Upper Lightning Lake Water Level Management

Environmental Assessment Worksheet

Attachment D

Design Report for Upper Lightning Lake

DESIGN REPORT

for

Upper Lightning Lake
Wetland Enhancement

MN-332-2

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

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Date 1/6/2014 Registration No. 18843
(Supersedes original report dated June 30, 2006)

PROJECT: Upper Lightning Lake
Wetland Enhancement
MN-332-2

LOCATION: Sections 24,25,36, T131 N, R44 W
Lat. 46°7.025′ Long. 96°9.138′
±13 Miles SSE of Fergus Falls
Otter Tail County, Minnesota

MARSH DATA: Upper Lightning Lake*
Culvert Runout Elevation @ 1083.3 (NAVD88)
± 600 Surface Acres @ Runout
± 1,853 Acre-Feet Capacity Estimated @ Runout
± 37.1 Inches Average Depth @ Runout

OHW – 1084.19 (NAVD88)
OHW – 1083.50 (NGVD29)

NAVD88 – 0.6857 = NGVD29

*Based on DNR Bureau of Engineering Plans/Data dated 3/20/1998 and existing culvert invert elevation for runout at 1083.30.

PROJECT DESCRIPTION:

In the 1990's, the Minnesota DNR completed a feasibility study on construction of an outlet channel that would allow better management of Upper Lightning Lake. For various reasons, the project did not continue through to final design or construction at that time. The project was resurrected in 2003 and Ducks Unlimited became involved in a survey of the outlet channel and preliminary design.

Upper Lightning Lake has a surface watershed of 9,030 acres or 14.1 square miles. The Lake currently outlets through about 2,000 feet of a densely-vegetated channel before passing through a 24″ diameter reinforced concrete pipe (RCP) in County Road #26 (CR #26). Refer to Figure 1 on page 3. The channel continues another 6,200 feet downstream through two field-crossing culverts before entering the east tract of Kube-Swift WMA. Parts of this upper channel contain dense stands of cattail and other vegetation that restricts flow. Local landowners contend vegetation in the east tract of the WMA (hereafter referred to as Swift WMA) also restricts discharge flows. Flows from the east tract pass through a 42″ x 30″ corrugated metal pipe (CMP) arch culvert in north-south CR #3. A channel continues through private land from CR #3 to the west tract of Kube-Swift WMA (hereafter referred to as Denton Slough).

