EMERGENCY DRAWDOWN OF TWIN LAKES

SD DOT DRAINAGE PERMIT TO BROOKINGS COUNTY DRAINAGE BOARD

PROJECT NH0081 (95) 112   PCN 03CU
KINGSBURY COUNTY & BROOKINGS COUNTY

US HIGHWAY 81 SOUTH OF US HIGHWAY 14
TEMPORARY DRAWDOWN OF TWIN LAKES

August 16, 2010

BANNER
Engineering | Architecture | Surveying
BAI No 21295-06

HYDROLOGIC/HYDRAULIC STUDY FOR DRAWDOWN EVALUATION OF TWIN LAKES ADJACENT TO U.S. HIGHWAY 81 IN BROOKINGS/KINGSBURY COUNTIES

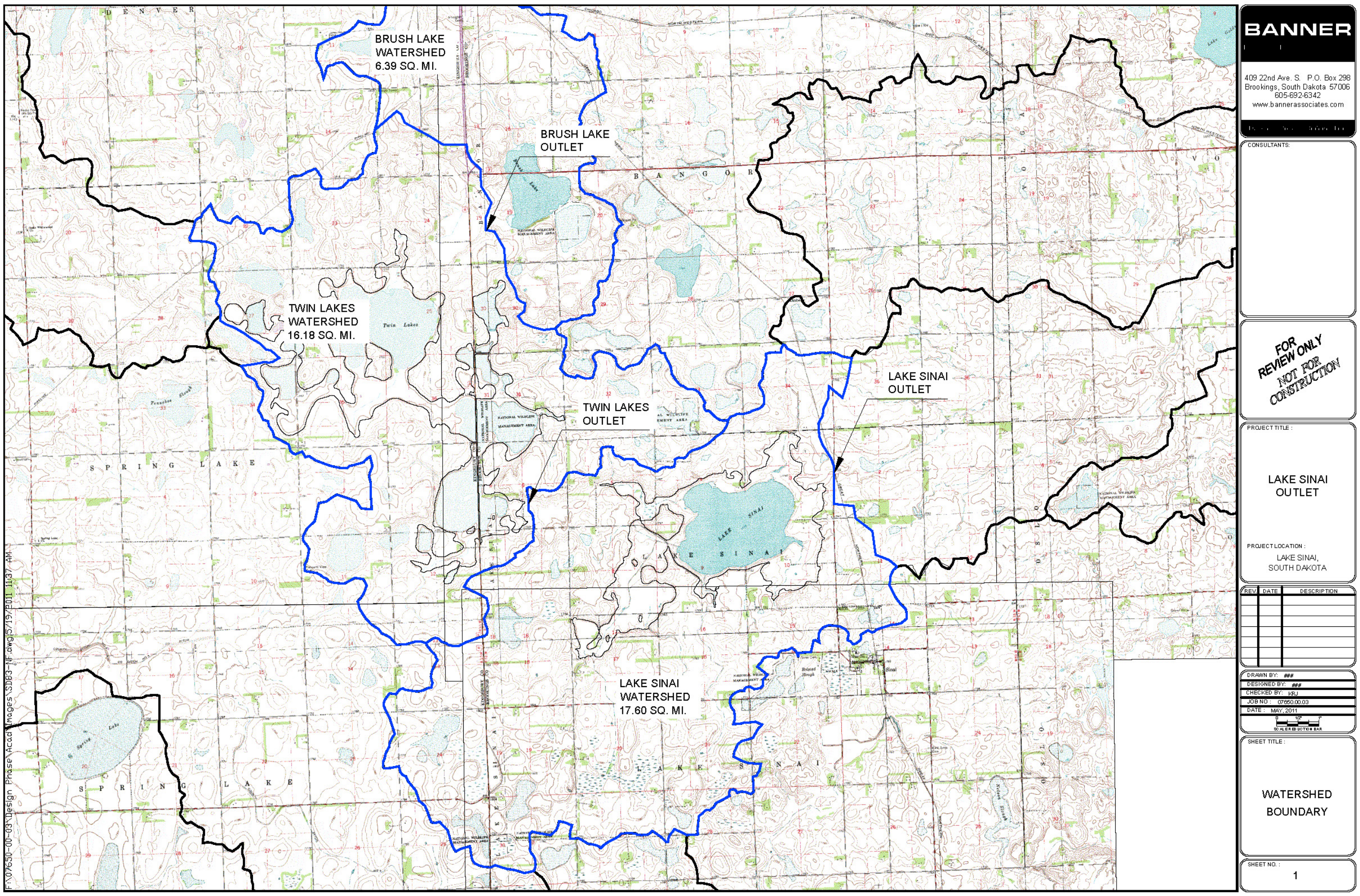
INTRODUCTION

The water level of Twin Lakes has been rising over the past several years due to above normal precipitation. On April 15, 2011 water was on the shoulder and near the white line of Highway 81 south of Arlington, SD. Wave action was starting to carry debris onto roadway and erode asphalt shoulder. The water level on April 18 was estimated to be at elevation 1762 as the water was nearing the centerline of Highway 81. On April 28 the water was at the centerline of the road. The low point of the centerline of Highway 81 is 1762.33.

The water was rising steadily through May due to the heavy rains. At the end of May the road was closed to cars. Heavy rains over Memorial Day Weekend caused the water to rise 5”+ above the centerline of the Highway. The deepest water was documented at 6” to 6 ½” above the centerline of the road. The road was re-opened to car traffic July 26, 2011 after water had finally receded to about 1” over the low centerline elevation.

Due to highway operation, safety and damage concerns stemming from these high water levels, the South Dakota Department of Transportation (SDDOT) has requested that a Hydrologic/Hydraulic study be completed to investigate temporary options for lowering the Twin Lakes water level. The study will evaluate the impacts and limitations of a temporary drawdown of the lake. This study will focus on evaluating the capacity of the existing drainage way downstream of Twin Lakes and Lake Sinai to the Big Sioux River and make recommendations on available capacity for a discharge from Twin Lakes.

The watershed map of the area studied is shown in Sheet 1.



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HDROLOGIC/HYDRAULIC ANALYSIS

1. PREVIOUS STUDIES

Water levels have been rising in this area since 1980. Previous studies were performed on Lake Sinai to evaluate the cause of the increased lake levels and the summaries of each study are as follows:

a. Hydrologic Analysis of Lake Sinai in Brookings County, by Department of Water and Natural Resources, August 1985.

Rising water of 3 to 5 feet per year since 1982 was causing concern among the landowners surrounding Lake Sinai. A water balance of the watershed was conducted. The report concluded that ground water inflow and outflow were negligible due to the clay soils in the watershed and overflow had not occurred based on historical record. Thus the water balance equation is reduced to:

$\Delta S = Pi + R - E$
Where: ΔS = change in storage
Pi = Precipitation
R = Run-off
E = Evaporation

The report also evaluated the impact of man made drainage alterations. In 1910 a drainage ditch was constructed in the Lake Sinai watershed and then in the 1920's the ditch was expanded to drain 3 sloughs. The report by SD DENR states that there is an impact but this impact is 20% of the total runoff contribution. The conclusion of the report states, "High water levels on Lake Sinai can be attributed primarily to the annual precipitation occurring from 1982-1984. The drainage ditch has definitely increased water levels in Lake Sinai, but the increase is relatively insignificant."

b. Flood Damage Reduction Study Lake Sinai and Vicinity, South Dakota by US Army Corps on Engineers Omaha District, January 1997

The report indicates that Lake Sinai rose over 10 feet from 1993 to 1996 and was at an approximate elevation of 1743 on October 1, 1996 covering about 1,700 acres. The previous known high-water mark was at about elevation 1734 in 1987. Lake Sinai's natural outlet is at elevation approximately 1746 and flows to the Big Sioux River.

Twin Lakes is upstream from Lake Sinai and was at elevation 1758.2 on October 1, 1996. Twin Lakes will begin to flow into Lake Sinai at an elevation of 1760.6. Twin Lakes will also overtop US Highway 81 at elevation 1761.1. US Highway 81 has been raised twice since 1987 to avoid overtopping and the embankment was riprapped to prevent wave erosion.

The conclusion of the COE report is: add 1,250 feet of 48" culvert pipe with a gate control to Twin Lakes with an upstream invert elevation of 1754 and a downstream invert elevation of 1749. This outlet structure would have a maximum capacity of 62 cfs. Lake Sinai would get a similar outlet structure of approximately 1,900 feet of 48" culvert pipe with a gate control and an upstream invert elevation of 1733 and a downstream invert elevation of 1731. This outlet structure would have a maximum capacity of 50 cfs.

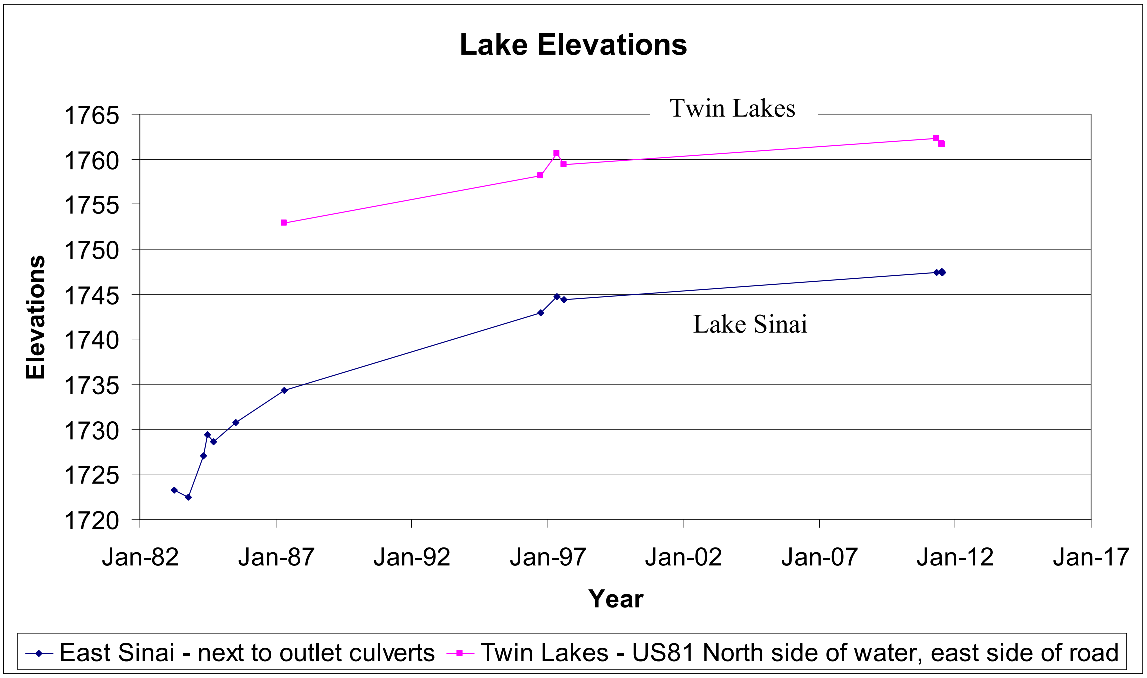
None of this work can be completed without a flood control permit from Brookings County and the State of South Dakota and a 404 permit from the Corp of Engineers. This report also recommends adding pipe to some of the downstream crossings and creating a defined drainage ditch all the way to the Big Sioux River. The report further recommends that the discharge from the lakes only occur when the Big Sioux River flow is less than 500 cfs to reduce the effects of this discharge on landowners along the Big Sioux River.

c. <u>Lake Sinai Letter Report(s) to Brookings County Commission</u> by Banner Assoc. Inc. May-June, 2011

Lake Sinai water elevation was 1747.4 on April 28, 2011 and was overflowing. Twin Lakes water elevation was 1762.3 on April 28, 2011 and was overflowing. Brush Lake which is upstream of Twin Lakes had a water elevation of 1767.3 on April 28, 2011 and was overflowing into Twin Lakes. This report investigated five alternatives and calculated the resulting flow and estimated days to drawdown Lake Sinai to an acceptable level. The conclusion of these letter reports is the addition of 1 culvert at each road crossing sized to accommodate the additional flow and that the legal side of drainage law must be reviewed prior to the selection of an outlet size. Following the writing of these letter reports Twin Lakes began to overflow the saddle contributing water to Lake Sinai. The Brookings County Highway Department recommended to the Brookings County Drainage Board. Following input from citizens affected by the water and an evaluation of the downstream culverts the Brookings County Drainage Board decided to have 4 culverts installed.

2. CURRENT CONDITIONS

a. LAKE ELEVATIONS



Lake elevations have been rising since the 1980's and for the first time in recent history both Lake Sinai and Twin Lakes have been reported to be overflowing. Brush Lake is above Twin lakes and is overflowing into Twin Lakes. Twin Lakes is above Lake Sinai and is overflowing into Lake Sinai. Lake Sinai is overflowing into a natural drainage way that eventually drains into the Big Sioux River between Brookings and Volga, South Dakota.

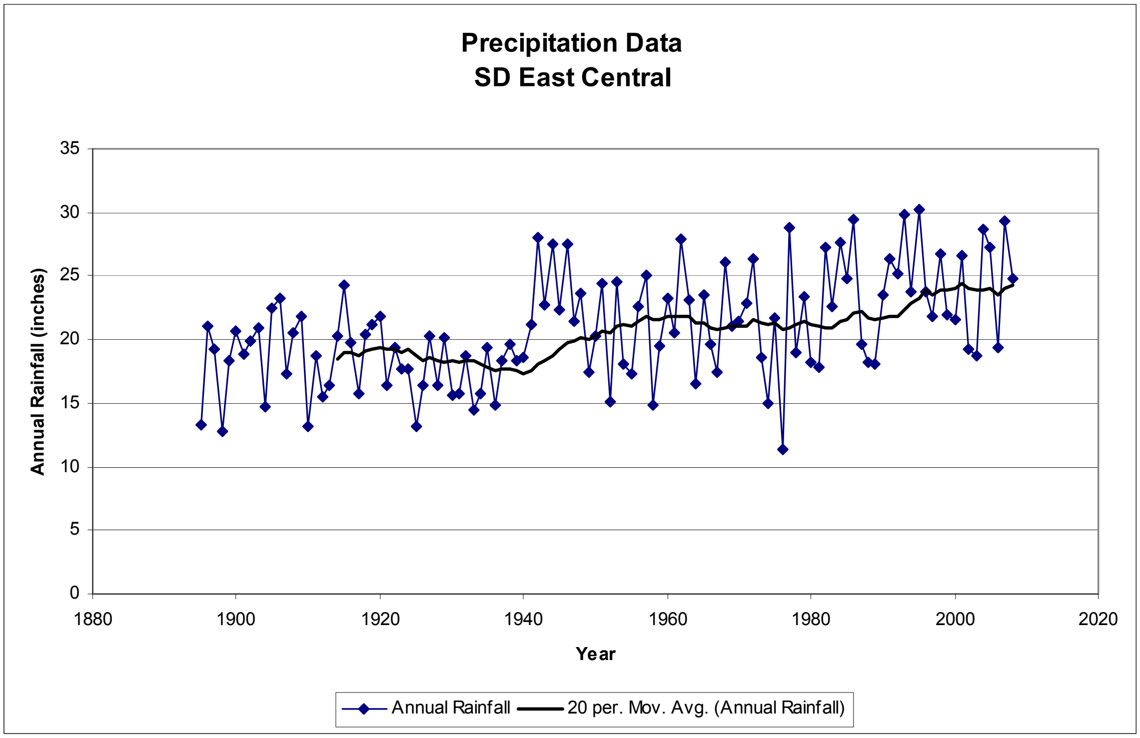
In the Spring of 2011 water began to overflow out of Lake Sinai. The existing 18" culvert did not have the capacity for the flows that were coming from Lake Sinai and the County Road began to act as a dam raising the water level in the lake. On June 16, 2011 four additional culverts were installed to relieve the water stored upstream of the county road. Compounding the high water in Lake Sinai was the overflowing water from Twin Lakes. In mid to late May, it was reported that Twin Lakes began overflowing for the first time in recent history. The estimated flows recorded on several days are as follows:

