐ Domestic ☐ Irrigation ☐ Industrial

☐ Stock ☐ Municipal ☒ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored

☒ Forward Rotary ☐ Jetted ☐ Other

If other, specify ___

5. WATER QUALITY

Was a water sample collected for chemical analysis?

☒ Yes ☐ No

If so, to what laboratory was it sent State Lab.

6. WELL CONSTRUCTION

Diameter of hole 2 inches. Depth 34 feet.

Casing: ☒ Steel ☐ Plastic ☐ Concrete

☐ Threaded ☐ Welded ☐ Other

If other, specify ___

Pipe Weight:	Diameter:	From:	To:
___ lb/ft.	2 inches	0 feet	41 feet
___ lb/ft.	___ inches	___ feet	___ feet
___ lb/ft.	___ inches	___ feet	___ feet
___ lb/ft.	___ inches	___ feet	___ feet

Was perforated pipe used? ☐ Yes ☒ No

Length of pipe perforated ___ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material armco Diameter 1¼ inches
(stainless steel, bronze, etc.)

Slot size 18 set from 41 feet to 44 feet

Slot size ___ set from ___ feet to ___ feet

Slot size ___ set from ___ feet to ___ feet

Slot size ___ set from ___ feet to ___ feet

Was a packer or seal used? ☐ Yes ☐ No

If so, what material ___

Type of well: Straight screen ☒ Gravel packed ☐

Was the well grouted? Yes ☐ No ☒

To what depth? ___ feet

Material used in grouting ___

Well head completion: Pitless adapter ___

12″ above grade ___ Other ___

If other, specify ___

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level 1½″ feet below land surface

If flowing: closed-in pressure ___ psi

GPM flow ___ through ___ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ___

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

15-2″ ft. after 19 hrs. pumping ___ gpm

___ ft. after ___ hrs. pumping ___ gpm

___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
fine sand	0	5
till	5	21
fine sand	21	22½
till	22½	25
sand	25	26
~~till~~ sand	26	37½
gravel	37½	47
silty clay	47	103
shale	103	120

(Use separate sheet if necessary.)

10. DATE COMPLETED 3-29-73

11. WAS WELL PLUGGED OR ABANDONED?

☒ Yes ☐ No

If so, how ___

12. REMARKS:

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Mann Drilling Co. 3

Driller's or Firm's Name Certificate No.

Garrison, N. Dak.

Address

Signed by Tony Mann 3-29-73 Date

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[NO Water Levels Available] [NO Water Chemistry Available]

136-061-04 DDD

Data Source	ND State Water Commission	Well Index	20675
County	LaMoure	Date Drilled	10/25/1974
Aquifer	No Obs Well Installed	Purpose	Test Hole
Basin	James River	Casing Type	None
MP Elevation (ft)	0.00	Diameter (in.)	0.0
Surface Elev. (ft)	0.00	Screened Interval (ft)	0 - 0
Elevation Source (Datum)	(NVGD29)	Coord (Long,Lat)	-98.34913, 46.61719
Total Depth (ft)	80.00	USGS ID	
Bedrock Depth (ft)	56.00		

Lithologic Log

Interval (ft)	Unit	Description
0 - 1	TOPSOIL	Silty loam, dusky yellow-brown
1 - 23	CLAY	Very silty, sandy, pebbly, dark yellow-brown, iron-stained, moderately plastic, tight, organic, few thin gravel and sand lenses (till)
23 - 30	SAND AND GRAVEL	Sand (80), gravel (20); partially oxidized above 25 ft., fine to very coarse, angular to rounded, silty; gravel, fine to coarse; sand, 70% quartz, 20% carbonate, 10% shale, igneous; gravel, 80% shale, 20% igneous, carbonates
30 - 56	CLAY	Silty, sandy, pebbly, dark gray, firm, dense, few thin gravel and sand lenses, moderately plastic (till)
56 - 80	SHALE	Siliceous, grayish black, non-calcareous, fractured upper zone; soft, plastic lower

North Dakota State Water Commission
900 EAST BOULEVARD AVE • BISMARCK, ND 58505-0850 • (701) 328-2750

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

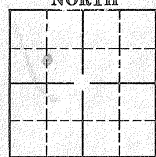
Name: City of Marion

Address: Marion, N. Dak.

2. WELL LOCATION

Sketch map location must agree with written location.

NORTH



1 Mile

County: Lamoure

___ ¼ ___ ¼ ___ ¼ Sec. 10 Twp. 136 N. Rg. 61 W.

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Industrial
☐ Stock ☐ Municipal ☒ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Other

If other, specify ______

5. WATER QUALITY

Was a water sample collected for chemical analysis?
☐ Yes ☒ No

If so, to what laboratory was it sent ______

6. WELL CONSTRUCTION

Diameter of hole 5 inches. Depth ______ feet.

Casing: ☐ Steel ☐ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☐ Other

If other, specify None

Pipe Weight:	Diameter:	From:	To:
______ lb/ft.	______ inches	______ feet	______ feet
______ lb/ft.	______ inches	______ feet	______ feet
______ lb/ft.	______ inches	______ feet	______ feet
______ lb/ft.	______ inches	______ feet	______ feet

Was perforated pipe used? ☐ Yes ☐ No

Length of pipe perforated ______ feet

Was casing left open end? ☐ Yes ☐ No

Was a well screened installed? ☐ Yes ☐ No

Material ______ Diameter ______ inches
(stainless steel, bronze, etc.)

Slot size ______ set from ______ feet to ______ feet
Slot size ______ set from ______ feet to ______ feet
Slot size ______ set from ______ feet to ______ feet
Slot size ______ set from ______ feet to ______ feet

Was a packer or seal used? ☐ Yes ☐ No

If so, what material ______

Type of well: Straight screen ☐ Gravel packed ☐

Was the well grouted? Yes ☐ No ☐

To what depth? ______ feet

Material used in grouting ______

Well head completion: Pitless adapter ______

12" above grade ______ Other ______

If other, specify ______

Was well disinfected upon completion? ☐ Yes ☐ No

7. WATER LEVEL

Static water level ______ feet below land surface

If flowing: closed-in pressure ______ psi

GPM flow ______ through ______ inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify ______

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

______ ft. after ______ hrs. pumping ______ gpm
______ ft. after ______ hrs. pumping ______ gpm
______ ft. after ______ hrs. pumping ______ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Topsoil	0	2
Coarse sand	2	15
Med. Sand	15	21
Coarse sand	21	26
silty clay	26	80

(Use separate sheet if necessary.)

10. DATE COMPLETED 3-29-72

11. WAS WELL PLUGGED OR ABANDONED?

☒ Yes ☐ No

If so, how ______

12. REMARKS:

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Mann Drilling Co. — 2

Driller's or Firm's Name — Certificate No.

Langdon, N. Dak.

Address

Larry Mann — 3-29-72

Signed by — Date

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Appendix D – Water Balance Calculation

Appendix D - Boom Lake Water Balance

Summary:

A water balance was calculated to estimate how the magnitude of pumping inflows to Boom Lake relative to other inflows and to compare to results predicted by the hydrologic model in **Appendix F**. To date Boom Lake was surveyed twice, once on 04/20/10 and once on 11/01/11. Assuming the lake level was balanced when it was surveyed on 04/20/10 the lake rose approximately 1.5 feet between those two dates. Using known and estimated quantities, inflows and outflows can be itemized to better understand the hydrology of the lake between those two measurements. Unfortunately only measurements of direct precipitation exist and all other parameters must be estimated. As a result, the water balance for Boom is a rough estimate.

Outflows:

Currently, lake does not have an outlet, so water can only exit through evapotranspiration (ET) and seepage. Jelmer Shjeflo of the USGS performed a study on prairie potholes in central North Dakota during the 1960s and performed a water balance on ten potholes (Shjeflo, 1968).

ET occurred during the warmest 6 month period each year and averaged roughly 2.24 ft for clear potholes (Shjeflo, 1968). This is assumed to be similar the ET occurring at Boom Lake. Approximately 4.5 ft of loss can be attributed to ET between the survey events.

Estimating seepage is less certain, as water levels in surrounding sloughs, suggest a through flow condition is occurring. Additionally, the removal of water with sump pumps may be depressing the water table and allowing for seepage. Shjeflo measured an average seepage of 0.6 ft during his study that occurs mainly during the non-winter months. A loss of 1 ft is assumed for Boom Lake between survey events.

Inflows:

Inflows to the lake consist of direct precipitation, snowmelt and snow runoff, rain runoff, and discharge from pumping stations.

Shjeflo found that direct precipitation was the largest contributing input. At the Marion North Dakota Agricultural Weather Network (NDAWN) weather station 3.0 ft of rainfall fell between the survey events.

Inflows from snowmelt and spring runoff and runoff from summer rainstorms are unknown. However, Shjeflow found that roughly 30% of the total inflow could be attributed to the spring melt (including snow that fell directly on the pothole and from snowmelt runoff) and 20% of the total inflow was from rainfall runoff. This is likely different for each basin, but for this estimate it is assumed that snowmelt inflows are roughly 50% greater than runoff inflows annually because the 2011 snowmelt event was estimated to roughly equate to a 50-year 10-day snowmelt event by National Operational Hydrologic Remote Sensing Center (NOHRSC) model estimates. Since there was only one snowmelt event and two runoff seasons, it is assumed runoff is roughly 30% greater than snowmelt between the surveyed events.