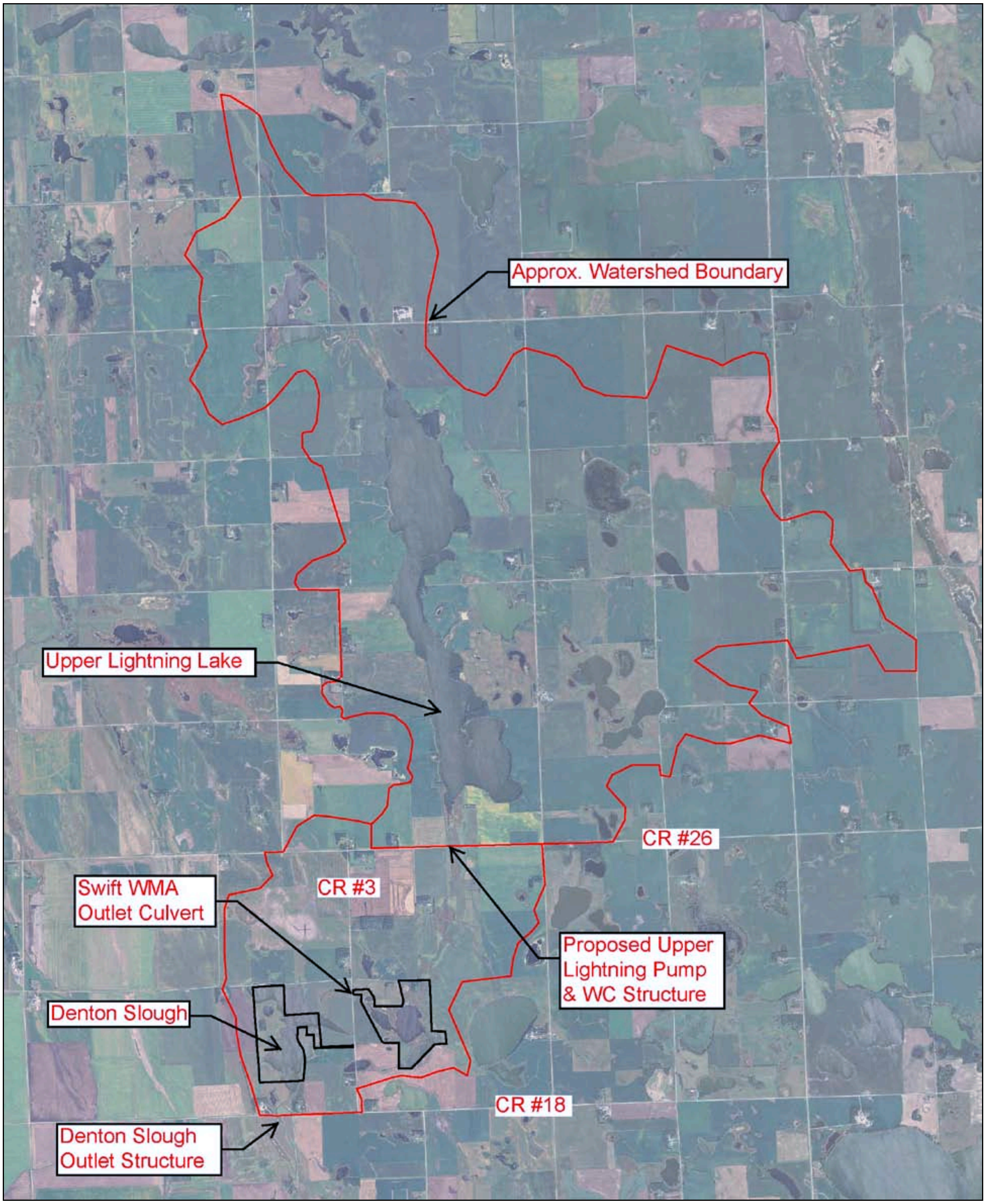

Figure 1.
Approximate Surface Watershed for
Upper Lightning Lake, Swift WMA & Denton Slough

Outlet flows from Denton Slough pass through a 30″ diameter RCP in CR #18 and are controlled by a 3-foot wide stoplog structure installed in 2011 just downstream of CR #18. The stoplog structure sets the full pool level in Denton Slough at 1071.0 which was the original culvert runout elevation for the RCP through CR #18.

The surface watershed for Swift WMA is estimated at 1,306 acres or 2.04 square miles plus a contribution from Stony Lake through a 15″ diameter CMP, plus the discharge flows from Upper Lightning Lake. It was determined that the Stony Lake contribution should not exceed 8 cubic feet per second (cfs), therefore, the 8 cfs was included as base flow in all design calculations for that watershed. The surface watershed for Denton Slough is about 1,165 acres or 1.82 square miles, plus the discharge flows from Swift WMA.

From Denton Slough, the outlet channel continues about 6,100 feet southeast, with one road crossing (36″ diameter CMP) before approaching CR #43. The culvert at CR #43 is a 36″ diameter RCP. From CR #43, the channel loops south, then west to a Township road with a 42″ x 30″ RCP arch culvert that acts as a fish barrier. This culvert was installed in 2007. The channel between Denton Slough and the fish barrier culvert was cleaned out in 2011.

The limitation with trying to provide better management options for Upper Lightning Lake is that the lake bottom on the south end is estimated to be at elevation 1079 with the north end being a foot lower at 1078, and the existing culvert in CR #26 one-half mile south of the lake is at 1083.3. To provide gravity flow drawdown capability, the structure in CR #26 would have to be lowered significantly, and a channel excavated from the lake outlet all the way to the outlet of Swift WMA. Such excavation would likely cause potential wetland issues.

After analysis of the elevations and possible options, the proposed alternative is to (1) conduct relatively minor cleaning/maintenance of silt, vegetation and debris in the outlet channel from the lake to Swift WMA, and at the outlet of Swift WMA, and (2) install a permanent electric pump station for drawdown of the lake below the existing culvert runout elevation.

During DU’s topographic survey in December 2004, the top of ice in Upper Lightning Lake was at 1086.18 or two feet above the Ordinary High Water (OHW) mark set by the DNR. To accommodate drawdown of the lake, a channel would be excavated from the lake to the pump station located on the north side of CR #26. A new stoplog structure would be connected to the existing 24″ RCP through CR #26. The existing culvert runout would still serve as the control elevation for the outlet of Upper Lightning Lake. The outlet channel between CR #26 and Swift WMA would simply be cleaned as noted previously. The outlet channel from Swift WMA and inlet channel into Denton Slough would also be cleaned of silt, excess vegetation and debris to provide normal water movement through the system. All spoil material from the channel work will be removed from the wetland areas and deposited on upland cultivated areas.