Lake Elevations and Corresponding Overflow Rates

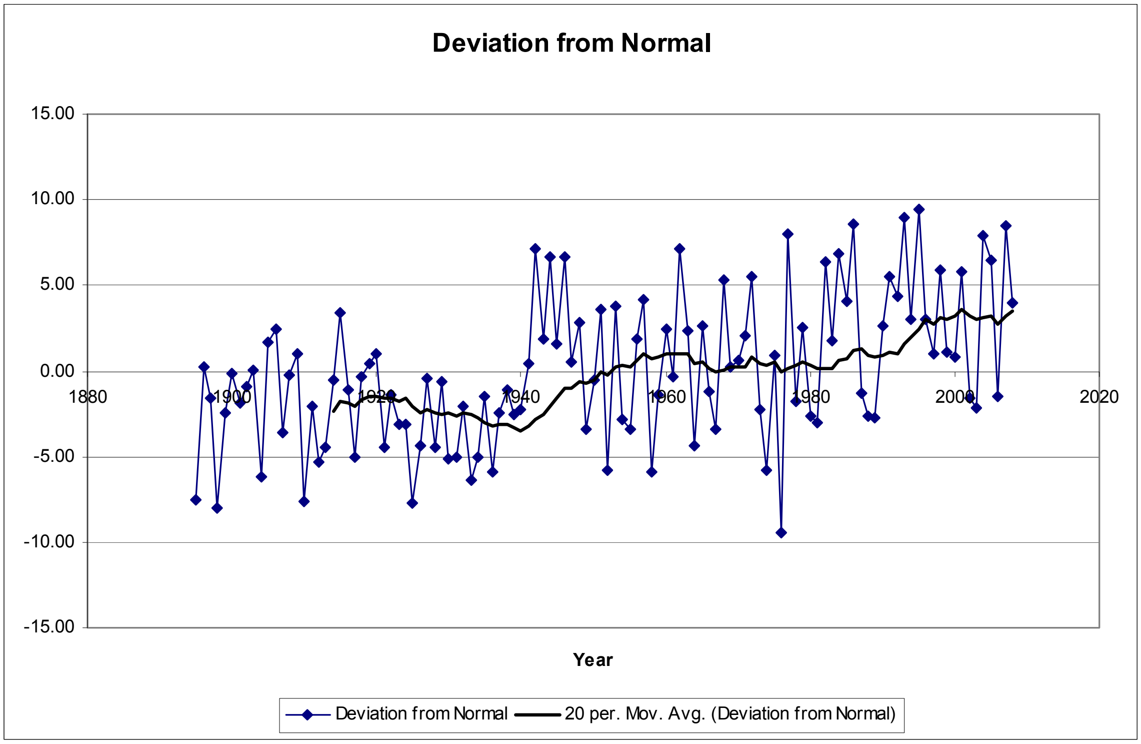
Date	Lake Sinai		Twin Lakes		Comments
	Flow (cfs)	Water Elevation	Flow (cfs)	Water Elevation	
16-Jun-11					4 culverts installed at outlet to Lake Sinai - CR-11
17-Jun-11	76.11	1748.09			Calc. Elev. based on headwater depth measurement
20-Jun-11	50.00	1747.76			Calc. Elev. based on headwater depth measurement
21-Jun-11	90.00	1748.26			Calc. Elev. based on headwater depth measurement
23-Jun-11	65.08	1747.96			Calculated Elevation Based on measured flow
27-Jun-11	58.00	1747.86			Calculated Elevation Based on measured flow
7-Jul-11	37.86	1747.59	20.48	1762.74	Calculated flow Based on measured Elevation
8-Jul-11	36.43	1747.57	19.39	1762.71	Calculated flow Based on measured Elevation
11-Jul-11	30.36	1747.49	18.46	1762.68	Calculated flow Based on measured Elevation
13-Jul-11	27.50	1747.44	15.70	1762.59	Calculated flow Based on measured Elevation
14-Jul-11	30.78	1747.49	9.50	1762.38	Calculated Elevation Based on measured flow
15-Jul-11	30.71	1747.49	17.85	1762.66	Calculated flow Based on measured Elevation
18-Jul-11	27.50	1747.44	17.23	1762.64	Calculated flow Based on measured Elevation
19-Jul-11	27.3	1747.44	9.17	1762.37	Calculated Elevation Based on measured flow
1-Aug-11	17.29	1747.27	6.51	1762.25	Calculated Elevation Based on measured flow
2-Aug-11			12.07	1762.47	Calculated flow Based on measured Elevation

b. PRECIPITATION

The charts below are a compilation of annual rainfall records for East Central South Dakota. The year to year data shows that there is a wide variation in annual rainfall from year to year. The dark line running through the middle of the annual data is a 20 year moving average. The 20-year moving average shows that the average annual rainfall is trending upward and has been trending upward since 1940. The result of this increase in annual rainfall is an increase in the water surface elevations of the local lakes.



We also looked at how this data compares to the normal precipitation in this region. The chart shown below indicates that annual precipitation was below normal up until approximately 1950, was near normal from 1950 to 1980, and then started a steady climb of above normal annual precipitation from 1980 to the present time. Northeastern and East Central South Dakota have been dealing with above normal precipitation and below normal evaporation for nearly 30 years. This excess water has culminated into water bodies that are much higher than normal, flooding property, damaging farmland and damaging the local and state roadway system.



3. LENGTH OF TIME REQUIRED TO REMOVE THE DESIRED VOLUME OF WATER FROM TWIN LAKES

The volume of water to be removed from the lake is dependent on the amount of rainfall and evaporation that occurs during the discharge. For this analysis a starting water surface elevation of 1762.64 was used based on a survey of the actual water elevation on July 18 2011. At that time there was approximately 4-inches of water on the centerline of US Highway 81. The intended target for the water elevation after the dewatering is 1758.8 which is 3 feet below the shoulder of US Highway 81. The water surface elevation would be 3.84 feet lower than it was on July 18, 2011.

Several pumping rates were evaluated to determine the number of days it would take to lower the water to the desired elevations based on below normal precipitation, normal precipitation and above normal precipitation. For this analysis the normal daily precipitation data was obtained from the South Dakota State University Climatology website for a weather station north of Brookings. The normal precipitation was reduced by 25% for the below normal model which also had a 25% increase in evaporation. The normal precipitation was increased by 25% for the above normal precipitation with a 25%

reduction in evaporation. The actual volume to be pumped will vary with actual precipitation and evaporation. To keep this in perspective the annual rainfall in 2010 was 37.5% above normal and evaporation was 34% less than normal. The detailed table which includes the Lake Sinai comparison is included in Appendix A.

Number of Days required to lower Twin Lakes to Elevation 1758.8

Discharge Rate (cfs)	Below Normal Precipitation	Normal Precipitation	Above Normal Precipitation
10	181	237	383
20	111	134	163
30	89	101	116
35	80	91	103
40	75	83	93
50	66	72	78

Based on the number of days available and capacity of the channel the anticipated discharge rate recommended is 35 cfs. At this rate it can be expected that the target water surface elevation of 1758.8 would be reached in 80 to 103 days.

DRAWDOWN ALTERNATIVES

1. NATURAL OUTLET - DO NOTHING

a. Natural Outlet

The natural outlet began flowing in mid April. The outlet flow shortly after a nearly 3-inch rainfall event on June 20 and 21 was 20 cfs. The water flow rate has dropped down to 6 cfs and will continue to drop until there is another rainfall event. The outflow rate will vary with rainfall and evaporation rates.

The flowing water cleared a path through the grass and cattails that is approximately 12’ wide. The width varies from top to bottom. Water is spread out at the saddle and as it breaks over the top it concentrates and the velocity increases. The water drops 10’ in elevation as it traverses the water course to the township road. This natural outlet controls the water surface elevation on Twin Lakes and may cause water to flood Highway 81 to a depth of 6 to 7 inches above the centerline elevation depending on the rain storm event. To gain storage the water would have to evaporate out to of the lake and that would take several

years at normal rainfall and evaporation rates. Under normal conditions the water surface elevation of the lake would only drop 6-inches annually, thus if this region received average precipitation and had average evaporation it would take 7 years for the water to drop 3 feet below the shoulder of the road. The precipitation data shown above indicates that this region has been receiving above normal precipitation and below normal evaporation. Thus with the "Do Nothing" alternative it is anticipated that the flooding of Highway 81 would be a chronic problem.

Thus it can be expected that water would flow out the overflow on a regular basis. There may be time during the low rainfall months that the flow would stop but it would start flowing again at the next major rainstorm event. Intermittent flow would allow the clay soils in the flow channel to dry and begin to crack. During the next storm event water would begin flowing and erode soil particle from within those cracks and higher concentrated velocity would result and increase the likely hood of eroding the channel. The concern with a "Do Nothing" alternative is that the natural channel would erode until Twin Lake and Sinai would be connected by an uncontrolled channel.

b. IMPACTS AND LIMITATIONS

The impact of a "Do Nothing" alternative would be an anticipated chronic flooding problem on US Highway 81 and the potential for an uncontrolled release of Twin Lakes through an eroded channel connection between the lakes.

2. SIPHON OUTLET STRUCTURE WITH CONTROLS

a. SIPHON DISCHARGE

One alternative evaluated is the installation of siphon pipes at the outlet of Twin Lakes. These siphon pipes would have to be installed with control valving on each end and a connection port at the high spot to allow for filling of the siphon pipe in order to create the siphon. SD Game Fish and Parks have also indicated that the intake and discharge end of each siphon pipe would have to be screened to prevent fish transfer between the lakes. The control valves and fish screens add headloss to the pipe and reduce the flow of water through each siphon pipe. It is anticipated that approximately 1, 150 feet of pipe would have to be installed from intake to discharge. The intake would have to be located far enough out into the lake to allow 3.5' of water level drop and allow some cover over the fish screens

to prevent floating moss and algae from fouling up the screens. Pipe sizes evaluated ranged from 16-inch to 24-inch Diameter HDPE fuse welded pipe.

b. ESTIMATED COST

Each siphon system would consist of multiple pipes laid on the northerly side of the existing overflow channel. The line that extends into the water would have to be anchored to the bottom to prevent it from floating. A 4" trash pump would be used to fill the pipe. The number of pipes required for the siphon varies with the diameter of the pipe. The number of pipe, size and associated costs are shown below:

Size	Number	Cost
24" Siphon	4	$343,100
20" Siphon	6	$370,100
18" Siphon	7	$366,450
16" Siphon	9	$401,650

c. IMPACTS AND LIMITATIONS

The siphon pipe could be operated during cold weather and even very cold weather because there would be very little maintenance associated with a siphon pipe. Access to the gate valves on either end would be more difficult during the winter months. Ice fishing does occur during the winter months so once there is ice-over, withdrawal of water could cause an air void to form under the ice which would be dangerous to fishermen that are venturing out onto the ice with vehicles. Withdrawal from the lake after ice-over should be limited and carefully monitored. Velocity and slot size of the fish screen will be as required by SD Game Fish and Parks. Delivery of material and manufactured fish screen may also limit the time frame when the water withdrawal can begin. An option would be to construct a temporary fish screen using a wire gabion basket wrapped with geotextile drainage fabric allowing for an earlier start to the water transfer. SD Game Fish and Parks would also allow the pipe to be buried under rock like a coffer dam using the rock to screen out the fish. Placing rock or fill in the lake will require a 404 permit from the Corp of Engineers.

3. PUMPING

Another option is to pump water from Twin Lakes rather than siphon water from the lake. Three ways to pump water from the lake are described below:

a. DIESEL ENGINE DRIVE PUMPS

Eight, 8-inch, diesel engine, trailer mounted self contained dewatering pumps could be installed near the saddle of the Twin Lakes overflow channel. Three pumps would be connected to one 12" Poly line and be discharged approximately 900' from the pumps near the Township road. Each pump would pump approximately 2,000 gpm. The intake of the pump would have to be screened to prevent fish from entering the pumps. The discharge end of the pipe would have to be installed with erosion control to prevent a washout from occurring at the pump discharge. The erosion control could be riprap, concrete energy dissipation structure or other means that would protect the soil from erosion.

i. **LIMITATION:** The limitation to this alternative is getting fuel to the diesel engine during in-climate weather including rain or snow. The fuel consumption will be in the range of 1.5 to 3 gph per pump or approximately 580 gallons per day. A nurse tank could be provided to extend the time between refueling operations. Regular visits would have to be made to the site check on the pumps as they operate.

ii. **ESTIMATED COST:** The estimated cost for this alternative which includes pump rental, discharge pipe rental, delivery, installation, intake and discharge screens, operation and maintenance and estimated fuel consumption based on a cost of $3.98/gal. Please note that other combination of pumps would be allowed as well and cost may vary accordingly.

$310,200

b. ELECTRIC PUMPS WITH TEMPORARY POWER SERVICE

Another pumping alternative is to install four 55Hp 460V 3 phase submersible pumps and a 94 Hp 460V 3 phase submersible pump and get a temporary power drop from the local Rural Electric Company. This scenario would also require a soft start on the 94 Hp pump. This system would also require the three 12" water lines, intake screens, and a base for the pumps. The discharge lines would also require erosion control to prevent washout. A specific pump and operation system was evaluated and costs were evaluated for this specific system. Other pumps sizes and combinations would be allowed and costs may vary from those included in this report.

i. **LIMITATION:** The limitation to this alternative is the 3 week delay in getting the temporary power to the site.

ii. **ESTIMATED COST:** The estimated cost for this alternative which includes pump rental, discharge pipe rental, delivery, installation, intake and discharge screens, operation and maintenance and estimated power demand and power usage is:

$242,800

c. ELECTRIC PUMPS WITH DIESEL TRAILOR MOUNTED GENERATOR

Another pumping alternative is to install four 55Hp 460V 3 phase submersible pumps and a 94 Hp 460V 3 phase submersible pump and rent diesel engine driven generators to provide the temporary power. This scenario would also require a soft start on the 94 Hp pump. Other pumps sizes and combinations would be allowed and costs may vary from those included in this report.

This system would also require the three 12" water lines, intake screens, and a base for the pumps. The discharge lines would also require erosion control to prevent washout.

i. **LIMITATION:** The power generators would be placed at the Township road allowing for easier fuel delivery but very long power cord would be necessary to power the pumps. A nurse tank for fuel would reduce the number of fueling operations that would need to take place during the pumping operation. Regular visits would have to be made to the site to make sure that the generators are operating properly.

ii. **ESTIMATED COST:** The estimated cost for this alternative which includes pump rental, generator renal, discharge pipe rental, delivery, installation, intake and discharge screens, operation and maintenance and estimated fuel consumption is:

$136,400

SUMMARY OF ALTERNATIVES AND ESTIMATED COSTS

1. NATURAL OUTLET - DO NOTHING

The impact of a "Do Nothing" alternative would be an anticipated chronic flooding problem on US Highway 81 and the potential for an uncontrolled release of Twin Lakes through an eroded channel connection between the lakes.

2. **SIPHON OUTLET STRUCTURE WITH CONTROLS**

   Three 24" water lines installed with control valves and intake screens. Maintenance would be minimal and weather would not affect the operation and maintenance of the dewatering operation. **Estimated Cost - $343,100**

3. **PUMPING**

   a. **DIESEL ENGINE DRIVE PUMPS**
      Pumps located near the saddle and mounted on a trailer. Pumps would be equipped with suction lines for the intake that can be screened and be placed out in the lake without disturbance to the natural ground. Fuel would need to be delivered to the saddle on a daily basis. **Estimated Cost - $310,200**

   b. **ELECTRIC PUMPS WITH TEMPORARY POWER SERVICE**
      Electric submersible pumps located near the saddle. Pump placement would be in the water, requiring some excavation to bring deeper water to the shore allowing for a near shore pump access point. Temporary power would require 3 weeks from notice to proceed and the delivery of power. **Estimated Cost - $242,800**

   c. **ELECTRIC PUMPS WITH DIESEL TRAILOR MOUNTED GENERATOR**
      Electric submersible pumps located near the saddle. Pump placement would be in the water, requiring some excavation to bring deeper water to the shore allowing for a near shore pump access point. Generators would be located at the Township Road allowing for easier access for fuel delivery. **Estimated Cost - $136,400**

RECOMMENDATION

Based on costs and availability of material the recommended plan is to install electric submersible pumps powered with diesel engine generator. Estimated Cost $154,000

Banner recommends that five 5' diameter x 10' high manholes be installed at the shoreline of the existing Twin Lakes high water line in the shape of a circle. (See attached map) A 4' diameter pipe would be stubbed out of each of the manhole 3 feet towards the center of the circle. The circular shape inside of the manhole ring of five manholes would then be filled with oversized rock to a depth of approximately 6 feet. This rock would then cover the 4' diameter pipes and filter out any fish that venture into the discharge location. The 4' diameter pipe is chosen to keep velocity low at this location to reduce the amount of silt and debris that would be carried by the water current towards the pumps. With a 4' diameter pipe the velocity going into each manhole would be less than 1 ft. /sec.

Five submersible pumps would be installed in each of the manholes. (4-55 hp pumps and 1-94 hp pump.) The 94 hp pump weighs nearly 1200 lbs and is approximately 3' in diameter and stands approximately 4' high. A crane or large backhoe would be needed to install these pumps, thus the pumps must be installed within reach of shoreline.

The single 94 hp pump would connect to a single 12" water line that would be laid on the ground and meander along the existing channel to a point of discharge approximate 900' down stream. Two other 12" lines would be installed with two 55 hp pumps connected to each. Thus each 12" line would be discharging approximately 5,000 gpm of water.

Each discharge line would have to be installed with some kind of energy dissipation method. The energy dissipation could consist of riprap, or headwall with energy dissipaters or the pipe could discharge into the upper section of a 4' diameter manhole where the water drops down and discharges out a 24" diameter hole at the bottom of the manhole section. Some riprap will still be required around the manhole to prevent soil erosion.

1. **IMPACTS AND LIMITATIONS:** The power generators would be placed at the Township road allowing for easier fuel delivery but very long power cords would be necessary to power the pumps. A nurse tank for fuel would reduce the number of fueling operations that would need to take place during the pumping operation. Regular visits would have to be made to the site to make sure that the generators are operating properly. The generators would need to set in the field just off the Township road to allow traffic to continue to use the road while the pumping operation is in progress. A temporary easement would be required for the pumps, pipeline, generators and ingress and egress for operation and maintenance. Noise would be produced by the generators, but it is believed that wildlife would soon adapt to the noise because it would be constant and not a start/stop.