Inflows from pumping have been estimated at roughly 84 acre ft per year or 0.35 ft per year with the lake at elevation 1455 ft NAVD88 in **Appendix E**. Assuming the pumping occurs from March through October each year the inflows from pumping between the surveys are estimated to be 0.6 ft.

North Dakota State Water Commission

Project: Boom Lake Investigation

Project No.: 1285

Prepared By: M. Weier

Date:

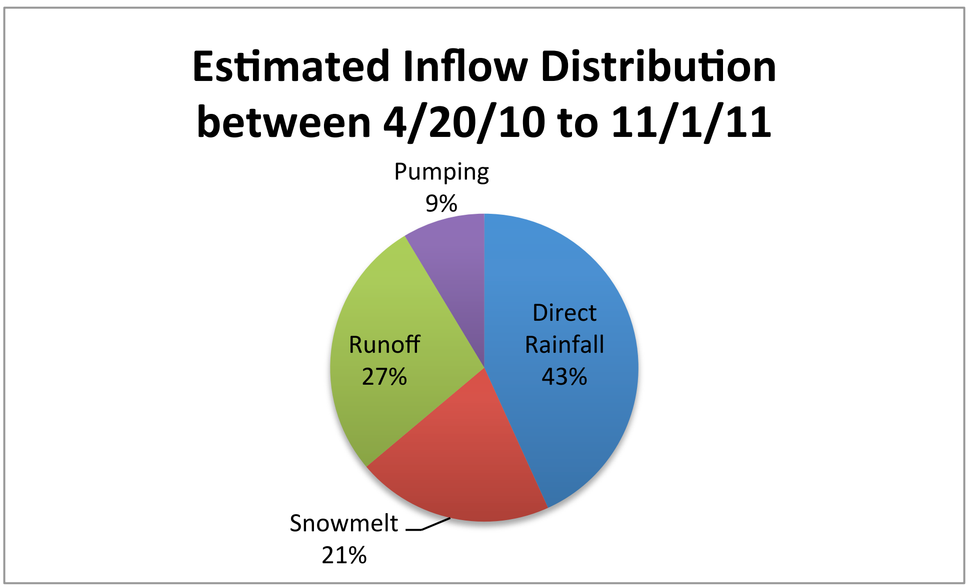
Checked By:

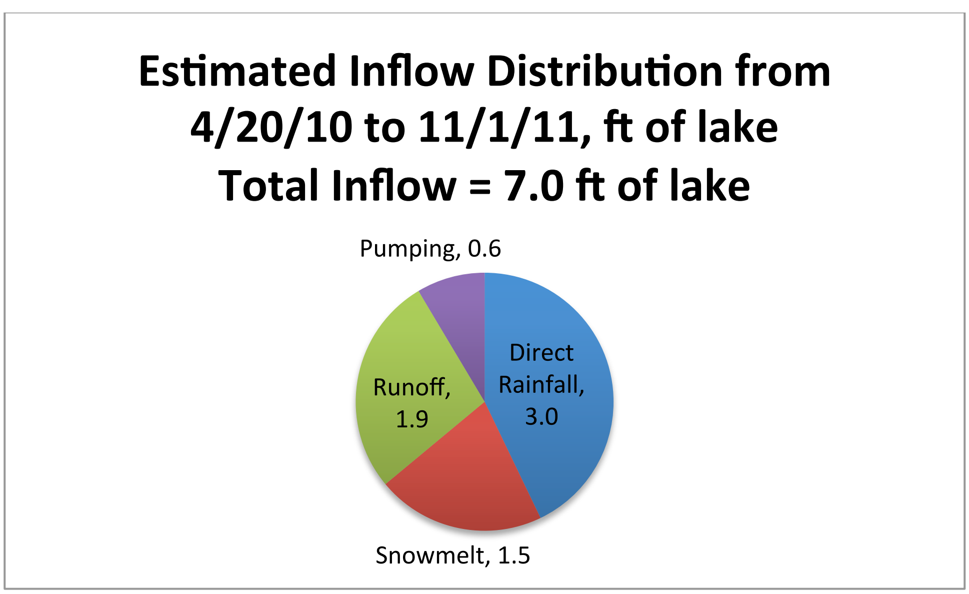
Date:

Balance:

$$Change\ in\ Lake\ Level = Inflows - Outflows$$
$$Change\ in\ Lake\ Level = Direct\ Precip + Snowmelt + Runoff + Pumping - ET - Seepage$$
$$1.5\ ft = 3.0ft + Snowmelt + Runoff + 0.6ft - 4.5ft - 1.0\ ft$$
$$3.4\ ft = Snowmelt + Runoff$$
$$Assume: 1.3 * Snowmelt = Runoff$$
$$3.4\ ft = Snowmelt + 1.3 * Snowmelt$$
$$3.4\ ft = 2.3 * Snowmelt$$
$$Snowmelt = 1.5ft$$
$$Runoff = 1.5\ ft * 1.3$$
$$Runoff = 1.9ft$$

Inflow Distribution:





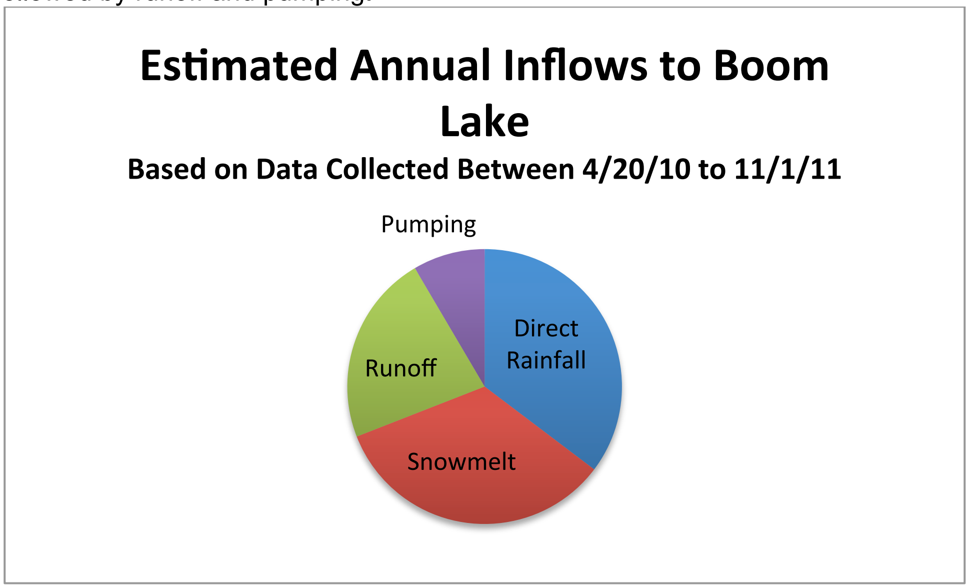
North Dakota State Water Commission

Project: Boom Lake Investigation
Project No.: 1285

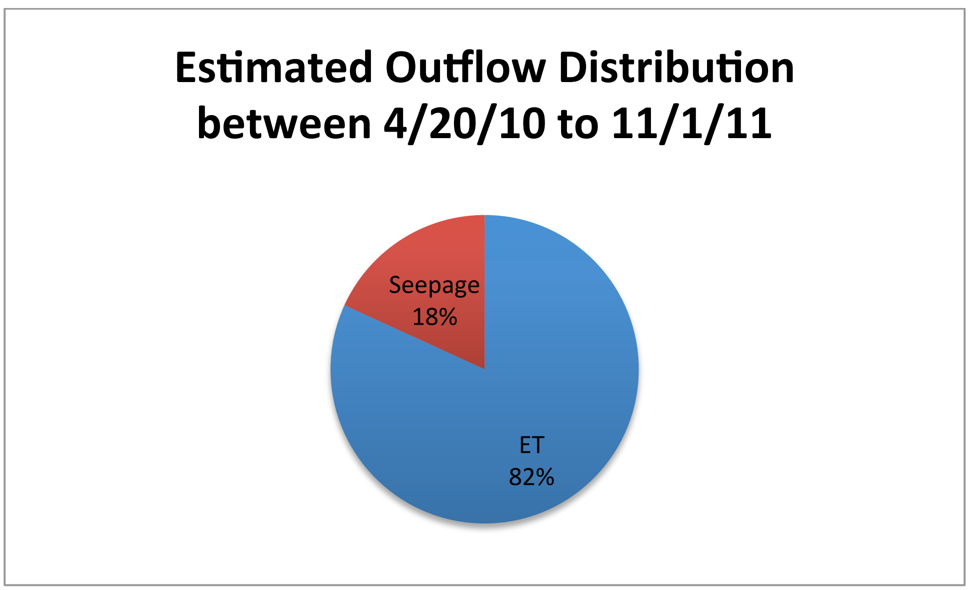
Prepared By: M. Weier
Date:
Checked By:
Date:

