Diamond Lake TMDL Implementation, Hubbard, Schultz, Wheeler Implementation Activity

Engineer's Report **February 28, 2014**

Houston Engineering Inc.

MIDDLE FORK CROW RIVER WATERSHED DISTRICT

Diamond Lake TMDL Implementation

Hubbard, Schultz, Wheeler Implementation Activity

February 28, 2014

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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Acronyms and Abbreviations List

ACP	Agricultural Conservation Practices (ACP)
BMP	Best Management Practice
CD	County Ditch
cfs	cubic feet per second
CMP	Corrugated Metal Pipe
CN	Curve Number
DEM	Digital Elevation Model
DU	Ducks Unlimited, Inc.
EDA	Environmental Data Access
HEI	Houston Engineering, Inc.
LiDAR	Light Detection and Ranging
MFCRWD	Middle Fork Crow River Watershed District
MnDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
SSTS	Subsurface Sewage Treatment Systems
RCP	Reinforced Concrete Pipe
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TP 40	Technical Paper 40

1 INTRODUCTION

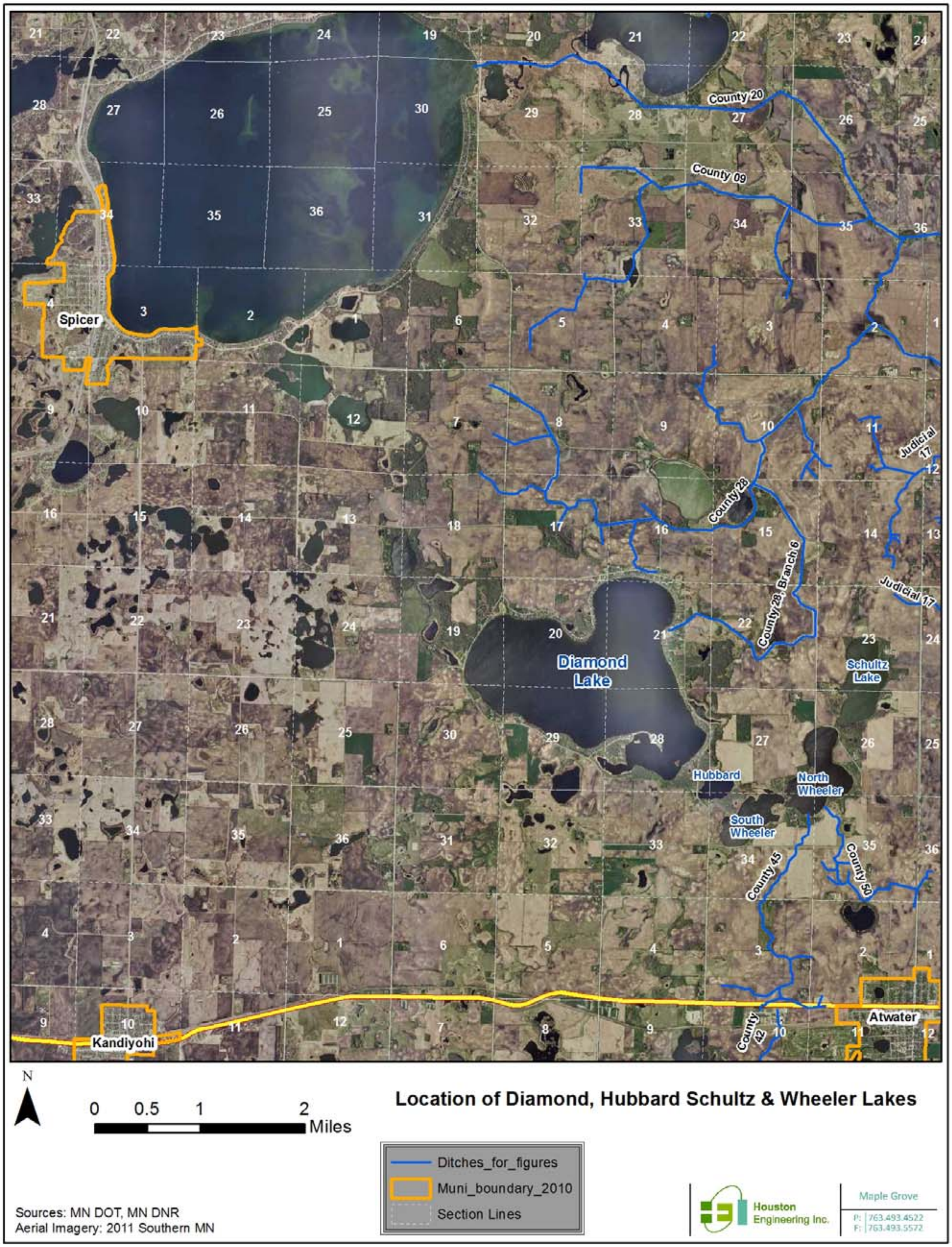
In a 2011 Total Maximum Daily Load (TMDL) report on Diamond Lake, prepared for the Middle Fork Crow River Watershed District (MFCRWD), Houston Engineering (HEI) recommended various implementation activities which would help reduce both external and internal sources of total phosphorus (HEI, 2011). Upstream lake management was identified as one activity to help significantly reduce external sources of total phosphorus. Monitoring data from 2008 and 2009 evaluated during the 2011 Diamond Lake TMDL indicated that an estimated 74% (2008) and 83% (2009) of the total phosphorus entering Diamond Lake from surface runoff came from the upstream lakes of Schultz, Wheeler and Hubbard. Converting the upstream shallow lakes of Hubbard, Wheeler and Schultz to a clear state is expected to considerably reduce the amount of total phosphorus load to Diamond Lake (see **Figure 1**).

Observations during the 2008 and 2009 monitoring period confirmed that the elevated turbidity was most likely the result of a large carp population. Carp have the ability to stir up sediments and disturb vegetation, mobilizing phosphorus that otherwise could be retained in the bottom sediments of the shallow lakes. Controlling rough fish like carp has the ability to alter the state of a shallow lake from turbid to clear. Converting these upstream lakes from a turbid state to a clear state has considerable potential for improving not only the water quality of the upstream lakes, but the water quality of Diamond Lake.

Following the Diamond Lake TMDL recommendation to implement an upstream lake management project consisting of temporary lake level drawdowns of Hubbard, Wheeler, and Schultz lakes to achieve clear water states, the Middle Fork of the Crow River Watershed District (District) solicited the services of Ducks Unlimited to complete a Feasibility Report (DU, 2012a). The Feasibility Report provided a recommendation for a project which would draw down the lakes by means of water control structures, allowing for temporary discharge to the north and through a new pipeline leading to County Ditch #28, Branch 6 (CD 28). This Feasibility Report is included in **Appendix A** this Engineer's Report.

Subsequent to the DU Feasibility Report, the MFCRWD Board of Managers received a petition from numerous residents of the District to establish the proposed project to be known as the "Diamond Lake TMDL Implementation, Hubbard, Schultz, Wheeler Implementation Activity." In accordance with the Minnesota Statute 103D.601, the District initiated this project by resolution on September 3, 2013. This resolution is included in **Appendix B** of this Engineer's Report. The Resolution designated Houston Engineering, Inc. as the project engineer responsible for preparing this Engineer's Report which provides the additional technical analysis, maps, and information necessary to satisfy the requirements of Minnesota Statute 103D.711, which outlines the requirements for a Watershed District to establish a project.

Figure 1: Location of Diamond, Hubbard, Schultz, and Wheeler Lakes



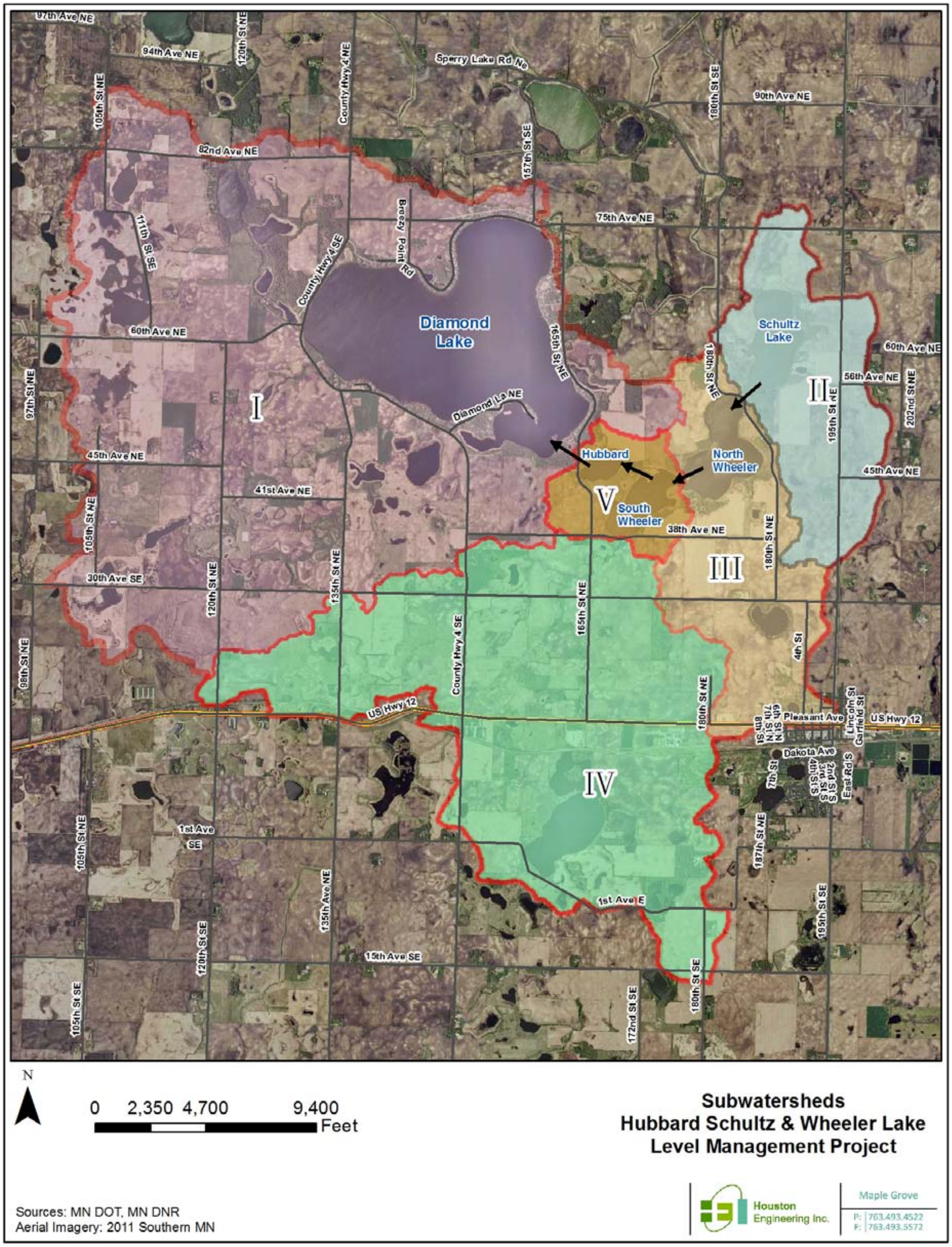
2 PROJECT DESCRIPTION

2.1 Existing Conditions

The DU Feasibility Report (2012a) divides Diamond Lake's 28.1 square mile watershed into the five subwatersheds as shown in **Figure 2**. Surface runoff from Subwatersheds II, III, IV and V all pass through one or more of the upstream lakes of Schultz, Wheeler (North and South) and Hubbard. Schultz Lake discharges directly into North Wheeler Lake through a 24" diameter corrugated metal pipe (CMP) passing under 180th Street. North Wheeler and South Wheeler are separated by a trail and three culverts: a 15" diameter CMP, an 18" diameter CMP and a 24" diameter CMP. Hubbard Lake discharges directly into Diamond Lake through an existing 4' x 10' precast concrete box culvert under County Road 137 (165^{th} Street NE).

Monitoring data from 2008 and 2009 gathered for the Diamond Lake TMDL (HEI 2011) had shown that the upstream shallow lakes had elevated turbidity and total phosphorus concentrations. **Section 4.3.1** of this report provides a detailed review of water quality data collected since 2009 and finds that the total phosphorus (TP) in the upstream lakes has remained fairly consistent. There have been no further data collected of total suspended solids (TSS).

Figure 2: Diamond Lake Subwatersheds



2.2 Proposed Project Description

Shallow lakes and wetlands require periods of low water or droughts to stay healthy and productive. Through water level management, undesirable fish such as carp can be controlled and basin sediments are exposed to become consolidated and aerated. Rooted aquatic plants germinate from the natural seed bank and help anchor those sediments further. Aquatic vegetation also buffers nutrients from the water column and provides valuable habitat for aquatic animals, invertebrates, and waterfowl. Research shows that the removal of rough fish including carp to a level less than approximately 100 kg/acre result in a predator - prey relationship conducive to the clear phase (the specific ecological reasons remain unclear)

The proposed project will periodically lower the water levels within Hubbard, Schultz and Wheeler Lakes. Benefits associated with the proposed project include: 1) stimulating the winter kill of undesirable rough fish within Hubbard, Schultz and Wheeler Lakes; 2) stimulating the growth of submerged aquatic plants within the lakes; and 3) improved water quality within Diamond Lake, as well as within Hubbard, Schultz and Wheeler Lakes themselves.

The feasibility report recommended a project which would drawdown the lakes by rerouting flows from Hubbard Lake/South Wheeler Lake to North Wheeler Lake to Schultz Lake, and then finally into County Ditch #28, Branch 6 (CD 28) located downstream of the Diamond Lake outlet near 180th Street. This design would enable each of the lakes to be drawn down in sequence.

The proposed project as presented in the Feasibility Report would include a 24" pipeline controlled by a gate from Schultz Lake to County Ditch #28, Branch 6 located downstream of the Diamond Lake outlet near 180th Street (see **Figure 3**). Water control structures installed between Schultz and North Wheeler and between North and South Wheeler would allow each of the lakes to be drawn down in sequence. The proposed water control structures are precast concrete box risers with stoplogs and 24" outlet barrels. Inlet and outlet channels between the lakes would have to be excavated to an elevation which would allow close to complete water level drawdown in order to expose bottom sediment. This elevation has been determined to be at 1167.0[1] (DU, 2012a).

A concrete in-line water control structure is proposed on the northwest corner of Schultz Lake with the purpose of managing water levels (see Site #1 in **Figure 3**). During drawdown, the structure would discharge to an approximately 2,100 foot long, 24" pipe leading to CD 28, Branch 6. At Site #*2*, a concrete water control structure is being proposed on North Wheeler Lake, under 180th Street, which would allow for the drawdown of North

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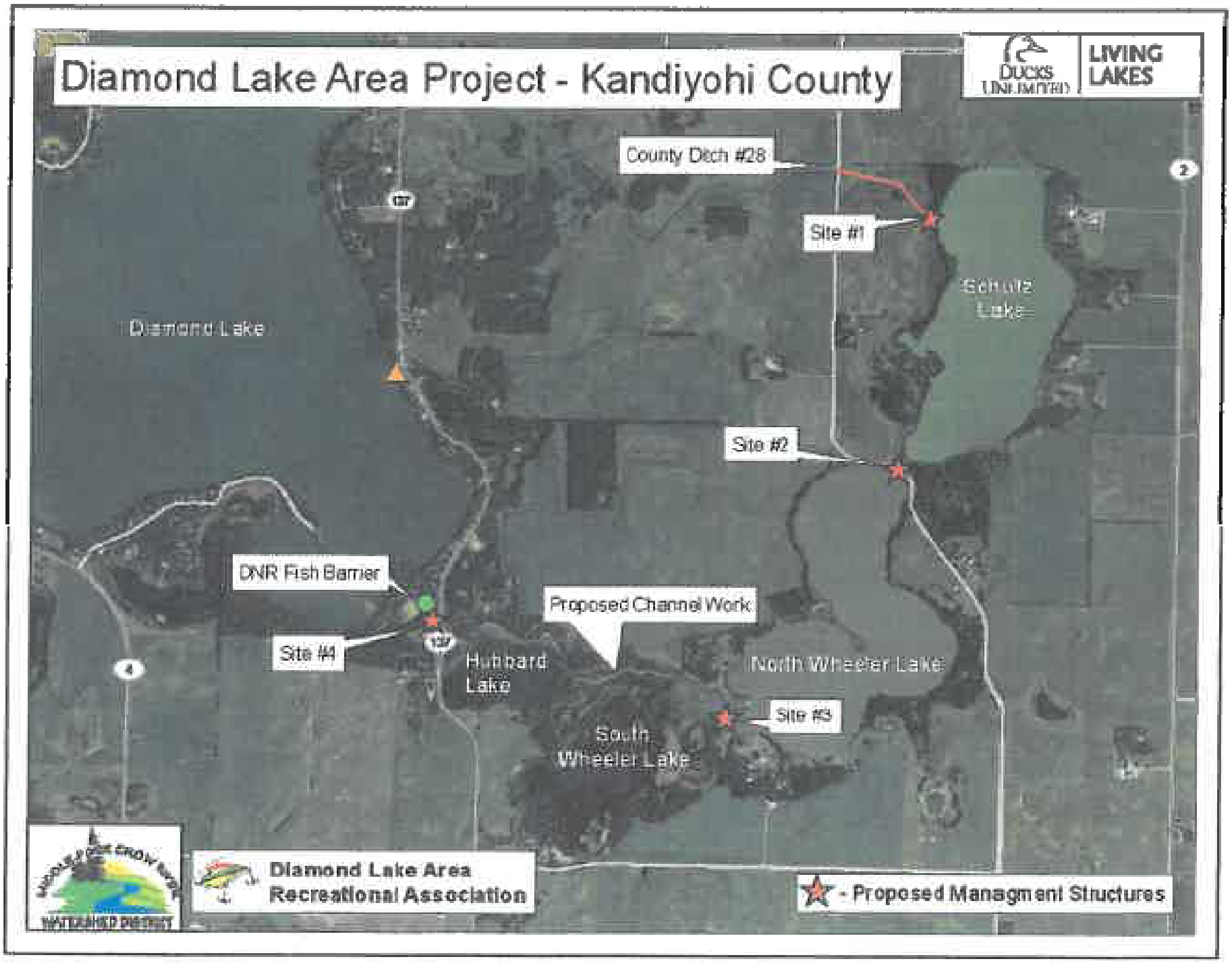
[1] Note that all elevations listed in this report are in NAVD 1988 datum

Wheeler. In order to draw down Hubbard and South Wheeler Lakes, a concrete water control structure is also being proposed between North and South Wheeler Lakes at Site #3.

A temporary water level maintenance structure will be installed at Site #4 during upstream lake drawdown to maintain water levels on Diamond Lake by preventing water from flowing back into the upstream lakes as their levels are lowered. The structure will include two 5' wide stoplog bays, and the stoplogs will be placed in the structure up to elevation 1172.8 during the drawdown of South Wheeler/Hubbard and then removed during normal operating conditions. It is proposed that the temporary water level maintenance structure will be installed between the outlet of Hubbard Lake and Diamond Lake, downstream of a filter type fish barrier which was installed by the Minnesota DNR in the fall of 2012. It is important to note that the design and analyses carried out for this Engineer's Report have been carried out under the assumption that the newly installed fish barrier provides the same flow capacity as the existing conditions outlet from Hubbard Lake which is a 4-foot by 10-foot culvert.