CAPACITY OF EXISTING STRUCTURES WITHIN THE DRAINAGE WAY AND IMPACT TO LAKE SINAI

Capacity of Structures Within the Waterway

Sec	Street ID	Existing Structure	Top of Pipe Flow (cfs)	Proposed pipe	Capacity	Overtopping Flow (cfs)
6/5	455th Ave	2-48" Arch	19	2-48" Arch	38	40
5	Driveway	1-18" CMP	5	4-24" Arch	40	48
3/2	Co Rd 11	4-48" Arch 18" steel pipe	180	None	180	580
2/1	459th Ave	1-48" CMP, 1-54" CM Arch	280	None	280	300
1/36	214th St	3'x4' Box, 1-18"CMP, 1- 48" CM Arch	160	None	160	170
36/31	460th Ave	2-36" CMP, 2-54" CMP	300	None	300	350
31/32	461st St	2-48" CM Arch, 2-48" CMP	250	None	250	245
32/29	213th St	3-60" CM Arch, 1-48" CMP	355	None	355	375
29/28	462nd Ave	3-60" CMP, 1-48" CMP	375	None	375	375
28/27	463rd Ave	2-48" CMP	210	None	210	220
22/23	Co Rd 5	19' Bridge	1400	None	1400	1425
23	Golf Course #4 (S)	Golf Cart Bridge	path overtops before reaching top	None	20	20
23	Golf Course #4 (N)	Golf Cart Bridge	path overtops before reaching top	None	70	70
23	Golf Course #8	Golf Cart Bridge	path overtops before reaching top	None	35	35
23	Golf Course #1	Golf Cart Bridge	path overtops before reaching top	None	50	50
23/24	465th Ave	15' Bridge	750	None	750	1460

The selected discharge rate from Twin Lakes was established based on the number of days available for a discharge and keeping the resultant discharge from Lake Sinai below the flow rate that occurred in mid June when the four pipes were installed. The intention is to have a controlled flow that is less than what this area experienced this spring and summer. An

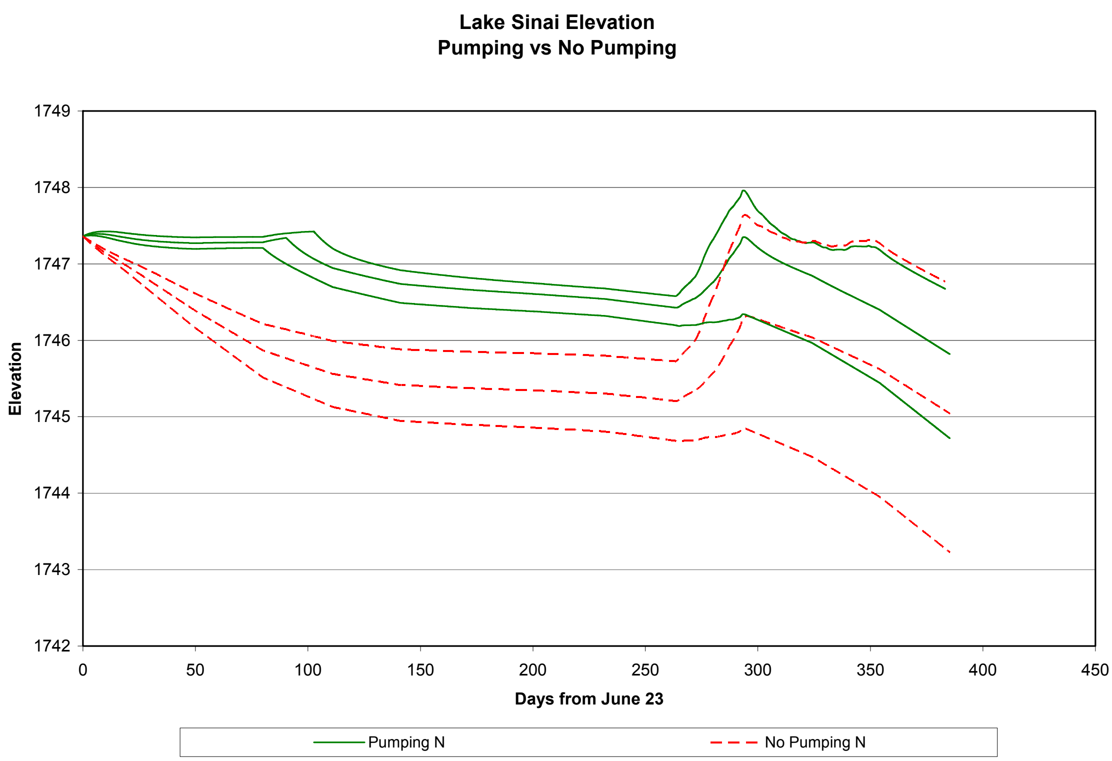
inundation map was prepared comparing the flow that occurred on June 21, 2011 and the proposed 35 cfs discharge from Twin Lakes. (Appendix C)

Based on the computer analysis summarized above, Banner is recommending that the capacity of two crossings be increased. The crossings that will be improved are the two crossing between Twin Lakes and Lake Sinai. *(First two in the table above).* The estimated cost for installation of these additional culverts is approximately $ 18,000 to $20,000.

There is one structure in the Meadow Creek Golf Course that does not have the capacity to pass the proposed flow. This structure is located on golf cart path that crosses the slough within the golf course. The thick cattails in the slough restrict the flow through this area. The SD DOT is willing to work with the Golf Course on a temporary solution that would allow golfers to traverse the course in this area.

IMPACT TO LAKE SINAI

The model indicates that the water surface elevation in Lake Sinai will hold fairly constant during the pumping operation (90 to 100 days). When the pumping stops the lake elevation will drop and once again be totally dependant on rainfall and evaporation. If we have above normal rainfall next spring, Lake Sinai will see a slight benefit resulting from the pumping due to the storage that will be provided in the Twin Lakes. That benefit would be larger if we have another year like 2010. SD DOT will monitor the water surface elevation of Lake Sinai throughout the pumping operation and shut the pumps off if Lake Sinai reaches a water surface elevation of 1747.5.



IMPACT TO THE BIG SIOUX RIVER

The Big Sioux River is currently flowing at approximately 900 cfs. The peak outflow from Lake Sinai during the pumping operation is expected to be between 20 cfs and 25 cfs. The peak outflow lags behind the Twin Lakes flow because of the size and volume of water in Lake Sinai. This flow rate is only 3% of the Big Sioux River flow, thus will not cause a significant impact to the Big Sioux River flood plain. The landowners along the Big Sioux River experience flooding on their land immediately following the installation of the 4 culverts at the outlet of Lake Sinai. The peak measure flow coming out of Lake Sinai was approximately 90 cfs. The gauging station data for the Big Sioux River was reviewed and the data indicates that following the June 16th installation of the Lake Sinai culverts the flow in the Big Sioux River went from approximately 1,800 cfs to approximately 3,000 cfs. The 90 to 100 cfs discharge from Lake Sinai cannot change the river flows by 1200 cfs. Thus the river flow increase was caused by a rainfall event. Precipitation data indicates that there was a thunder storm that went through East Central South Dakota the evening/day (June 20 and 21) after the installation of the culverts in which approximately 3-inches of rain was reported in some areas. The run-off from this rainfall event increased the flow in the Big Sioux River.

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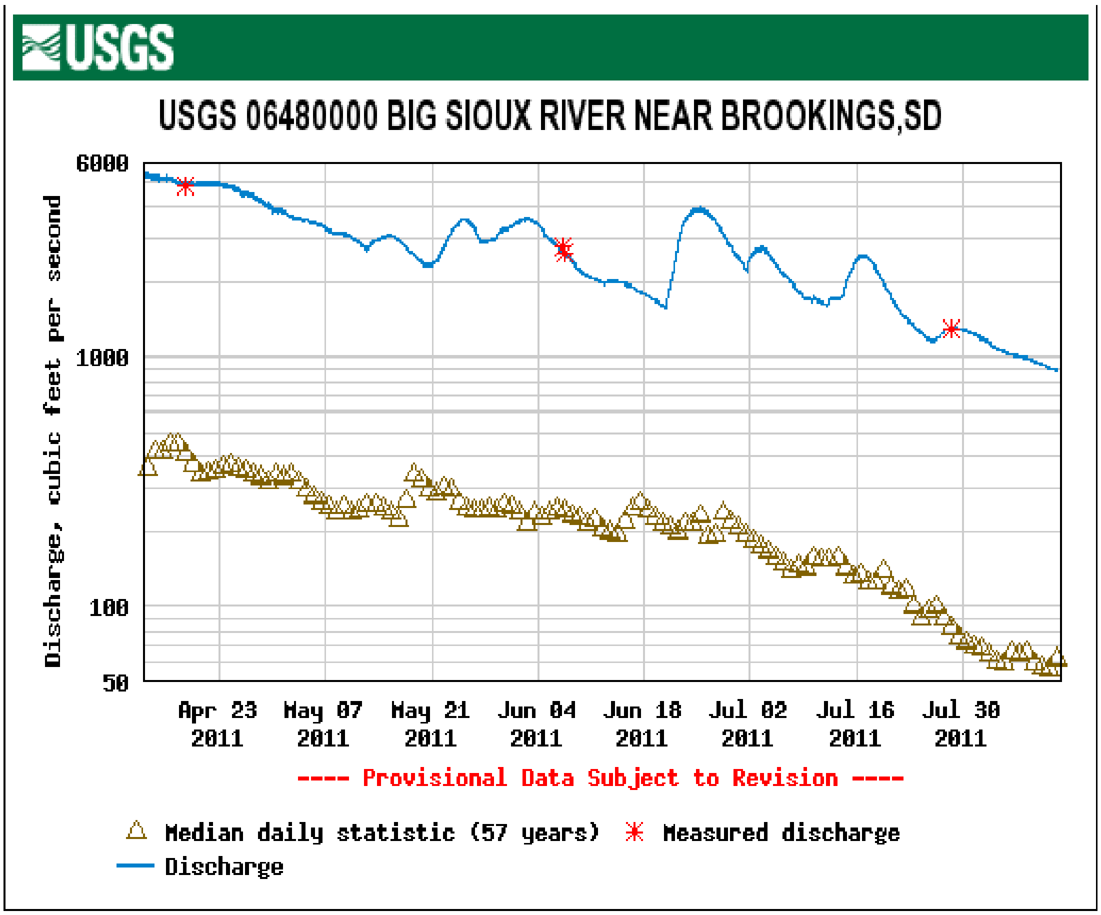
This event does indicate that the entire region is affected by the above normal rainfall that has been occurring in this region for the past several years. SD DOT is very aware of the fact and will stop the pumps at Twin Lakes if the Big Sioux River flows exceed 2,000 cfs to prevent flows from Twin Lakes contributing to any flooding problems that landowners along the Big Sioux River are experiencing in the Brookings vicinity.



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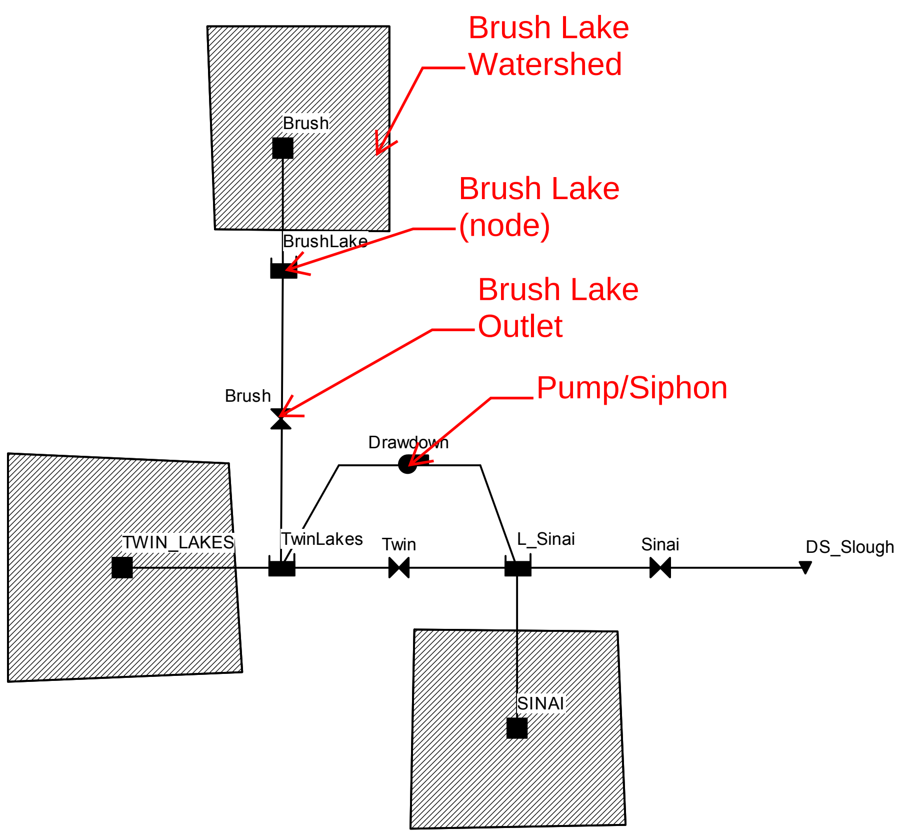
Appendix A

Summary of Computer Model (SWMM) Water Hydraulics Results

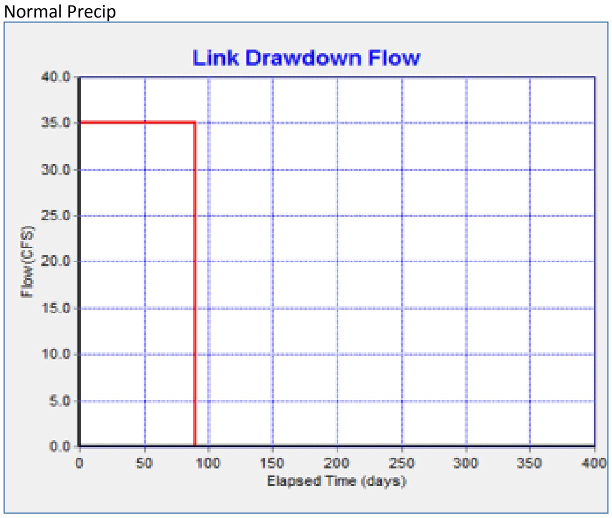
SWMM RESULTS - TWIN LAKES PUMPING RATES, LAKE ELEVATIONS, AND FLOWS

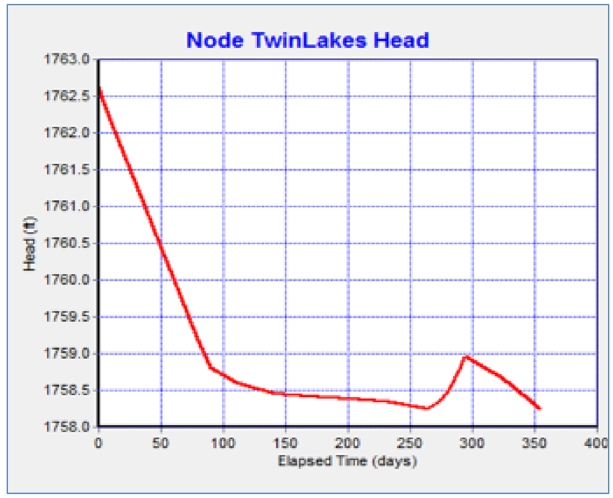
	Twin Lakes (starting lake EL. 1762.64)			Lake Sinai (starting lake EL. 1747.36)		
Pumping Rate (cfs)	# Days to Drain to EL. 1758.8	Peak Flow Out	Total Volume Pumped gal x 10^6	L. Sinai Peak WS EL.	# Days above I.E. (Sinai)	Peak Flow Out
Normal Precipitation						
50	72	67	2327	47.51	360	32.4
40	83	57	2146	47.42	361	26.3
35	91	52	2058	47.39	361	24.5
30	101	47	1958	47.38	362	23.2
20	134	37	1732	47.44	363	22.5
10	237	27	1532	47.55	364	22.5
Above Normal Precipitation (25% more precip, 25% less evaporation)						
50	78	67	2520	47.93	383	36.9
40	93	57	2404	47.95	383	28.9
35	103	52	2330	47.96	383	26.6
30	116	47	2249	47.97	383	24.6
20	163	37	2107	48	383	22.5
10	383	27	2475	48.18	383	22.5
Below Normal Precipitation (25% less precip, 25% more evaporation)						
50	66	67	2133	47.45	174	28.2
40	75	57	1939	47.39	232	24.4
35	80	52	1810	47.37	258	23.2
30	89	47	1726	47.36	294	22.5
20	111	37	1435	47.36	312	22.5
10	181	27	1170	47.36	248	22.5
Above Normal Precipitation (Yr 2010 - 37.5% more precip, 34% less evap)						
50	178	67	5752	48.64	700+	122.3
40	217	57	5610	48.52	700+	112.6
35	242	52	5474	48.48	700+	108.3
30	279	47	5409	48.43	700+	104.6
20	700+	37		48.39	700+	100.6
10	700+	27		48.36	700+	98.6