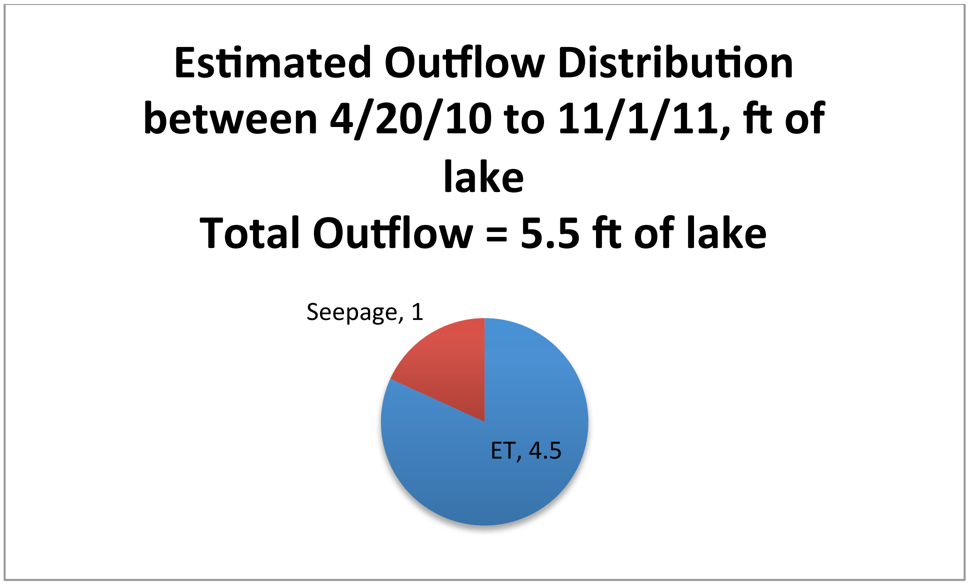
Annual Inflows:

Scaling these results to represent annual inflows shows direct rainfall is the greatest input, followed closely by snowmelt, and followed by runoff and pumping.



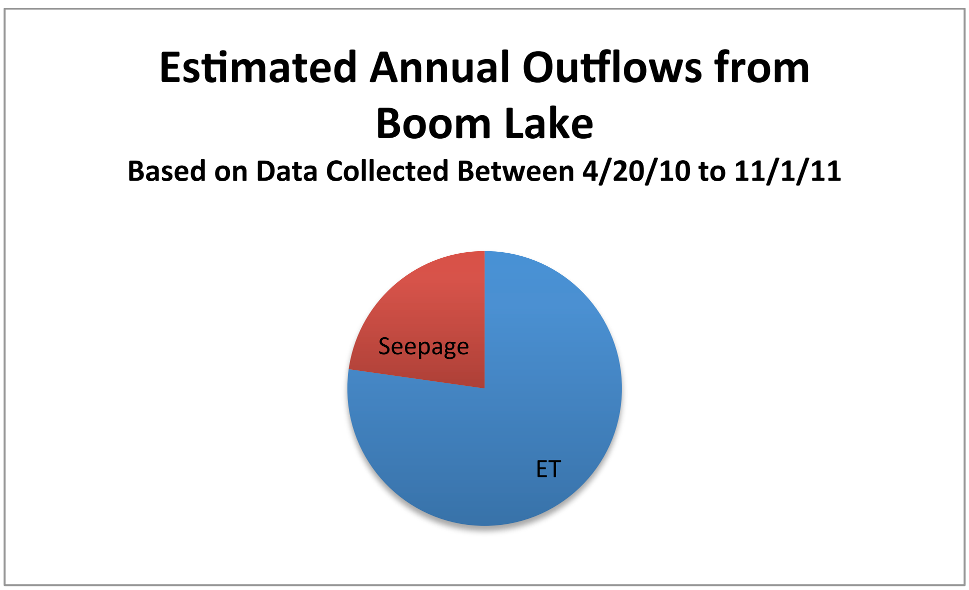
Outflow Distribution:





Annual Outflows:

Scaling these results to represent annual outflow shows ET accounts for over 3/4ths of the loses followed by seepage which accounts for the remainder.



Reference:

Shjeflo, J. B., 1968, Evapotranspiration and the water budget of prairie pothole in North Dakota: U.S. Geol. Survey Prof. Paper 585-B, 49 p.

Appendix E – Pumping Station Discharge Estimate

North Dakota State Water Commission

Project: Boom Lake Investigation

Project No.: 1285

Prepared By: M. Weier

Date:

Checked By:

Date:

Appendix E - Boom Lake Pumping Volume Estimate

Summary:

The City of Marion has been pumping water from a drainage ditch that no longer drains by gravity into the lake (Pumping Station 1) and a slough complex near County Highway 61 (Pumping Station 2). Many factors can effect the actual volume that is being discharged into the lake (e.g. seepage, pumping efficiency, operating time, etc.…), so this estimate is approximate.

To date Boom Lake was surveyed twice, once on 04/20/10 and once on 11/01/11. Assuming the lake level was balanced when it was surveyed on 04/20/10 the lake rose approximately 1.5 feet between those two dates.

Pumping Volume Estimate for Pumping Station 1:

Pump is a Honda WT40X Trash Pump. From the pump manufacturer website its maximum pumping rate is 433 gpm. From the City of Marion, the pump has been operated approximately 5 hrs per day from mid-March to November.

Assume 80% efficiency and 30% loss from lake seepage that causes redundant pumping.

$$(0.8)(0.7)\left(433\frac{gal}{\text{min}}\right)\left(5\ \frac{hrs}{day}\right)\left(8\frac{mon}{year}\right)\left(30\frac{day}{mon}\right)\left(60\frac{min}{hr}\right)\left(1\frac{acft}{325{,}851gal}\right)=54\frac{acft}{year}$$

or about 0.22 ft assuming the lake at elevation 1455 ft (240 acres).

Pumping Volume Estimate for Pumping Station 2:

Pump is a diesel engine powered trash pump w/ a 6” discharge and is pumped through 1,900 ft of 6” metal pipe and supplies approximately a 10 ft lift. From similar engine powered pumps a pumping rate 500 gpm is assumed and 60% efficiency is assumed.

From the City of Marion the pump was run approximately 2 weeks during the spring, 1 week in early summer, 10 days during July, and 3 to 5 days during October 2011, which is approximately 34 days.

$$(0.6)\left(500\frac{gal}{\text{min}}\right)\left(24\ \frac{hrs}{day}\right)\left(34\ \frac{days}{year}\right)\left(60\frac{min}{hr}\right)\left(\frac{acft}{325{,}851gal}\right)=45\frac{acft}{year}$$

or about 0.19 ft assuming the lake at elevation 1455 ft (240 acres).

Alternatively this can be estimated by summing the change in volume within the slough per pumping event. The slough is approximately 3 acres and based on a surveyed water level in November 2011 and a surveyed high water mark there was an approximately 2 ft difference. Assume the slough level changes 2 ft over the 3 acres per event.

$$\left(5\ \frac{events}{year}\right)\left(2\frac{ft}{events}\right)(3\ acres)=30\frac{acft}{year}$$

or about .13 ft assuming the lake at elevation 1455 ft (230 acres). It is assumed that this estimate is more accurate.

Pumping Volume Estimate Between Surveyed Water Levels:

Assuming that the pumps operated similarly last year they pumped approximately 0.35 ft of water annually between 4/20/10 and 4/20/11. Approximately 6 additional months were pumped this year, which results in an additional 0.26 ft (6/8*0.35). So an approximately total of 0.6 ft of lake rise could be attributed to the pumping stations between the two survey dates.

Appendix F – Hydrologic Model

Appendix F - Boom Lake Investigation HEC-HMS Model and Documentation

Summary:

Boom Lake (also known as Marion Lake) is a terminal lake located near the City of Marion, LaMoure County, North Dakota. Since the early 1990s, the lake and surrounding groundwater levels have risen in response to above average precipitation. As part of an investigation agreement with the LaMoure County Water Resource District the SWC has developed a hydrologic model to aid in the assessment of the problem.

The HEC-HMS (Version 3.5) model was used to determine the response of Boom Lake for several storm events. Infiltration losses and the runoff transformation were based on the Soil Conservation Service (SCS) Curve Number Method and SCS Runoff Transformation Method, respectively. Other inputs include the watershed area, soil type, land use, lag time, storage elevation relationship for Boom Lake, and temporal precipitation distributions. A simple weir outlet was used to estimate outflows for a potential outlet. The model calculates inflow, lake stage, and outflow hydrographs. No gauging data was available to calibrate this model. This documentation details the model development and model.

Watershed Area:

The drainage area surrounding Boom Lake is a complex network of depressions and sloughs. It is difficult to determine the exact contributing area because of the accuracy of the available data; sloughs have variable storage depending on recent precipitation patterns; and drainage culverts that may or may not be functional.

The watershed draining into Boom Lake was estimated by using and the 1/3 arc second scaled Digital Elevation Map (DEM) from the National Elevation Dataset (NED) and terrain processing with the United States Army Corps (USACE) Geospatial Hydrologic Modeling Extension (HEC-GEOHMS) (Gesh et. al., 2002; Gesh, 2007). The basin was refined using aerial photos and USGS 1:24,000 scale quadrangle topographic maps of the area. The watershed area is conservatively 4.0 square miles, with the lake accounting for approximately 10 percent; although, up to 1.5 square miles to east is currently non-contributing because of digressional storage (**Figure 1**). Smaller depressions within the drainage area may resulting in additional non-contributing areas for most storm events.

The non-contributing area potentially could be included in the drainage area in the future if currently non-functioning culverts are restored and a gravity drain is installed to drain a slough located near County Highway 61 to the lake. Currently pumping drains the slough. It is unlikely that the entre non-contributing area would contribute if a gravity drain is installed; however, conservatively the entire area is included the analysis.