To protect downstream interests, the project must avoid increasing any peak flows and volumes following runoff events. No road culverts are being replaced as part of this project. The existing outlet structure at Denton Slough will still be the controlling point for the watercourse downstream. See Figure 1. Peak discharge flows from the project area for the larger runoff events are predicted to be nearly identical to the existing case as shown.

A significant portion of this project involves private land. The Minnesota Department of Natural Resources (DNR) owns Swift WMA and Denton Slough, however, easements or other legal means of access have been or will be pursued by the DNR before the project can proceed. The project engineer has been in contact with the Otter Tail County Highway Department engineer regarding CR #26 and will adhere to all County design and construction requirements. The County engineer has preliminarily indicated the culvert in CR #26 will not need to be replaced. However, two field crossing culverts on private land between CR #26 and Swift WMA will be replaced as part of the channel maintenance work.

The project is located in a rural area near the Otter Tail and Grant County line. Based on information obtained in the field, data present on the U.S.G.S. quadrangular maps, the rural location of the site, and downstream land use, it would appear the road crossing at the outlet of Upper Lightning Lake, if applicable, could be considered a low hazard, Class III dam. Property losses in the unlikely event of a failure, would be restricted to mainly local county and township roads. The project as proposed, would actually lower downstream risks as the maximum pool level for Upper Lightning Lake would be reduced from what currently exists.

DESIGN DATA:

As previously mentioned, outflows from Upper Lightning Lake are currently controlled by a 24” diameter RCP through CR #26. The upstream culvert invert is at elevation 1083.30. The OHW for Upper Lightning Lake is at elevation 1084.19 (NAVD88). An 8’ x 6’ drop box inlet with 36” long stoplogs, will be connected to the existing 24” diameter RCP outlet barrel through CR #26. The box and upstream culvert invert will be at elevation 1083.3 to act as the normal control for the lake. The stoplog structure will control all discharge rates for the various runoff design events.

The 8′ x 6′ concrete box will also serve as the discharge box for an electric pump station. Two pumps with a total capacity of 10,000 gallons per minute (gpm) or 22.3 cubic feet per second (cfs) will be installed to provide drawdown of the lake from culvert elevation 1083.3 to lake-bottom elevation ±1078-1079. Stoplogs will be installed in the structure when pumping to prevent backflow into the lake. The inlet channel from the lake to the pump will be at bottom elevation 1078.0. All spoil from such inlet channel excavation will be removed from the wetland.

For hydrological design purposes, the traditional NRCS runoff method using the TR-20 model and a 24-Hour Type II rainfall event was utilized. The watershed was divided up into five sub-basins and HydroCAD (version 10.00) was used to flood route flows through both the existing system and the proposed system of channels and structures. Spillway capacities were calculated using the weir flow formula and formulas for determining head loss through various pipe materials via HydroCad and Hy-8 Culvert Hydraulic Analysis Program software available from the Federal Highway Administration.

Table 1 shows the relationship between peak inflows, corresponding outflows, and reservoir elevations for the existing case, and for the proposed case during non-pumping operations. Table 2 shows the same for the existing case and for the proposed case when pumping 10,000 gpm. As can be seen in the tables, the peak discharge flows through the existing and proposed structures are quite low due to the fairly large storage capacity in Upper Lightning Lake. The assumption that considers the lake and wetlands are at full pool at the start of the runoff event should provide a worst-case condition provided the proposed channel cleaning/maintenance is completed downstream. The proposed 36″ long weir (stoplogs) at CR #26 controls the discharge rates from Upper Lightning Lake for the smaller design runoff events. For the larger runoff events, the 24″ culvert controls. Obviously, if Upper Lightning Lake is at an elevation below full pool at the start of a runoff event and all stoplogs are in-place, some permanent storage will provide flood control benefits.

The existing structure at the outlet of Denton Slough controls flows in the system as well. That structure too has 36″ long stoplogs with a 30″ outlet pipe. The stoplogs control flow rates for all runoff events. As evident in Table 1, discharge flows from Denton Slough are nearly identical for the existing and proposed cases when no pumping from Upper Lightning Lake is occurring.

Table 2 shows that discharge rates from Denton Slough are slightly higher for the smaller runoff events when 10,000 gpm pumping is

Table 1.