Once the upstream lake elevations are lowered to the target elevation, the water levels will be held there for a period of time (see **Section 3.1**, Conceptual Operating Plan) to maximize the probability of a winter fish kill. This low level maintenance period also helps achieve suitable water depths for the stimulation and growth of submerged aquatic plants because of better light penetration to the substrate.

Figure 3: Proposed Hubbard, Schultz, and Wheeler Lake Level Drawdown Project (Source: DU 2012e)



3 CONCEPTUAL OPERATING PLAN

A conceptual operating plan provides a general outline for the operational periods, process, and criteria associated with operating a project. Based on the project description found in the Feasibility Report and the technical analysis performed by both DU and HEI, an operating plan has been conceptualized for the purposes of evaluating the probable benefits and impacts of the project. The conceptual operating plan assumes the complete drawdown of the upstream lakes and therefore provides a conservative estimate of the volume of water flowing directly into the county ditch from the upstream lakes of Schultz, Wheeler, and Hubbard drawdown.

This conceptual operating plan is not intended to serve as a final operation and maintenance plan. Rather, it is intended to serve as a tool to obtain general agreement about project operation among the many project participants, as well as for the purposes of evaluating the benefits and potential consequences of the project. Subsequently, a final Operation Plan document will be developed in accordance with requirement of the State of Minnesota for final project approval using the guidelines established here.

3.1 Conceptual Operating Plan

The conceptual operating plan presented below is assumed for the purposes of this Engineer's Report in assessing water quality benefits, potential impacts to Diamond Lake levels, as well as potential impacts to CD 28 as a result of the proposed lake drawdown project.

1. **Start date of the drawdown: September 1**
    - Schultz Lake will be allowed to discharge through the 24-inch RCP to CD 28, Branch 6.

2. **Sequence of drawdown: Schultz Lake, North Wheeler Lake, then South Wheeler/Hubbard**
    - Schultz Lake will be drawn down first, followed by North Wheeler and then the South Wheeler/Hubbard Lake system, by removing stop logs in the outlet structures.

3. **Target Elevation of drawdown: 1167.00**
    - A complete drawdown cycle means lowering the lakes from their current normal water levels to elevation 1167.0. Schultz Lake would be lowered from its current normal water level of 1173.25 to within approximately 1 -2 feet of the lake bottom. North Wheeler, South Wheeler, and Hubbard Lakes are all currently controlled by the outlet of Diamond Lake at elevation 1172.8. North Wheeler will be drawn down to approximately 2 feet from the lake bottom, South Wheeler is expected to be completely dewatered, and Hubbard Lake will be drawn down to approximately 1 to 2 feet from the lake bottom (DU 2012a and DU 2012b).

4. **Drawdown end date: December 19 (approximate)**.
    - The approximate end date of December 19 for the bulk of the drawdown is 110 days after the beginning of the drawdown period. The drawdown of Schultz Lake to elevation 1168.0 is expected to take approximately 35 days. The complete drawdown to elevation 1167.0 will eventually be attained at lower discharge rates due to the lower head on the outlet. After 35 days, the stop logs between North Wheeler and Schultz Lake will be removed, and the drawdown of North Wheeler Lake is expected to take approximately 37 days. After the 37 days, the stop logs between North Wheeler and South Wheeler will be removed, and the drawdown of South Wheeler and Hubbard Lake is expected to take approximately 38 days. Note that December 19 corresponds closely to a median ice-in date of Green Lake, located approximately 3.5 miles to the north of Diamond Lake (MnDNR_a).

5. **Water level maintenance period: December 20 through June 30.**
    - The primary purposes of maintaining water levels at the target elevation of 1167.0 within Hubbard, Schultz and Wheeler Lakes are to: 1) substantially increase the probability of a winter fish kill; and 2) achieve suitable water depths for the stimulation and growth of submerged aquatic plants during the early spring months because of better light penetration to the substrate (i.e., the June 30 date).
    - Maintaining the target elevation of 1167.0 through the maintenance period requires that the stoplogs on the structures between North Wheeler and South Wheeler to remain out and the gate on the new 24-inch PVC outlet from Schultz Lake to CD 28 Branch 6 remains open.

6. **Replace stop logs and begin water level recovery: July 1 (summer following fall drawdown period)**

7. **Estimated Water Level Recovery Period: June 30 to December 30 (year following fall drawdown)**
    - The time it takes for the upstream lakes to refill and begin discharging water to Diamond Lake will vary on the climatic conditions of each particular year. Simple water balance analysis based on long term average precipitation and evaporation show that Diamond Lake will begin receiving water from the upstream lake system within the first six months, if the recharge period begins on July 1, immediately following the low level maintenance period. However, this refill time will vary and could be either shorter or longer.
    - During the water level recovery period: 1) the stop logs will be placed back into the outlet structure between South Wheeler and North Wheeler at elevation 1172.80, and the gate will be closed on the 24-inch PVC outlet from Schultz Lake to CD 28 Branch 6.

8. **Frequency of Project Operation:** Every 5 years
    - The frequency of drawdown is expected to vary based upon operational experience (see **Section 3.2**, Adaptive Management). However, it is initially expected to occur once every 5 to 7 years.

3.2 Adaptive Management

The conceptual operating plan described in **Section 3.1** is the basis for evaluating the probable benefits and impacts of the project in this Engineer's Report. Once the project is constructed and operating, the District may consider an adaptive management approach. Adaptive management means making decisions as part of an on-going process, as the results of lowering water levels provide important new information about how the resource responds. This information can then be used to slightly adjust or modify subsequent operation of the project. New scientific findings or societal needs may also trigger a need to further modify the planned operation.

For example, the goal of managing water levels in the upstream lakes is to alter their state from a turbid state to a clear state, which is expected to improve water quality within both the upstream lakes and Diamond Lake. However, after a period of water quality monitoring, it may be found that some adjustments relative to the conceptual operating plan may be necessary to attain the clear phase. Likewise, should any adverse impacts arise due to, for example, extreme climatic conditions, the concept operating plan could also be altered.

Another situation which may trigger a modification to the conceptual operating plan is related to water levels within Diamond Lake. Executing a drawdown during a drought when the water level within Diamond Lake is already low could have too severe of any impact on Diamond Lake levels since it will be losing a significant portion of its inflow from the upstream lakes. Should low lake levels develop during a drought, the use of adaptive management may mean completing a drawdown only for Schultz Lake while allowing the runoff from Hubbard and Wheelers Lakes to proceed to Diamond Lake, or the drawdown may simply be delayed for one or more years. Likewise, during times of extreme high flow in the CD 28, the implementation of a drawdown may be delayed, or the amount of water discharged can be reduced to not exceed the available ditch capacity.

4 WATER QUALITY BENEFITS AND LAKE LEVEL IMPACTS TO DIAMOND LAKE

The principal goal of the proposed project is to improve the water quality of Diamond Lake. Therefore a critical component of this Engineer's Report is a quantification and assessment of the water quality benefits to the lake. The implementation of the project will also have temporary impacts on the lake levels in Diamond Lake, and these impacts need to be determined in order to draw a conclusion regarding their acceptability to the public. The water quality benefits to Diamond Lake and the lake level impacts have been estimated by developing water and total phosphorus (TP) balance model, drawing upon the results of the watershed loading and receiving water models which were prepared as part of the Diamond Lake TMDL. The analysis also takes into account the results of the Ducks Unlimited Feasibility Study; specifically the estimated drawdown time and estimated volume discharged to CD 28.

4.1 Developing Existing and Proposed Water and Nutrient Balance Models

The work carried out for the Diamond Lake TMDL (HEI, 2011) included the development of both a watershed model (SWAT) and a receiving water model (BATHTUB/CNET). The SWAT model was used to estimate 30-year (1980 through 2009, plus a 5-year "warm-up" period from 1975 through 1979) average annual nutrient and sediment loadings and runoff volumes from the entire Diamond Lake watershed to Diamond Lake, as wells as to Schultz, Hubbard and Wheeler Lakes. The average annual surface water runoff and total phosphorus load from the SWAT model was then used as input to the CNET model to estimate Diamond Lake's response. For this Engineer's Report, daily results from the SWAT model over its 30-year period of record were extracted and used to assist in estimating impacts of the proposed lake level drawdown project on lake Diamond Lake levels and water quality.

4.1.1 Existing Conditions Water Balance Model

The daily results from the SWAT model over its 30-year period of record were extracted and used to develop a 30-year water balance spreadsheet model. Existing conditions daily outflow from Diamond Lake was estimated using lake level data from the Minnesota DNR LakeFinder website (MnDNR_b). Due to the daily time step of the model, daily data needed to be estimated by filling in data gaps by linearly interpolating between lake level readings (see **Figure 4**). A stage-discharge curve of the Diamond Lake outlet (30-foot weir at elevation 1172.80) was generated using the HydroCAD model provided by DU (DU, 2012b) (see **Figure 5**). An equation was fit to the curve and then used to estimate the 30 years of daily discharge rates and volumes from Diamond Lake under current lake management conditions.

Figure 4: Historical Diamond Lake Level Data with Data Gaps Filled in by Linear Interpolation

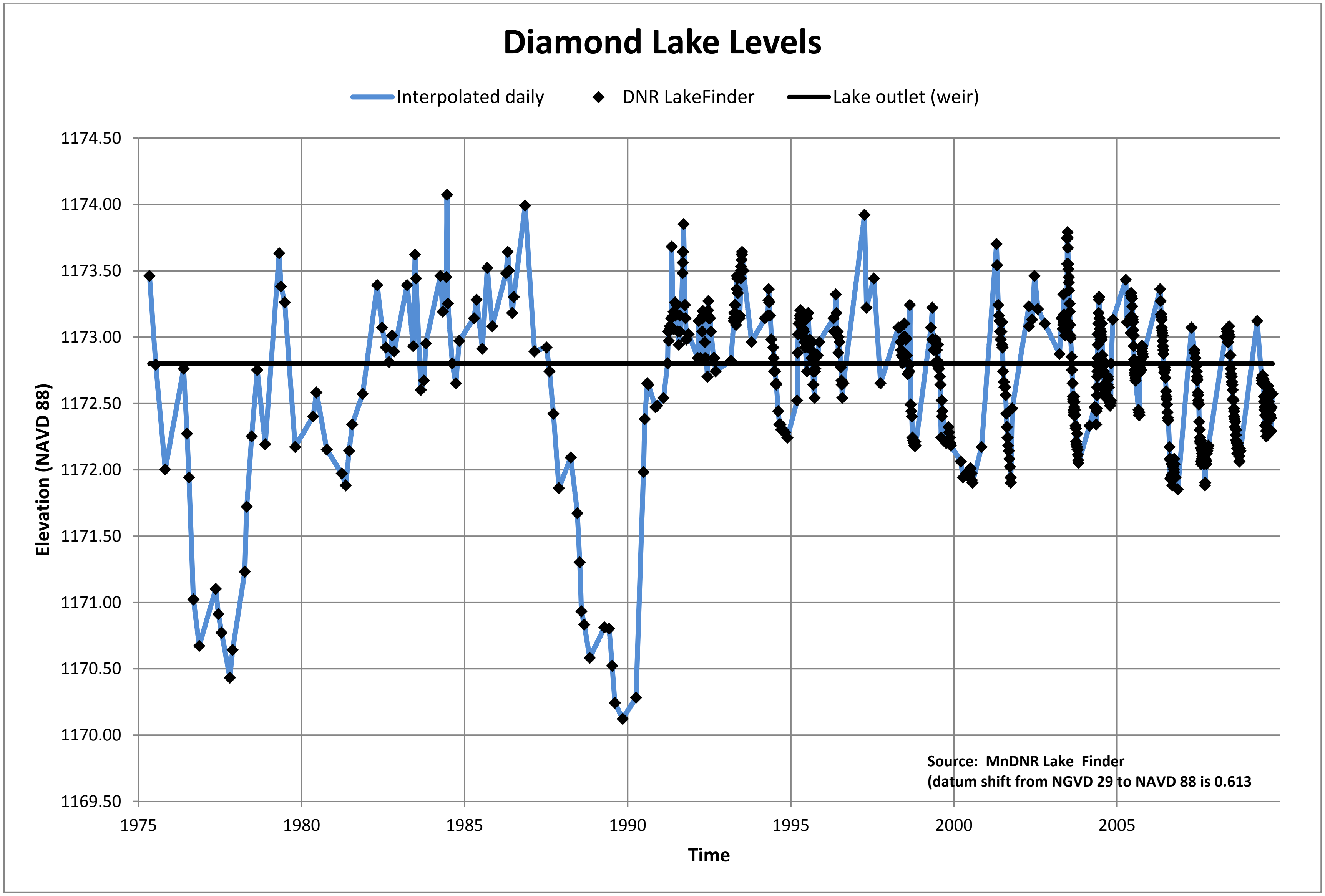
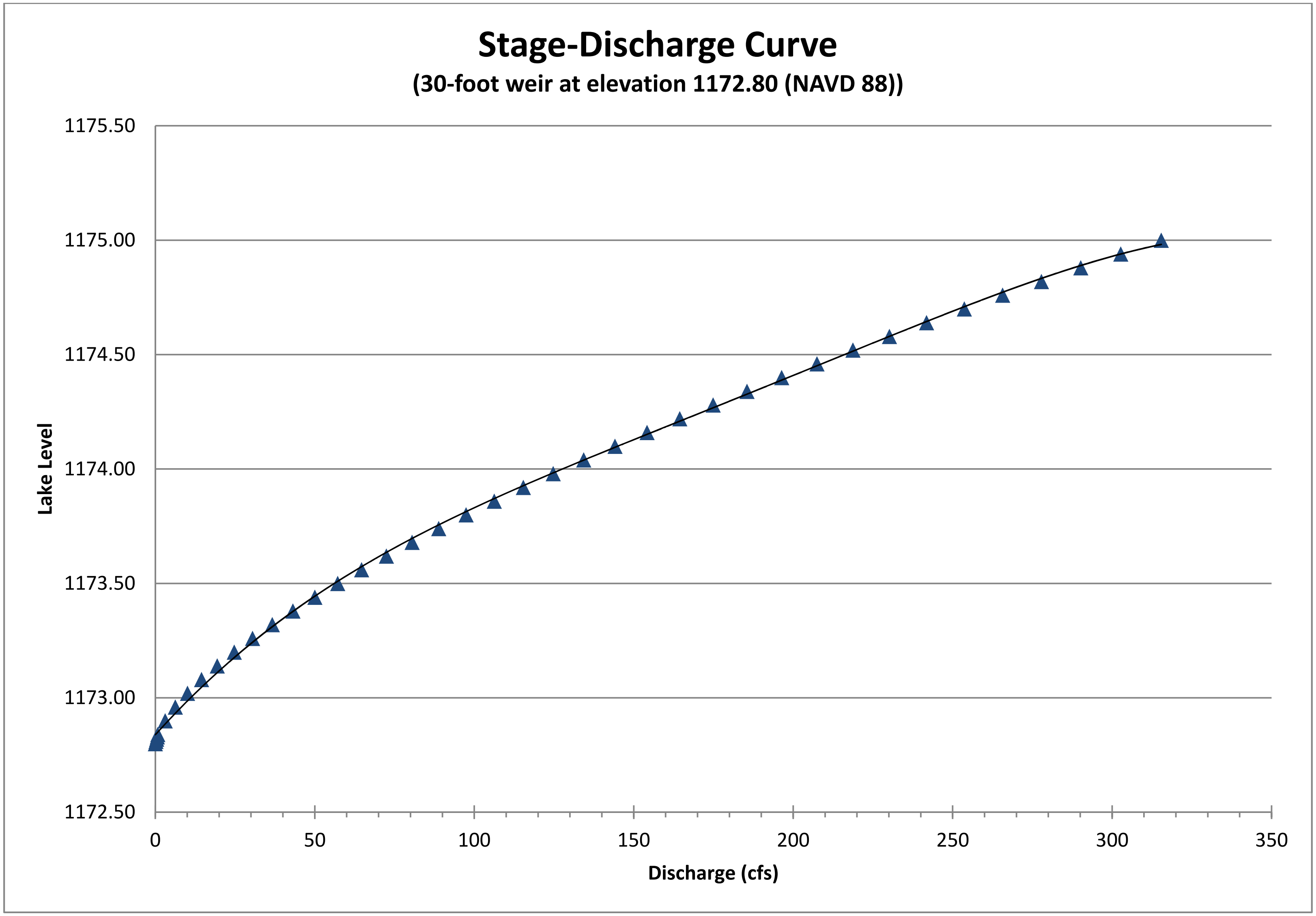


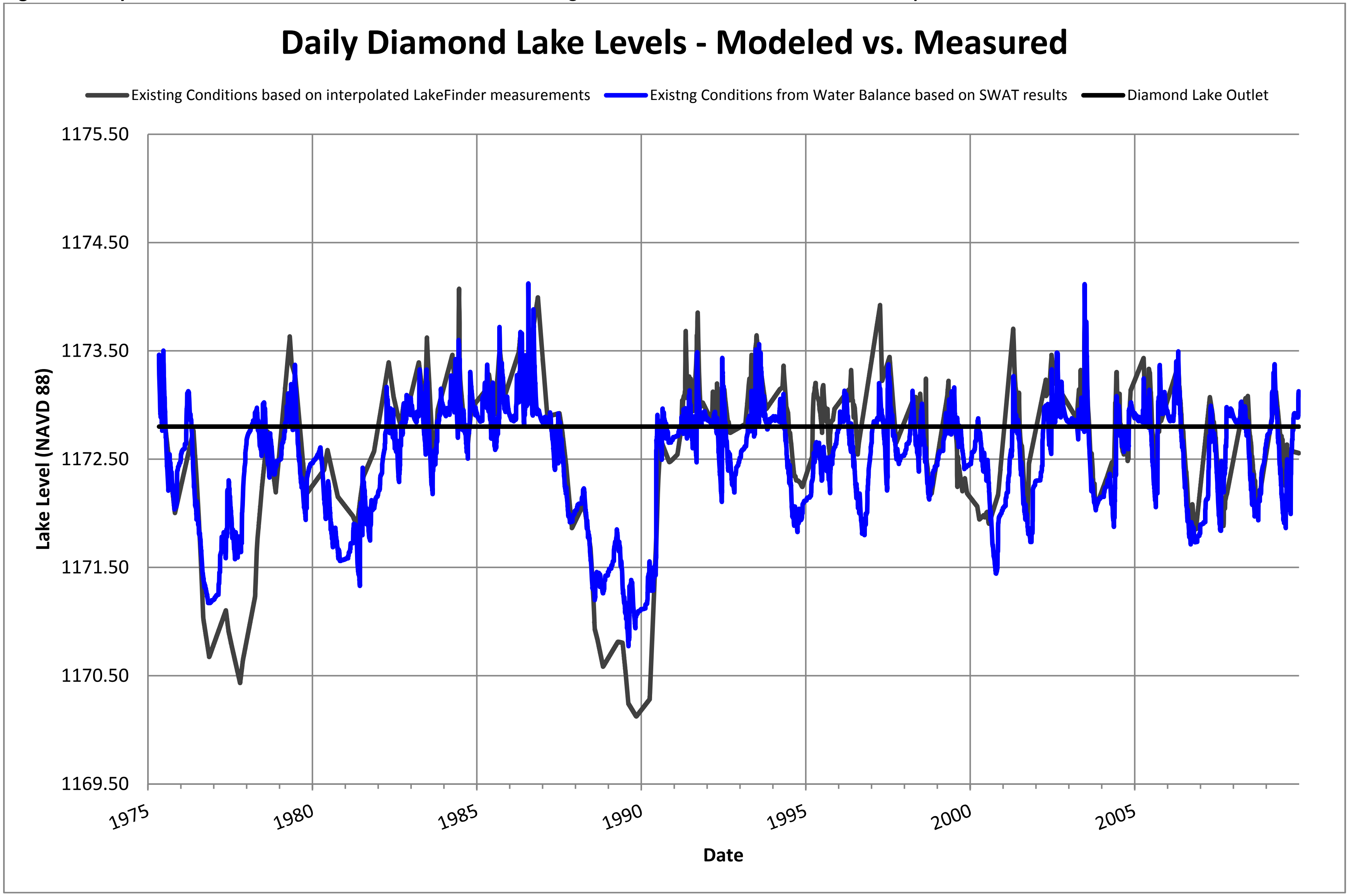
Figure 5: Stage-Discharge Curve Extracted from HydroCAD Model for Diamond Lake Outlet



Thirty-five years (1975-2009) of daily inflows to Diamond Lake were extracted from the Diamond Lake SWAT model, including inflow from upstream Hubbard Lake and eight other local inflow locations. Daily precipitation depths obtained from National Climatic Data Center (NCDC), and daily evaporation was extracting from the SWAT model results.