North Dakota State Water Commission

Project: Boom Lake Investigation
Project No.: 1285

Prepared By: M. Weier
Date:
Checked By:
Date:

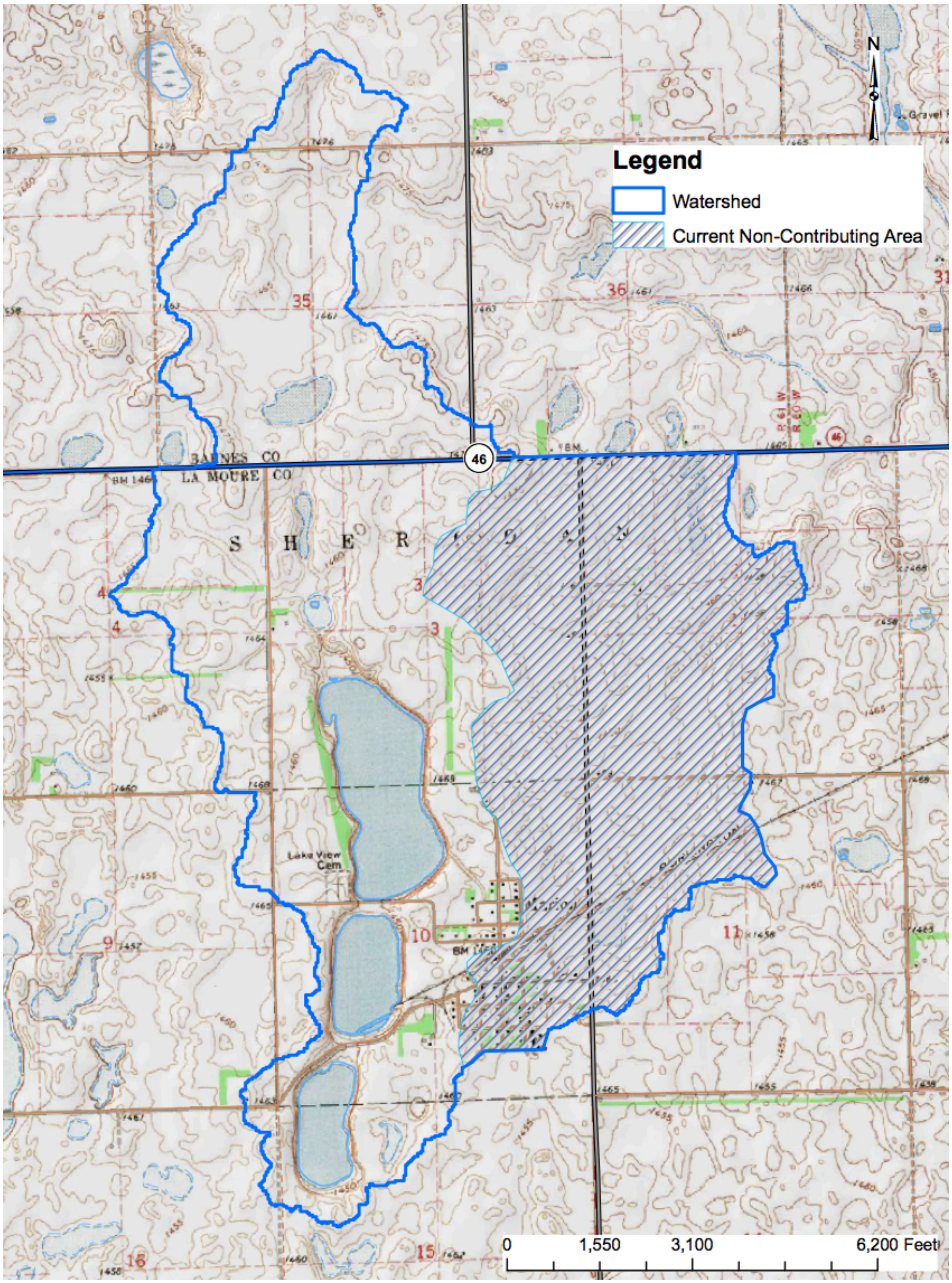


Figure 1. Watershed Area

Soil Classification and Land Use:

Hydrologic group soil classifications for soils within the basin were obtained from the Soil Survey Geographic (SSURGO) Database maintained by the Natural Resources Conservation Service (NRCS) National Geospatial Management Center (NGMC) for Barnes and LaMoure County (USDA, 2011). The distribution of the soil classifications is shown in **Figure 2.** Land use data for the basin was obtained from the 2006 National Land Cover Dataset (NLCD) from the USGS for Barnes and Lamoure County (Fry et al., 2011). Land use distribution is shown in **Figure 3**.

Table 1 shows a breakdown of NLCD land use classification and hydrologic soil group classification according to SSURGO for the watershed. Half of the drainage basin is used to cultivate crops and nearly one quarter is used to grow hay. Approximately 10 percent of the drainage basin is classified as open water, nearly all of which can be attributed to the lake itself. Another 8 percent is classified as wetlands. Nearly all of the soil is classified as a hydrologic group B soil. The remaining hydrologic group classes are defined mainly within wetlands or below the lake.

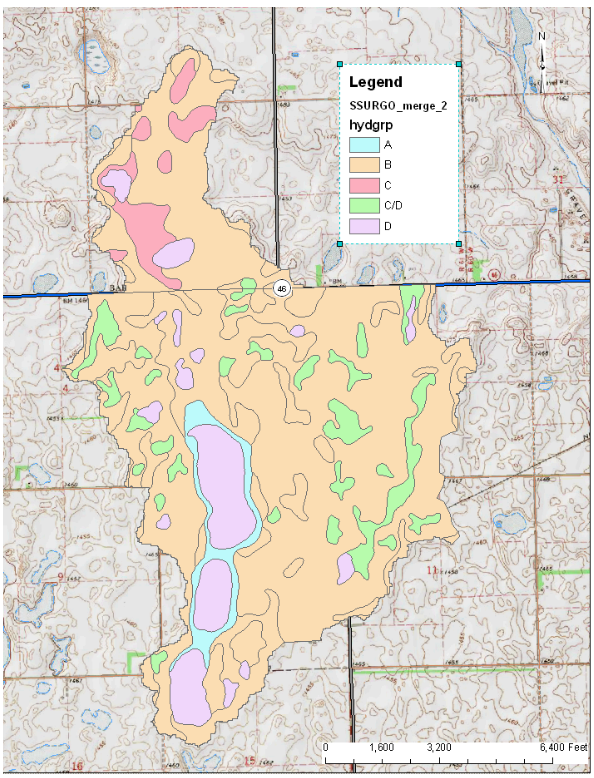


Figure 2: SSURGO Hydrologic Group Soil Classification

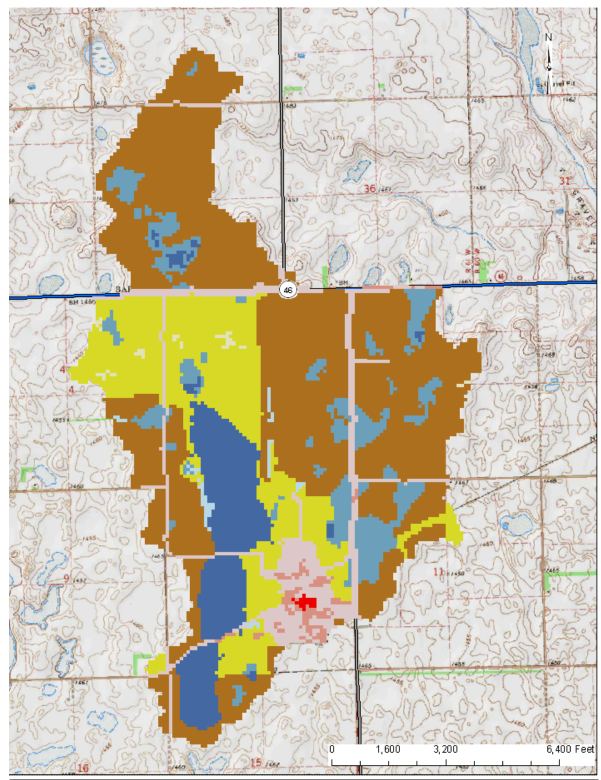


Figure 3: NLCD Land Use Distribution

		Percentage of Total Drainage Area				
		Hydrologic Soil Group				
NLCD Cover Classification	**Percentage of Total Drainage Area**	**A**	**B**	**C**	**C/D**	**D**
Cultivated Crops	50.1%	0.2%	44.5%	3.0%	2.0%	0.4%
Pasture Hay	19.6%	0.1%	17.6%	0.0%	1.6%	0.3%
Open Water	10.6%	2.4%	0.9%	0.1%	0.0%	7.2%
Emergent Herbaceous Wetlands	9.1%	0.0%	3.2%	0.9%	3.4%	1.6%
Developed/Open Space	8.1%	0.1%	7.1%	0.0%	0.6%	0.2%
Developed/Low Intensity	1.3%	0.0%	1.2%	0.0%	0.0%	0.0%
Woody Wetlands	0.6%	0.1%	0.5%	0.0%	0.0%	0.0%
Grassland	0.4%	0.0%	0.3%	0.0%	0.0%	0.0%
Developed/Med Intensity	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%
Sum	100.0%	2.9%	75.6%	3.9%	7.7%	9.9%

Table 1: Breakdown of Watershed Land Use and Soil Hydrologic Unit Classification

Curve Number Formulation:

A curve number was calculated for the watershed by following methods outlined in the Hydrology Manual of North Dakota (HMND) (USDA, n.d.). Land use classifications defined by the NLCD were correlated with the HMND land use classifications as shown in **Table 2**. **Table 2** also includes the curve number assigned by the HMND in Table 3-1 for each land use classification and hydrological soil group. A curve number is generated for the entire watershed by weighting each curve number assigned to a specific soil type and land use by the percentage of the watershed that contains that soil type and land use classification. The curve number was calculated by multiplying the land use and soil group area distribution in **Table 1** to the curve number classification in **Table 2**. Since there is no curve number assigned to type C/D soil, it is assumed that one half of the soils classified as type C/D are type C soils and they remaining half is a type D soil.