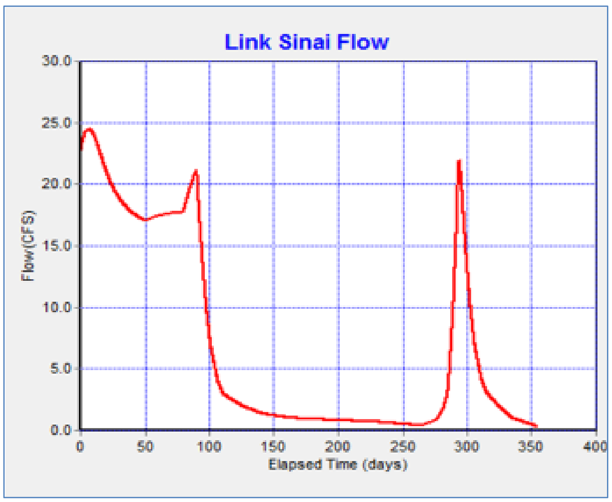
SWMM Model Node/Link Schematic

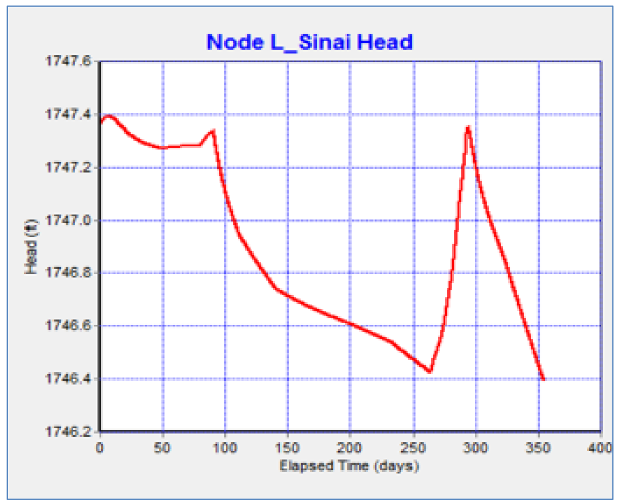


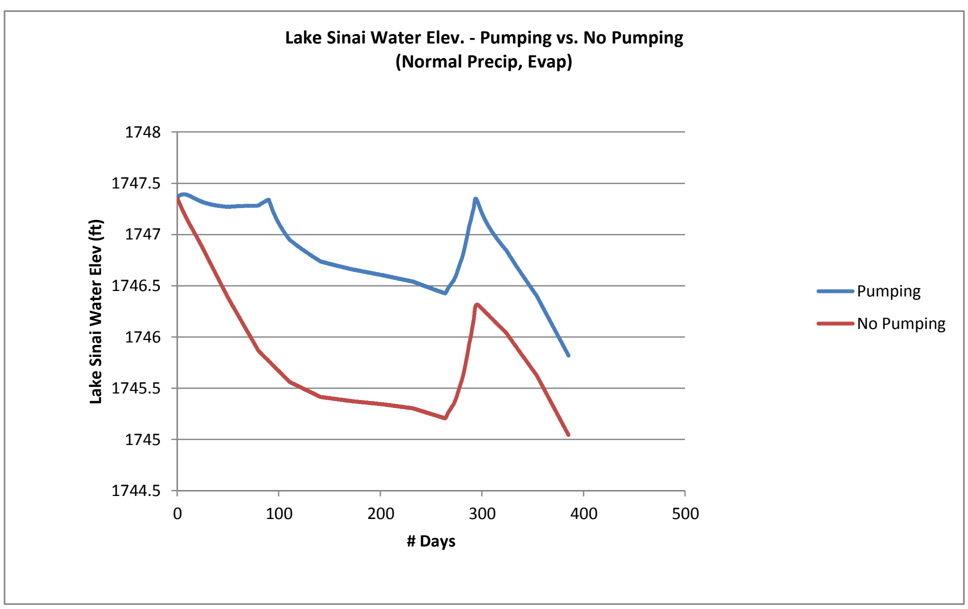
Drawdown pumping rate at 35 cfs
Normal Precip



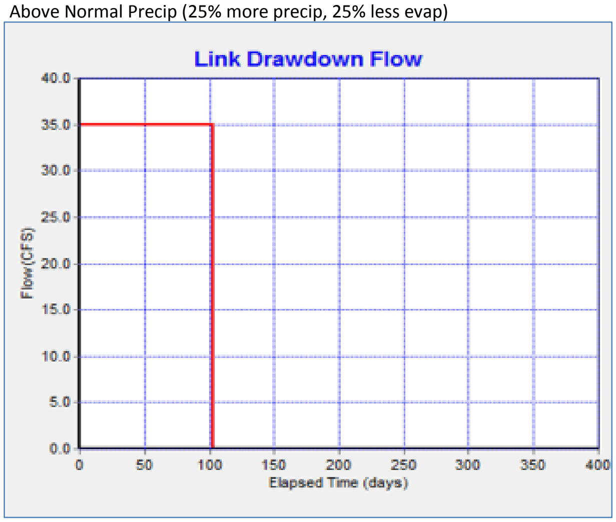


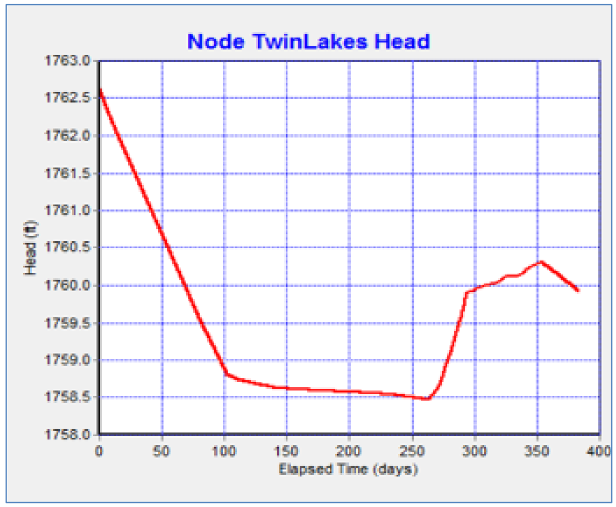


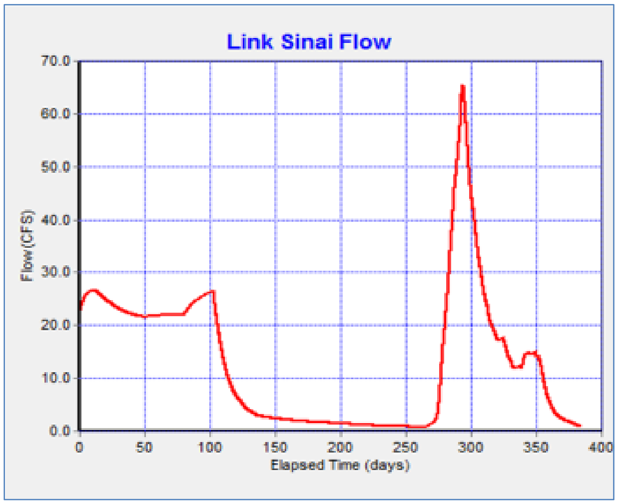


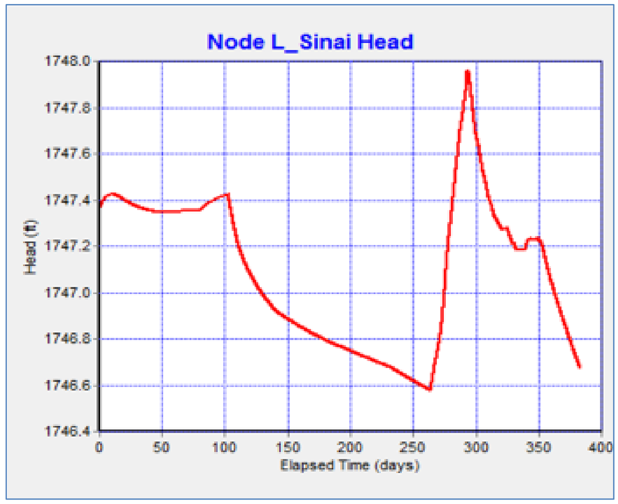


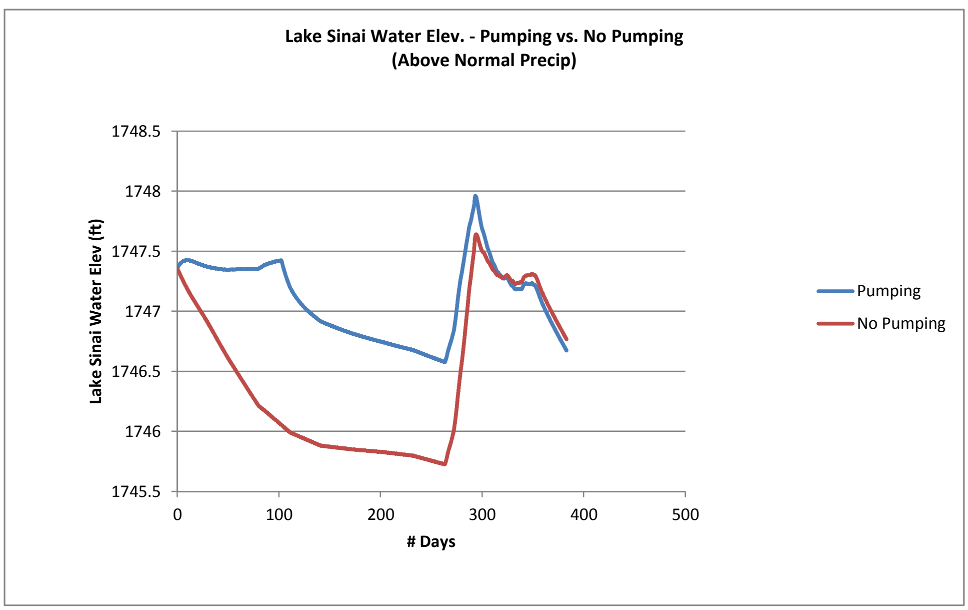
Drawdown pumping rate at 35 cfs
Above Normal Precip (25% more precip, 25% less evap)



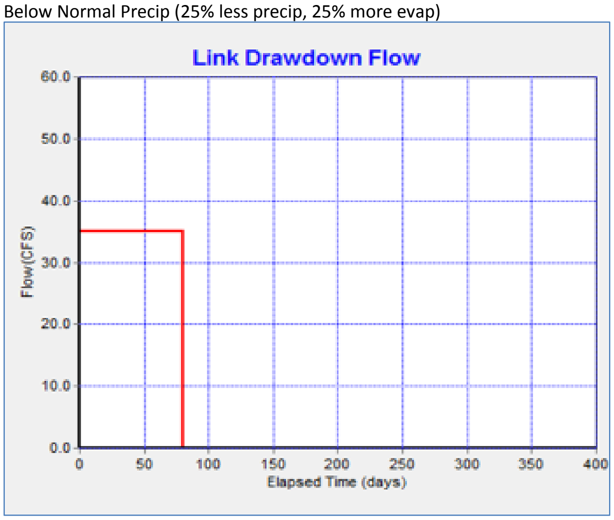


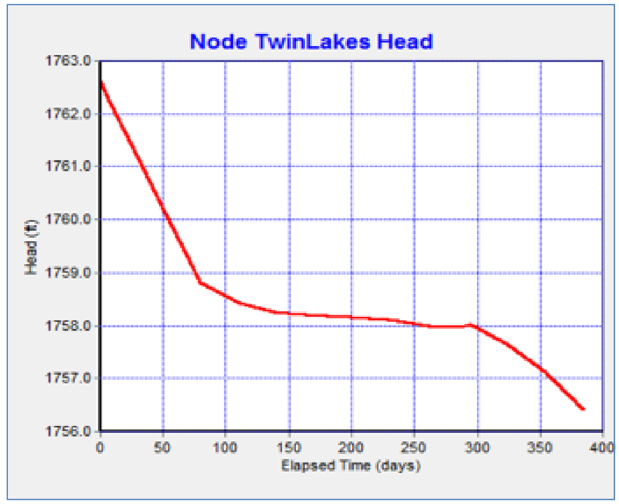


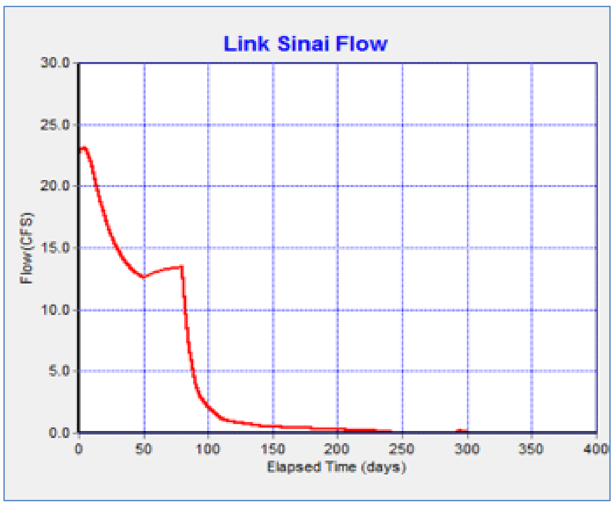


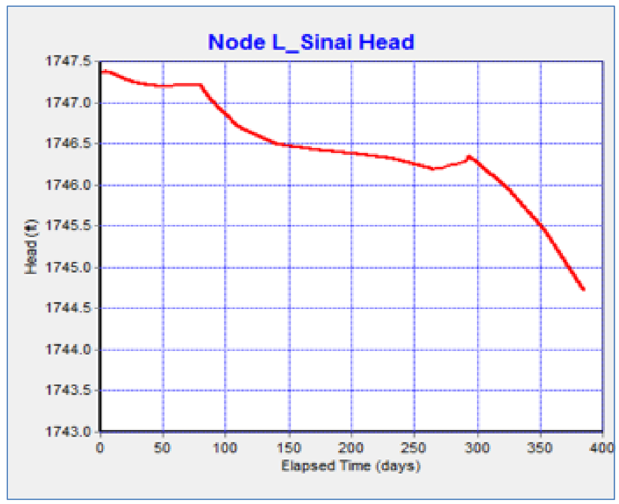


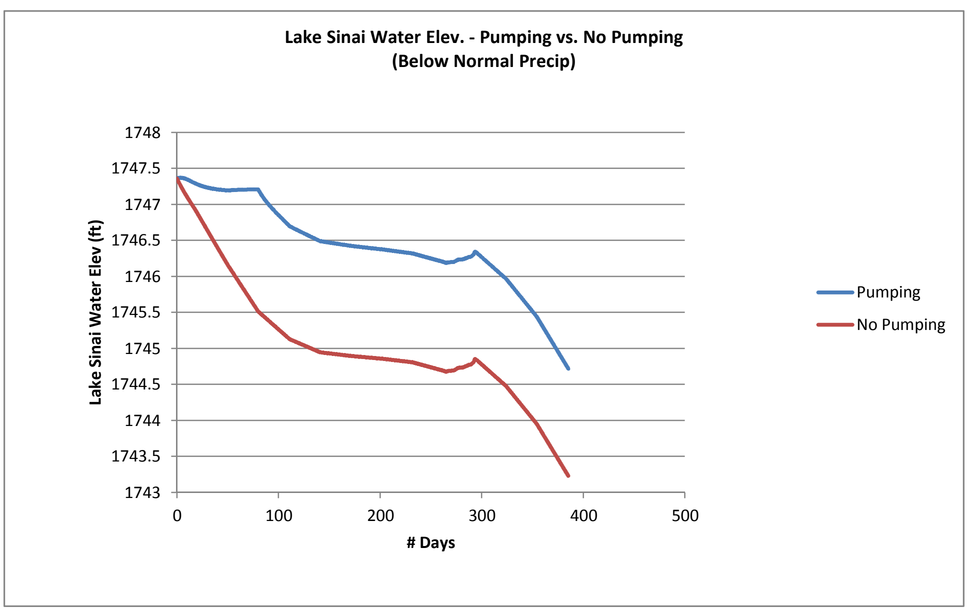
Drawdown pumping rate at 35 cfs
Below Normal Precip (25% less precip, 25% more evap)