To assess the performance of the water balance model, resulting lake levels from the existing conditions model were then compared to those from the DNR Lake Finder presented in **Figure 4** above. **Figure 6** below shows the match between the daily water surface elevations determined with the existing conditions water balance model and the lake levels recorded on the DNR LakeFinder website. For the purposes of this report, the existing conditions water balance model is considered sufficient to be used to simulate changes to the system which reflect the proposed condition drawdown scenario, as presented in the Conceptual Operating Plan (Section 3).

Figure 6: Daily Water Surface Elevations Determined with the Existing Conditions Water Balance Model as Compared to Lake Levels recorded on DNR LakeFinder



4.1.2 Proposed (With Project) Conditions Water Balance Model

In an effort to estimate both the impact the upstream lake drawdown project may have on Diamond Lake levels, as well as the estimated improvement to Diamond Lake water quality, a proposed conditions water balance model was constructed by modifying the existing conditions model to reflect the operational aspects of the drawdown period, low level maintenance period, and upstream lake refill period.

The inflow to Diamond Lake from the upstream lakes was removed for the estimated 110 day drawdown period (September 1 through December 19), through the low level maintenance period (through June 30), and then through to the end of the expected time it takes for the upstream lakes to refill. An important factor in evaluating benefits and impacts is the time it takes for the upstream lakes to refill and begin to discharge water again to Diamond Lake, which will in reality vary highly on the climatic conditions of each particular year. Simple water balance analysis based on long term average precipitation and evaporation show that Hubbard Lake will fill up within the first six months, if the recharge period begins July 1, immediately following the low level maintenance period. However, it may take longer than that for the discharge from the upstream lakes to reach a condition equivalent to the existing conditions. Therefore, the impact analysis of the upstream lake drawdown on the Diamond Lake levels was completed twice, once assuming an upstream lake recharge time of 6 months, and again assuming an upstream lake recharge time of 18 months (see **Section 4.2**).

The proposed conditions scenario was simulated by assuming an upstream lake level drawdown occurring every five years: 1980, 1985, 1990, 1995, 2000, and 2005.

4.2 Effects of Project on Diamond Lake Levels

Based on results from the proposed water balance model, the Diamond Lake daily water surface elevations were estimated, assuming both a 6 month upstream lake recharge time and an 18 month recharge time. The resulting lake levels for existing and proposed conditions are shown in **Figure 7** and **Figure 8**, respectively, for the entire period of record. Lake level traces displayed five years at a time are shown in **Appendix C** and **Appendix D**.

The Diamond Lake level impacts are quantified in **Table 1** and **Table 2** with respect to the lowest lake level occurring in a season, as well as lake level recovery time. For the scenario assuming a 6 month upstream lake recharge time beginning on July 1, following the low level maintenance period, model results show that the lowest seasonal Diamond Lake levels are expected to be 2 to 5 inches lower during the year following the drawdown, assuming climatic conditions similar to those between 1980 and 2009 and a drawdown frequency of once every 5 years. The total time that proposed Diamond Lake levels are lower than existing conditions levels (even by only 1/10 of a foot) varies between 1.0 and 1.8 years, following each drawdown. However, any difference less than 6 inches is probably not detectable. The water balance model shows that only during one drawdown cycle do proposed lake levels drop below 6 inches from existing conditions levels on Diamond Lake. Only the summer following the 1980 drawdown do the lake levels drop to more than 6 inches (for approximately 0.8 year or 9.5 months).

For the scenario assuming an 18 month upstream lake recharge time following the low level maintenance period, the lake undergoes a very slow recovery following the 1985 drawdown because of the extreme dry period in the late 1980's, (see **Figure 8**). Therefore, this exercise simulated an adaptive management (described in **Section 3**) approach by skipping the drawdown period of 1990, in order to allow Diamond Lake levels to recover. Model results show that the lowest seasonal Diamond Lake levels are expected to be 2 to 5 inches lower during the year following the drawdown. However, because the impacts to Diamond Lake are extended in this scenario due to the longer upstream lake recharge time, **Table 2** also shows the seasonal low elevations for the second year following the drawdown when the seasonal low levels vary from 5 inches to 1.2 feet below the existing conditions seasonal low. As expected, the recovery time is also longer in the scenario assuming a upstream lake refill time of 18 months. The total time that Diamond Lake levels are at all lower than existing conditions levels on Diamond Lake varies between 1.0 and 3.8 years. The total time that the proposed lake levels are lower than existing conditions levels on Diamond Lake by more than 6 inches varies between 0.5 and 2.4 years for the period of record studied. Note in **Table 2** that the recovery times of 2.4 and 3.8 years much longer than for the other drawdown cycles. These recovery times follow the 1985 drawdown which preceded the extremely low precipitation years of 1987-1989, preventing Diamond lake from fully recovering before the next scheduled drawdown in 1990. Therefore, an adaptive management practice was simulated, in that no drawdown was modeled in 1990 to allow Diamond Lake levels to fully recover (see **Figure 8**).

Figure 7: Estimated Existing and With Project Diamond Lake Levels (assuming 6 month refill period for upstream lakes)

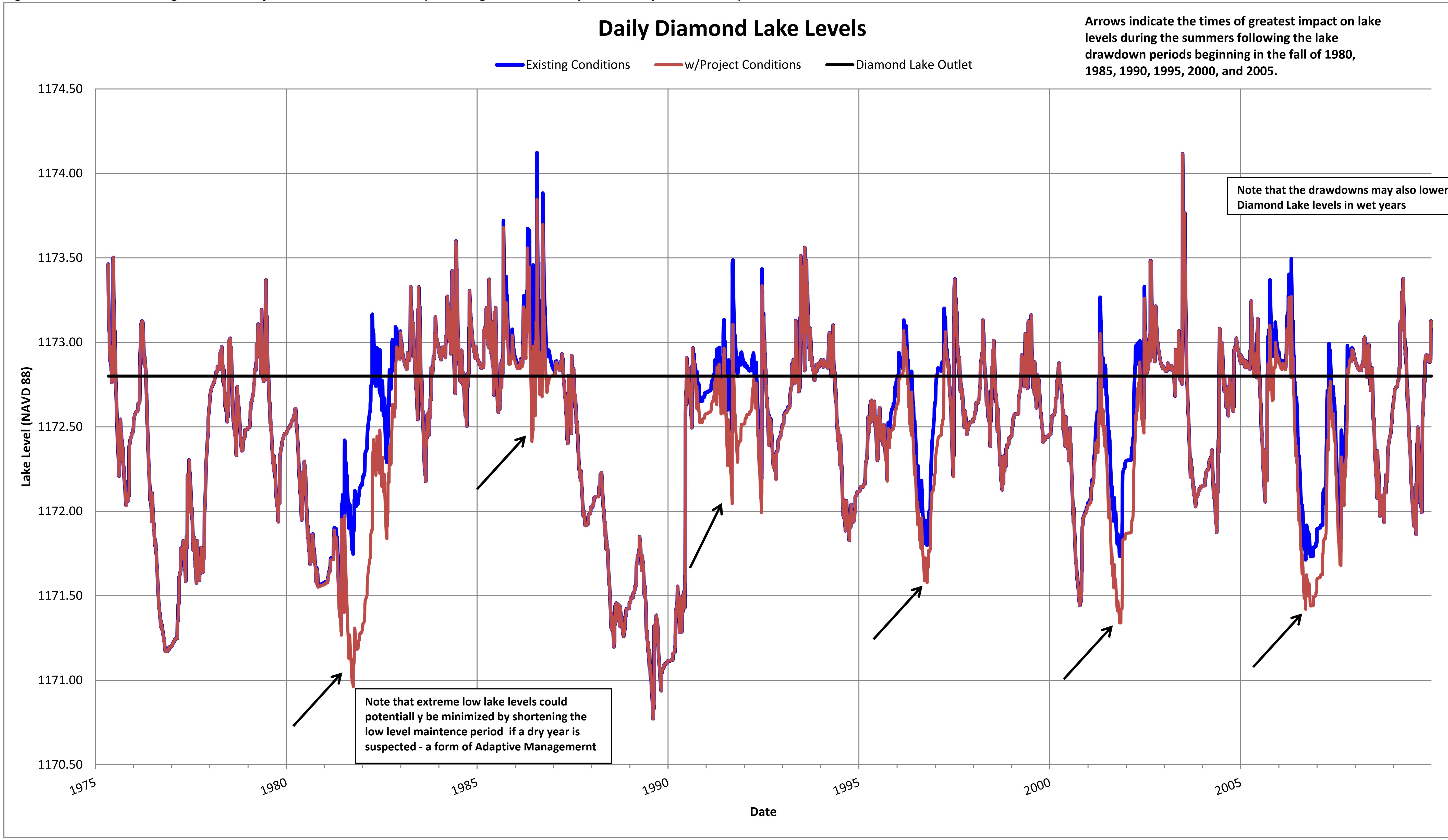


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Figure 8: Estimated Existing and With Project Diamond Lake Levels (assuming a 1.5 year refill period for upstream lakes)

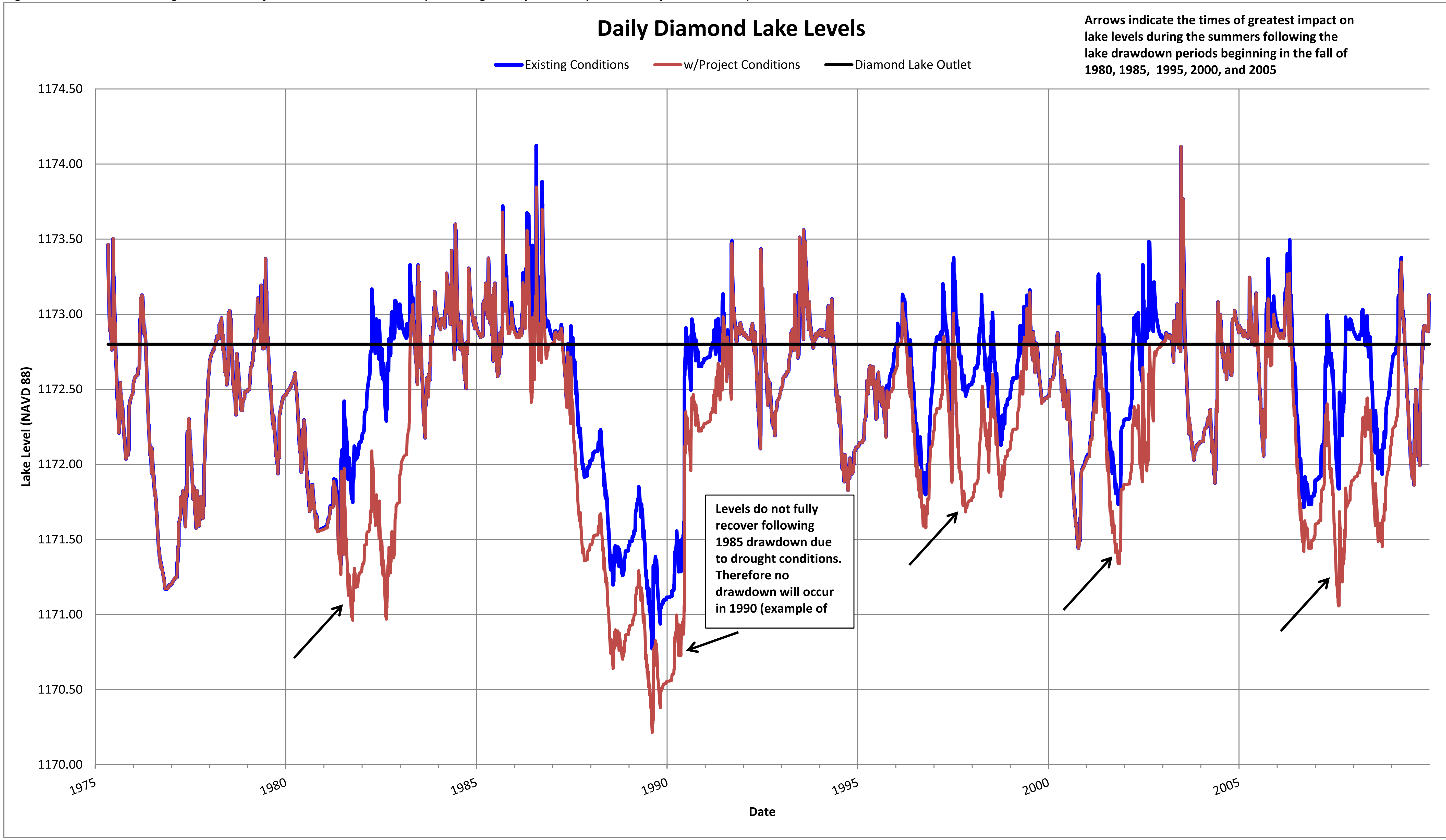


Table 1: Summary of Project Impacts on Diamond Lake Levels - Assuming 6 Month Refill Time

Drawdown/ Maintenance Period	Year Most Impacted	Season Low elevation			Length of Time Diamond Lake Level Impacted	
		Existing	Proposed	Difference (feet)	Total time (incl. winter) lake level lower than existing conditions (years)*	Total time lake lowered > 6 inches (years)
9/1/1980 - 6/30/1981	1981	1171.33	1170.96	0.37	1.6	0.8
9/1/1985 - 6/30/1986	1986	1172.81	1172.41	0.40	1.0	0
9/1/1990 - 6/30/1991	1991	1172.47	1172.04	0.43	1.8	0
9/1/1995 - 6/30/1996	1996	1171.80	1171.58	0.22	1.5	0
9/1/2000 - 6/30/2001	2001	1171.73	1171.34	0.39	1.3	0
9/1/2005 - 6/30/2006	2006	1171.71	1171.42	0.29	2.1	0

* Includes winter months when lake level not critical.
Also includes time when levels are only very slightly lower than existing conditions levels

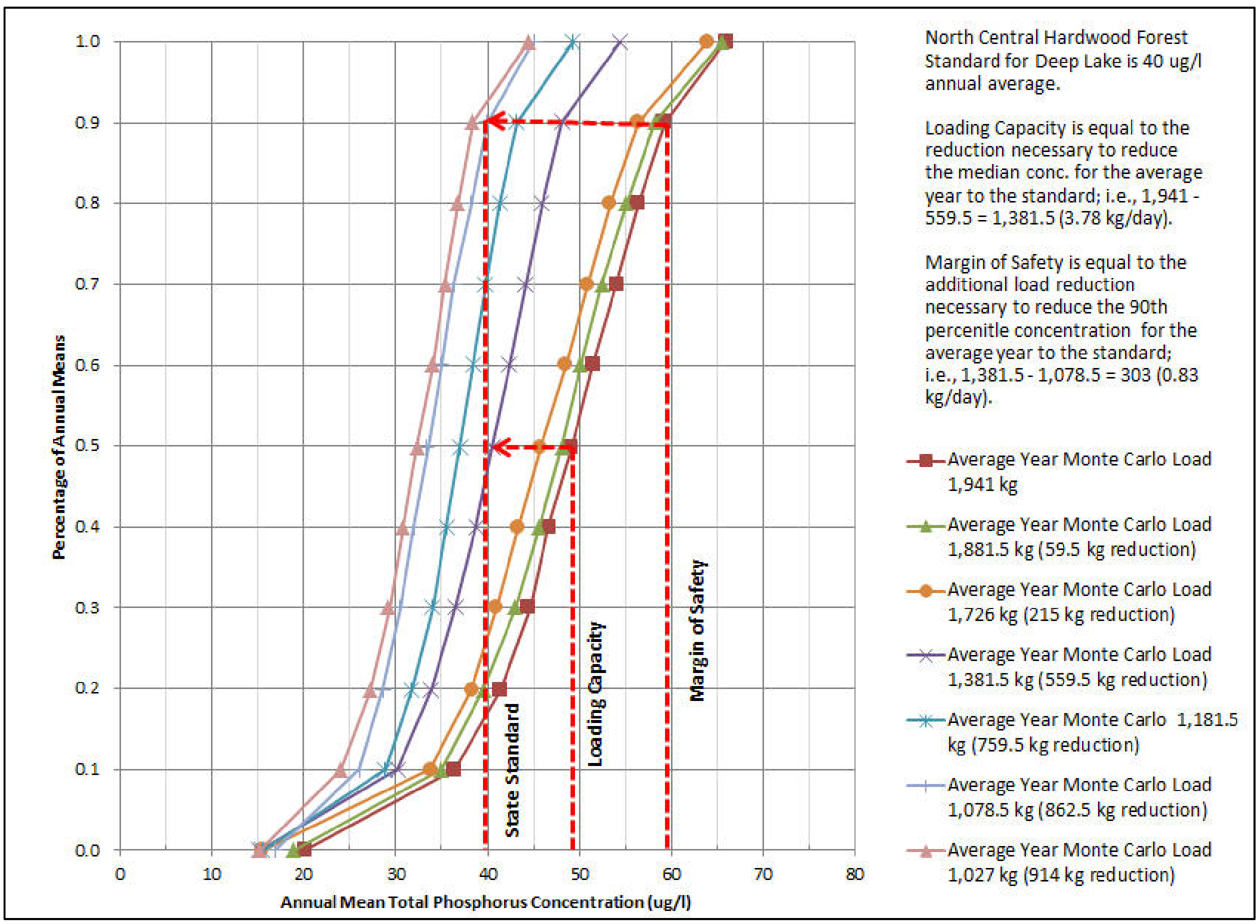
Table 2: Summary of Project Impacts on Diamond Lake Levels - Assuming 1.5 year Refill Time

Drawdown/ Maintenance Period	Year Most Impacted	Season Low elevation			Length of Time Diamond Lake Level Impacted	
		Existing	Proposed	Difference (feet)	Total time (incl. winter) lake level lower than existing conditions (years)	Total time lake lowered > 6 inches (years)
9/1/1980 - 6/30/1981	1981	1171.33	1170.96	0.37	2.0	1.7
	1982	1172.19	1170.97	1.22		
9/1/1985 - 6/30/1986	1986	1172.81	1172.41	0.40	3.8	2.4
	1987	1171.92	1171.36	0.56		
No drawdown in 1990	1991	1172.47	1172.27	0.20	N/A (no drawdown to allow full recovery from previous drawdown	
	1992	1172.10	1172.10	0.00		
9/1/1995 - 6/30/1996	1996	1171.80	1171.58	0.22	1.5	0.7
	1997	1172.21	1171.68	0.53		
9/1/2000 - 6/30/2001	2001	1171.73	1171.34	0.40	1.3	0.5
	2002	1172.30	1171.87	0.43		
9/1/2005 - 6/30/2006	2006	1171.71	1171.42	0.29	2.1	1.0
	2007	1171.84	117106	0.78		

4.3 Water Quality Benefits to Diamond Lake

The loading capacity of a lake in Minnesota is defined as the maximum allowable TP load to the lake which can occur, while still achieving the total phosphorus water quality numeric standard of the MPCA (40 ug/l). The loading capacity is normally based upon the long-term average hydrologic budget and total phosphorus mass balance, but ideally also reflects the range of hydrologic and total phosphorus load conditions. In the Diamond Lake TMDL project (HEI, 2011), the loading capacity of Diamond Lake was established using the CNET model and based on a Monte Carlo simulation for an "average year" directly incorporating the variability in hydrologic and total phosphorus load. The loading capacity was established as the mass loading rate (expressed on a daily basis) for the average year, resulting in the 50th percentile non-exceedance annual mean total phosphorus concentration, being equal to the MPCA numeric standard (40 ug/l). The CNET results were presented as a series of lines (**Figure 9**), where each line represents a statistical distribution of the total phosphorus annual mean values.