The weighted curve number calculated for the watershed is 79 and assumes an average antecedent soil moisture condition (AMC II) (**Table 2**). This corresponds to a 10-day curve number of 64 according to Table 3-4 of the HMND. For modeled snowmelt events 80% of the watershed was assumed to be impervious.

NLCD Cover	HMND Cover	Curve Number from HMND				Product of Curve Number and % of Watershed
		A Soils	B Soils	C Soils	D Soils	
Cultivated Crops	Row crops, straight row - Good condition	67	78	85	89	39
Pasture Hay	Pasture - Good Condition	49	69	79	84	14
Open Water	Open Water	100	100	100	100	11
Emergent Herbaceous Wetlands	Swamp - Open Water	85	85	85	85	8
Developed/Open Space	Open Space - Fair Condition	49	69	79	84	6
Developed/Low Intensity	Open Space - Low Density Residential	47	65	76	82	1
Woody Wetlands	Wood or Forest Land - Poor Condition	45	66	77	83	0
Grassland	Meadow	30	58	71	78	0
Developed/Med Intensity	Open Space - Med Density Residential	54	70	79	84	0
Weighted Curve Number						**79**

Table 2: Land Use Classification Correlation and Weighted Curve Number Calculation

Precipitation Loss

The default HEC-HMS SCS Curve Number Loss Model was used to determine the volume of precipitation lost to infiltration where 20 percent of the storage capacity of the soil is assumed to be the initial abstraction. Storage capacity is calculated from the curve number.

Time of Concentration

Time of concentration or the time for runoff to travel from the hydraulically most distant point in the watershed to the lake was calculated by using the methods described in Technical Release 55 (TR-55) (USDA, 1986). The travel path selected is shown in **Figure 4**. The slope of the travel path obtained from the NED is shown in **Figure 5**. The travel path was broken down into sections based on slope and flow type.

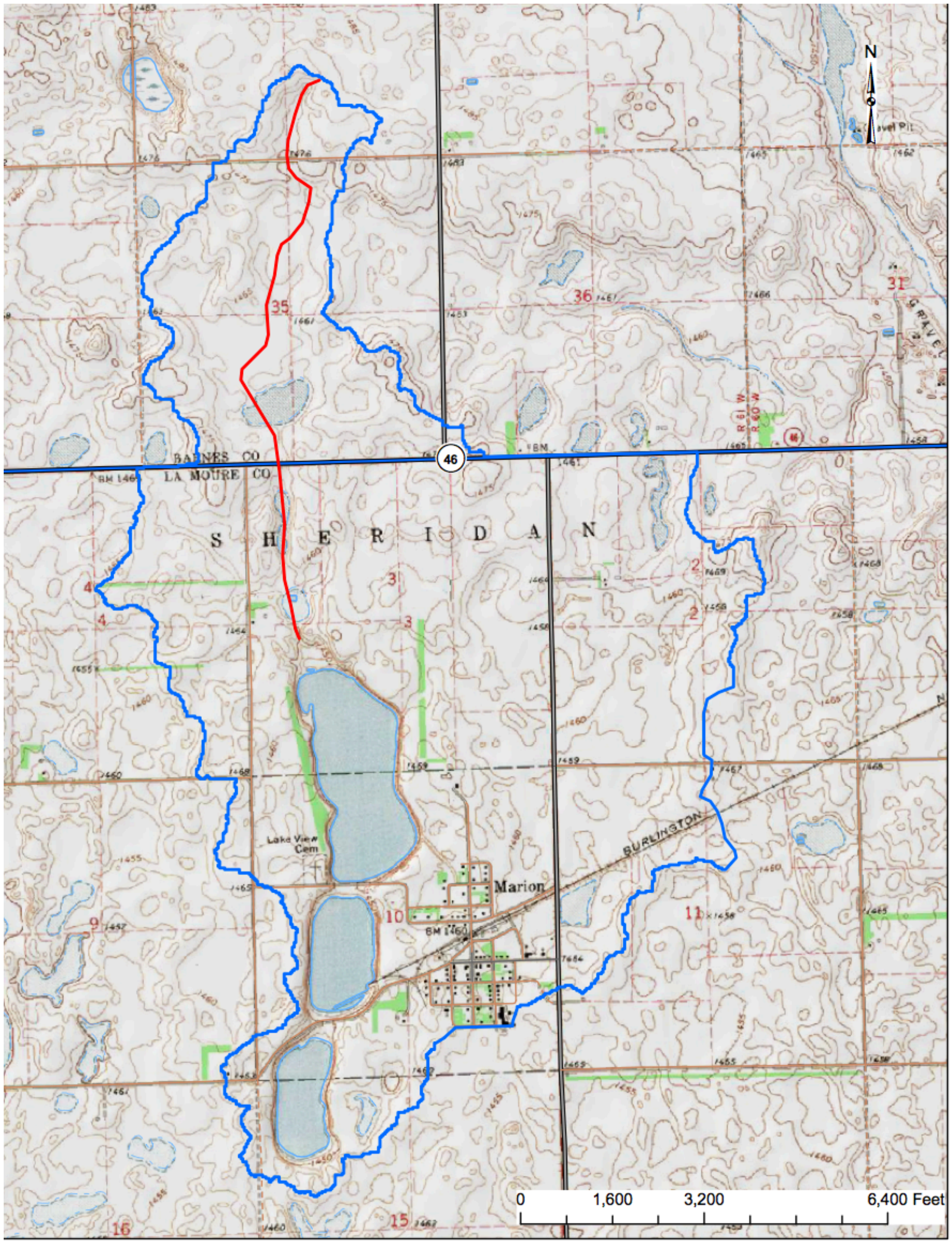


Figure 4: Plan of time of concentration travel path.

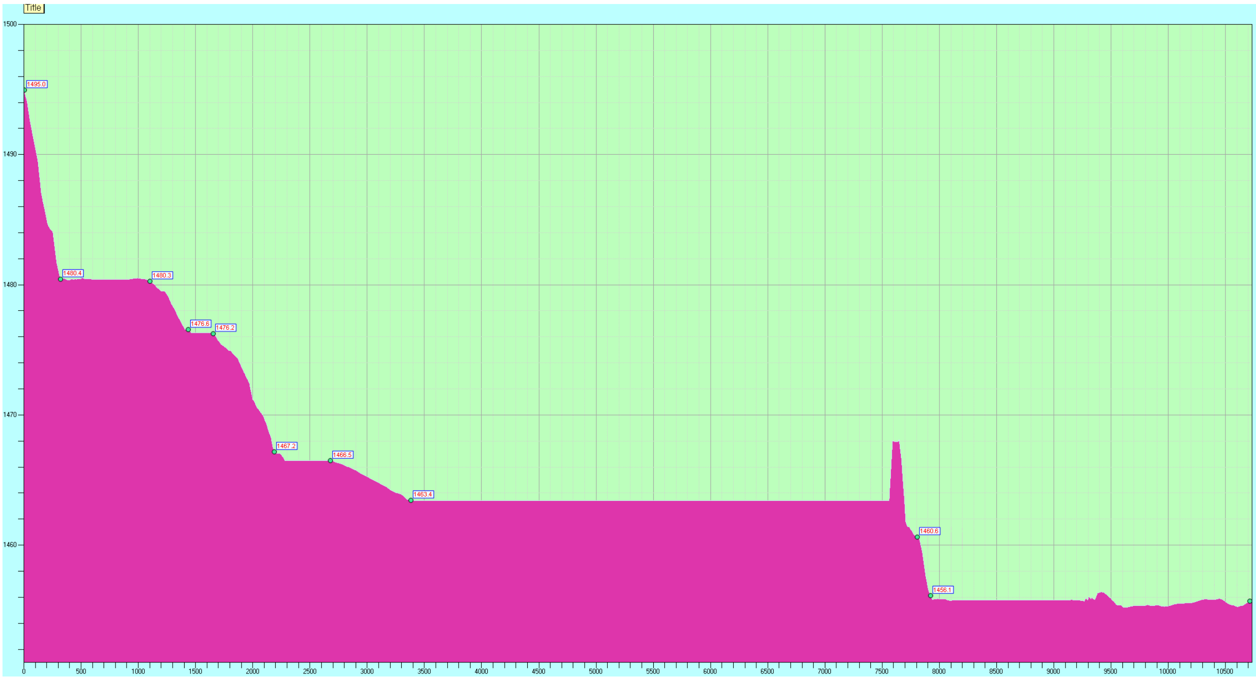


Figure 5: Profile of time of concentration travel path.