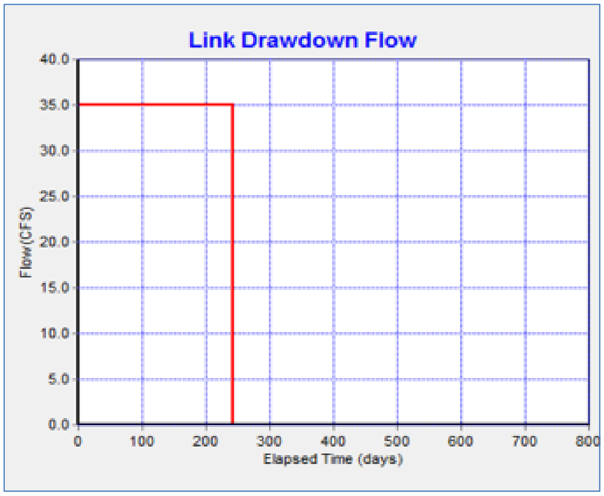


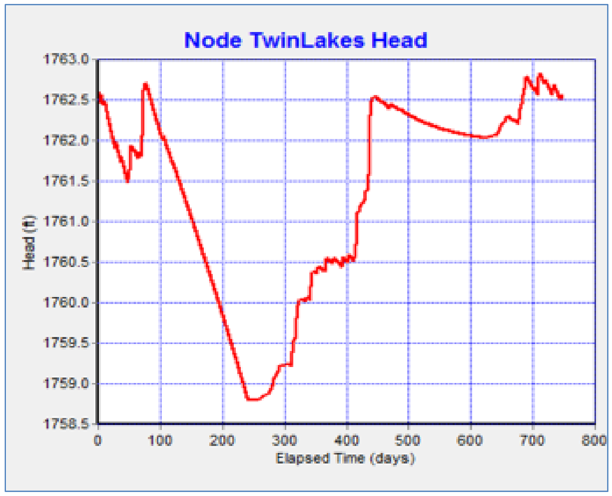


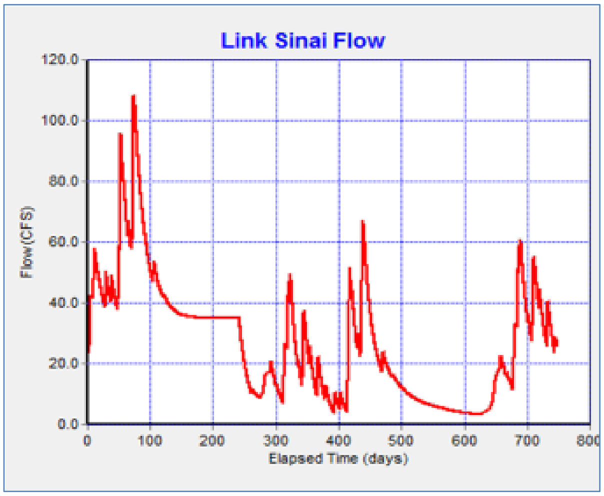


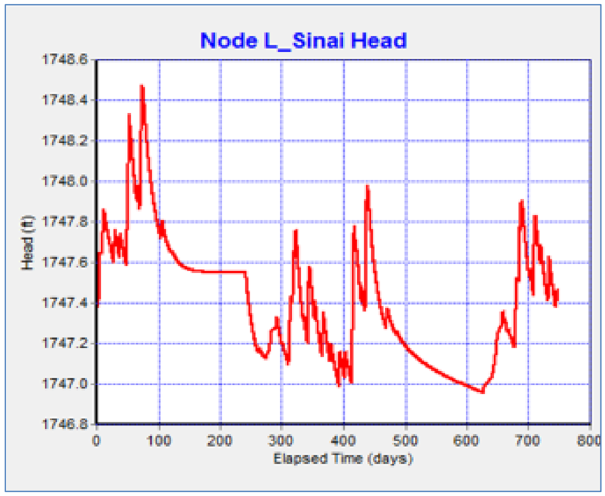


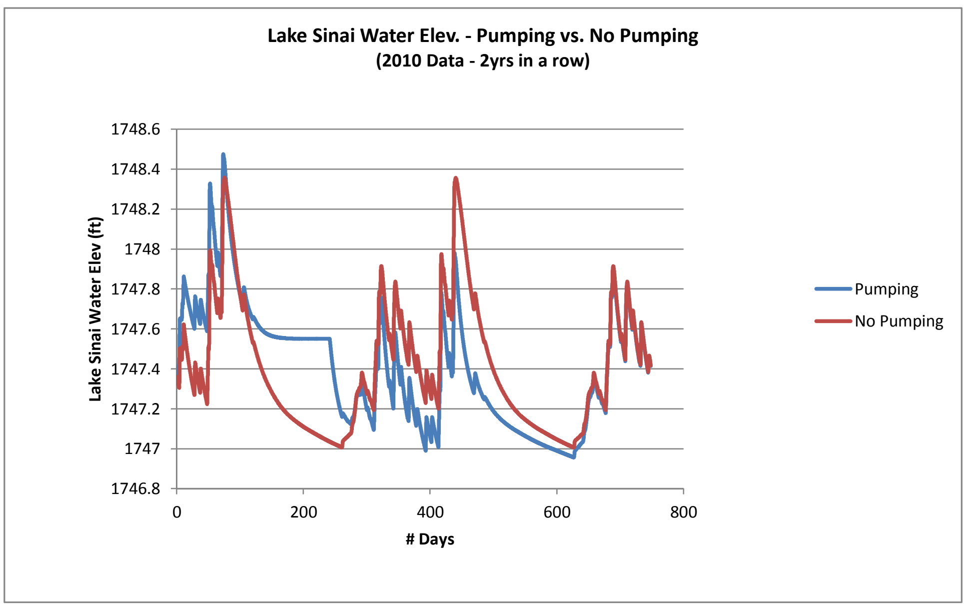
Drawdown pumping rate at 35 cfs
2010 precip (2yrs in a row)











Appendix B

Cost Estimates

Summary of Estimated Costs

Electric Pumps with Generators	$ 136,376.00
Electric Pumps with Temporary Power Drop	$ 242,816.06
Diesel Engine Driven Pumps	$ 310,179.20
24" Siphon	$ 343,079.28
20" Siphon	$ 370,031.24
18" Siphon	$ 366,444.18
16" Siphon	$ 401,633.48

16" Siphon

	Quantity	unit	Unit price	Amount
16" pipe	10350	LF	$ 18.13	$ 187,645.50
16" Inlet Valve	9	each	$ 6,059.91	$ 54,539.19
16" Outlet Valve	9	each	$ 6,059.91	$ 54,539.19
16" Flange Adapter and ring	18	each	$ 342.20	$ 6,159.60
Anchors	90	each	$ 100.00	$ 9,000.00
Installation	1	LS	$ 10,350.00	$ 10,350.00
Filling	1	LS	$ 900.00	$ 900.00
4" trash pump	1	LS	$ 4,500.00	$ 4,500.00
Maintenance	200	Hrs	$ 50.00	$ 10,000.00
Fish Strainer/Screen	18	each	$ 3,500.00	$ 63,000.00
Miscellaneous material/work	1	LS	$ 1,000.00	$ 1,000.00
Estimated Total for 16" pipe				**$ 401,633.48**

18" Siphon

	Quantity	unit	Unit price	Amount
18" pipe	8050	LF	$ 21.32	$ 171,626.00
18" Inlet Valve	7	each	$ 7,894.39	$ 55,260.73
18" Outlet Valve	7	each	$ 7,894.39	$ 55,260.73
18" Flange Adapter and ring	14	each	$ 360.48	$ 5,046.72
Anchors	70	each	$ 100.00	$ 7,000.00
Installation	1	LS	$ 8,050.00	$ 8,050.00
Filling	1	LS	$ 700.00	$ 700.00
4" trash pump	1	LS	$ 3,500.00	$ 3,500.00
Maintenance	200	Hrs	$ 50.00	$ 10,000.00
Fish Strainer/Screen	14	each	$ 3,500.00	$ 49,000.00
Miscellaneous material/work	1	LS	$ 1,000.00	$ 1,000.00
Estimated Total for 18" pipe				**$ 366,444.18**

20" Siphon

	Quantity	unit	Unit price	Amount
20" pipe	6900	LF	$ 26.31	$ 181,539.00
20" Inlet Valve	6	each	$ 9,480.62	$ 56,883.72
20" Outlet Valve	6	each	$ 9,480.62	$ 56,883.72
20" Flange Adapter and ring	12	each	$ 435.40	$ 5,224.80
Anchors	60	each	$ 100.00	$ 6,000.00
Installation	1	LS	$ 6,900.00	$ 6,900.00
Filling	1	LS	$ 600.00	$ 600.00
4" trash pump	1	LS	$ 3,000.00	$ 3,000.00
Maintenance	200	Hrs	$ 50.00	$ 10,000.00
Fish Strainer/Screen	12	each	$ 3,500.00	$ 42,000.00
Miscellaneous material/work	1	LS	$ 1,000.00	$ 1,000.00
Estimated Total for 20" pipe				**$ 370,031.24**

24" Siphon

	Quantity	unit	Unit price	Amount
24" pipe	4600	LF	$ 41.69	$ 191,774.00
24" Inlet Valve	4	each	$ 11,908.00	$ 47,632.00
24" Outlet Valve	4	each	$ 11,908.00	$ 47,632.00
24" Flange Adapter and ring	8	each	$ 755.16	$ 6,041.28
Anchors	40	each	$ 100.00	$ 4,000.00
Installation	1	LS	$ 4,600.00	$ 4,600.00
Filling	1	LS	$ 400.00	$ 400.00
4" trash pump	1	LS	$ 2,000.00	$ 2,000.00
Maintenance	200	Hrs	$ 50.00	$ 10,000.00
Fish Strainer/Screen	8	each	$ 3,500.00	$ 28,000.00
Miscellaneous material/work	1	LS	$ 1,000.00	$ 1,000.00
Estimated Total for 24" pipe				**$ 343,079.28**

Diesel Engine Driven Pumps

Description	Quantity	Units	Unit price	Amount
8" Sykes Diesel Self Contained Dewatering Pumps Rental - includes 2700' of dischar using 3-12" poly pipes with 3 pumps on each pipe with 160' of suction hose.	1	L.S.	$ 14,131.20	$ 14,131.20
Fuel Consumption	57600	gal.	$ 3.98	$ 229,248.00
Delivery	1	L.S.	$ 2,500.00	$ 2,500.00
Installation	1	L.S.	$ 4,800.00	$ 4,800.00
Intake and discharge screens	11	each	$ 3,500.00	$ 38,500.00
Permit	1	L.S.	$ 1,000.00	$ 1,000.00
Maintenance	400	hrs	$ 50.00	$ 20,000.00
Estimated Total				**$ 310,179.20**

Electric Pumps with Temporary Power Drop

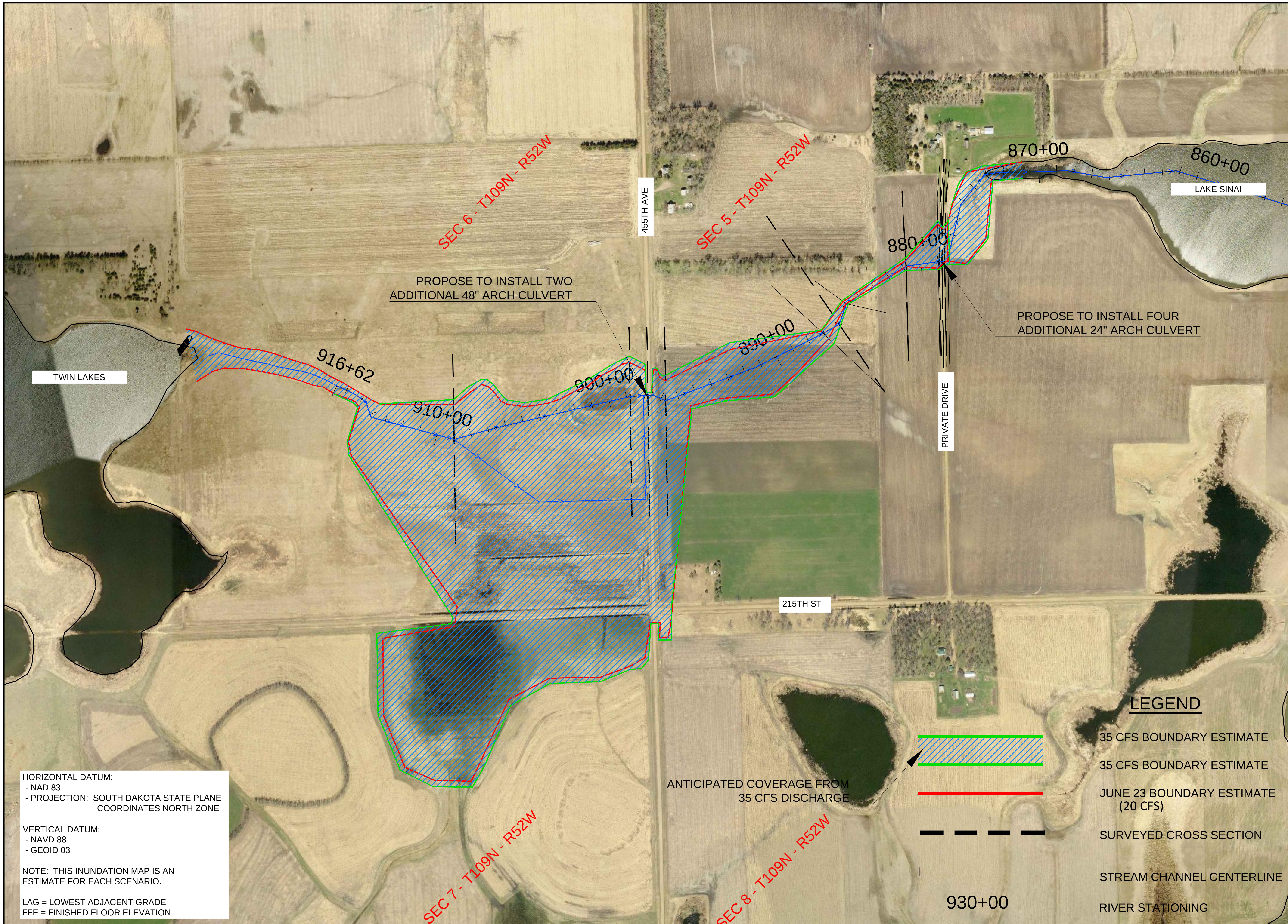
Description	Quantity	Units	Unit price	Amount
4 ABS J405 55 Hp submersible dewatering pumps (2500 gpm each @ 30' TDH) and 1 94 Hp submersible Dewatering Pump (5300 gpm @ 20' TDH) Rental - 460 V 3 phase includes 2700' of discharge using 3-12" poly pipes with 2 pumps on each pipe. Inlcudes breaker panels.	1	L.S.	$ 14,736.00	$ 14,736.00
Delivery	1	L.S.	$ 2,500.00	$ 2,500.00
Aggregate Base for pumps	30	C.Y.	$ 5.00	$ 150.00
Installation	1	L.S.	$ 4,800.00	$ 4,800.00
Intake and discharge screens	8	each	$ 3,500.00	$ 28,000.00
Temporary Power Drop	1	L.S.	$ 150,000.00	$ 150,000.00
Power Consumption	1	L.S.	$ 31,630.06	$ 31,630.06
Permit	1	L.S.	$ 1,000.00	$ 1,000.00
Maintenance	200	hrs	$ 50.00	$ 10,000.00
Estimated Total				**$ 242,816.06**

Electric Pumps with Generators

Description	Quantity	Units	Unit price	Amount
4 ABS J405 55 Hp submersible dewatering pumps (2500 gpm each @ 30' TDH) and 1 94 Hp submersible Dewatering Pump (5300 gpm @ 20' TDH) Rental - 460 V 3 phase includes 2700' of discharge using 3-12" poly pipes with 2 pumps on each pipe. Inlcudes breaker panels.	1	L.S.	$ 14,736.00	$ 14,736.00
Delivery	1	L.S.	$ 2,500.00	$ 2,500.00
Aggregate Base for pumps	30	C.Y.	$ 10.00	$ 300.00
Installation	1	L.S.	$ 4,800.00	$ 4,800.00
Intake and discharge screens	8	each	$ 3,500.00	$ 28,000.00
Generator Rental	1	L.S.	$ 5,340.00	$ 5,340.00
Fuel Consumption	15000	gal	$ 3.98	$ 59,700.00
Permit	1	L.S.	$ 1,000.00	$ 1,000.00
Maintenance	400	hrs	$ 50.00	$ 20,000.00
Estimated Total				**$ 136,376.00**

Appendix C

Inundation Maps and HEC-RAS Summary of Drainage Way



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CONSULTANTS:

GRID BEARING

0 250' 500'

ALL DIMENSIONS SHOWN ARE IN TERMS OF U.S. SURVEY FEET

PROJECT TITLE:

TWIN LAKES EMERGENCY DRAWDOWN

PROJECT LOCATION:

SINAI SOUTH DAKOTA

REV.	DATE	DESCRIPTION

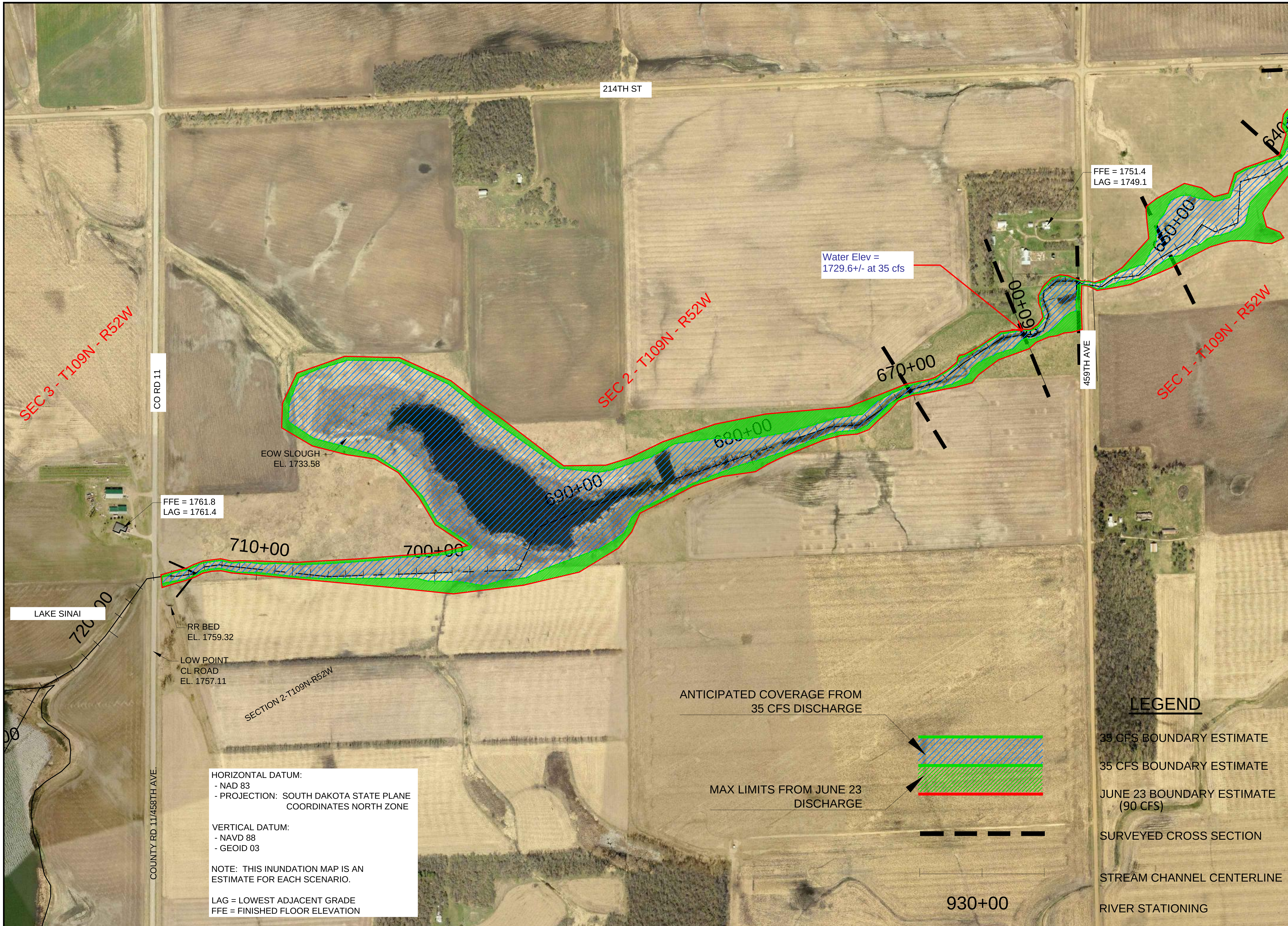
DRAWN BY: JLU
DESIGNED BY: CAM
CHECKED BY: KRJ
JOB NO: 21295-06
DATE: AUG 2011

SCALE REDUCTION BAR

SHEET TITLE:

INUNDATION MAPS (ESTIMATE)

FIGURE NO.: 1



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PROJECT LOCATION :

SINAI
SOUTH DAKOTA

REV.	DATE	DESCRIPTION

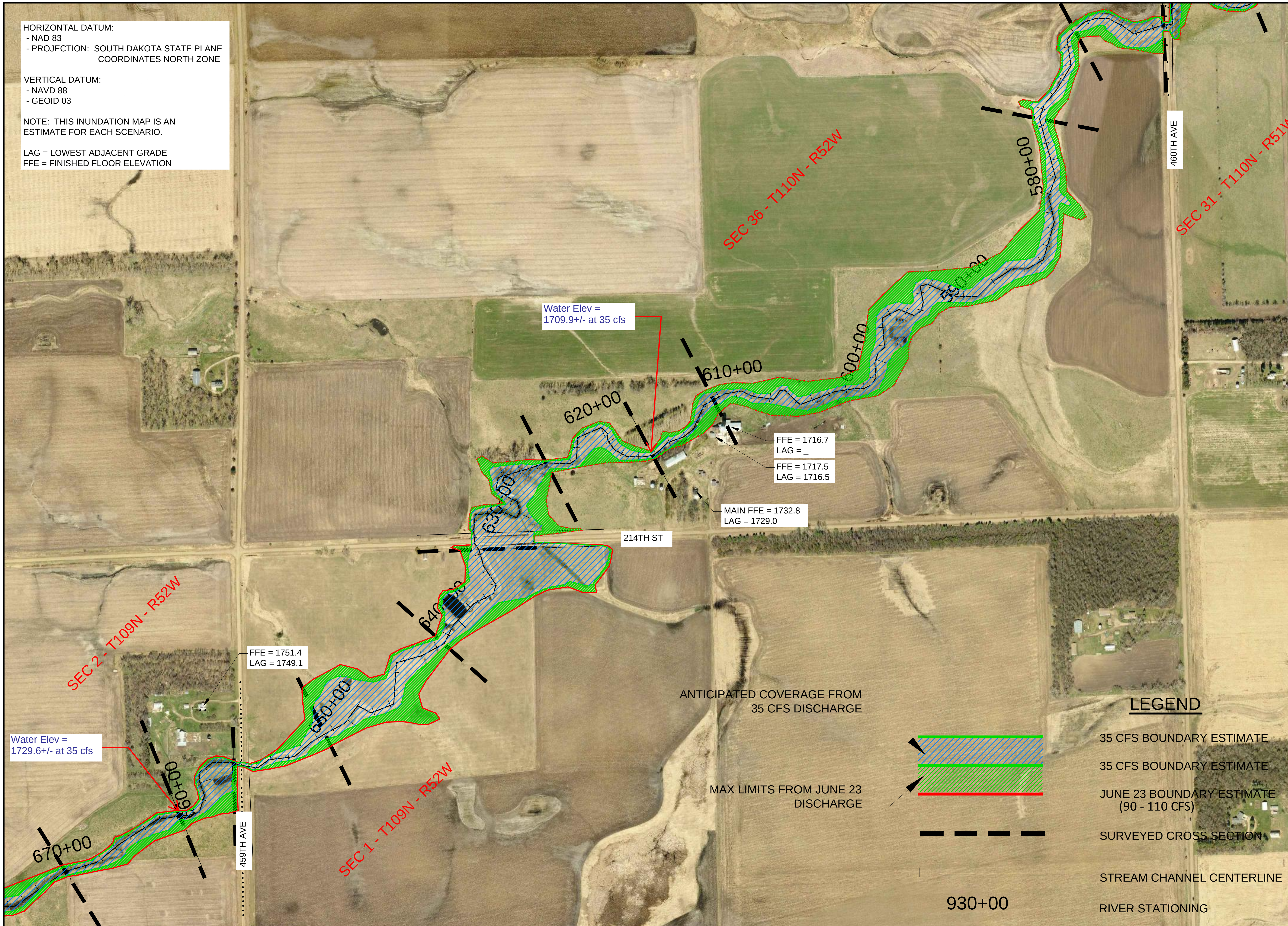
DRAWN BY: JLU
DESIGNED BY: CAM
CHECKED BY: KRJ
JOB NO : 21295-06
DATE : AUG 2011

SCALE REDUCTION BAR

SHEET TITLE :

INUNDATION MAPS (ESTIMATE)

FIGURE NO. : 2



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TWIN LAKES EMERGENCY DRAWDOWN

PROJECT LOCATION:

SINAI SOUTH DAKOTA

REV.	DATE	DESCRIPTION

DRAWN BY: JLU
DESIGNED BY: CAM
CHECKED BY: KRJ
JOB NO.: 21295-06
DATE: AUG 2011

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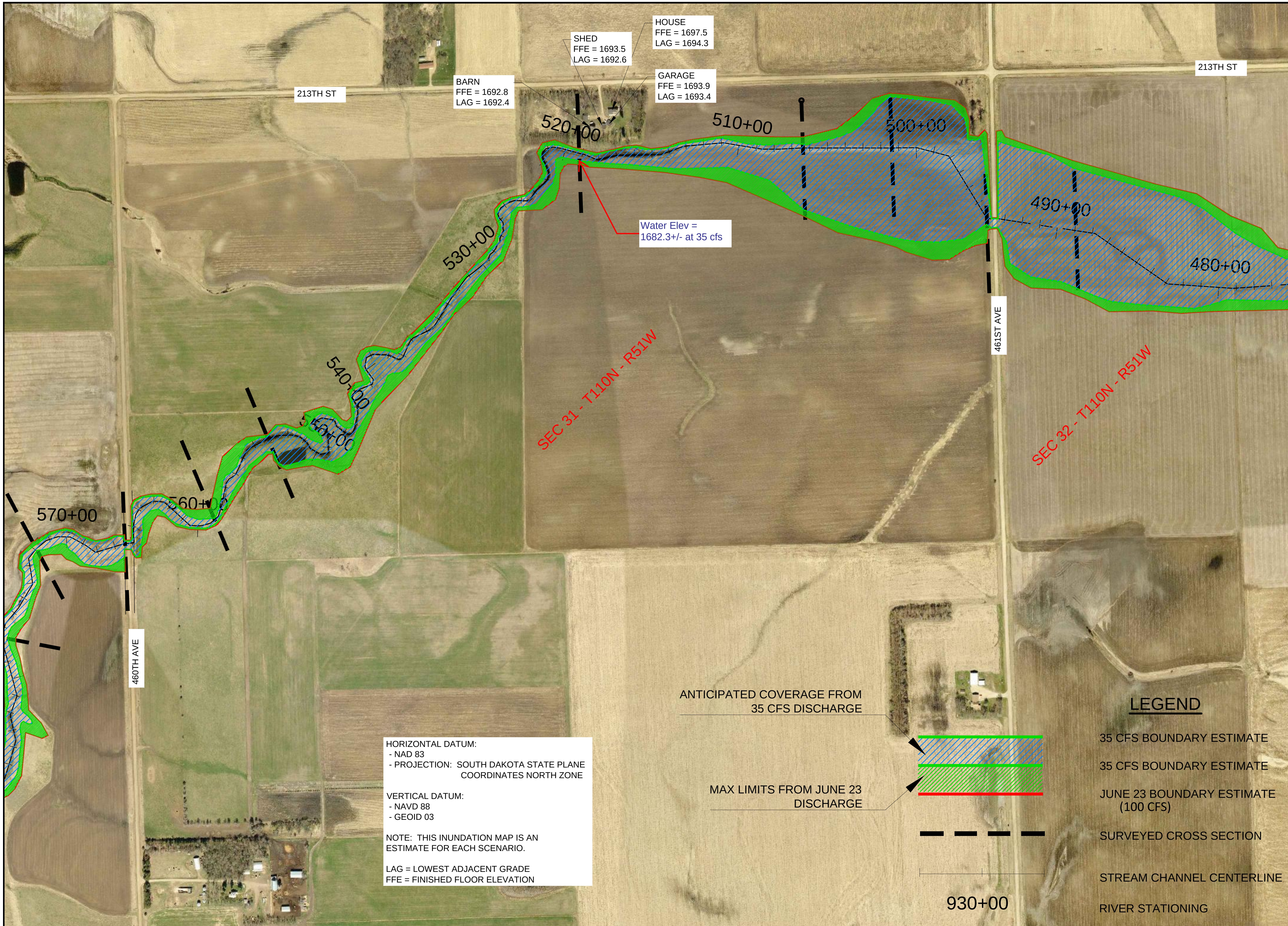
SHEET TITLE:

INUNDATION MAPS (ESTIMATE)

FIGURE NO.: 3



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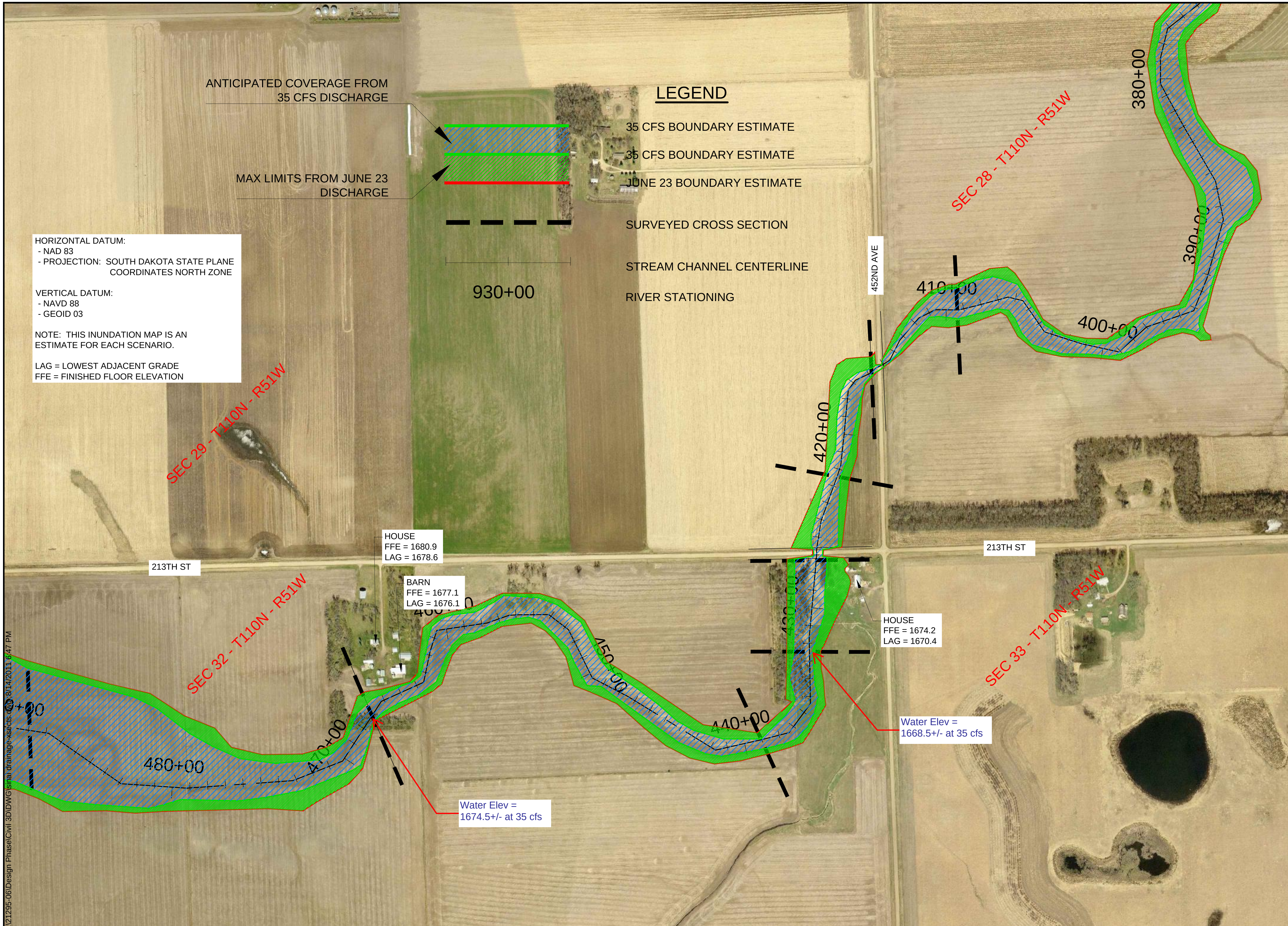
SHEET TITLE:

INUNDATION MAPS (ESTIMATE)

FIGURE NO.: 4



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GRID BEARING

0 250' 500'

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PROJECT TITLE:

TWIN LAKES EMERGENCY DRAWDOWN

PROJECT LOCATION:

VOLGA, SOUTH DAKOTA

REV.	DATE	DESCRIPTION

DRAWN BY: JLU
DESIGNED BY: CAM
CHECKED BY: KRJ
JOB NO: 21295-06
DATE: AUG 2011

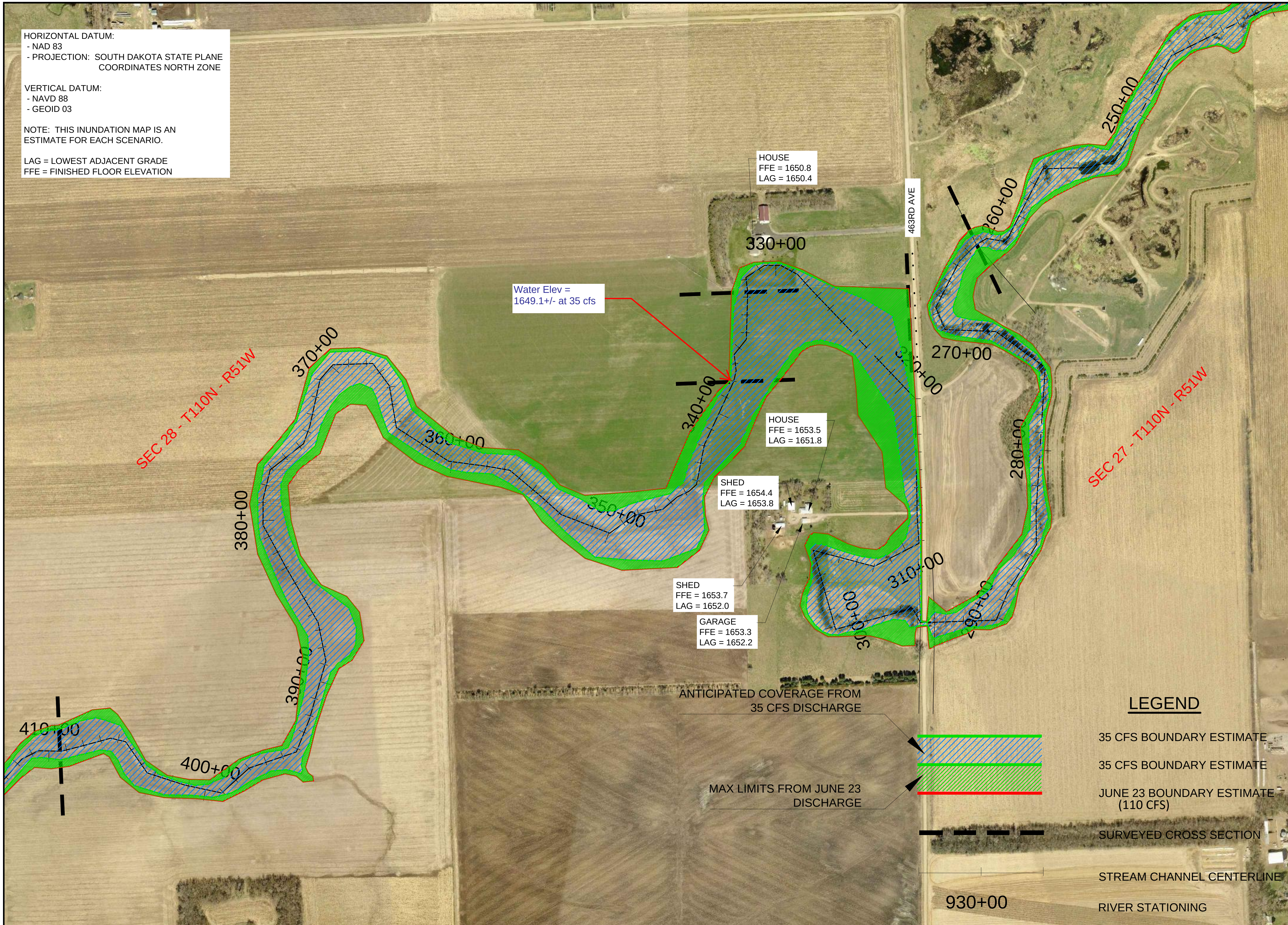
SCALE REDUCTION BAR

SHEET TITLE:

INUNDATION MAPS (ESTIMATE)

FIGURE NO.:

5



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0 250' 500'

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PROJECT TITLE:

TWIN LAKES EMERGENCY DRAWDOWN

PROJECT LOCATION:

VOLGA, SOUTH DAKOTA

REV.	DATE	DESCRIPTION

DRAWN BY: JLU
DESIGNED BY: CAM
CHECKED BY: KRJ
JOB NO.: 21295-06
DATE: AUG 2011

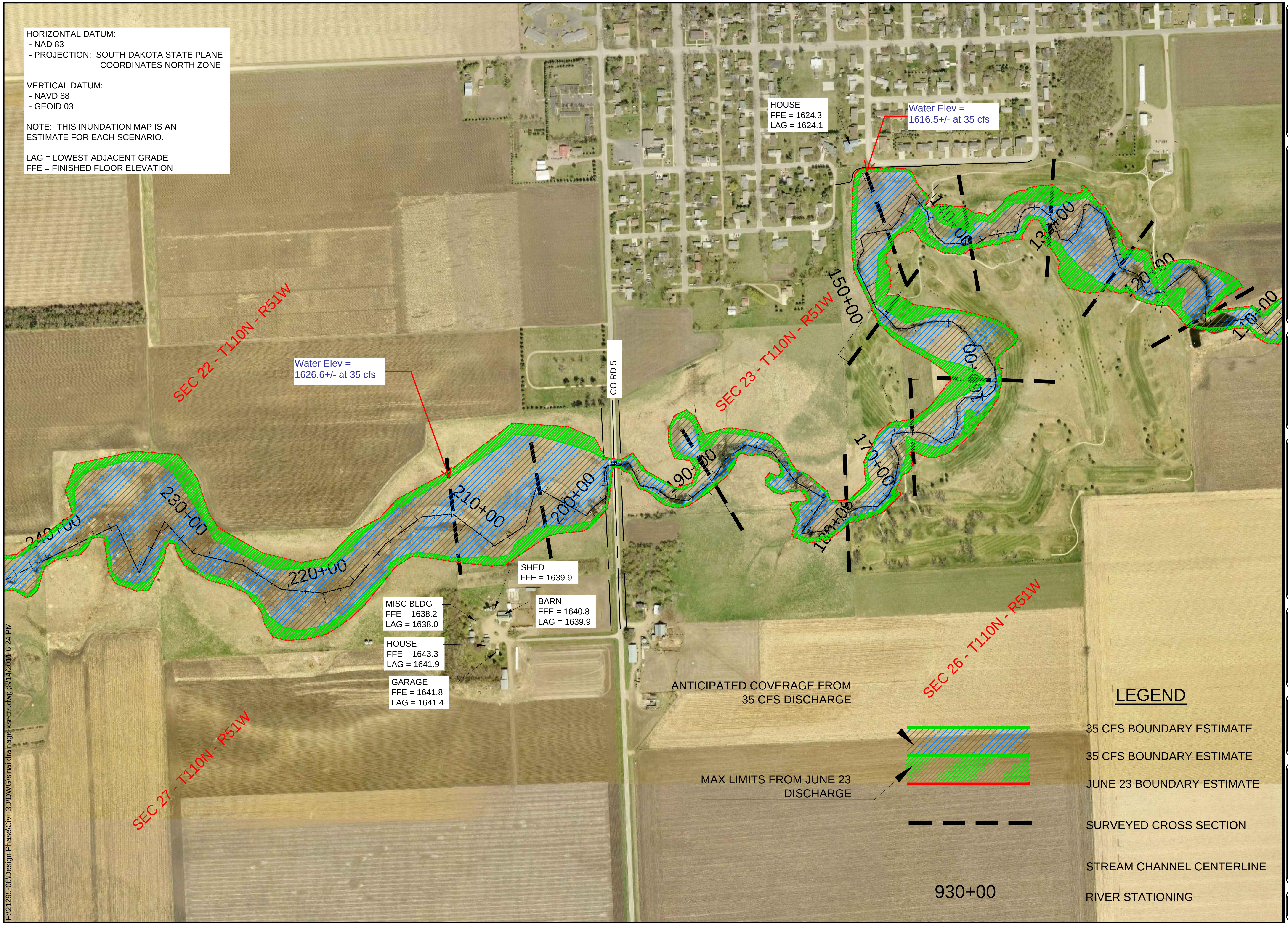
SCALE REDUCTION BAR

SHEET TITLE:

INUNDATION MAPS (ESTIMATE)

FIGURE NO.:

6



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GRID BEARING

0 250' 500'

ALL DIMENSIONS SHOWN ARE IN TERMS OF U.S. SURVEY FEET

FOR REVIEW ONLY
NOT FOR CONSTRUCTION

PROJECT TITLE :

TWIN LAKES EMERGENCY DRAWDOWN

PROJECT LOCATION :

VOLGA, SOUTH DAKOTA

REV.	DATE	DESCRIPTION

DRAWN BY: JLU
DESIGNED BY: CAM
CHECKED BY: KRJ
JOB NO : 21295-06
DATE : AUG 2011

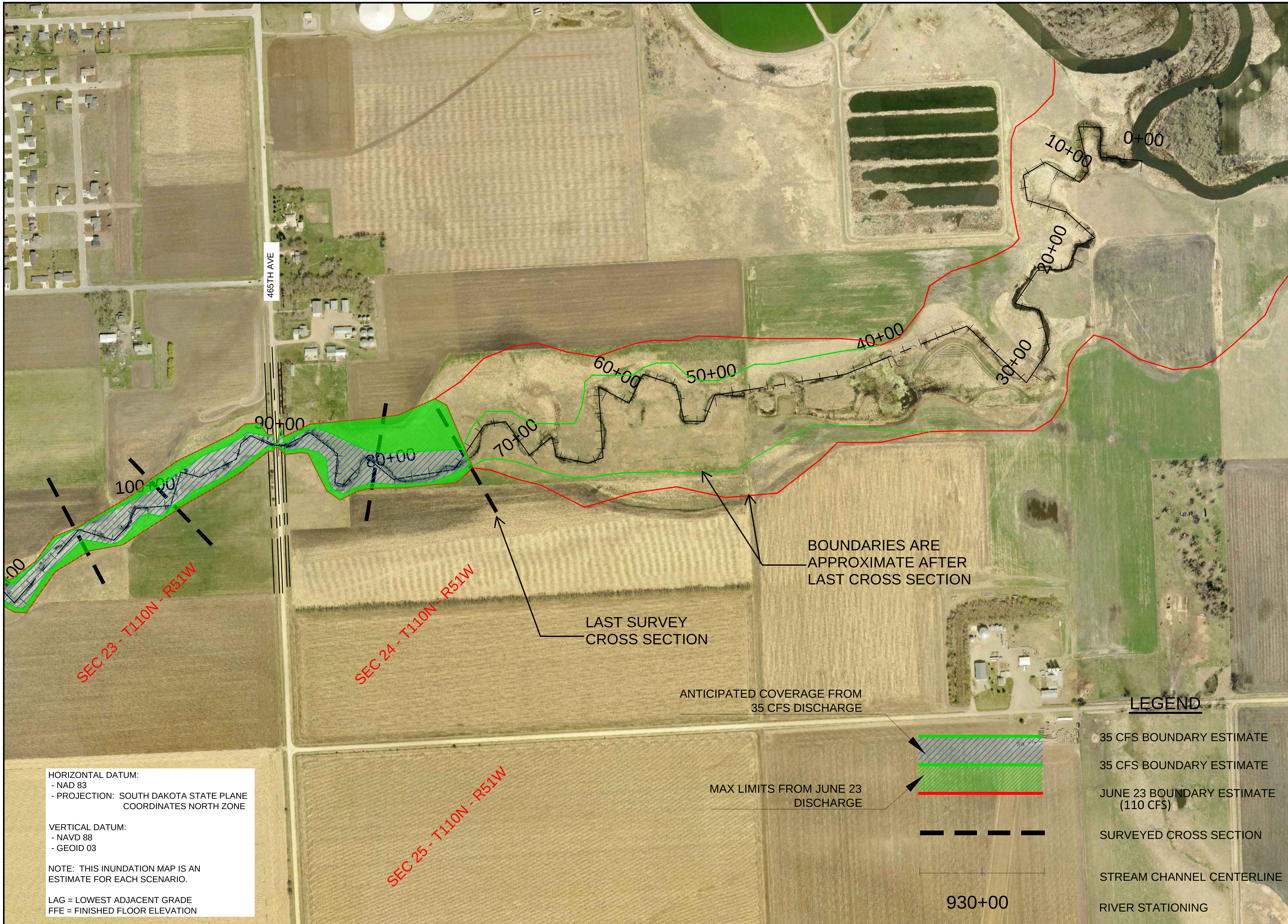
0 1/2" 1"
SCALE REDUCTION BAR

SHEET TITLE :

INUNDATION MAPS (ESTIMATE)

FIGURE NO. :

7



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GRID BEARING

0 250' 500'

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PROJECT TITLE :

TWIN LAKES
EMERGENCY
DRAWDOWN

PROJECT LOCATION :

VOLGA,
SOUTH DAKOTA

REV.	DATE	DESCRIPTION

DRAWN BY: JLU
DESIGNED BY: CAM
CHECKED BY: KRJ
JOB NO : 21295-06
DATE : AUG 2011

0 1/2" 1"
SCALE REDUCTION BAR

SHEET TITLE :

INUNDATION
MAPS
(ESTIMATE)

FIGURE NO. :
8

HEC-RAS Plan: Complete Exist River: Unnamed Trib to Reach: Twin Lakes

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)	
Twin Lakes	90900	June 23	21.00	1748.37	1750.72	0.01	2277.87	1216.49	0.00
Twin Lakes	90900	Pump at 35 cfs	52.00	1748.37	1751.88	0.01	3718.17	1270.54	0.00
Twin Lakes	89878	June 23	21.00	1748.61	1750.72	0.01	2337.58	1453.33	0.00
Twin Lakes	89878	Pump at 35 cfs	52.00	1748.61	1751.88	0.02	4128.21	1621.48	0.00
Twin Lakes	89779		Culvert						
Twin Lakes	89672	June 23	21.00	1749.32	1750.42	0.04	685.79	979.99	0.01
Twin Lakes	89672	Pump at 35 cfs	52.00	1749.32	1750.94	0.05	1237.61	1141.66	0.01
Twin Lakes	88707	June 23	21.00	1748.50	1750.41	0.68	31.10	58.86	0.16
Twin Lakes	88707	Pump at 35 cfs	52.00	1748.50	1750.93	0.70	74.62	108.39	0.15
Twin Lakes	88481	June 23	21.00	1748.50	1750.13	1.38	15.36	20.02	0.26
Twin Lakes	88481	Pump at 35 cfs	52.00	1748.50	1750.65	1.99	28.75	40.03	0.31
Twin Lakes	88083	June 23	21.00	1747.62	1748.14	2.71	7.76	35.48	1.02
Twin Lakes	88083	Pump at 35 cfs	52.00	1747.62	1748.34	2.91	18.00	70.44	0.99
Twin Lakes	87895	June 23	21.00	1745.82	1748.00	0.53	223.07	200.62	0.07
Twin Lakes	87895	Pump at 35 cfs	52.00	1745.82	1747.16	0.51	80.14	134.55	0.10
Twin Lakes	87880		Culvert						
Twin Lakes	87865	June 23	90.00	1745.82	1747.28	1.13	96.24	148.25	0.20
Twin Lakes	87865	Pump at 35 cfs	35.00	1745.82	1746.80	0.94	39.15	90.80	0.23
Twin Lakes	87800	June 23	90.00	1745.52	1747.25	0.81	139.48	169.88	0.13
Twin Lakes	87800	Pump at 35 cfs	35.00	1745.52	1746.76	0.59	67.13	122.37	0.12
Twin Lakes	67016	June 23	90.00	1731.99	1733.32	1.56	57.64	57.12	0.27
Twin Lakes	67016	Pump at 35 cfs	35.00	1731.99	1732.80	1.15	30.39	47.93	0.25
Twin Lakes	66293	June 23	90.00	1728.98	1729.80	3.84	23.44	52.37	1.01
Twin Lakes	66293	Pump at 35 cfs	35.00	1728.98	1729.57	2.68	13.05	39.83	0.83
Twin Lakes	65730	June 23	90.00	1725.18	1728.37	0.55	163.29	143.65	0.09
Twin Lakes	65730	Pump at 35 cfs	35.00	1725.18	1727.10	1.40	25.01	29.76	0.27
Twin Lakes	65685		Culvert						
Twin Lakes	65640	June 23	90.00	1725.18	1726.71	5.56	16.19	17.15	1.01
Twin Lakes	65640	Pump at 35 cfs	35.00	1725.18	1726.17	4.45	7.87	13.21	1.02
Twin Lakes	65147	June 23	90.00	1722.43	1723.09	1.03	96.31	301.61	0.27
Twin Lakes	65147	Pump at 35 cfs	35.00	1722.43	1722.94	0.60	59.89	193.26	0.19
Twin Lakes	64152	June 23	90.00	1718.77	1719.86	2.00	46.89	85.34	0.44
Twin Lakes	64152	Pump at 35 cfs	35.00	1718.77	1719.31	3.00	11.65	43.12	1.02
Twin Lakes	63475	June 23	90.00	1717.00	1719.88	0.14	1016.60	725.75	0.02
Twin Lakes	63475	Pump at 35 cfs	35.00	1717.00	1718.67	0.22	266.28	501.62	0.04
Twin Lakes	63420		Culvert						
Twin Lakes	63373	June 23	90.00	1717.00	1718.26	1.22	108.90	285.19	0.25
Twin Lakes	63373	Pump at 35 cfs	35.00	1717.00	1717.99	0.98	44.78	163.57	0.22
Twin Lakes	62445	June 23	90.00	1713.68	1714.55	3.31	27.16	50.15	0.79
Twin Lakes	62445	Pump at 35 cfs	35.00	1713.68	1714.19	3.10	11.31	37.88	1.00
Twin Lakes	61631	June 23	90.00	1708.38	1710.47	2.31	45.46	47.45	0.34
Twin Lakes	61631	Pump at 35 cfs	35.00	1708.38	1709.91	1.56	23.84	30.90	0.29