Upper Lightning Lake System

Hydraulics Summary for Various Design Events

EXISTING CASE

Design Event	Upper Lightning Lake			Swift WMA (East Tract)			Denton Slough (West Tract)		
	Assumed Starting Water Surface Elevation 1083.3			Assumed Starting Water Surface Elevation 1074.4			Assumed Starting Water Surface Elevation 1071.0		
	Peak Qin (cfs)	Max. W.S. Elevation	Peak Qout thru 24" RCP (cfs)	Peak Qin (cfs)	Max. W.S. Elevation	Peak Qout thru 42"x30" CMP (cfs)	Peak Qin (cfs)	In CR #26 Max. W.S. Elevation	Peak Qout thru 30" RCP (cfs)
2-Year	424	1084.16	3	167	1075.83	11	153	1072.13	9
5-Year	733	1084.70	7	290	1076.42	20	274	1072.71	16
10-Year	963	1085.07	11	383	1076.82	26	365	1073.13	20
25-Year	1,223	1085.48	15	486	1077.24	32	468	1073.57	24
50-Year	1,493	1085.87	17	593	1077.66	36	574	1073.98	28
100-Year	1,771	1086.26	19	703	1078.06	40	684	1074.34	31

Upper Lightning Lake:
Assume FSL at Elev. 1083.3
Existing 24" RCP thru CR #26
U/S Invert of 24" RCP at 1083.3
D/S Invert of 24" RCP at 1083.0
North Shoulder on CR #26 at 1092.3

Swift WMA (East Tract):
Assume FSL at Elev. 1074.4
Existing 42" x 30" CMP thru CR #3
Includes 8 cfs baseflow from Stoney Lake
U/S Invert of 24" RCP at 1074.4
D/S Invert of 24" RCP at 1074.2
East Shoulder on CR #3 at 1079.7

Denton Slough (West Tract):
Assume FSL at Elev. 1071.0
Existing 30" RCP thru CR #26
U/S Invert of 30" RCP at 1068.0
D/S Invert of 30" RCP at 1068.0
North Shoulder on CR #18 at 1077.0
Top of Stoplogs in Control Str D/S at 1071.0
30" RCP Outlet Pipe, But Weir Controls
TW From Stoplog Structure Considered

PROPOSED CASE - No Pumping Occurring

Design Event	Upper Lightning Lake			Swift WMA (East Tract)			Denton Slough (West Tract)		
	Assumed Starting Water Surface Elevation 1084.19			Assumed Starting Water Surface Elevation 1074.4			Assumed Starting Water Surface Elevation 1071.0		
	Peak Qin (cfs)	Max. W.S. Elevation	Peak Qout thru 24" RCP (cfs)	Peak Qin (cfs)	Max. W.S. Elevation	Peak Qout thru 42"x30" CMP (cfs)	Peak Qin (cfs)	In CR #26 Max. W.S. Elevation	Peak Qout thru 30" RCP (cfs)
2-Year	424	1084.95	6	167	1075.95	12	153	1072.18	10
5-Year	733	1085.42	13	290	1076.46	20	274	1072.79	17
10-Year	963	1085.76	18	383	1076.84	26	365	1073.23	21
25-Year	1,223	1086.12	20	486	1077.27	32	468	1073.64	25
50-Year	1,493	1086.49	21	593	1077.69	37	574	1074.03	28
100-Year	1,771	1086.84	23	703	1078.09	40	684	1074.37	31

Upper Lightning Lake:
Assume FSL at Elev. 1084.19
3' Weir on RC Box Riser U/S
Top of Stoplogs in Control Str at 1084.19
Extended 24" RCP thru CR #26
U/S Invert of 24" RCP at 1083.3
D/S Invert of 24" RCP at 1083.0
North Shoulder on CR #26 at 1092.3

Swift WMA (East Tract):
Assume FSL at Elev. 1074.4
Existing 42" x 30" CMP thru CR #3
Includes 8 cfs baseflow from Stoney Lake
U/S Invert of 24" RCP at 1074.4
D/S Invert of 24" RCP at 1074.2
East Shoulder on CR #3 at 1079.7

Denton Slough (West Tract):
Assume FSL at Elev. 1071.0
Existing 30" RCP thru CR #26
U/S Invert of 30" RCP at 1068.0
D/S Invert of 30" RCP at 1068.0
North Shoulder on CR #18 at 1077.0
3' Weir on RC Box Riser D/S
Top of Stoplogs in Control Str D/S at 1071.0
30" RCP Outlet Pipe, But Weir Controls
TW From Stoplog Structure Considered

Table 2.