The first 300 feet of travel distance was calculated as sheet flow using Equation 3-3 from TR-55 where P_2 = 2.3 inches (from the HMND), n = 0.17 for cultivated soils, residue cover greater than 20% (from Table 3-1 of TR-55), and s = 4.9% from the NED data. The travel time was calculated to be 0.49 hours for this section.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} s^{0.4}} \qquad \text{[eq. 3-3]}$$

where:

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

TR-55 Equation 3-3: Sheet Flow Travel Time Equation from TR-55.

Figure 3-1 (average velocities for estimating travel time for shallow concentrated flow):

Unpaved $V = 16.1345 (s)^{0.5}$
Paved $V = 20.3282 (s)^{0.5}$

where

V= average velocity (ft/s)
s = slope of hydraulic grade line (watercourse slope, ft/ft)

These two equations are based on the solution of Manning's equation (eq. 3-4) with different assumptions for n (Manning's roughness coefficient) and r (hydraulic radius, ft). For unpaved areas, n is 0.05 and r is 0.4; for paved areas, n is 0.025 and r is 0.2.

Equation for TR-55 Figure 3-1: Shallow Concentrated Flow Velocity Equation from TR-55.

Travel time for shallow, concentrated flow was calculated for the remainder of the flow path since a defined channel is not evident. Distance, slope, velocity, and travel time for the remaining segments are shown in **Table 3**. As shown in **Figure 5**, from station 3400 to 7500 the NED data indicates no change in elevation. The segment was extended to 7800 ft to calculate a slope and the change in elevation from the road embankment was ignored. The velocity was calculated by the **Equation TR-55 Figure 3-1** for unpaved conditions located in Appendix F of TR-55.

End Station	Segment Distance, ft	Slope	Average Velocity, ft/sec	Travel Time, hr
1106.19	806.19	0.02%	0.20	1.09
1431.26	325.07	1.13%	1.71	0.05
2188.13	756.87	1.25%	1.81	0.12
2673	484.87	0.14%	0.60	0.22
3381.66	708.66	0.43%	1.06	0.19
7801	4419.34	0.06%	0.40	3.04
7918	117	3.87%	3.17	0.01
10717	2799	0.01%	0.19	4.14
Sum				**8.86**

Table 3: Travel Time Calculation for Shallow, Concentrated Flow

Summing the travel times for the sheet flow portion and the shallow, concentrated flow portion of the travel path results in a total travel time of 9.3 hrs.

Clark Unit Hydrograph Storage Parameter

The Clark unit hydrograph was selected as a transform method that performs the surface runoff calculations. The Clark unit hydrograph is a function of the time-area curve, time of concentration, and the storage coefficient; however, HEC-HMS assumes a dimensionless time-area curve. Since the basin is not gauged, the storage coefficient, R, was estimated using the following regression equation developed by the USACE during their Phase I Hydrologic Modeling Red River of the North Tributaries (USACE, 2011):

$$\frac{R}{T_c} = 0.1875 + 0.0721X_1 + 0.1801X_2$$

Where:
R = Storage Coefficient
X_1 = Percentage of Drainage Area Classified as Wetlands
X_2 = Percentage of Drainage Area Classified as Lakes

The regression equation relates R to wetland areas and lakes. Wetland and lake areas were calculated by using areas included in the United States Fish and Wildlife Service (USFWS) National Wetland Inventory for the drainage basin (**Figure 6**) which were calculated as 10.3% and 6.7% respectively. Areas classified as ponds were assumed to be lakes, and the area of the lake as defined by the USFWS was included in the calculation. The storage parameter was calculated as 20.0 hrs.

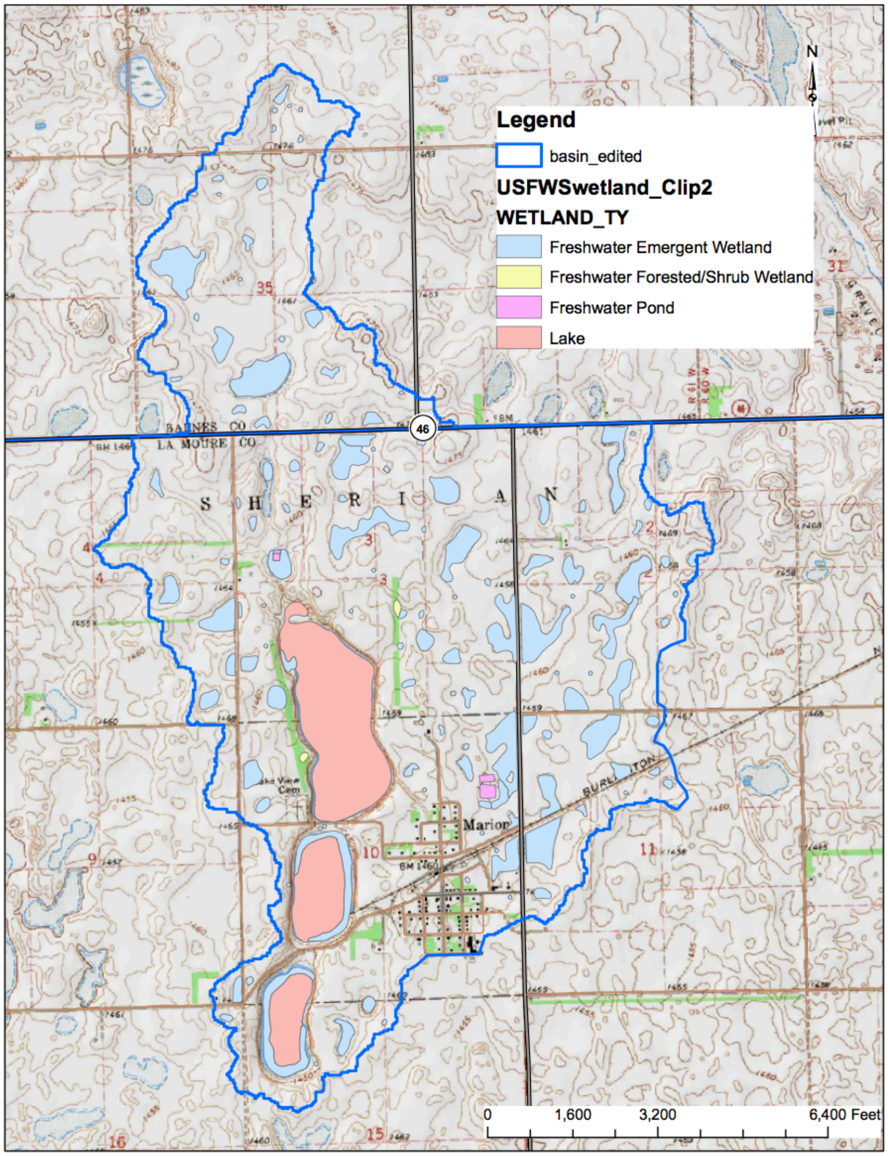


Figure 6: USFWS Wetland Classification within the Watershed.

Lake Storage Elevation Curve

A relationship between water storage and elevation for Boom Lake was approximated by calculating the volume of the lake at a given stage with the NED data and preliminary LIDAR survey data obtained from the USACE (**Table 4**). The survey data the NED is based on was obtained between 1960 and 1979, when the lake was a lower level, and more bank line was exposed (Evans, 2011). The curve assumes that the three portions of the lake are hydraulically connected and balanced regardless of stage. Bathymetry data is not available for the lake, so it was estimated that the lake storage is approximately 1,000 acre feet at elevation 1450 ft based on an assumed average depth of 5 ft.

The lake will begin to overflow into the northern portion of Marion at elevation 1458.5 ft, and the curve assumes that this overflow area is not available for storage. At elevation 1459 ft the lake begins to outlet to the south.

Elevation, ft NAVD88	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461
Estimated Storage, acre feet	1000	1197	1400	1608	1829	2074	2335	2620	2937	3281	3654	4056

Table 4: Storage and Elevation Relationship for Boom Lake.

Natural Outlet

At elevation 1459 ft the lake will outlet from near its southern end at least one location and potentially more locations. Based on the available elevation data, the lake will spill through a 150 ft wide channel. This spillway was modeled as a 150 ft broad crested weir with a coefficient of 2.75. Downstream tailwater effects were not considered.

Metrological Models

The 2, 5, and 100 year 24 hour rainfall events were interpolated from the HMND and were distributed by the SCS Storm in HEC-HMS (**Table 5**). The 100 year 10 day rainfall event was interpolated from the HMND and was distributed by the frequency storm method in HEC-HMS. The event duration distribution for the 100 year 10 day rainfall event is shown in **Table 6** and was developed by using the 100 year 1 hr, 2 hr, 3, hr, 6 hr, 12 hr, 1 day, 2 day, 4 day, and 10 day event totals derived in Technical Paper 40 (TP-40) and TP-49 (NWS, 1961; NWS 1964). The 48 hour probable maximum precipitation (PMP) event over a 10 square mile basin was interpolated from Hydrometorological Report 51 (HMR-51) and was distributed using the user specified hyetograph in HEC-HMS as shown in **Table 7** (NWS, 1978).