Figure 9: Frequency Distribution of Annual Mean Total Phosphorus Concentrations corresponding to Various Total Phosphorus Load Scenarios
Source: Diamond Lake TMDL, Figure 5-16 (HEI, 2011)



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As discussed in previous sections of this report, the upstream lakes of Hubbard, Schultz and Wheeler are in a turbid state, and conversion to the clear state has considerable potential for improving not only the water quality of the upstream lakes, but the water quality of Diamond Lake. Available water quality data from Lake Christina in central Minnesota shows that total phosphorus and chlorophyll-a concentrations can be reduced dramatically by maintaining a shallow lake in the clear state compared to the turbid state. Average annual total phosphorus concentrations within Lake Christina are near 100 ug/l when in the turbid state, compared to near 40 ug/l when in clear state (a reduction of 2.5 times). Based on this information, and the fact that monitoring data from 2008 and 2009 evaluated during the Diamond Lake TMDL indicated that an estimated 74% (2008) and 83% (2009) of the total phosphorus entering Diamond Lake from surface runoff came from the upstream lakes of Schultz, Wheeler and Hubbard, it is expected that the conversion of the upstream lakes to the clear state has the potential of reducing average annual total phosphorus and chlorophyll-a concentrations by 2 and 4 times, respectively.

In the Diamond Lake TMDL report (HEI, 2011), existing and with/project loads to Diamond Lake were estimated from the average annual volume contributed from the upstream lakes and the average TP concentration (years 2008 and 2009) measured in the most downstream waterbody (Hubbard Lake). A similar calculation is made for this report and presented in **Section 4.3.2**. However, the average TP concentration used will be based not only on 2008 and 2009 monitoring data, but also on monitoring data collected since that time.

4.3.1 Evaluation of Additional Water Quality Monitoring Data since TMDL

The model calibration effort for the 2011 Diamond Lake TMDL analysis relied on 2008 and 2009 water quality monitoring data within Diamond Lake, as well as monitoring data from the upstream lakes. This section includes an evaluation of additional water quality monitoring data since 2009 to determine if water quality has changed significantly or has remained unchanged. The locations of In-lake monitoring stations providing water quality data used in the 2011 Diamond Lake TMDL are shown in **Figure 10**. **Table 3** summarizes the data collected during 2008 and 2009 in Schultz, North Wheeler, and South Wheeler/Hubbard Lake. In estimating load reductions to Diamond Lake from the upstream lakes, the 2011 Diamond Lake TMDL used the annual average total phosphorus concentration for 2008 and 2009 of 117 ug/l because it was for the most downstream waterbody prior to discharge into Diamond Lake. Because the MFCRWD does not have additional water quality monitoring data since 2009 for the upstream lakes, the Environmental Data Access (EDA) website (MPCA) was reviewed as part of this effort to complete the Engineer's Report to for any further data collected on these lakes. The data compilation process can be found in **Appendix E.**

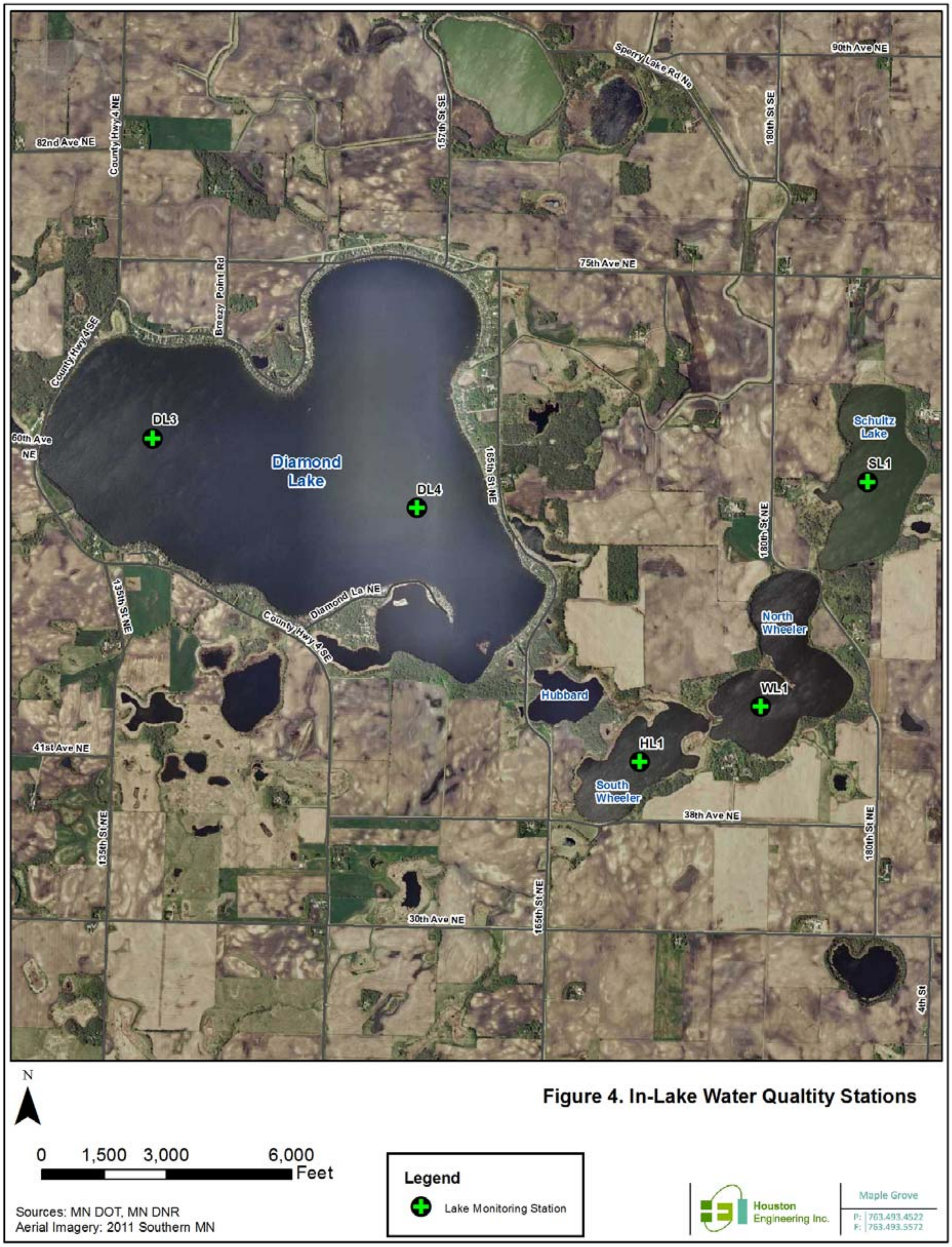
Table 3: Mean values (2008 – 2009) for selected measurements for lakes upstream of Diamond Lake

Site Name	Number of samples	Total Phosphorus (mg/L)
S.Wheeler/Hubbard (HL1)	9	0.117
N.Wheeler Lake (WL1)	10	0.354
Schultz Lake (SL1)	10	0.187

As presented in Appendix E, the mean concentration of all of the TP measurements on the South Wheeler/Hubbard system is 0.167 mg/l, which is higher than the mean value for 2008 and 2009 only of 0.117 mg/l. On North Wheeler Lake, the mean of all the TP concentration readings since 2008 is 0.333 mg/l, which is slightly lower than the mean concentration based on just 2008 and 2009 data of 0.354 mg/l. The mean of all the TP concentration readings on Schultz Lake is 0.200 mg/l, which is slightly higher than the mean for just 2008 and 2009 of 0.187 mg/l. For the purposes of estimating the water quality benefits of the proposed project, as well as water quality impacts to CD 28 (see **Section 4.3.2** and **Section 5.1**), the mean values of all data since 2008 will be assumed as the existing in-lake TP concentrations.

TP data collected since the Diamond Lake TMDL has also been evaluated because it is important in the assessment of downstream water quality impacts to CD 28 in **Section 5.1** of this report. The mean TP concentrations for 2008 and 2009 are 41 ug/l and 36 ug/l for DL3 and DL4, respectively. No further data was collected at station DL4 subsequent to 2009. However, there is data through 2012 for DL3. The mean in-lake TP concentration for the entire data collection period is 58 ug/l, well exceeding the total phosphorus water quality numeric standard of the MPCA of 40 ug/l.

Figure 10: In-Lake Water Quality Monitoring Stations used for the Diamond Lake TMDL



4.3.2 Water Quality Benefits to Diamond Lake

The average total phosphorus concentration in the discharge to Diamond Lake from the upstream lakes, as determined from available monitoring data, is 167 ug/l (see **Section 4.3.1**). As discussed in **Section 4.3**, based on experience with similar shallow lakes, the annual average total phosphorus concentration has the potential to be reduced by a factor of 2 to 83.5 ug/l. Average annual volumes discharged to Diamond Lake from the upstream lakes were derived from the existing and proposed water balance models developed for this Engineer's Report and presented in **Section 4.1**. Assuming the conceptual project operation plan as described in **Section 3** of this report, it is estimated that the upstream lake level drawdown project would reduce the average annual TP load to Diamond Lake from the upstream lakes by 303 kg/year, as shown in **Table 4**, assuming a 6 month recharge time. If, during dry climatic conditions, it takes up to 18 months for the upstream lakes to refill following the low level maintenance period, it is estimated that the average annual TP load to Diamond Lake from the upstream lakes will be reduced by 335 kg/year, as shown in **Table 5**. Note that **Figure 9** in **Section 4.3** demonstrates that an approximate total 559.5 kg reduction in TP load to Diamond Lake is needed to achieve the MPCA's total phosphorus water quality numeric standard of 40 ug/l (note this result from the Diamond Lake TMDL was based on water quality data in Hubbard Lake from 2008 and 2009 so that the necessary reduction could be greater since monitoring data has shown that the TP concentration in Hubbard Lake has increased since then). The remaining load reduction can be achieved through other implementation activities introduced in the Diamond Lake TMDL (HEI, 2011) and discussed in **Section 10** of this Engineer's Report.

Table 4: Annual Average Reduction in Loading from Upstream Lakes due to Upstream Lake Level Drawdown Project (Assuming a 6 month recharge time for the upstream lakes)

Existing Conditions			With/Project Conditions			Reduction
Inflow Volume from Hubbard	TP Conc. of Inflow from Hubbard	TP Load from Hubbard	Inflow Volume from Hubbard	TP Conc. of Inflow from Hubbard	TP Load from Hubbard	TP Load from Hubbard
(AF/yr)	(mg/l)	(kg/yr)	(AF/yr)	(mg/l)	(kg/yr)	(kg/yr)
2,257	167	465	1,570	83.5	162	303

Table 5: Annual Reduction in Loading from Upstream Lakes due to Upstream Lake Level Drawdown Project (Assuming an 18 month recharge time for the upstream lakes)

Existing Conditions			With/Project Conditions			Reduction
Inflow Volume from Hubbard	TP Conc. of Inflow from Hubbard	TP Load from Hubbard	Inflow Volume from Hubbard	TP Conc. of Inflow from Hubbard	TP Load from Hubbard	TP Load from Hubbard
(AF/yr)	(mg/l)	(kg/yr)	(AF/yr)	(mg/l)	(kg/yr)	(kg/yr)
2,257	167	465	1,258	83.5	130	335

5 ASSESSMENT OF POTENTIAL DOWNSTREAM IMPACTS ON CD 28, BRANCH 6

This section presents estimates of potential downstream impacts to County Ditch 28, Branch 6 due to the Hubbard, Schultz, and Wheeler drawdown project when managed according to the conceptual operation plan described in **Section 3**. This assessment includes estimates of the potential water quality impacts to CD 28, potential impacts to the drainage capacity of CD 28, and the potential impacts to the risk of flooding downstream structures.

5.1 Potential Water Quality and Volume Impacts to CD 28 During Lake Level Drawdown Period

It is proposed that the lakes of Schultz, North Wheeler, and the combination of South Wheeler and Hubbard will be drawn down individually in sequence. It is expected that during the drawdown period (assuming September 1 to December 19 for the purposes of this Engineer's Report), that there will be a temporary increase in volume, TP and TSS discharged to CD 28, Branch 6. **Table 6** presents the total volume discharged to CD 28, Branch 6 over the 110-day drawdown period from the upstream lakes, as estimated by the HydroCAD model developed by Duck's Unlimited, as well as the estimated TP and TSS Load.

Table 6: Estimated Volume, TP Load, and TSS Load Discharged to CD 28 from Upstream Lakes during Lake Drawdown Period (from September 1 to December 19)

Lake System	Volume Discharged to CD 28 (AF)	Mean TP Concentration (mg/l)	TP Load (kg)	Mean TSS Concentration (mg/l)	TSS Load (kg)
Schultz	898	0.200	222	53.7	59,482
North Wheeler	681	0.333	280	30.5	25,620
South Wheeler / Hubbard	535	0.167	110	12.4	8,183
Total	**2,114**	**- -**	**611**	**- -**	**93,285**

Note: Mean TP and TSS concentrations determined as described in Appendix E

As presented in **Section 4.3.1** of this report, based on available monitoring data at Station DL3 (longest period of record) the mean in-lake TP concentration in Diamond Lake is 58 ug/l, and the mean in-lake TSS concentration in Diamond Lake is 7.5 mg/l. **Table 7** presents the total volume discharged from Diamond Lake to CD 28 over the 110-day drawdown period, for existing and proposed conditions, as estimated with the water balance model for the years when drawdown was simulated (5-year frequency). The volume discharged in the proposed conditions is less in than the existing conditions because it is assumed that Diamond Lake is not receiving inflow from the upstream Lakes during the drawdown period.

Table 7: Estimated Volume, TP Load, and TSS Load Discharged to CD 28 during Lake Drawdown Period (from September 1 to December 19) Assuming a 5-Year Drawdown Cycle

	Existing Conditions			Proposed Conditions								
	From Diamond Lake			From Diamond Lake			From Upstream Lakes*			Total Proposed		
Draw-down Year	Volume (AF)	TP Load (kg)	TSS Load (kg)	Volume (AF)	TP Load (kg)	TSS Load (kg)	Volume (AF)	TP Load (kg)	TSS Load (kg)	Volume (AF)	TP Load (kg)	TSS Load (kg)
1980	0	0	0	0	0	0	2,114	611	93,285	2,114	611	93,285
1985	4,064	291	37,598	2,627	188	24,302	2,114	611	93,285	4,741	799	117,587
1990	95	7	876	39	3	359	2,114	611	93,285	2,153	614	93,644
1995	0	0	0	0	0	0	2,114	611	93,285	2,114	611	93,285
2000	0	0	0	0	0	0	2,114	611	93,285	2,114	611	93,285
2005	2,335	167	21,606	592	42	5,473	2,114	611	93,285	2,706	653	98,758

* TP and TSS loads to CD 28 are conservative estimates because with repeated drawdowns, the water quality in the upstream lakes will improve which will reduce the TP and TSS loads discharged during the drawdown period.

The estimated TP load of 611 kg and TSS load of 93,285 kg discharged to CD 28 from the upstream lakes during the proposed condition drawdown (see **Table 6**), added together with the proposed loads from Diamond Lake during the drawdown period, is significantly more than that which is discharged from Diamond Lake under existing conditions. However, this short-term downstream impact is expected to be mitigated by the long-term decrease in load by maintaining the upstream lakes in the clear state phase. In addition, the TP and TSS loads to CD 28 showed in **Table 7** are conservative estimates because with repeated drawdowns, the upstream lakes will remain in the clear phase, and water quality in these lakes will improve which will reduce the TP and TSS loads discharged during drawdown periods. Therefore, **Table 7** actually best characterizes six likely scenarios which could occur during the first drawdown period only, depending on the particular climatic conditions and lake levels at the beginning of the drawdown. It should also be noted that TSS is a measure of total solids, not sediment, and it therefore will not all deposit in the ditch. However, the District may choose to monitor for sediment accumulations in CD 28, Branch 6.

A complete drawdown to elevation 1167.0 from Schultz, Wheeler, and Hubbard Lakes would require the discharge of approximately 2,114 acre-feet to CD 28, Branch 6. However this increase in volume discharged to CD 28 will occur during the months of September through December, typically a drier time of the year. Also, during the subsequent upstream lake recharge period (6-18 months), there will be less overall volume discharged to CD 28 than in the existing conditions due to no outflow occurring from these lakes to either CD 28 or Diamond Lake. Because the project has no impact on hydrologic conditions, there will be no net change in overall volume discharged to CD 28. There are also no downstream water bodies with outlets structures that could be affected by a temporary increase or decrease in the volume of water. In summary, there appears to be negligible negative water quality or volume impacts to downstream CD 28.

5.2 Potential Project Impacts to Drainage Capacity of CD 28, Branch 6

County Ditch 28 is a public drainage system created to provide drainage to agricultural lands. The proposed project will create a new outlet to Branch 6 of CD 28 that will periodically convey flows during both during the drawdown period of Hubbard, Wheeler, and Schultz Lakes (September through December), as well as during the low level maintenance period through June, according to the operating plan outlined in **Section 3.1** of this report. For projects creating a new outlet to the public drainage system, Minnesota Statute 103E requires the Engineer to evaluate potential impacts which could reduce the capacity and function of the public drainage system. The potential impacts to CD 28 are evaluated relative to existing conditions discharge to the ditch, agricultural drainage capacity, and channel stability.

5.2.1 Potential Impacts to Existing Conditions Discharge to CD 28

The average historic daily discharge from Diamond Lake was estimated based on historical measured lake levels (MnDNR_b) and a stage-discharge rating curve extracted for the 30-foot outlet weir from the DU HydroCAD Model prepared for the Feasibility Study (DU 2012a). The resulting average historic daily discharge from Diamond Lake is shown in **Figure 11.** **Table 8** presents the non-exceedance frequency discharges, based on all days within 1980-2009, as well as just days within the proposed drawdown period of September through December. Note that during September through December, 75% of Diamond Lake historic discharges are below 16 cfs, and 90% are below 41 cfs. The average, or mean discharge during September through December is 15 cfs.