Upper Lightning Lake System

Hydraulics Summary for Various Design Events

EXISTING CASE

Design Event	Upper Lightning Lake (Assumed Starting Water Surface Elevation 1083.3) Peak Qin (cfs)	Max. W.S. Elevation	Peak Qout thru 24" RCP (cfs)	Swift WMA (East Tract) (Assumed Starting Water Surface Elevation 1074.4) Peak Qin (cfs)	Max. W.S. Elevation	Peak Qout thru 42"x30" CMP (cfs)	Denton Slough (West Tract) (Assumed Starting Water Surface Elevation 1071.0) Peak Qin (cfs)	In CR #26 Max. W.S. Elevation	Peak Qout thru 30" RCP (cfs)
2-Year	424	1084.16	3	167	1075.83	11	153	1072.13	9
5-Year	733	1084.70	7	290	1076.42	20	274	1072.71	16
10-Year	963	1085.07	11	383	1076.82	26	365	1073.13	20
25-Year	1,223	1085.48	15	486	1077.24	32	468	1073.57	24
50-Year	1,493	1085.87	17	593	1077.66	36	574	1073.98	28
100-Year	1,771	1086.26	19	703	1078.06	40	684	1074.34	31

Upper Lightning Lake:
Assume FSL at Elev. 1083.3
Existing 24" RCP thru CR #26
U/S Invert of 24" RCP at 1083.3
D/S Invert of 24" RCP at 1083.0
North Shoulder on CR #26 at 1092.3

Swift WMA (East Tract):
Assume FSL at Elev. 1074.4
Existing 42" x 30" CMP thru CR #3
Includes 8 cfs baseflow from Stoney Lake
U/S Invert of 24" RCP at 1074.4
D/S Invert of 24" RCP at 1074.2
East Shoulder on CR #3 at 1079.7

Denton Slough (West Tract):
Assume FSL at Elev. 1071.0
Existing 30" RCP thru CR #26
U/S Invert of 30" RCP at 1068.0
D/S Invert of 30" RCP at 1068.0
North Shoulder on CR #18 at 1077.0
Top of Stoplogs in Control Str D/S at 1071.0
30" RCP Outlet Pipe, But Weir Controls
TW From Stoplog Structure Considered

PROPOSED CASE - Pumping at 10,000 gpm (22.3 cfs)

Design Event	Upper Lightning Lake (Assumed Starting Water Surface Elevation < 1084.19) Peak Qin (cfs)	Max. W.S. Elevation In Marsh*	Pumped Qout thru 24" RCP (cfs)	Swift WMA (East Tract) (Assumed Starting Water Surface Elevation 1074.4) Peak Qin (cfs)	Max. W.S. Elevation	Peak Qout thru 42"x30" CMP (cfs)	Denton Slough (West Tract) (Assumed Starting Water Surface Elevation 1071.0) Peak Qin (cfs)	In CR #26 Max. W.S. Elevation	Peak Qout thru 30" RCP (cfs)
2-Year	424	< 1084.19	22.3	189	1076.79	25	155	1072.64	15
5-Year	733	< 1084.19	22.3	312	1076.99	38	276	1073.11	20
10-Year	963	< 1084.19	22.3	405	1077.19	31	367	1073.44	23
25-Year	1,223	< 1084.19	22.3	508	1077.57	36	470	1073.79	26
50-Year	1,493	< 1084.19	22.3	615	1077.96	39	577	1074.12	29
100-Year	1,771	< 1084.19	22.3	725	1078.33	42	687	1074.44	32

Upper Lightning Lake:
*When umping, the only discharge from the wetland is what's being pumped. It is assumed the lake would be below FSL.
24" RCP thru CR #26
U/S Invert of 24" RCP at 1083.3
D/S Invert of 24" RCP at 1083.0
North Shoulder on CR #26 at 1092.3

Swift WMA (East Tract):
Assume FSL at Elev. 1074.4
Existing 42" x 30" CMP thru CR #3
Includes 30.2 cfs baseflow (pump & Stoney)
U/S Invert of 24" RCP at 1074.4
D/S Invert of 24" RCP at 1074.2
East Shoulder on CR #3 at 1079.7

Denton Slough (West Tract):
Assume FSL at Elev. 1071.0
Existing 30" RCP thru CR #26
U/S Invert of 30" RCP at 1068.0
D/S Invert of 30" RCP at 1068.0
North Shoulder on CR #18 at 1077.0
3' Weir on RC Box Riser D/S
Top of Stoplogs in Control Str D/S at 1071.0
30" RCP Outlet Pipe, But Weir Controls
TW From Stoplog Structure Considered

occurring. This would be expected as the pumping rate of flow (22.3 cfs) is comparably higher than the estimated discharge from surface runoff for the smaller events (9-20 cfs). However, this does not mean pumping will cause problems downstream as the flow rates when pumping are still less than the existing case discharge rates for the larger rainfall events.