	Total, inches
2 Year 24 Hour Rainfall, inches	2.3
5 Year 24 Hour Rainfall, inches	3.0
100 Year 24 Hour Rainfall, inches	5.1

Table 5: 2 year, 5 year, and 100 year 24 Day Rainfall Totals

100 Year 10 Day Rainfall, inches	**1 hrs**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**1 day**	**2 day**	**4 day**	**7 day**	**10 day**	**Total**
	2.83	3.25	3.42	3.96	4.67	5.10	5.9	6.86	7.9	8.78	8.78

Table 6: 100 Year 10 Day Rainfall Distribution – Frequency Storm Distribution

All Season Probable Max Precip., 48 hr, 10 sq. miles, inches	**6 hrs**	**12 hrs**	**18 hrs**	**24 hrs**	**30 hrs**	**36 hrs**	**42 hrs**	**48 hrs**	**Total**
	0.92	0.92	0.92	3.35	21.81	0.92	0.92	0.92	30.7

Table 7: All Season Probable Max Precipitation, 48 hr, 10 sq. miles – User Specified Hyetograph Distribution

The 50 and 100 year snowmelt events were obtained from the HMND and were distributed by using the frequency storm method in HEC-HMS (**Table 8**). The 2010 spring runoff event appears to have exceeded the 100 year 10 day runoff event, so a storm event was created based on the National Operational Hydrologic Remote Sensing Center's (NOHRSC) modeled runoff at the MRON8 station near Marion (**Table 8**). It was assumed that the runoff event distributions were similar to the 100 year rainfall event distribution.

Runoff Event	1 hrs	2 hrs	3 hrs	6 hrs	12 hrs	1 day	2 day	4 day	7 day	10 day	Total
50 Year 10 Day Runoff, inches	1.2	1.4	1.5	1.7	2.0	2.2	2.5	2.9	3.4	3.7	3.7
100 Year 10 Day Runoff, inches	1.4	1.6	1.7	2.0	2.3	2.6	3.0	3.4	4.0	4.4	4.4
2010 10 Day Runoff Event, inches	2.0	2.3	2.4	2.8	3.3	3.6	4.2	4.8	5.6	6.2	6.2

Table 8: Runoff Event Distribution – Frequency Storm Distribution

Constructed Outlet

Boom Lake currently does not have an outlet, and a simple, weir outlet was modeled to estimate what capacity an outlet would need to be designed for. A 6 ft long broad crested spillway with a coefficient of 2.75 set at elevation 1451 ft was used to estimate outlet volumes. A 6 ft long spillway was used instead of a longer spillway because discharges must be somewhat limited based on downstream concerns.

Basin Models

Six basin models were developed to model 24 hr rainfall events, 10 day rainfall events, and 10 day runoff events for the lake at elevation 1455 ft, the lake at its natural outlet elevation 1459 ft, and the lake at elevation 1451 ft with a constructed outlet. Each of the basin models are described below.

No Outlet – This basin assumes a standard curve number of 79 and the natural outlet at elevation 1459 ft. This basin is used to model the lake's response to 24 hr and 48 hr rainfall events. The basin area was alternated from 4 square miles and 2.5 square miles and the lake elevation was alternated from 1455 ft and 1459 ft depending on the model run.

No Outlet 10 Day Rainfall – This basin is similar to the "No Outlet" basin except the 10 day curve number of 64 was used.

No Outlet 10 Day Snowmelt – This basin is similar to the "No Outlet 10 Day Rainfall" basin except the 80% of the basin was considered impervious.

Outlet Standard CN – This basin assumes a standard curve number of 79, a constructed outlet at elevation 1451 ft, and the natural outlet at elevation 1459 ft. This basin is used to model the lake's response to 24 hr and 48 hr rainfall events with the constructed outlet. The lake's initial elevation is the same as the constructed outlets. The basin area was alternated from 4 square miles and 2.5 square miles.

Outlet 10 Day Rainfall – This basin is similar to the "Outlet Standard CN" basin except the 10 day curve number of 64 was used.

Outlet 10 Day Snowmelt – This basin is similar to the "Outlet 10 Day Rainfall" basin except the 80% of the basin was considered impervious.

Model Results

Existing Condition - Initial Stage 1455 ft

Table 9 summarizes the model predicted inflows, peak lake stage, and runoff volume for the existing condition (lake elevation 1455 ft). Although the current area contributing to runoff is likely 2.5 square miles for the 100 year return period, 4 square miles was also analyzed for a basis of comparison.

Existing Condition - Initial Stage 1455 ft		2.5 mi Basin		4 mi Basin	
Event	Total Precipitation, in	Inflow Volume, ac-ft	Peak Lake Stage, ft	Inflow Volume, ac-ft	Peak Lake Stage, ft
Rainfall					
2 Year 24 Hr Rainfall	2.3	94	1455.4	151	1455.6
5 Year 24 Hr Rainfall	3.0	154	1455.6	246	1455.9
100 Year 24 Hr Rainfall	5.1	385	1456.4	616	1457.2
100 Year 10 Day Rainfall	8.8	583	1457.1	932	1458.5
100% PMP 48 Hr - 10 sq mi basin	30.7	3,694	1460.5*	5,911	>1461
Snowmelt					
50 Year 10 Day Snow Melt - 80% Impervious	3.7	418	1456.6	669	1457.4
100 Year 10 Day Snow Melt - 80% Impervious	4.4	498	1456.8	797	1457.8
2010 10 Day Snow Melt - 80% Impervious	6.2	721	1457.6	1,153	1458.8

*Assumes discharge from 150 ft wide broad crested spillway outlet at 1459 ft and no tailwater effect

Table 9: Summary of Model Results for Existing Condition (Lake Elevation 1455 ft)

Existing Condition HMS Model Results Summary

Considering the results from the 2.5 square mile basin HMS model, it is evident that PMP event would cause flooding and the lake would outlet naturally. The model predicts a rare snowmelt event exceeding a 1 percent annual accordance such as the 2010 snowmelt event would cause the lake elevation to increase by about 2.6 ft.

HMS Model and Water Balance Comparison

Since the lake has not been gauged, calibrating the model for a given storm event or a known storm event is not possible. However, a water balance was calculated to determine inflows into the lake between two events when the lake was surveyed (April 20, 2010 to November 1, 2011). This water balance calculation is included in **Appendix D**. Using storm events recorded and estimated between the survey events, inflows estimated by the HMS model can be totaled and compared to the water balance estimate.

A 50-year 10-day snowmelt event, a 5-year 24-hour rainfall event, and three 2-year 24-hour rainfall events occurred between survey events based on NOHRSC estimates and measurements collected at the NDAWN station in Marion. **Table 10** shows a comparison of estimated inflows predicted by the HMS model and from the water balance calculation for the storm events. The rainfall runoff for all storms is included in the water balance estimate and the rainfall runoff for only the 2 year and 5 year storms is estimated with the HMS model. Therefore, the HMS model rainfall runoff estimates should be lower than the rainfall runoff estimated from the water balance. The 2.5 sq mi basin estimate appears to compare better to the water balance estimate than the 4.0 sq mi basin, which is expected because for the 100 year return period only the 2.5 sq mi basin is contributing inflow.

Rainfall Event	**Total Precipitation, in**	**Number of Occurrences From 4/20/10 to 11/1/11**	**HMS Model 2.5 sq mi Basin Runoff Volume, ft of lake[1]**	**HMS Model 4 sq mi Basin Runoff Volume, ft of lake[1]**	**Water Balance Runoff Volume, ft of lake**
2 Year 24 Hr Rainfall	2.3	3	0.6	1.2	NC
5 Year 24 Hr Rainfall	3.0	1	0.5	0.9	NC
Subtotal			1.0	1.9	1.9*
Snowmelt Event	**Total Precipitation, in**	**Number of Occurrences From 4/20/10 to 11/1/11**	**HMS Model 2.5 sq mi Basin Total Event Volume, ft of Lake**	**HMS Model 4 sq mi Basin Total Event Volume, ft of Lake**	**Water Balance Total Event Volume, ft of Lake**
50 Year 10 Day Snow Melt - 80% Impervious	3.7	1	1.6	2.4	1.5
Rainfall and Runoff Total			**2.6**	**4.3**	**3.4***

[1] Note: Includes only runoff from storm, not direct precipitation.

*Note: Includes rainfall runoff from all storms, not just the 2 year and 5 year 24 hr events

Table 10: Summary of HMS and Water Balance Inflow Estimates for Storm Events Occurring between 4/20/10 and 11/1/11.

Natural Outlet Elevation - Initial Stage 1459 ft

Table 10 summarizes the model predicted inflows, predicted outflows, and peak lake stage for the lake at the natural outlet elevation (lake elevation 1459 ft). Although the current area contributing to runoff is likely 2.5 square miles, 4 square miles was also analyzed in the event the non-functioning culverts are restored and Pumping Station 2 is replaced with a gravity drain system.