HEC-RAS Plan: Complete Exist River: Unnamed Trib to Reach: Twin Lakes (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)	
Twin Lakes	61063	June 23	90.00	1707.04	1707.98	2.80	34.17	65.53	0.62
Twin Lakes	61063	Pump at 35 cfs	35.00	1707.04	1707.71	1.92	18.36	52.76	0.55
Twin Lakes	57760	June 23	100.00	1695.37	1696.66	1.37	72.83	89.98	0.27
Twin Lakes	57760	Pump at 35 cfs	35.00	1695.37	1696.22	0.97	36.04	73.29	0.24
Twin Lakes	57192	June 23	100.00	1692.94	1693.74	4.28	23.35	41.76	1.01
Twin Lakes	57192	Pump at 35 cfs	35.00	1692.94	1693.39	3.30	10.61	31.30	1.00
Twin Lakes	56649	June 23	100.00	1690.78	1693.51	0.41	246.54	207.14	0.06
Twin Lakes	56649	Pump at 35 cfs	35.00	1690.78	1692.43	0.35	100.01	109.35	0.06
Twin Lakes	56622		Culvert						
Twin Lakes	56595	June 23	100.00	1690.78	1692.49	0.94	106.14	111.83	0.17
Twin Lakes	56595	Pump at 35 cfs	35.00	1690.78	1691.94	0.68	51.48	87.27	0.16
Twin Lakes	55721	June 23	100.00	1689.30	1690.85	3.28	31.88	45.54	0.59
Twin Lakes	55721	Pump at 35 cfs	35.00	1689.30	1690.33	2.44	14.33	27.81	0.60
Twin Lakes	55310	June 23	100.00	1686.83	1688.27	2.57	38.88	40.56	0.46
Twin Lakes	55310	Pump at 35 cfs	35.00	1686.83	1687.82	1.63	21.44	37.49	0.38
Twin Lakes	51922	June 23	100.00	1681.08	1682.94	1.23	88.48	90.38	0.19
Twin Lakes	51922	Pump at 35 cfs	35.00	1681.08	1682.31	0.86	40.92	62.36	0.18
Twin Lakes	50641	June 23	100.00	1679.67	1680.52	2.02	62.94	185.60	0.56
Twin Lakes	50641	Pump at 35 cfs	35.00	1679.67	1680.39	1.06	42.65	145.89	0.31
Twin Lakes	50145	June 23	100.00	1679.06	1680.11	0.35	326.56	852.72	0.10
Twin Lakes	50145	Pump at 35 cfs	35.00	1679.06	1679.84	0.25	124.92	609.83	0.11
Twin Lakes	49400	June 23	100.00	1678.72	1680.04	0.22	477.65	637.35	0.04
Twin Lakes	49400	Pump at 35 cfs	35.00	1678.72	1679.38	0.36	97.36	441.26	0.13
Twin Lakes	49357		Culvert						
Twin Lakes	49320	June 23	100.00	1678.72	1679.41	0.91	110.63	492.63	0.33
Twin Lakes	49320	Pump at 35 cfs	35.00	1678.72	1679.27	0.57	61.11	269.66	0.21
Twin Lakes	48895	June 23	100.00	1677.40	1678.06	0.71	141.02	593.19	0.26
Twin Lakes	48895	Pump at 35 cfs	35.00	1677.40	1677.79	1.02	34.44	242.48	0.48
Twin Lakes	46710	June 23	100.00	1673.53	1674.79	1.14	113.97	191.05	0.21
Twin Lakes	46710	Pump at 35 cfs	35.00	1673.53	1674.50	0.69	62.42	160.30	0.15
Twin Lakes	43900	June 23	100.00	1668.82	1669.78	1.64	61.09	104.38	0.38
Twin Lakes	43900	Pump at 35 cfs	35.00	1668.82	1669.19	2.69	13.00	58.48	1.01
Twin Lakes	43247	June 23	110.00	1666.69	1668.23	1.17	94.27	144.97	0.25
Twin Lakes	43247	Pump at 35 cfs	35.00	1666.69	1667.94	0.60	58.30	106.87	0.14
Twin Lakes	42720	June 23	110.00	1666.36	1667.58	1.00	161.10	317.03	0.20
Twin Lakes	42720	Pump at 35 cfs	35.00	1666.36	1667.00	2.14	17.98	102.10	0.69
Twin Lakes	42686		Culvert						
Twin Lakes	42660	June 23	110.00	1666.36	1667.29	2.04	76.98	261.26	0.50
Twin Lakes	42660	Pump at 35 cfs	35.00	1666.36	1666.91	2.99	11.71	43.58	1.02
Twin Lakes	42242	June 23	110.00	1663.81	1665.68	2.09	76.28	145.06	0.33
Twin Lakes	42242	Pump at 35 cfs	35.00	1663.81	1665.36	1.07	40.29	81.02	0.19

HEC-RAS Plan: Complete Exist River: Unnamed Trib to Reach: Twin Lakes (Continued)

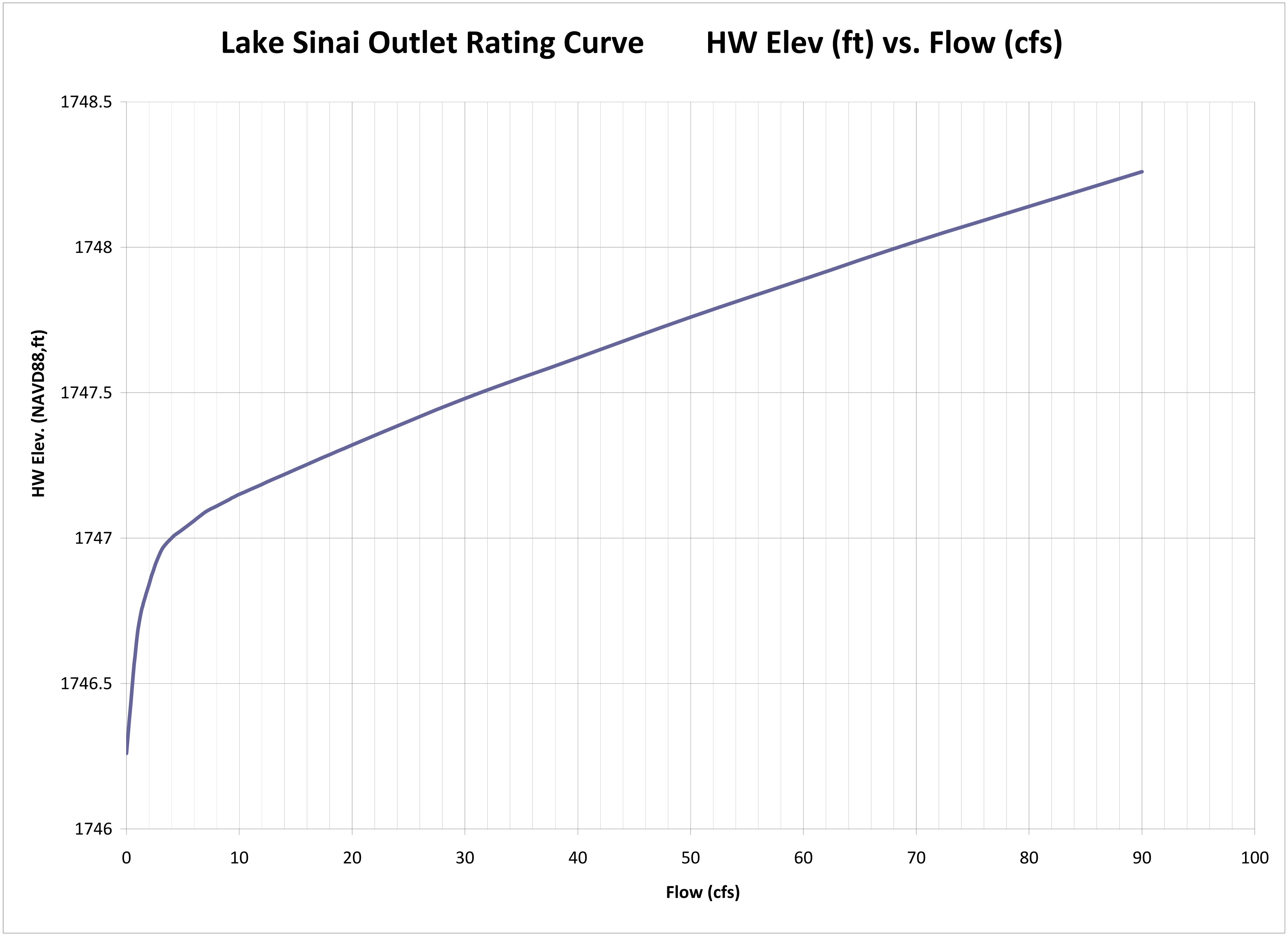
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)	
Twin Lakes	41580	June 23	110.00	1663.10	1665.16	1.00	170.57	228.97	0.14
Twin Lakes	41580	Pump at 35 cfs	35.00	1663.10	1664.07	1.81	19.37	39.83	0.46
Twin Lakes	41526		Culvert						
Twin Lakes	41500	June 23	110.00	1663.10	1664.23	4.22	26.42	50.58	0.96
Twin Lakes	41500	Pump at 35 cfs	35.00	1663.10	1663.81	3.41	10.26	28.99	1.01
Twin Lakes	40936	June 23	110.00	1661.80	1663.25	0.87	146.69	251.42	0.16
Twin Lakes	40936	Pump at 35 cfs	35.00	1661.80	1662.82	0.59	61.25	166.61	0.15
Twin Lakes	33802	June 23	110.00	1648.25	1649.51	3.88	35.46	92.08	0.85
Twin Lakes	33802	Pump at 35 cfs	35.00	1648.25	1649.05	3.62	9.67	25.49	1.01
Twin Lakes	29460	June 23	110.00	1641.31	1644.52	0.26	451.55	335.03	0.03
Twin Lakes	29460	Pump at 35 cfs	35.00	1641.31	1643.09	0.29	121.73	127.10	0.05
Twin Lakes	29420		Culvert						
Twin Lakes	29380	June 23	110.00	1641.31	1642.87	1.15	95.42	109.43	0.22
Twin Lakes	29380	Pump at 35 cfs	35.00	1641.31	1642.19	0.96	36.44	67.43	0.23
Twin Lakes	26339	June 23	110.00	1635.11	1636.22	2.07	53.06	80.30	0.45
Twin Lakes	26339	Pump at 35 cfs	35.00	1635.11	1635.86	1.23	28.42	60.23	0.32
Twin Lakes	21090	June 23	110.00	1625.82	1627.00	0.69	158.58	312.69	0.17
Twin Lakes	21090	Pump at 35 cfs	35.00	1625.82	1626.55	0.68	51.12	129.55	0.19
Twin Lakes	20343	June 23	110.00	1624.34	1624.91	3.18	34.54	109.88	1.00
Twin Lakes	20343	Pump at 35 cfs	35.00	1624.34	1624.86	1.21	28.86	102.40	0.40
Twin Lakes	19875	June 23	110.00	1622.70	1624.25	0.47	234.93	281.60	0.09
Twin Lakes	19875	Pump at 35 cfs	35.00	1622.70	1623.55	0.63	55.34	204.89	0.21
Twin Lakes	19706	June 23	110.00	1622.32	1624.18	1.07	107.39	278.35	0.17
Twin Lakes	19706	Pump at 35 cfs	35.00	1622.32	1623.31	0.94	39.14	134.47	0.21
Twin Lakes	19643		Bridge						
Twin Lakes	19605	June 23	110.00	1620.63	1623.69	2.06	54.02	44.53	0.31
Twin Lakes	19605	Pump at 35 cfs	35.00	1620.63	1623.00	1.19	29.48	28.31	0.21
Twin Lakes	18945	June 23	110.00	1619.86	1621.60	1.86	59.17	101.74	0.43
Twin Lakes	18945	Pump at 35 cfs	35.00	1619.86	1620.91	3.00	11.66	40.54	0.99
Twin Lakes	17550	June 23	110.00	1618.32	1620.69	0.81	135.21	82.93	0.11
Twin Lakes	17550	Pump at 35 cfs	35.00	1618.32	1619.67	0.57	60.88	62.58	0.10
Twin Lakes	16861	June 23	110.00	1616.87	1620.44	0.50	220.92	149.34	0.07
Twin Lakes	16861	Pump at 35 cfs	35.00	1616.87	1619.46	0.32	109.16	91.19	0.05
Twin Lakes	16841		Bridge						
Twin Lakes	16798	June 23	110.00	1617.53	1620.31	0.57	194.47	135.25	0.08
Twin Lakes	16798	Pump at 35 cfs	35.00	1617.53	1619.37	0.38	91.77	87.17	0.07
Twin Lakes	16059	June 23	110.00	1615.64	1619.30	0.58	190.14	279.08	0.12
Twin Lakes	16059	Pump at 35 cfs	35.00	1615.64	1618.39	0.73	48.13	75.54	0.16
Twin Lakes	15196	June 23	110.00	1614.73	1617.65	0.61	180.55	166.63	0.10
Twin Lakes	15196	Pump at 35 cfs	35.00	1614.73	1616.71	0.47	73.72	77.19	0.09
Twin Lakes	15127		Bridge						

HEC-RAS Plan: Complete Exist River: Unnamed Trib to Reach: Twin Lakes (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)	
Twin Lakes	15110	June 23	110.00	1614.48	1617.24	1.57	73.37	75.90	0.21
Twin Lakes	15110	Pump at 35 cfs	35.00	1614.48	1616.52	0.87	40.20	34.16	0.14
Twin Lakes	14535	June 23	110.00	1614.15	1616.97	0.22	509.06	431.16	0.04
Twin Lakes	14535	Pump at 35 cfs	35.00	1614.15	1616.11	0.19	179.95	289.35	0.04
Twin Lakes	14194	June 23	110.00	1613.10	1616.81	1.20	94.73	84.79	0.14
Twin Lakes	14194	Pump at 35 cfs	35.00	1613.10	1615.87	0.91	38.61	25.55	0.13
Twin Lakes	14170		Bridge						
Twin Lakes	14165	June 23	110.00	1613.10	1616.68	1.35	85.06	73.62	0.17
Twin Lakes	14165	Pump at 35 cfs	35.00	1613.10	1615.78	0.96	36.46	24.85	0.14
Twin Lakes	13777	June 23	110.00	1612.53	1615.11	0.89	123.43	158.76	0.18
Twin Lakes	13777	Pump at 35 cfs	35.00	1612.53	1614.18	0.91	38.60	65.50	0.21
Twin Lakes	13188	June 23	110.00	1611.68	1614.85	0.25	432.50	278.59	0.04
Twin Lakes	13188	Pump at 35 cfs	35.00	1611.68	1613.49	0.26	132.61	175.81	0.05
Twin Lakes	12338	June 23	110.00	1610.79	1614.81	0.16	566.67	279.09	0.01
Twin Lakes	12338	Pump at 35 cfs	35.00	1610.79	1613.40	0.17	211.02	226.61	0.02
Twin Lakes	12024	June 23	110.00	1610.92	1614.77	1.33	118.33	199.51	0.13
Twin Lakes	12024	Pump at 35 cfs	35.00	1610.92	1613.31	1.51	24.23	24.39	0.21
Twin Lakes	12007		Bridge						
Twin Lakes	11991	June 23	110.00	1610.92	1613.11	5.77	19.71	20.49	0.86
Twin Lakes	11991	Pump at 35 cfs	35.00	1610.92	1612.98	2.08	17.17	17.93	0.32
Twin Lakes	11495	June 23	110.00	1609.82	1611.03	1.38	79.85	83.70	0.25
Twin Lakes	11495	Pump at 35 cfs	35.00	1609.82	1610.42	1.09	32.08	73.92	0.29
Twin Lakes	10505	June 23	110.00	1607.83	1610.05	1.06	104.23	95.12	0.18
Twin Lakes	10505	Pump at 35 cfs	35.00	1607.83	1609.41	0.70	50.21	70.20	0.15
Twin Lakes	9848	June 23	110.00	1607.47	1609.03	1.63	67.35	140.82	0.42
Twin Lakes	9848	Pump at 35 cfs	35.00	1607.47	1608.71	1.06	33.16	80.99	0.29
Twin Lakes	9060	June 23	110.00	1605.55	1607.50	1.31	86.67	92.52	0.21
Twin Lakes	9060	Pump at 35 cfs	35.00	1605.55	1606.64	1.26	27.86	51.25	0.30
Twin Lakes	9030	June 23	110.00	1601.84	1607.51	0.61	179.35	93.64	0.06
Twin Lakes	9030	Pump at 35 cfs	35.00	1601.84	1606.65	0.26	132.16	62.28	0.03
Twin Lakes	9011		Bridge						
Twin Lakes	8970	June 23	110.00	1601.84	1607.47	0.80	138.33	90.87	0.07
Twin Lakes	8970	Pump at 35 cfs	35.00	1601.84	1606.64	0.32	109.45	62.19	0.03
Twin Lakes	8953	June 23	110.00	1604.80	1607.43	1.46	77.29	98.39	0.21
Twin Lakes	8953	Pump at 35 cfs	35.00	1604.80	1606.62	0.94	37.26	40.85	0.17
Twin Lakes	8137	June 23	110.00	1604.24	1606.46	1.21	91.08	136.27	0.26
Twin Lakes	8137	Pump at 35 cfs	35.00	1604.24	1605.64	1.40	25.08	36.00	0.29
Twin Lakes	7555	June 23	110.00	1602.77	1605.45	1.72	63.77	50.77	0.27
Twin Lakes	7555	Pump at 35 cfs	35.00	1602.77	1604.53	1.33	26.33	30.94	0.25

Appendix D

Lake Sinai Outlet Rating Curve


Lake Sinai Outlet Rating Curve HW Elev (ft) vs. Flow (cfs)
HW Elev. (NAVD88,ft)
1748.5
1748
1747.5
1747
1746.5
1746
0
10
20
30
40
50
60
70
80
90
100
Flow (cfs)

BANNER
Engineering | Architecture | Surveying

409 22nd Avenue South | PO Box 298, Brookings, South Dakota 57006
Tel (605) 692-6342 Fax (605) 692-5714

2307 West 57th Street, Suite 102, Sioux Falls, South Dakota 57108
Tel (605) 977-6342 Fax (605) 977-6344

14 West Main Street, Suite A, Vermillion, South Dakota 57069
Tel (605) 624-6342 Fax (605) 692-5714

730 South Street, Suite 201 | PO Box 2024 (57709), Rapid City, South Dakota 57701
Tel | Fax (605) 343-0700

119 Second Avenue SW, Suite 5, Pipestone, Minnesota 56164
Tel (507) 562-2957

424½ South Minnesota Avenue, Suite B, St. Peter, Minnesota 56082
Tel | Fax (507) 931-0930

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