For the larger runoff events such as the 50-year (2% chance) and 100-year (1% chance) storms, there is no significant difference between the existing and proposed discharge rates from Denton Slough, even when pumping 10,000 gpm as the Denton Slough structure controls and temporary storage in the wetland helps reduce peak flows.

The approximate drawdown stage in Upper Lightning Lake versus pumping time is shown in Table 3. The analysis assumes the water level in Upper Lightning Lake has been lowered by gravity to the runout invert of the existing culvert in CR #26 (1083.3) prior to any pumping being initiated.

Table 3.
Drawdown Model Results
Pumping 10,000 gpm = 22.3 cfs = 44.2 acre-feet/day

Water Surface Elev.	Approx. Volume In Lake (ac-ft)	Approx. Volume Pumped (ac-ft)	Time Required (days)	Cumulative Time From Start (days)	Pumping Rate Qout (cfs)
1083.3	1,853			0	22.3
1082.0	1,303	550	12.5	13	22.3
1081.0	835	468	10.6	23	22.3
1080.0	433	402	9.1	32	22.3
1079.0	140	293	6.6	39	22.3
1078.0	0	140	3.2	42	22.3

As shown in Table 3, it would take approximately 42 days to lower the Upper Lightning Lake level from full pool elevation 1083.3 down to elevation 1078.0. This analysis assumes inflow from rainfall equals the evaporation rate. Obviously, if rainfall exceeds evaporation, it will take additional time to lower the lake to the elevations noted. The analysis also assumes pumping at a continuous rate of 10,000 gpm. As lake levels fall, inflow to the pump may require a decrease in that pumping rate.

Per Table 2, the modeling effort shows that discharge rates from Denton Slough are slightly higher for the smaller runoff events when 10,000 gpm pumping from Upper Lightning Lake is occurring. Again, this would be expected as the pumping rate of flow (22.3 cfs) is comparably higher than the estimated discharge from surface runoff for the smaller events (9-20 cfs). However, this does not mean pumping will cause problems downstream as the flow rates when pumping are still less than the existing case discharge rates for the larger rainfall events. As with all pumping situations, runoff conditions downstream will likely dictate the ideal upstream rate of pumping.

CONCLUSIONS:

Table 1 indicates that during non-pumping times, there should be no change in peak discharge rates from the Upper Lightning and Kube-Swift WMA (Denton Slough) system due to the project. Downstream interests should not have any higher peak flows than what currently exists.

At times when the pumps are being operated to temporarily lower Upper Lightning Lake, there will be a slight increase in peak flow rate downstream versus existing conditions, primarily for the smaller runoff events. This is due to the pumps adding additional flow to the system over and above what would normally flow following a smaller runoff event. For the larger runoff events, there will essentially be no significant increase in the peak flow rate when pumping, due to the control structure at the outlet of Denton Slough regulating the discharge.

Obviously, the duration of flows will increase during the drawdown operations due to the volume of water that has to be evacuated from Upper Lightning Lake. However, under normal management following the initial drawdown, no change in water regimes should be noted. Upstream interests should benefit somewhat as a result of lower managed levels in Upper Lightning Lake. While there are no plans to change the full pool levels in the Kube-Swift WMA wetlands, the surrounding landowners should experience some improvement due to the channel cleanout/maintenance at the outlet of Swift WMA and the inlet area into Denton Slough.

With oversight and management when pumping, it should be possible to temporarily lower Upper Lightning Lake for vegetation management without adversely impacting upstream or downstream landowners. The pump and new structure at the outlet of the lake and channel cleanout/maintenance should provide for more efficient management of Upper Lightning Lake while maintaining the wetlands within Kube-Swift WMA. Re-vegetation of the lake should improve water quality and wildlife use, and through normal wildlife lake management, benefits in temporary and/or permanent flood storage will likely result.

Preliminary construction plans have been drafted outlining project specifics. A set of standard construction specifications is available upon request.