Natural Outlet - Initial Stage 1459		2.5 mi Basin			4 mi Basin		
Event	**Total Precipitation, in**	**Total Inflow Volume, ac-ft**	**Peak Outflow, cfs**	**Peak Lake Stage, ft**	**Total Inflow Volume, ac-ft**	**Peak Outflow, cfs**	**Peak Lake Stage, ft**
Rainfall							
100 Year 24 Hr Rainfall	5.1	385	93	1459.4	616	161	1459.5
100 Year 10 Day Rainfall	8.8	583	98	1459.4	932	169	1459.6
Snowmelt							
50 Year 10 Day Snow Melt - 80% Impervious	3.7	418	66	1459.3	669	112	1459.4
100 Year 10 Day Snow Melt - 80% Impervious	4.4	498	81	1459.3	797	137	1459.5
2010 10 Day Snow Melt - 80% Impervious	6.2	721	123	1459.4	1,153	209	1459.6

Assumes discharge from 150 ft wide broad crested spillway outlet at 1459 ft and no tailwater effect

Table 10: Summary of Model Results for Natural Outlet Condition (Lake Elevation 1459 ft)

If the lake reaches its natural outlet, the HMS model predicts that peak lake elevations will be limited below 1459.6 ft for most rare storm events for a 4 square mile contributing area. It appears that the contributing area does not greatly effect the peak lake stage because is because of the length of the outlet area(s), but peak outflows are affected by contributing area. Discharges for most rare storm events range between 100 to 200 cfs. The HMS model assumes a clean discharge and does not account for potential flow restrictions downstream.

Constructed Gravity Outlet Condition - Initial Stage 1451 ft

Table 11 summarizes the model predicted inflows, predicted outflows, and peak lake stage for the lake for a constructed gravity outlet condition (lake elevation 1451 ft). Although the current area contributing to runoff is likely 2.5 square miles, 4 square miles was also analyzed in the event the non-functioning culverts are restored and Pumping Station 2 is replaced with a gravity drain system.

Gravity Outlet Condition - Initial Stage 1451		2.5 mi Basin			4 mi Basin		
Event	Total Precipitation, in	Total Inflow Volume, ac-ft	Peak Outflow, cfs	Peak Lake Stage, ft	Total Inflow Volume, ac-ft	Peak Outflow, cfs	Peak Lake Stage, ft
Rainfall							
5 Year 24 Hr Rainfall	3.0	154	8	1451.6	246	14	1451.9
100 Year 24 Hr Rainfall	5.1	385	26	1452.4	616	49	1453.1
100 Year 10 Day Rainfall	8.8	583	34	1452.6	932	62	1453.4
PMP 48 Hr - 10 sq mi basin	30.7	3,694	451*	1459.3	5,911	1,289*	1460.6
Snowmelt							
50 Year 10 Day Snow Melt - 80% Impervious	3.7	109	23	1452.2	669	42	1452.9
100 Year 10 Day Snow Melt - 80% Impervious	4.4	498	29	1452.5	797	53	1453.2
2010 10 Day Snow Melt - 80% Impervious	6.2	721	47	1453.0	1,153	83	1453.9

Assumes discharge from 6 ft wide broad crested spillway outlet at 1451 ft and no tailwater effect

*Assumes discharge from 150 ft wide broad crested spillway outlet at 1459 ft and no tailwater effect

Table 11: Summary of Model Results for Constructed Gravity Outlet Condition (Lake Elevation 1451 ft)

For this condition it is likely that current non-contributing area will be integrated by replacing Pumping Station 2 with a gravity drain system, so the results for the 4 square mile basin area is likely a better representation of this condition. Peak outlet flows for storm events range from 14 cfs for the 5 year 24 hr rainfall to 83 cfs for a snowmelt event similar to the 2010 snowmelt event. Peak elevations are predicted to remain below elevation 1454 ft, which would prevent the drainage ditch at the north end of town from overtopping its banks. This outlet cannot prevent flooding for the PMP event.

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Appendix G – Cost Estimate

Table G1 Alternative 1
Cost Estimate Lowering Lake Levels via a Gravity Outlet at El 1451
Boom Lake
Marion, ND

Component	Unit	Unit Price		Quantity	Total Cost	
Lake Outlet						
1 Control Structure	Lump Sum	$	40,000	1	$	40,000
2 Channel Excavation and Construction	In Place CY	$	5	60,000	$	300,000
3 Road Crossings	Each	$	8,000	5	$	40,000
4 Downstream Channel Improvements	Lump Sum	$	30,000	1	$	30,000
5 Wetland Mitigation Costs	Acre	$	5,000	10	$	50,000
				Subtotal	$	460,000
				% Total Costs		65%
Gravity Drain to Replace Pumping Station 2						
1 Channel Excavation and Construction	In Place CY	$	5	9,000	$	45,000
2 Culvert Replacement/Restoration	Lump Sum	$	10,000	1	$	10,000
3 Road Crossing	Each	$	5,000	1	$	5,000
				Subtotal	$	60,000
				% Total Costs		8%
Long Term Maintenance						
1 20 Years Long Term Maintenance at 5% interest	per year	$	750	20	$	24,799
				% Total Costs		4%
COST SUMMARY						
Total Capital costs without contingency					$	520,000
Total LTM costs without contingency					$	24,799
Total Costs with out contingency					$	544,799
Contingency (30%)				30%	$	163,439.84
				% TOTAL COSTS		23%
				TOTAL COST	**$**	**708,239**

Table G2 Alternative 2
Cost Estimate Lowering Lake Levels via a Pumping System at El 1451
Boom Lake
Marion, ND

Component	Unit	Unit Price	Quantity	Total Cost
Lake Outlet				
1 Pump, housing, and inlet	Lump Sum	$ 75,000	1	$ 75,000
2 Channel Excavation, Fill, and Construction	In Place CY	$ 5	10,000	$ 50,000
3 Road Crossings	Lump Sum	$ 8,000	5	$ 40,000
4 Downstream Channel Improvements	Lump Sum	$ 30,000	1	$ 30,000
5 Wetland Mitigation Costs	Acre	$ 5,000	7	$ 35,000
6 Power Hookup	Lump Sum	$ 25,000	1	$ 25,000
			Subtotal	$ 255,000
			% Total Costs	41%
Gravity Drain to Replace Pumping Station 2				
1 Channel Excavation and Construction	In Place CY	$ 5	9,000	$ 45,000
2 Culvert Replacement/Restoration	Lump Sum	$ 10,000	1	$ 10,000
3 Road Crossing	Each	$ 5,000	1	$ 5,000
			Subtotal	$ 60,000
			% Total Costs	10%
Long Term Maintenance				
1 20 Years Operation and Maintenance at 5% interest	Lump Sum	$ 5,000	20	$ 165,330
			% Total Costs	26%
COST SUMMARY				
Total Capital costs without contingency				$ 315,000
Total LTM costs without contingency				$ 165,330
Total Costs with out contingency				$ 480,330
Contingency (30%)			30%	$ 144,098.93
			% TOTAL COSTS	23%
			TOTAL COST	**$ 624,429**

Table G3 Alternative 3
Cost Estimate Gravity Lake Outlet at El 1455
Boom Lake
Marion, ND

Component	Unit	Unit Price	Quantity	Total Cost
Lake Outlet				
1 Control Structure	Lump Sum	$ 40,000	1	$ 40,000
2 Channel Excavation and Construction	In Place CY	$ 5	20,000	$ 100,000
3 Road Crossings	Lump Sum	$ 8,000	4	$ 32,000
4 Downstream Channel Improvements	Lump Sum	$ 30,000	1	$ 30,000
5 Wetland Mitigation Costs	Acre	$ 5,000	10	$ 50,000
			Subtotal	$ 252,000
			% Total Costs	40%
Permanent Pumping Station at Pumping Station 1				
1 1,500 GPM Lift Station	Lump Sum	$ 100,000	1	$ 100,000
2 Power Hookup	Lump Sum	$ 25,000	1	$ 25,000
			Subtotal	$ 125,000
Gravity Drain to Replace Pumping Station 2				
1 Channel Excavation and Construction	In Place CY	$ 5	9,000	$ 45,000
2 Culvert Replacement/Restoration	Lump Sum	$ 10,000	1	$ 10,000
3 Road Crossing	Lump Sum	$ 5,000	1	$ 5,000
			Subtotal	$ 55,000
			% Total Costs	9%
Long Term Maintenance				
1 20 Years Operation and Maintenance Outlet at 5% Interest	Lump Sum	$ 500	20	$ 16,533
2 20 Years Operation and Maintenance Lift Station at 5% Interest	Lump Sum	$ 2,000	20	$ 40,000
			Subtotal	$ 56,533
			% Total Costs	9%
COST SUMMARY				
Total Capital costs without contingency				$ 432,000
Total LTM costs without contingency				$ 56,533
Total Costs with out contingency				$ 488,533
Contingency (30%)			30%	$ 146,559.89
			% TOTAL COSTS	23%
			TOTAL COST	**$ 635,093**

Table G4 Alternative 4
No Outlet
Boom Lake
Marion, ND

Component	Unit	Unit Price		Quantity	Total Cost	
800 ft of Protective Dike						
1 Dike Construction	In Place CY	$	20	500	$	10,000
				Subtotal	$	10,000
				% Total Costs		5%
Long Term Maintenance						
1 20 Years Maintenance of Dike at 5% intererst	Lump Sum	$	200	20	$	6,613
2 20 Years Operation and Maintenance Pumping Stations 1 and 2 at 5% Interest	Lump Sum	$	4,000	20	$	132,264
				Subtotal	$	138,877
				% Total Costs		72%
COST SUMMARY						
Total Capital costs without contingency					$	10,000
Total LTM costs without contingency					$	138,877
Total Costs with out contingency					$	148,877
Contingency (30%)				30%	$	44,663.10
				% TOTAL COSTS		23%
				TOTAL COST	**$**	**193,540**