Figure 11: Average Historic Daily Discharge from Diamond Lake to CD28, Branch 6

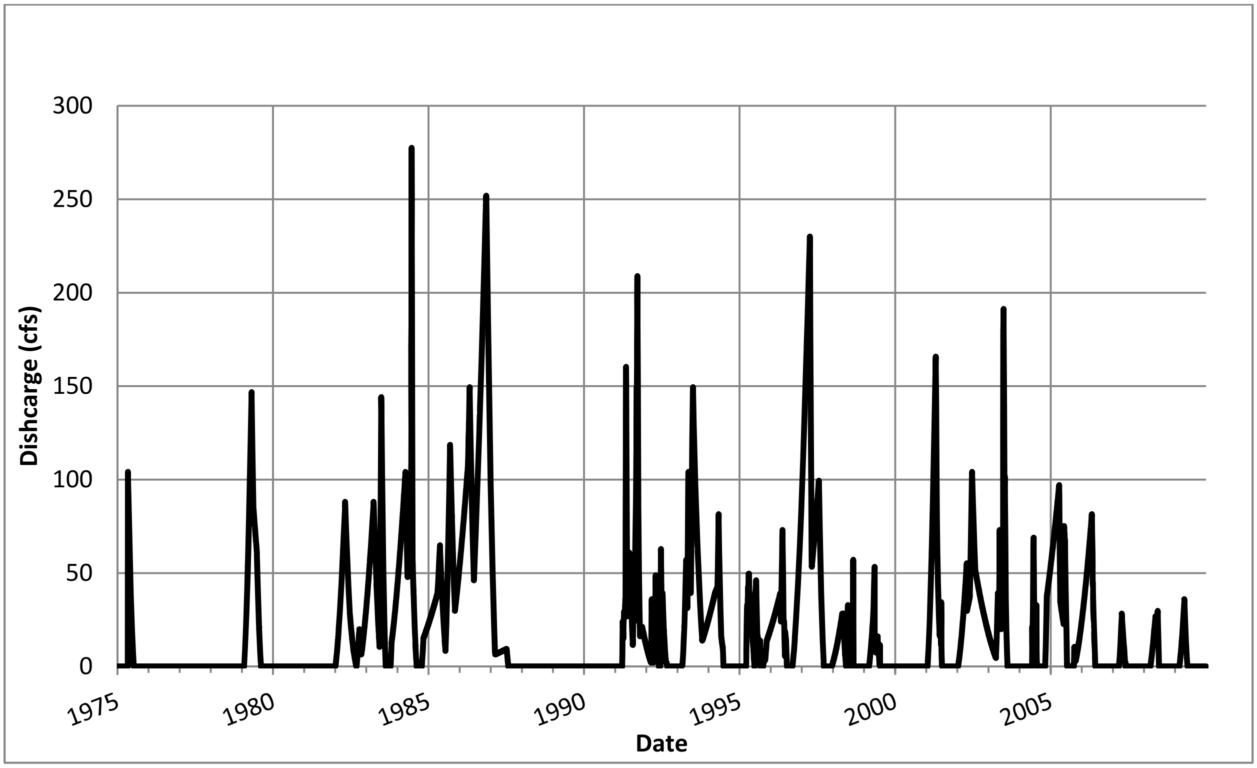


Table 8: Daily Non-Exceedance Frequency of Historical Diamond Lake Discharge to CD 28 (1980-2009) Estimated from Historic Lake Level Data and Stage-Discharge Rating Table

Non-Exceedance Frequency	Discharge from Diamond Lake (1975-2009)	
	All days	Days in Sept. - December
2.5%	0	0
10%	0	0
25%	0	0
50%	2	0
75%	32	16
90%	71	41
99.5%	211	231

The estimated maximum estimated discharge from the upstream lakes to CD 28 during the drawdown period (September through December), is shown in **Table 9**. Note that this instantaneous peak discharge occurs at the beginning of the drawdown of each lake when water elevations are highest and will decrease with time as the lake level decreases. In terms of the non-exceedance frequency information presented in **Table 8**, the discharge of 17 cfs or less during the drawdown period is compatible with approximately 75% of discharges which occur during that same time of the year and is therefore considered reasonable.

Table 9: Estimate of Peak Discharge to Branch 6 of CD 28 during the Drawdown of Each Upstream Lake

Lake	Peak Discharge at Beginning of Drawdown
Schultz	17 cfs
North Wheeler	13 cfs
South Wheeler/Hubbard	11 cfs

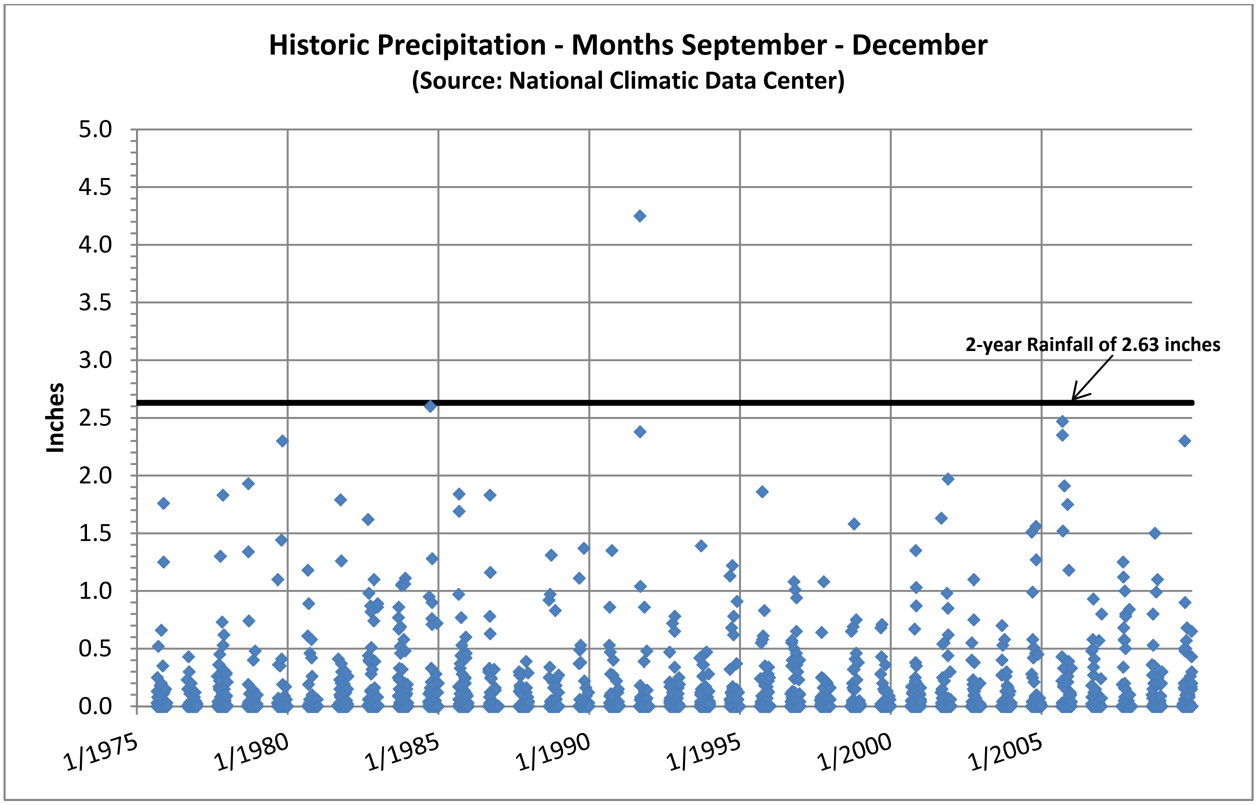
5.2.2 Potential Impacts to Agricultural Drainage Capacity

The system was also analyzed assuming a rainfall event occurs simultaneously with the peak discharge during the drawdown to ensure that CD 28 will be able to serve its intended purpose of agricultural drainage. Agricultural drainage systems typically are sized to drain peak flows resulting from a 2-year, 24-hour rainfall event (a rainfall event that statistically has a 50% chance of occurring in any given year). Under existing conditions, Diamond Lake is estimated to have a peak discharge of 30 cfs during a 2-year rainfall event to Branch 6 of CD 28, based on HydroCAD modelling (DU 2012a).

The maximum peak discharge to CD 28, Branch 6 during the drawdown period is 17 cfs, approximately one-half of the maximum 2-year outflow from Diamond Lake under existing conditions (30 cfs), as estimated with the DU HydroCAD model. A 2-year rainfall is estimated to be 2.63 inches in the project area (NRCS, 1975). Daily precipitation records from 1975 through 2009 collected from the NCDC at the Rainfall station in Willmar, MN for the Diamond Lake TMDL study (HEI, 2011) are presented in **Figure 12** for the months September through December, the approximate drawdown period. A 2-year rainfall event of 2.63 inches has occurred only once in the months of September through December over the thirty five year period. Thus, the simultaneous occurrence of a 2-year rainfall event resulting in 30 cfs discharge from Diamond Lake (actually only 26 cfs when upstream lakes are disconnected during drawdown) and the peak drawdown discharge of 17 cfs is very unlikely (1 in 35 or approximately a 3% chance).

Note that a depth discharge rating curve of CD 28, Branch 6, which is provided in the Feasibility Study (DU 2012a) indicates that a discharge 30 cfs results in a flow depth of only 1.5 feet, which also indicates that the ditch has plenty of capacity to accommodate the direct discharge from the upstream lakes during the proposed drawdown.

Figure 12: Daily September – December Precipitation Records from 1975 - 2009 (NCDC at the Rainfall station in Willmar, MN)



In the conceptual operating plan used for the hydrologic and hydraulic analysis of this Engineer's Report (see **Section 3**), Schultz, Wheeler and Hubbard Lakes would remain at low levels for an extended time until June 30 to ensure a winter fish kill and encourage the stimulation and growth of submerged aquatic plants due to better light penetration to the substrate. This will require occasional discharges from Schultz Lake into CD 28 as rainfalls occur. If a 2-year event occurs during this low level maintenance period, the hydrologic and hydraulic analysis estimates that a peak discharge of 6 cfs would occur from Schultz Lake to CD 28, in addition to a peak discharge of 26 cfs from Diamond Lake (the proposed discharge is less than under existing conditions due to an absence of inflow to Diamond Lake from Hubbard Lake). Since these two peak discharges occur nearly simultaneously, the total peak discharge to CD 28 would be approximately 32 cfs, only slightly higher than the estimated existing conditions 2-year peak discharge of 30 cfs.

5.2.3 Potential Impacts on Channel Stability

The peak discharge during the drawdown period, at the time when Schultz Lake begins drawing down, is estimated to be 17 cfs. Because the cross-section of CD 28, Branch 6 remains unchanged, the velocities in the ditch at the same discharge also remain unchanged, and therefore no impact on channel stability is expected with the operation of the lake drawn project.

5.3 Assessment of Potential Flooding Risk to Downstream Structures along CD 28, Branch 6

This section evaluates the risk of potential impacts with regards to downstream capacity of structures and safety. MFCRWD staff conducted a field visit to measure three downstream culverts along CD 28, Branch 6: CR 28 (75th Ave. NE), Sperry Lake Road, and a field road within Parcel 19-015-0072 (see **Figure 13**). All three culverts are 96-inch CMP's. Culverts crossing county roads are typically designed to accommodate 50-year peak flows, with 1-foot of freeboard below the sag point in the roadway. The HydroCAD model developed by DU was used to simulate a 50-year, 24-hour storm event of 5.22 inches (NRCS, 1975) occurring simultaneously with the peak discharge during the lake drawdown period. This peak discharge was then simulated in a steady state model of the three road crossings, the data and results of which are presented in **Table 10.** The total peak 50-year discharge to CD 28, Branch 6 resulting from a the 50-year rainfall event and a simultaneous peak lake drawdown is 190 cfs, which results in a freeboard of greater than 6 feet for each crossing. Therefore, the downstream culverts are considered substantially sized to convey flows from the drawdown period in conjunction with the design 50-year rainfall event.

Table 10: Results of Simulating a 50-year Storm Event Simultaneously with the Peak Discharge during Lake Drawdown

<table>
<tr><th>Culvert</th><th>Culvert Dia/Type</th><th>Height of Road above culvert invert</th><th>Peak Discharge Diamond Lake</th><th>Peak Discharge Schultz Lake</th><th>Peak Discharge to CD 28*</th><th>Peak Elevation</th><th>Freeboard</th></tr>
<tr><td>CR 28 / 75th Ave NE</td><td>8 ft. CMP</td><td>17.8 ft.</td><td rowspan="3">172

(@51 hours)</td><td rowspan="3">18

(@27 hours)</td><td rowspan="3">190

(@51 hours)</td><td rowspan="3">5.6 ft</td><td>12.2 ft.</td></tr>
<tr><td>Sperry Lake Rd</td><td>8 ft. CMP</td><td>12.0 ft.</td><td>6.4 ft.</td></tr>
<tr><td>Driveway to Parcel 19-015-0075 (residence of Jeffrey Pagel)</td><td>8 ft. CMP</td><td>13.3 ft.</td><td>7.7 ft.</td></tr>
</table>

*Resulting from the summation of discharge hydrographs from Diamond Lake and Schultz Lake

Figure 13: Downstream Culverts along CD 28, Branch 6

6 DESIGN OF WATER CONTROL STRUCTURES ON UPSTREAM LAKES

The proposed water control structures have been designed to not only allow for the drawdown of the upstream lakes of North Wheeler and South Wheeler/Hubbard, but also so as to “perform similarly” to the existing outlet structures under normal operations when stoplogs are replaced and flow direction is returned to its original route (from Schultz to North Wheeler to South Wheeler/Hubbard to Diamond Lake). Performing similarly is defined here as having the same or nearly the same water depth (normal water surface elevation). DU prepared a preliminary design of the outlet structures (DU 2012b), and a description of the structures is provided in the DU Feasibility Report (DU 2012a), which is included as **Appendix A**.

A useful method to compare the performance of the existing and proposed outlet structures is through stage-discharge curves, which indicate the expected discharge at any given water surface elevation. Although the curves show the relationship between the elevation of water and discharge, the ultimate runout and therefore normal pool elevation is governed by the crest/invert elevations of the structures. The 4’ x 10’ box culvert outlet from Hubbard Lake to Diamond Lake will remain unchanged. **Figure 14** and **Figure 15** compare the stage-discharge curves for the proposed outlet structures when discharging in the direction of Diamond Lake. The existing and proposed stage-discharge curves representing the hydraulic behavior of the control structure managing flows from North Wheeler to South Wheeler. The elevation of the stoplogs of 1172.85 can be noted on **Figure 14**.

To improve the match between existing and proposed hydraulic performance for the water control structure between Schultz Lake and North Wheeler (**Figure 15**) a 24" RCP at elevation 1172.8 is proposed in addition to the concrete structure with stop logs to plug up the drawdown pipe at 1167.0, It can be seen on the curve that when the stoplogs are set to 1175.5, the stage-discharge curves begin to deviate. However, even during a 100-year event, it is not expected that the lake reaches this elevation.

Also important to the design of the water control structures is that the lakes can be managed at a water level conducive to maintaining the clear phase. Expectations are that the proposed design is capable of attaining the existing annual average water levels as operating experience is gained, although the frequency and duration at specific elevations may differ slightly. Through the use of the adaptive management approach and in consultation with the DNR and DU, it may be shown to be advantageous to maintain the lakes at a (lower) elevation more conducive to maintaining the clear state. Management at a lower elevation would not increase the amount of land inundated and therefore, no loss of land or takings would occur. The lakes lack public access and recreational fishing opportunities. Management by the District in consultation with the DNR would occur according to M.S. 103G.408, Temporary Drawdown of Public Water. Long term water levels are in part dependent upon project operation. Additional details related to long term water levels, should they be expected to differ from the existing water levels, need to be described in the final operating plan.

Figure 14: Stage-discharge Curve for Proposed Outlet Structure on between North Wheeler and South Wheeler/Hubbard Lakes

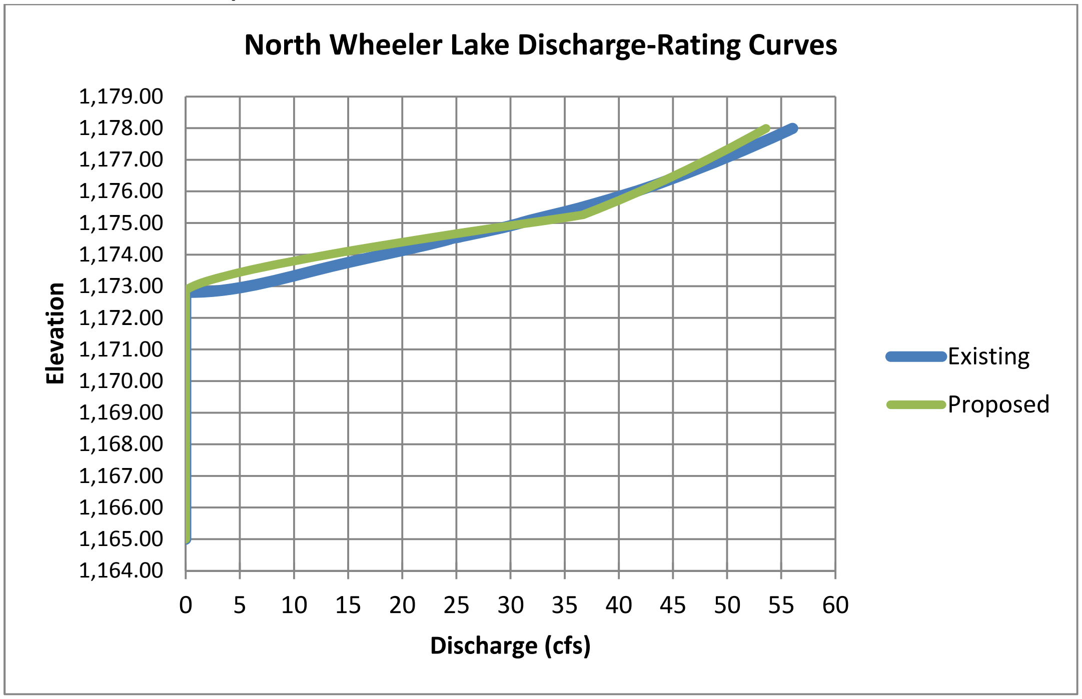
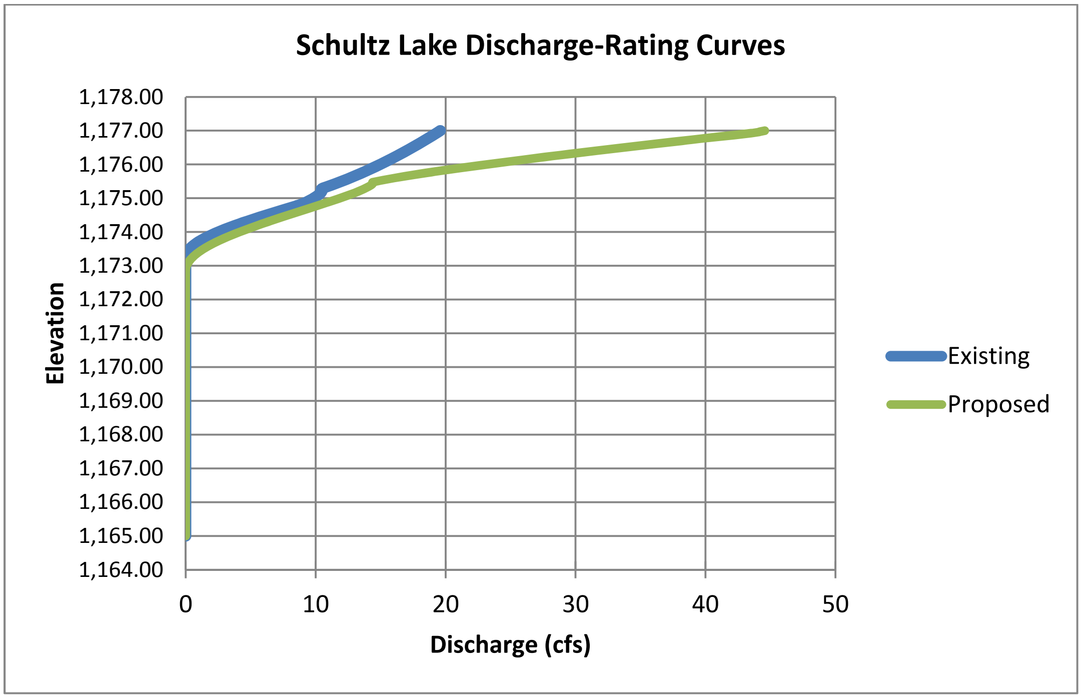


Figure 15: Stage-discharge Curve for Proposed Outlet Structure on between Schultz and North Wheeler Lake



7 POTENTIAL WETLAND IMPACTS AND PERMITS

This task includes estimating the area of wetlands impacted by the construction of the proposed project. Data from the National Wetland Inventory (NWI, **Figure 16**) and the Minnesota Public Waters Inventory (PWI, **Figure 17**), as well as estimated construction limits based on preliminary construction plans, were used to provide a preliminary estimation of wetland impacts. Wetland impacts from the project are isolated to the physical construction of infrastructure (i.e. access, ditch excavation, dredging, and water control structure installation). The review looked at wetlands subject to Minnesota Department of Natural Resources (DNR) Public Waters jurisdiction, Wetland Conservation Act (WCA) administered by Kandiyohi County, and US Army Corps of Engineers (USACE), Section 404 of the Clean Water Act jurisdiction. Waters inventoried as part of the Minnesota Public Waters Inventory, by definition, are not regulated under the state Wetland Conservation Act. The completion of the construction elements of this project will require permits from the USACE, a DNR Public Waters Work Permit, and may require a permit from the Board of Water and Soil Resources for WCA. For the purposes of identifying probable jurisdictions throughout the project area, we utilized the published Ordinary High Water Levels (OHW's) on Schultz, Wheeler, Hubbard and Diamond Lake.

Water level control structures will be installed and connected below the Ordinary High Water Mark (OHW) of the lakes. The water level manipulation will be conducted under an approved operation plan that will limit the temporary drawdowns to enhance public waters, while not altering the OHW of the lakes. The runout elevations for the public waters will not be altered due to the elevation of the outlet of Diamond Lake. The lakes will continue to function as they currently do except during temporary drawdown events. The temporary impacts from in-lake dredging for hydraulic connectivity to the drawdown structures will be offset by the overall habitat and water quality improvements to the public waters. The result of the project will enhance habitat, recreation, water quality and the public benefits of the lakes; therefore, no lasting negative effects are anticipated to public waters, and the offsetting benefits are anticipated to be sufficient to not require any mitigation.

Based on our screening level review of the NWI data and aerial photography, it doesn't appear that any wetland impacts will be subject to the Wetland Conservation Act (WCA) authority identified in the impacted project area. A permit to Work in Public Waters will likely be required from the MN DNR, for the work that is proposed. At the time that the project is ordered, it will be verified whether a full permit is required under the Public Waters Work Program. A Permit to Work in a Water of the United States will likely be required from the USACE. At the time that the project is ordered, the permit type that is required from the USACE will be verified.

Figure 16: Wetlands Impacted by Project Construction

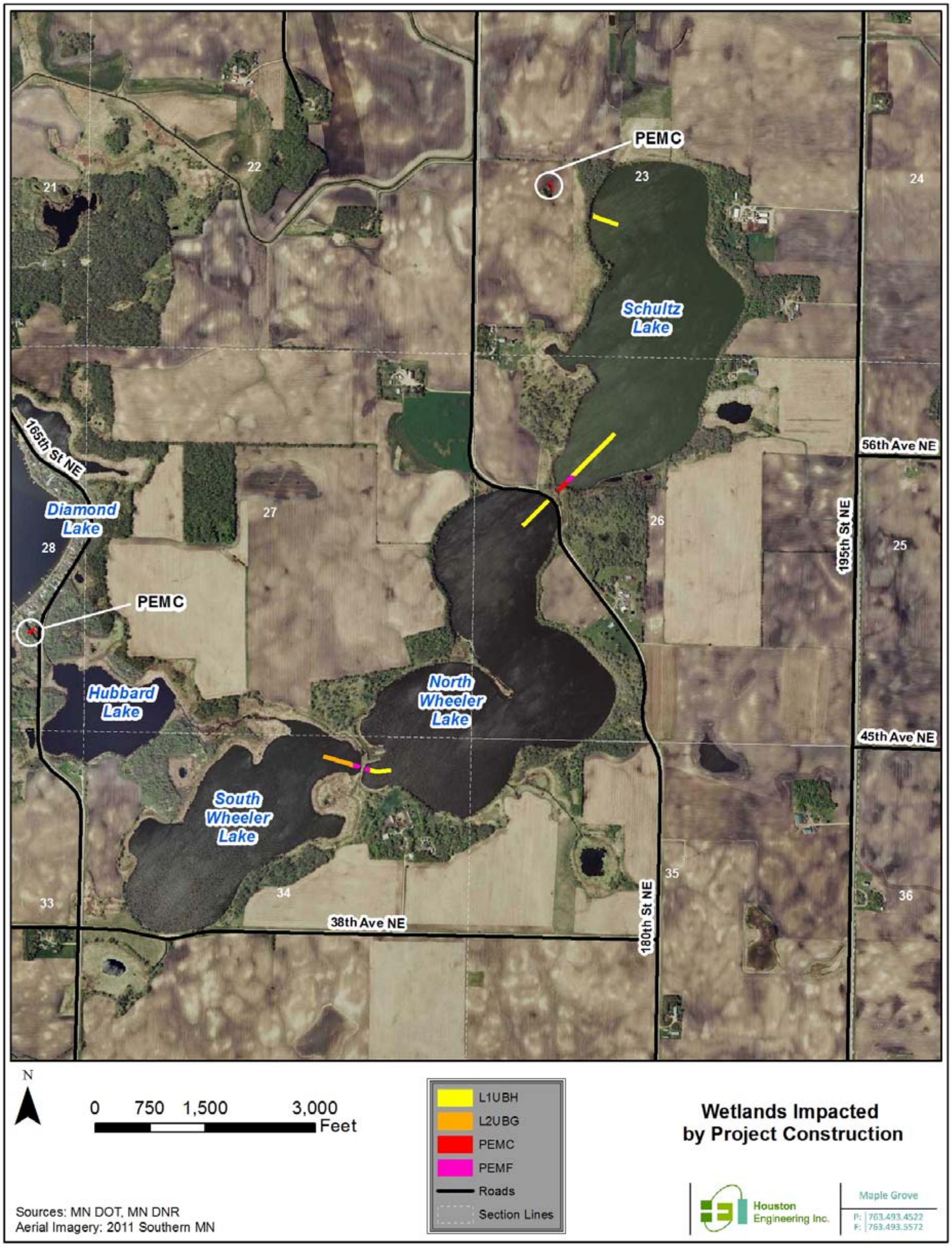
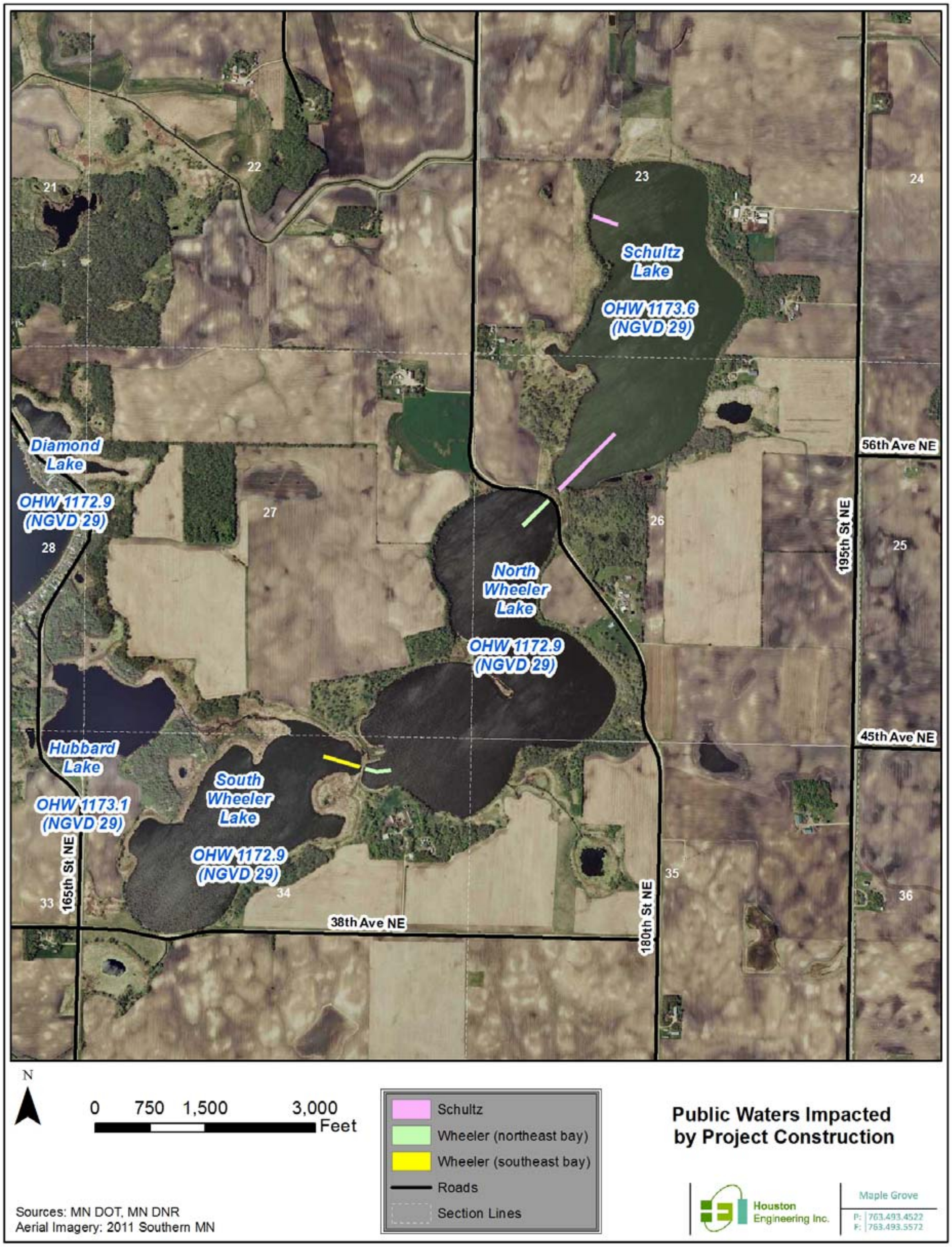


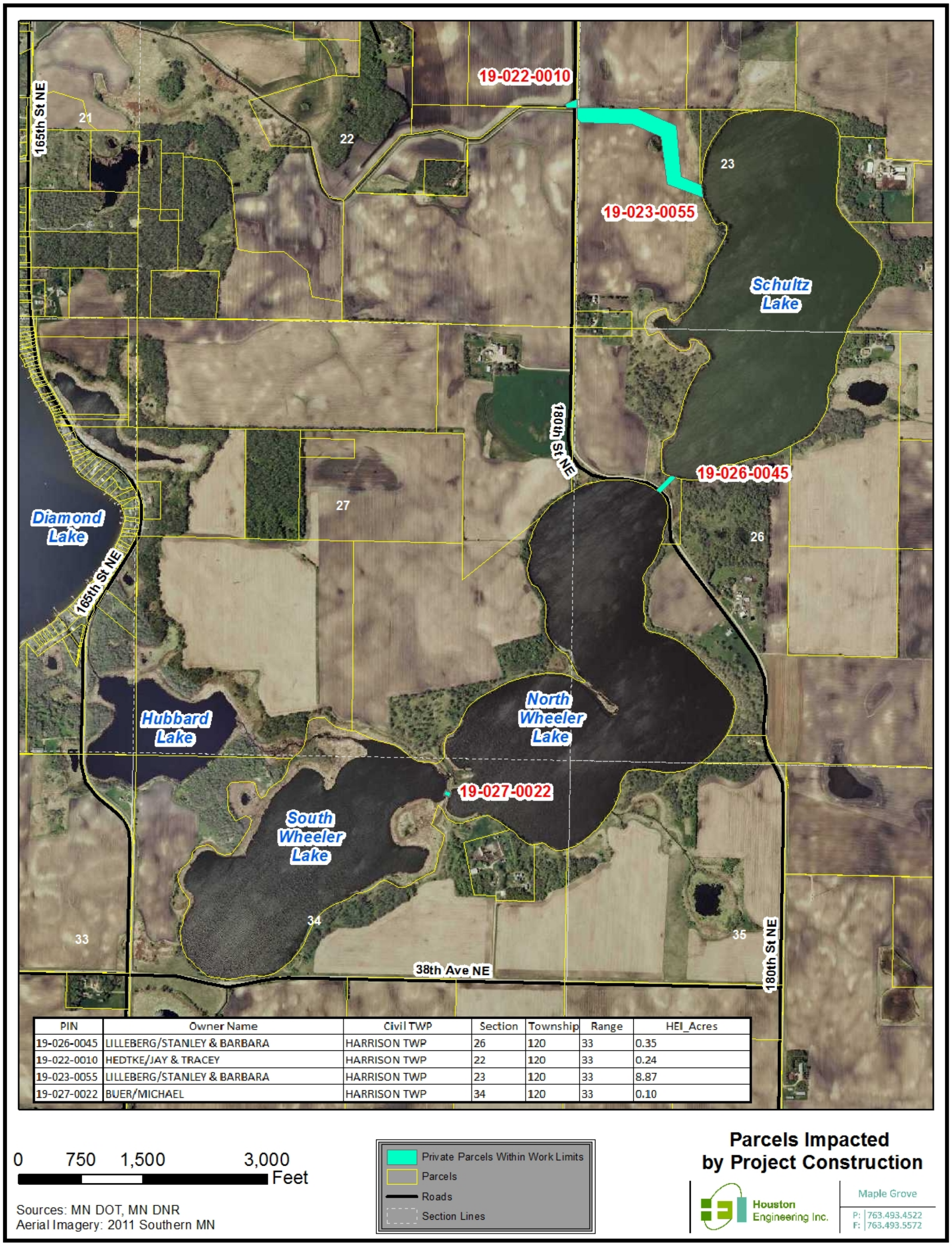
Figure 17: Public Waters Impacted by Project Construction



8 ACREAGE REQUIRED AS EASEMENT

The acreage required as easement was estimated based on the preliminary construction plans provided by DU. For the purposes of this estimate, all easements were conservatively assumed to be permanent. However, it is possible that a right-to-access may be obtained for a portion of the site by obtaining temporary easements in lieu of permanent easements, at a reduced cost. **Figure 18** displays the required easements divided up among all parcels, as determined with the Kandiyohi County parcel shape file. An estimated value for the easements is presented in the Preliminary Opinion of Probable Cost POPC in **Section 9** of this Engineer's Report.

Figure 18: Parcels Impacted by Project Construction



PIN	Owner Name	Civil TWP	Section	Township	Range	HEI_Acres
19-026-0045	LILLEBERG/STANLEY & BARBARA	HARRISON TWP	26	120	33	0.35
19-022-0010	HEDTKE/JAY & TRACEY	HARRISON TWP	22	120	33	0.24
19-023-0055	LILLEBERG/STANLEY & BARBARA	HARRISON TWP	23	120	33	8.87
19-027-0022	BUER/MICHAEL	HARRISON TWP	34	120	33	0.10

9 PREPARE PRELIMINARY OPINION OF PROBABLE COST

Duck's Unlimited has prepared both a preliminary set of construction plans (DU, 2012b) and a preliminary cost estimate for construction and professional services (DU, 2012c). HEI reviewed this preliminary estimate and found no significant discrepancies between the plans and quantities. The unit costs in the preliminary cost estimate also appear reasonable. Although both quantities and costs will be updated during the final design process, the preliminary cost for construction prepared by DU appears acceptable for use in the overall cost estimate.

For the purposes of this Engineer's Report, the preliminary cost estimate prepared by DU has been supplemented in **Table 11** with estimated costs expected beyond the scope of construction.

Table 11: Preliminary Opinion of Probable Cost for the Completion of Hubbard, Schultz, and Wheeler Lake Drawdown Project

ITEM	DESCRIPTION	EST. QUANT.	UNIT	UNIT PRICE	TOTAL
1	**Construction**				
	DU's Estimate for Materials and Installation	n/a	n/a	n/a	$ 569,413.00
	Estimated cost for back hoe to remove sediment from CD 28, Branch 6 following initial drawdown cycle	40	HOUR	200	$ 8,000.00
2	**Professional Services**				
	DU's Estimate for final engineering plans, bidding, construction staking, construction management, contract management, soils and project administration, including public and partner meetings	n/a	n/a	n/a	$ 66,944.00
3	**Ecological (Wetland Impact Avoidance)**				
	Purchase Easements	10.4	ACRE	$10,000.00	$ 95,600.00
	Wetland Mitigation (from Existing Bank) - Outside of Public Waters*	0	ACRE	n/a	n/a
4	**Legal/Administration**				
	Preparation of Engineer's Report	n/a	n/a	n/a	$ 38,000.00
	Permit Costs**	2	L.S.	$3,500.00	$ 7,000.00
	Legal Services	1	L.S.	$15,000.00	$ 15,000.00
	District Administration	1	L.S.	$10,000.00	$ 10,000.00
	Indirect Costs and Travel (est. by DU)	1	L.S.	n/a	$ 67,383.00
5	**Overall Contingency**				
	20% of Total				$ 175,4648.00
				TOTAL ESTIMATE	**$ 1,052,808.00**

* Assume self-mitigating project

** Assuming only required are permits from the USACE and a DNR Public Waters Work Permit, and not a permit from the Board of Water and Soil Resources for WCA

There will also be costs to the District associated with annual maintenance. The District will be responsible to carry out annual inspections of the project's infrastructure, including exercising (e.g. moving the gate valves back and forth, pulling and replacing stop logs, etc.). It will likely be necessary to excavate the channels periodically to keep them open (possibly every 5 years) at a cost of approximately $ 5,000 - $10,000.

The life span of the metal infrastructure components (e.g. control structures and sheet piling) is estimated at 30 years. The district is responsible for repair and/or complete replacement, if necessary. A complete replacement is expected to cost approximately $ 110,000, or $3,700 per year over a 30-year life span in 2014 dollars.

10 ALTERNATIVES AND RECOMMENDED IMPLEMENTATION ACTIVITIES

The Diamond Lake TMDL prepared (HEI, 2011) includes a comprehensive study of alternative implementation measures/activities to reduce both external watershed and internal in-lake sources of total phosphorus. Three primary watershed sources of total phosphorus to Diamond Lake were identified in the TMDL that could be controlled to help achieve the water quality numeric standards for total phosphorus, chlorophyll-a, and Secchi disk visibility. The three primary sources and associated implementation activities include:

1. Subsurface Sewage Treatment Systems (SSTS) / Connect to the Green Lake Sanitary Sewer District
2. Upstream Lakes / Convert and maintain upstream lakes in a clear state, and
3. Surface Inflow / Agricultural Conservation Practices (ACPs) and Urban Best Management Practices (BMPs)

The TMDL recommended four implementation activities to control these sources of total phosphorus:

Implementation Activity WS-1: Connect Diamond Lake SSTSs to the Green Lake Regional Wastewater Treatment System. Note that this activity has been completed.

Implementation Activity WS-2: Upstream Lake Management To Achieve Clear Water States within Hubbard and Wheeler Lakes

Implementation Activity WS-3: Implement Agricultural Conservation Practice Program (in progress)

Implementation Activity WS-4: Lakeshore and Urban Best Management Practices (in progress)

Implementation Activity WS-2 was selected to be implemented due to its effectiveness in reducing total phosphorus in Diamond Lake. The Diamond Lake TMDL (HEI 2011) provides further detail on each of the implementation activities.

11 CONCLUSION AND RECOMMENDATIONS

The proposed project, known as the “Diamond Lake TMDL Implementation, Hubbard, Schultz, Wheeler Implementation Activity,” will periodically lower the water levels within Hubbard, Schultz and Wheeler Lakes, with the goals of: 1) stimulating the winter kill of undesirable rough fish within Hubbard, Schultz and Wheeler Lakes; 2) stimulating the growth of submerged aquatic plants within the lakes; and ultimately 3) improved water quality within Diamond Lake, as well as within Hubbard, Schultz and Wheeler Lakes themselves.

Both this Engineer’s Report and the Feasibility Report provide results of technical analyses performed to estimate the benefits and impacts due to the implementation of the proposed project. In accordance with the Minnesota Statute 103D.601, this Engineer’s Report is intended not only to provide the information necessary to satisfy the requirements of Minnesota Statute 103D.711, but also to serve as a tool for the District Managers to determine the “benefits and damages” of the project, according to the Minnesota Statute 103D.721.

The results of analyses carried out in this Engineer’s report are summarized as follows:

- The proposed upstream lake drawdown project has been determined to be technically feasible, and the water quality in Diamond Lake is expected to substantially improve with the implementation of the proposed project (as discussed in **Section 4.3.2)**. TP loads to Diamond Lake are expected to decrease by 300 to 335 kg/yr, over half the total reduction needed to achieve the MPCA’s TP numeric standard of 40 ug/l, as was determined in the Diamond Lake TMDL.

- It is important that the implementation of this project not cause any unreasonable negative impacts to lake levels on Diamond Lake. Due to the removal of inflows from the upstream lakes, Diamond Lake will undergo a temporary drop in lake levels during the upstream lake drawdown period, low level maintenance period, and subsequent refill period, which will vary according to climatic conditions. **Section 4.2** of this Report presents an analysis which concludes that under most climatic conditions, levels on Diamond Lake should not drop more than 6 inches. If the year following the fall drawdown turns out to be very dry, which could increase upstream lake refill times, the drop in Diamond Lake levels could be a foot or more during the driest time of the year. However, such impacts will only be temporary.

- The TP load discharged to CD 28, Branch 6 during the initial upstream lake drawdown period will be significantly higher than it would be without the implementation of the project. However, this short-term downstream impact is expected to be mitigated by the long-term decrease in load by maintaining the upstream lakes in the clear state phase.

- A complete drawdown of Schultz, Wheeler, and Hubbard Lakes would require the discharge of approximately 2,114 acre-feet to CD 28, Branch 6. However this increase in volume will occur during the months of September through December, typically a drier time of the year. Also, during the subsequent upstream lake recharge period (6-18 months), there will be less overall volume discharged to CD 28 than in the existing conditions due to no outflow occurring from these lakes to either CD 28 or Diamond Lake. Because the project has no impact on hydrologic conditions, there will be no net change in overall volume discharged to CD 28. There are also no downstream water bodies with outlet structures that could be affected by a temporary increase or decrease in the volume of water.

- The potential impacts to CD 28 have been evaluated relative to existing conditions discharge to the ditch, agricultural drainage capacity, and channel stability:

    - The maximum discharge expected from the upstream lakes during the drawdown period is compatible with approximately 75% of historic discharges which occur during that same time of the year.
    - Agricultural drainage systems typically are sized to drain peak flows resulting from a 2-year, 24-hour rainfall event. The maximum peak discharge to CD 28 from the upstream lakes during the drawdown period is approximately one-half of the maximum 2-year discharge from Diamond Lake under existing conditions. There is only about a 3% chance of a 2-year rainfall event occurring during the drawdown period so that any impact to agricultural drainage would be negligible.
    - Because the cross-section of CD 28, Branch 6 remains unchanged, the velocities in the ditch at the same discharge also remain unchanged, and therefore no impact on channel stability is expected with the operation of the lake drawn project.

- Culverts crossing county roads are typically designed to accommodate 50-year peak flows, with 1-foot of freeboard. The three downstream culverts are substantially sized to convey flows due the lake drawdown occurring in conjunction with a 50-year rainfall event.

- The proposed water control structures have been designed to not only allow for the drawdown of the upstream lakes of North Wheeler and South Wheeler/Hubbard, but also so that the upstream lakes should have nearly the same water depth as in the existing conditions. As operating experience is gained, it is expected that the proposed design is also capable of attaining the existing annual average water levels.

- The public waters affected by the project are part of a habitat and water quality improvement initiative. The impacts from the project are temporary drawdown and disturbance of the bed due to construction of new outlets. These impacts are offset by the subsequent habitat and water quality improvements and improved lake functions. It is anticipated that the permanent public benefits will outweigh the temporary impacts and not require mitigation. This will need to be verified within the permitting review by the DNR.

- It is anticipated that permits will be required from the USACE and a DNR. The waters are subject to regulation by these two authorities. However, in some cases individual permits may not be required for activities that have been authorized without a permit, or through a general permit. It does not appear that there are any impacts to waters that would be subject to the Wetland Conservation Act as all the anticipated construction appears to only effect areas within the Ordinary High Water Level of public waters. This will be confirmed in the permitting phase of the project.

- It is recommended that the District inspect the ditch periodically during upstream lake drawdown to make sure sediment is not deposited and remove the sediment, if necessary.

- Following the first drawdown period, it is recommended that the District make observations and adjustments to the project operation as needed, as discussed in the Adaptive Management section of this report to prevent negative impacts to the Diamond Lake levels or CD 28, Branch 6.

12 REFERENCES

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APPENDIX A

FEASIBILITY REPORT

FOR

HUBBARD, SCHULTZ & WHEELER LAKES

DU-MN-435-1

DUCKS UNLIMITED®

November, 29 2012

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.

James Streifel, P.E.   11/29/2012

James A. Streifel, P.E.
For Ducks Unlimited, Inc.
License No. 47359   Date

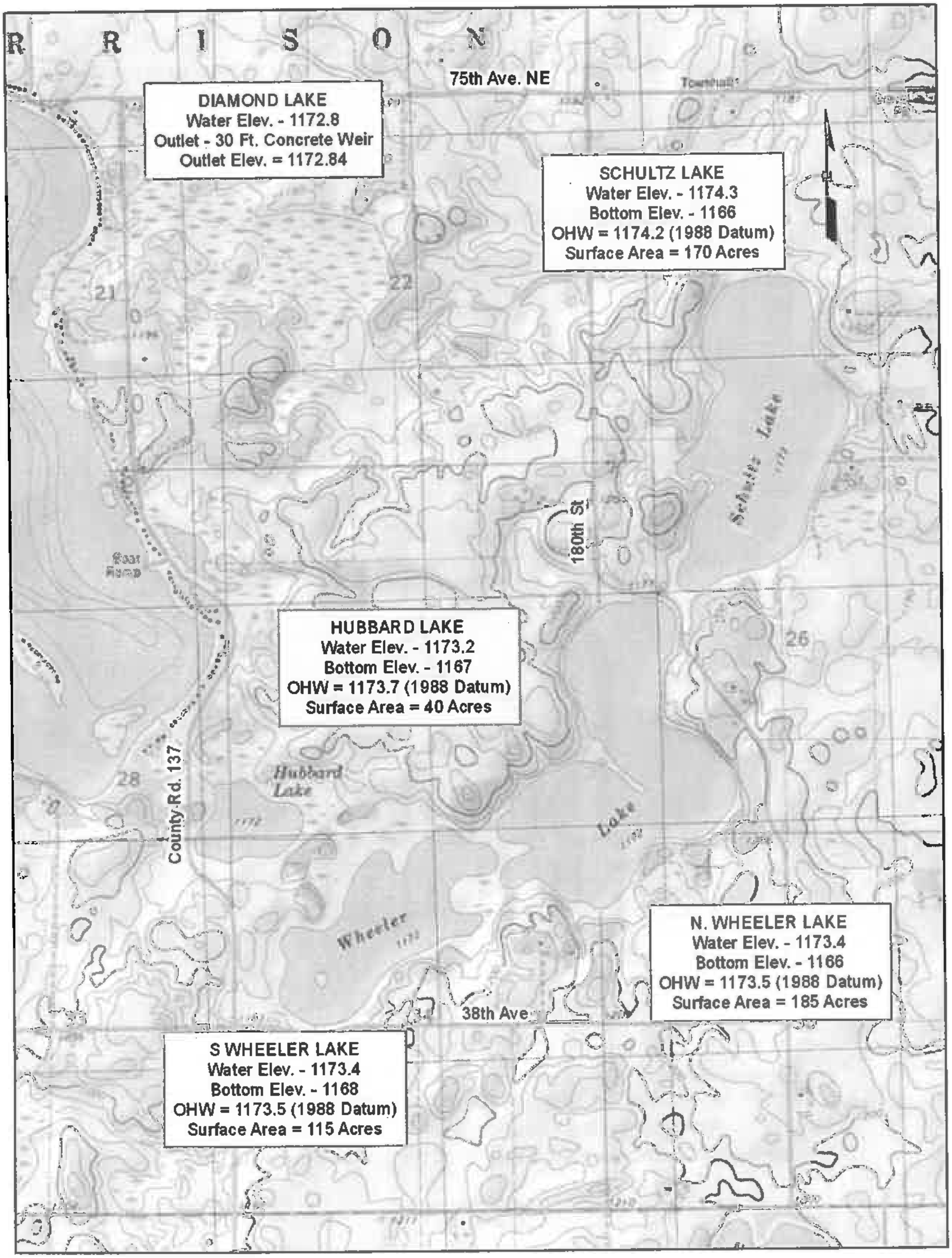


Figure 1: Site Map

PROJECT DESCRIPTION

Ducks Unlimited in cooperation with the Middle Fork Crow River Watershed District and Diamond Lake Area Recreation Association is performing an engineering and biological study to determine the feasibility of managing water levels on the lakes of Hubbard, Schultz and Wheeler. Hubbard, Schultz and Wheeler are located immediately upstream of Diamond Lake with outflows from Hubbard Lake entering directly into Diamond Lake. Diamond Lake currently is experiencing water quality problems and has been classified as impaired by the State of Minnesota. With Hubbard, Schultz and Wheeler contributing directly into Diamond Lake and also having poor water quality due to the presence of undesirable fish and a lack of both submersed and emergent vegetation, the Watershed District and Lake Association would like to improve water quality flowing into Diamond Lake by enhancing the upstream shallow lakes. The presence of undesirable fish can degrade water quality by uprooting bottom vegetation and creating a turbid condition. This turbidity prevents light penetration and limits vegetation growth. The elimination of fish by means of temporary water level drawdown to induce a winter fish kill has proven to be an effective management technique. Water level draw down is a tool that can be used to flip Hubbard, Schultz and Wheeler Lakes from its current turbid water condition to a clear water, healthy condition which should also benefit Diamond Lake.

This feasibility study will investigate the options available and the means by which each of the shallow lakes can be enhanced by temporary drawdowns. In addition to the water level management options available, to limit the movement of fish between Diamond Lake and the upstream shallow lakes, fish barrier options will also be investigated. This report will evaluate the existing hydrology and the effect on Diamond Lake if a portion of the watershed is rerouted during a period of temporary drawdown upstream.

ELEVATION AND SURVEY STATEMENT

Ducks Unlimited established vertical control for the topographic survey using a Trimble R6 receiver configured to operate within the Minnesota DOT VRS-GPS surveying system. The vertical datum was checked with the Diamond Lake Water Level Report benchmark, standard disc set in a concrete post near the west shore of the lake at the community park, with a published elevation of 1178.83 on the NGVD 29 datum. The datum shift between the 29 datum and 88 for this area is +0.613'. The elevation that DU shot on the benchmark in the NAVD 88 datum was 1179.48. Taking into account the datum shift, this converts to a NGVD 29 elevation of 1178.86 or 0.03' difference.

Ducks Unlimited also found and shot two DNR Waters benchmarks listed on the Water Level Reports for Schultz and Wheeler Lakes. The Wheeler Lake benchmark is listed as 1177.85 NGVD 29 and DU shot that benchmark at 1178.09 NAVD 88 for a difference of +0.24'. The Schultz Lake benchmark is listed at 1180.44 NGVD 29 and DU shot that benchmark at 1180.94 for a difference of +0.50'. Because the DNR benchmarks did not fit the NGVD 29 information, it was decided for the purposes of this feasibility study, all elevations will reference the NAVD 88 datum and the accepted datum shift being +0.613'.

HYDROLOGY

Inflows into Diamond Lake are primarily from surface runoff from a 28.1 square mile watershed with the primary land use being agricultural row crops. The Diamond Lake watershed was divided into four subwatersheds, with 13.2 square miles or approximately 47% contributing through the lakes of Hubbard, Schultz and Wheeler.

Diamond Lake Watershed				
Subwatershed	I	II	III	IV
Drainage Area	9,536 ac.	1,478 ac.	2,195 ac.	4,775 ac.
Land Use in Percent of Drainage Area				
Agriculture	70%	78.5%	82%	82.3%
Lakes & Ponds	20%	11.5%	11%	2.7%
Other	10%	10	7%	15%

Table 1: Diamond Lake Watershed

Therefore, by proposing to drawdown Hubbard, Schultz and Wheeler lakes, almost one half of the watershed for Diamond Lake would be cut off and re-routed during the period of temporary drawdown.

For the purposes of this report, Wheeler Lake will be referred to as North Wheeler and South Wheeler as a trail separates the two bodies of water. Schultz Lake discharges directly into N. Wheeler Lake through a 24" diameter CMP under 180th St. N. Wheeler discharges into S. Wheeler through three culverts located in the trail. The culverts are a 15" diameter CMP, an 18" diameter CMP and 24" diameter CMP respectively. The S. Wheeler subwatershed contributes directly into S. Wheeler and enters the lake through a 72" diameter CMP located at 38th Ave. The three subwatersheds combine and contribute inflows to Hubbard Lake which discharges directly into Diamond Lake through a 4' x 10' precast concrete box culvert under County Road 137.

The outlet of Diamond Lake is a 30' long concrete spillway and is located at the NE side of the lake. Outflow from Diamond Lake discharges into County Ditch #28 Branch 6 which eventually flows into the Middle Fork Crow River approximately 5 miles downstream.

The watershed for Diamond Lake and the associated subwatersheds were obtained from the USGS website utilizing the online application "Minnesota StreamStats". The application can be accessed at http://water.usga.gov/osw/streamstats/minnesota.html. Minnesota StreamStats incorporates regression equations for estimating peak flows on ungaged sites as developed in USGS *"Water Resources Investigations Report 97-4249, **Techniques for Estimating Peak Flow on Small Streams in Minnesota**" by David L. Lorenz, George H. Carlson, and Chris A. Sanocki.*

Schultz to N. Wheeler Connection

N. Wheeler to S. Wheeler Connection

Hubbard Lake Outlet

Diamond Lake Outlet

County Ditch at Diamond Lake Outlet

County Ditch 28 at 180th St.

Figure 2 - Watershed Map

To analyze the existing and design conditions for Diamond Lake and the associated upstream lakes of Hubbard, Schultz and Wheeler, HydroCAD Stormwater Modeling software was used and compared with the regression equation results determined in StreamStats. HydroCAD incorporates the NRCS TR-20 runoff method to produce hydrographs for various design storms. The hydrographs were routed through each of the lakes for both the existing conditions and the proposed drawdown design structures. This yielded outflow hydrographs that determined peak discharges at maximum reservoir elevations corresponding to the various runoff events.

The summary of design parameters and assumptions for the TR-20 stormwater model are shown in Table 2 below.

Subwatershed	**I**	**II**	**III**	**IV**
Runoff Area (Acres)	9,536	1,478	2,195	4,775
T_c (Minutes)	600	166	490	850
Runoff CN	78	74	76	71
AMC	2	2	2	2
24 Hr. Type II Rainfall Distribution				
24 Hr. Rainfall Depths (Kandiyohi County, MN) from "Rainfall Frequency Atlas of the United States" by the U.S. Weather Bureau. 1 – Year = 2.23" 10 – Year = 4.05" 100 – Year = 5.80" 2 – Year = 2.63" 25 – Year = 4.64" 5 – Year = 3.45" 50 – Year = 5.22"				

Table 2: TR-20 Stormwater Model Design Parameters

STORMWATER MODEL – EXISTING CONDITIONS

To model the existing conditions for the Diamond Lake watershed, runoff hydrographs generated in the HydroCAD model were routed through the existing outlet structures on Schultz, N. Wheeler and Hubbard Lakes. A summary of the stormwater model results are shown in the following tables for each of the lakes.

Diamond Lake – Existing Conditions				
Event	Inflow (cfs)	Outflow (cfs)	Elevation (feet)	Storage (acre-feet)
1- Year	481	17.9	1,173.12	25,302
2 – Year	690	29.7	1,173.25	25,510
5 – Year	1,185	62.5	1,173.54	25,981
10 – Year	1,581	93.5	1,173.77	26,356
25 – Year	1,993	129.0	1,174.01	26,741
50 – Year	2,417	168.3	1,174.24	27,130
100 - Year	2,852	210.6	1,174.48	27,519
Starting Elevation of Diamond Lake for each Event was 1172.84				

Table 3: TR-20 Stormwater Model Results for Diamond Lake Existing Conditions

For comparison purposes, the drainage area for Diamond Lake was analyzed using StreamStats and the Minnesota regression equations. The drainage area characteristics and results are shown in Table 4.

Drainage Area (square miles) = 28.1 *Stream Slope (feet/mile) = 3.64* *Percent Lake & Ponds (%) = 12.36* *Generalized Runoff (inches) = 4.13* **Peak Discharge for Diamond Lake**	
Event	**Q (cfs)**
1 Year	49 cfs
2 Year	68 cfs
5 Year	129 cfs
10 Year	181 cfs
25 Year	259 cfs
50 Year	327 cfs
100 Year	405 cfs

Table 4: Regression Equation Results

The regression equations resulted in higher discharge rates than those generated in the TR-20 model. The TR-20 results however take into account the effects of flood routing utilizing basin storage and existing outlet structure hydraulics. The capacity of the existing weir structure on Diamond Lake is approximately 130 cfs prior to it overtopping the structure abutments which have an elevation of 1174.0. Therefore, without a history of the structure overtopping, the TR-20 model more closely reflect the existing conditions and will be utilized for this study. The structure rating table for the Diamond Lake structure is shown in Table 5 below.

Diamond Lake Existing 30' Concrete Weir Structure		
Measured Head, (ft)	Elevation (ft)	Discharge (cfs)
0.0	1172.84	0.0
0.1	1172.94	3.2
0.2	1173.04	8.9
0.3	1173.14	16.2
0.4	1173.24	25.0
0.5	1173.34	34.9
0.6	1173.44	45.9
0.7	1173.54	58.0
0.8	1173.64	73.9
0.9	1173.74	84.8
1.0	1173.84	99.5
1.1	1173.94	115.1
1.2	1174.04	131.4

Table 5: Diamond Lake Structure Rating Table

The TR-20 model results for each of the upstream lakes are shown in the following tables.

Schultz Lake – Existing Conditions				
Event	Inflow (cfs)	Outflow (cfs)	Elevation (feet)	Storage (acre-feet)
1- Year	138	0.6	1,173.60	842
2 – Year	218	1.2	1,173.76	868
5 – Year	412	3.3	1,174.13	930
10 – Year	573	5.1	1,174.42	981
25 – Year	741	7.1	1,174.72	1,035
50 – Year	913	9.2	1,175.03	1,089
100 - Year	1,090	10.5	1,175.34	1,146
Starting Elevation of Schultz Lake for each Event was 1173.25				

Table 6: TR-20 Stormwater Model Results for Schultz Lake Existing Conditions

N. Wheeler Lake – Existing Conditions				
Event	Inflow (cfs)	Outflow (cfs)	Elevation (feet)	Storage (acre-feet)
1- Year	84	4.1	1,173.23	749
2 – Year	124	5.3	1,173.42	784
5 – Year	221	8.9	1,173.87	865
10 – Year	300	12.1	1,174.22	931
25 – Year	384	15.1	1,174.57	998
50 – Year	471	18.0	1,174.92	1,065
100 - Year	561	20.7	1,175.25	1,133
Starting Elevation of Diamond Lake for each Event was 1172.80				

Table 7: TR-20 Stormwater Model Results for N. Wheeler Lake Existing Conditions

S. Wheeler and Hubbard Lakes – Existing Conditions				
Event	Inflow (cfs)	Outflow (cfs)	Elevation (feet)	Storage (acre-feet)
1- Year	102	30.1	1,173.48	609
2 – Year	151	47.4	1,173.84	665
5 – Year	301	91.4	1,174.62	794
10 – Year	443	127.2	1,175.18	891
25 – Year	585	165.3	1,175.73	989
50 – Year	725	208.1	1,176.30	1,093
100 - Year	872	243.8	1,176.93	1,212
Starting Elevation of S. Wheeler & Hubbard Lake for each Event was 1172.80				

Table 8: TR-20 Stormwater Model Results for S. Wheeler & Hubbard Lake Existing Conditions

DESIGN

The design objectives for the Hubbard, Schultz and Wheeler feasibility study are the following:

1. Evaluate the feasibility and options available to temporarily drawdown each of the shallow lakes located upstream of Diamond Lake for the purposes of improving water quality and wildlife habitat.
2. Determine the effects on Diamond Lake if the contributing watersheds of Hubbard, Schultz and Wheeler Lakes are rerouted around Diamond Lake during periods of temporary drawdown.
3. Evaluate the impact of discharging water from Hubbard, Schultz and Wheeler into the county ditch downstream of the Diamond Lake outlet.
4. Evaluate the feasibility and type of fish barrier required to prevent undesirable fish from migrating back into Hubbard, Schultz and Wheeler following water level draw down.

Hubbard, Schultz and Wheeler Drawdown Design

In order to achieve the desired drawdown of Hubbard, Schultz and Wheeler, a pipeline could be installed from Schultz Lake to County Ditch #28, Branch 6 located downstream of the Diamond Lake outlet near 180th St. And with a water control structure installed between Schultz and North Wheeler, both Wheeler Lakes and Hubbard could then be routed and drawn down through Schultz. Water control structures installed between Schultz and North Wheeler and between North and South Wheeler would allow each of the lakes to be drawdown in sequence. The water control structures would be precast concrete box risers with stoplogs and 24" outlet barrels. Inlet and outlet channels would have to be excavated to elevations which would allow close to complete water level drawdown.

To calculate the estimated time to drawdown each of the lakes, it is assumed that they will be drawn down in sequence. The calculated times also do not include the effects of evaporation, additional rainfall during the drawdown period or infiltration due to groundwater. The amount of time required to drawdown each of the lakes is shown in Tables 9 - 13.

	18"Ø PVC Pipeline		24"Ø PVC Pipeline	
Elevation (ft)	Q (cfs)	Time (days)	Q (cfs)	Time (days)
1174	8.0	0	16.6	0
1173	7.6	11	15.6	5
1172	7.1	22	14.6	11
1171	6.6	33	13.5	16
1170	6.1	44	12.3	21
1169	5.7	55	10.6	27
1168	2.7	66	3.4	35
Assumed starting elevation of 1274.3				

Table 9: Schultz Lake Estimated Drawdown Times.

Estimated Time to Drawdown North Wheeler Lake wit 18"Ø Outlet from Schultz Lake

N. Wheeler Lake Drawdown			Schultz Lake Outlet	
Elevation (ft)	Q (cfs)	Time (days)	Elevation (ft)	Q (cfs)
1173	35.7	0	1168	2.7
1172	29.0	3	1169.5	5.8
1171	15.8	6	1170.2	6.2
1170	3.0	20	1170.0	6.1
1169	2.9	42	1169.0	5.8
1168	1.1	63	1168.0	2.5
Estimated drawdown times for N. Wheeler Lake and Schultz Lake discharge rates are based on an 18"Ø outlet from Schultz Lake. Assumed starting elevation of Schultz Lake is 1168.0 and all stoplogs removed from N. Wheeler structure.				

Table 10: North Wheeler Lake Estimated Drawdown Time.

Estimated Time to Drawdown North Wheeler Lake with 24"Ø Outlet from Schultz Lake				
N. Wheeler Lake Drawdown			Schultz Lake Outlet	
Elevation (ft)	Q (cfs)	Time (days)	Elevation (ft)	Q (cfs)
1173	35.7	0	1168	3.4
1172	29.7	3	1169.2	11.9
1171	19.3	6	1169.8	12.1
1170	7.4	12	1169.8	12.1
1169	5.2	22	1168.9	9.8
1168	1.4	37	1168.0	3.0
Estimated drawdown times for N. Wheeler Lake and Schultz Lake discharge rates are based on a 24"Ø outlet from Schultz Lake. Assumed starting elevation of Schultz Lake is 1168.0 and all stoplogs removed from N. Wheeler structure.				

Table 11: North Wheeler Lake Estimated Drawdown Time.

Estimated Time to Drawdown S. Wheeler and Hubbard with 18"Ø Outlet from Schultz						
S. Wheeler & Hubbard Drawdown			N. Wheeler Lake Outlet		Schultz Lake Outlet	
Elev. (ft)	Q (cfs)	Time (days)	Elev. (ft)	Q (cfs)	Elev. (ft)	Q (cfs)
1173	31.8	0	1168	0	1168	0
1172	26.0	3	1169.1	11.7	1168.3	4.0
1171	18.4	6	1169.6	14.5	1168.8	5.8
1170	9.2	10	1169.6	10.0	1169.3	5.7
1169	1.2	30	1169	3.5	1168.9	5.9
1168.7	1.0	38	1168.7	3.1	1168.6	5.2
Estimated drawdown times for S. Wheeler and Hubbard Lake through N. Wheeler and Schultz Lake based on an 18"Ø outlet from Schultz Lake. Assumed starting elevations of 1168.0 for both N. Wheeler and Schultz Lakes and all stoplogs are removed from N. Wheeler and S. Wheeler outlet structures.						

Table 12: South Wheeler and Hubbard Lakes Estimated Drawdown Time.

Estimated Time to Drawdown S. Wheeler and Hubbard with 24"Ø Outlet from Schultz

S. Wheeler & Hubbard Drawdown			N. Wheeler Lake Outlet		Schultz Lake Outlet	
Elev. (ft)	Q (cfs)	Time (days)	Elev. (ft)	Q (cfs)	Elev. (ft)	Q (cfs)
1173	31.8	0	1168	0	1168	0
1172	26.0	3	1169.1	11.7	1168.2	5.0
1171	18.4	6	1169.6	14.5	1168.7	8.2
1170	10.3	10	1169.6	13.0	1169	10.8
1169	2.1	20	1168.9	5.6	1168.7	8.5
1168.7	0.2	38	1168	1.4	1168	2.8

Estimated drawdown times for S. Wheeler and Hubbard Lake through N. Wheeler and Schultz Lake based on a 24"Ø outlet from Schultz Lake. Assumed starting elevations of 1168.0 for both N. Wheeler and Schultz Lakes and all stoplogs are removed from N. Wheeler and S. Wheeler outlet structures.

Table 13: South Wheeler and Hubbard Lakes Estimated Drawdown Time.

A summary of the time required to drawdown each of shallow lakes beginning with Schultz and progressing through South Wheeler and Hubbard is shown below. The estimated drawdown time does not take into account additional rainfall, evaporation or infiltration.

	18"Ø Schultz Lake Outlet	24"Ø Schultz Lake Outlet
Schultz Lake	66 days	35 days
North Wheeler Lake	63 days	37 days
S. Wheeler & Hubbard Lakes	38 days	38 days
TOTAL	**167 days**	**110 days**

By routing flows from Hubbard, Schultz and Wheeler into the county ditch during the temporary drawdown period, approximately one half of the watershed for Diamond Lake would be cut off. The lake association would like to ensure that this would not have any negative impacts to the water levels on the lake. In order to evaluate the potential impacts, the remaining watershed (9,536 acres) was evaluated for the potential to keep the lake levels stable given the affects of evaporation. Given average conditions, for rainfall and evaporation, the remaining watershed should be able to keep lake levels stable. However, during periods of low or no rainfall, evaporation rates could exceed inflow and lake levels could decline temporarily.

The estimated refill times for each of the lakes assuming average precipitation and evaporation is, Schultz Lake – 1.5 years, North Wheeler – 1.0 years and South Wheeler/Hubbard – 0.5 years.

County Ditch Capacity

With the drawdown flowrates added to County Ditch 28 downstream of Diamond Lake, there was some concern as to how the channel would be impacted. The channel section in the vicinity of the proposed pipeline outlet and the next road crossing downstream is very well defined and can easily pass the additional flows. Assuming outflow from Diamond Lake is at the structure capacity of 130 cfs and 20 cfs is added through the pipeline, the water surface profile would rise approximately 0.3'. A water level gauge could be installed near the County Road and Ditch #28 to monitor flows during draw down. Erosion protection will have to be added to the pipeline outlet due to the velocity and duration of flow. The erosion protection can consist of rock riprap. The rating table for the county ditch section downstream of the proposed outlet is shown in Table 14.

Discharge	Depth	Velocity
(cfs)	(ft)	(fps)
0	0.0	0.0
10	0.82	0.96
20	1.23	1.21
30	1.54	1.38
40	1.81	1.51
50	2.05	1.61
60	2.27	1.70
70	2.46	1.78
80	2.65	1.85
90	2.82	1.92
100	2.98	1.98
110	3.14	2.03
120	3.28	2.08
130	3.42	2.13
140	3.56	2.17
150	3.69	2.21

Table 14: County Ditch Rating Table Downstream of Proposed Pipeline

Hydrology Model for Design Conditions

To compare the proposed design conditions to the existing conditions, the same TR-20 model was run to determine the peak discharge rates and maximum lake elevations for the same runoff events. The model was run assuming each of the lakes was at their full operating levels at the start of each runoff event. The design structures are intended to manage each of the lakes at their current operating levels and be able to provide drawdown capability as management issues dictate. The proposed structure between Schultz and North Wheeler is a 4' x 6' precast concrete box riser with stoplogs and a 24" diameter RCP outlet barrel. The structure will replace the existing 24" CMP culvert. The stoplog bay opening is 3.5' wide with an invert of 1167.0. An inlet and outlet channel excavated to elevation 1167.0 will be required to drawdown North Wheeler.

A similar structure is planned in the existing trail separating North and South Wheeler to replacing the three existing culverts. This structure will allow North Wheeler to be drawn down independently from South Wheeler and Hubbard. Inlet and outlet channels would have to be excavated to ensure drawdown to the desired elevation.

If water levels on Diamond Lake are not to be affected by the drawdown of Hubbard, Schultz and Wheeler, a water control structure would need to be installed at the outlet of Hubbard Lake (Diamond Lake Inlet near the proposed DNR Fish Barrier). The existing runout elevation of Hubbard (4' x 10' box culvert invert) is 1172.34. Therefore, without a structure, the surface elevation of Diamond Lake would be lowered by approximately 0.5' from the elevation shot at the time of the DU survey (1172.8). Also without a structure, drawdown times for Hubbard, Schultz and Wheeler would be increased. Therefore, the proposed Hubbard Lake structure would be a sheet pile weir or similar type structure having a hydraulic capacity which matches that of the existing 4' x 10' box culvert. The design hydraulic conditions assume no changes to the existing outlet structure on Diamond Lake.

The results of the hydrologic and hydraulic TR 20 model for each of the lakes are shown in Tables 15-18. The model was run with simultaneous routing which takes into account the effects of tailwater at each of the lake outlets.

Diamond Lake – Design Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	481	18.1	1,173.12	25,305
2 – Year	690	29.9	1,173.25	25,512
5 – Year	1,184	62.8	1,173.54	25,984
10 – Year	1,580	93.8	1,173.77	26,359
25 – Year	1,993	129.2	1,174.01	26,743
50 – Year	2,417	168.4	1,174.24	27,131
100 - Year	2,852	210.9	1174.48	27,521
Starting Elevation of Diamond Lake for each Event was 1172.84				

Table 15: TR-20 Stormwater Model Results for Diamond Lake Design Conditions

Schultz Lake – Design Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	138	10.3	1,173.47	821
2 – Year	218	11.1	1,173.63	847
5 – Year	412	13.0	1,174.01	910
10 – Year	573	14.3	1,174.31	962
25 – Year	741	15.6	1,174.61	1,015
50 – Year	913	17.4	1,174.92	1,069
100 - Year	1,090	21.1	1,175.22	1,124
Starting Elevation of Schultz Lake for each Event was 1173.25				

Table 16: TR-20 Stormwater Model Results for Schultz Lake Design Conditions

N. Wheeler Lake – Design Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	93	7.6	1,173.30	761
2 – Year	133	8.4	1,173.48	794
5 – Year	231	11.3	1,173.92	874
10 – Year	310	15.2	1,174.25	935
25 – Year	394	19.4	1,174.58	1,000
50 – Year	481	23.2	1,174.91	1,065
100 - Year	572	27.0	1,175.26	1,134
Starting Elevation of Diamond Lake for each Event was 1172.80				

Table 17: TR-20 Stormwater Model Results for N. Wheeler Lake Design Conditions

S. Wheel and Hubbard Lakes – Design Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	105	30.5	1,173.50	611
2 – Year	152	47.8	1,173.85	667
5 – Year	305	92.0	1,174.63	796
10 – Year	447	127.7	1,175.19	893
25 – Year	589	165.3	1,175.74	991
50 – Year	730	207.6	1,176.31	1,097
100 - Year	876	245.6	1,176.94	1,215
Starting Elevation of S. Wheeler & Hubbard Lake for each Event was 1172.80				

Table 18: TR-20 Stormwater Model Results for S. Wheeler & Hubbard Lake Design Conditions

From the results of the hydraulic model, the proposed design does not significantly change the way in which the system currently is working. Discharge rates and water elevations remain approximately the same as the existing conditions. During periods when the shallow lakes are in drawdown, they would also serve as flood storage in the event of a large runoff event.

Fish Barrier Alternatives

Currently the Minnesota DNR, Diamond Lake Area Recreation Association and Middle Fork Crow River Watershed District are working together on a fish barrier design for the outlet of Hubbard Lake. The proposed fish barrier as designed consists of 4 – 36" diameter perforated culverts and a rock riprap spillway section. The barrier is proposed to be installed just downstream of the existing 4' x 10' box culvert. For situations such as this, where there is little or no difference in water levels between the two lakes, making an effective low maintenance fish barrier design difficult. Because water levels are basically static or at times flowing backwards, any type of screen will require regular cleaning and maintenance. Electric fish barriers are very expensive and require regular maintenance for them to remain effective.

Even with the potential maintenance issues associated with a fish barrier at this location, it is a necessary component of the shallow lake enhancement efforts. While no fish barrier can ever guarantee that the restored lakes will remain fish free, it will extend the period of time required between drawdown efforts.

Under normal operating conditions, fish movement from the County Ditch into Schultz Lake will not be an issue because the pipeline will only be used when the lakes are actively being drawn down. Likewise, if the fish barrier is installed between Diamond Lake and Hubbard Lake, the movement of fish from Diamond back into the chain of lakes should also be reduced. Fish barriers could be installed in the proposed water control structures at the S. Wheeler and N. Wheeler outlets to further prevent fish movement. The proposed type of barrier in these structures will be screens which can be lowered in the channel guides in combination with stoplogs.

Conclusion and Recommendations

Shallow lake water level management, including undesirable fish control and reestablishment of vegetation, has been a relatively common and proven management tool in improving water quality and wildlife habitat in Minnesota. Even though this does not guarantee the improvement of Diamond Lake, it has the potential to reduce one of the primary sources contributing to the degradation of Diamond Lake. Improving the conditions of Hubbard, Schultz and Wheeler can also have the beneficial effect of improving habitat for waterfowl and other wildlife. Although the infrastructure required to manage Hubbard, Schultz and Wheeler lakes with a gravity drawdown system is expensive and ambitious, it is a feasible enhancement option that would benefit both humans and wildlife alike.

Addendum to

Feasibility Report for Hubbard, Schultz & Wheeler Lakes

Tables 1- 3, 6-8, 15- 18

February 26, 2014

Diamond Lake Watershed					
Subwatershed	I	II	III	IV	V
Drainage Area	9,537 ac.	1,480 ac.	1,670 ac.	4,775 ac.	525 ac.
Land Use in Percent of Drainage Area					
Agriculture	70%	78.5%	82%	82.3%	45.7%
Lakes & Ponds	20%	11.5%	11%	2.7%	29.5%
Other	10%	10	7%	15%	24.8%

Table 1: Diamond Lake Watershed

Subwatershed	**I**	**II**	**III**	**IV**	**V**
Runoff Area (Ac.)	9,537	1,480	1,670	4,775	525
T_c (Minutes)	600	166	490	850	63.3
Runoff CN	78	74	76	71	78
AMC	2	2	2	2	2
24 Hr. Type II Rainfall Distribution					
24 Hr. Rainfall Depths (Kandiyohi County, MN) from "Rainfall Frequency Atlas of the United States" by the U.S. Weather Bureau. 1 – Year = 2.23" 10 – Year = 4.05" 100 – Year = 5.80" 2 – Year = 2.63" 25 – Year = 4.64" 5 – Year = 3.45" 50 – Year = 5.22"					

Table 2: TR-20 Stormwater Model Design Parameters

Diamond Lake – Existing Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	491	18.4	1,173.13	25,311
2 – Year	703	30.5	1,173.26	25,523
5 – Year	1,204	64.3	1,173.56	26,004
10 – Year	1,606	96.3	1,173.79	26,387
25 – Year	2,023	133.0	1,174.03	26,782
50 – Year	2,452	173.6	1,174.27	27,181
100 - Year	2,894	217.0	1,174.51	27,575
Starting Elevation of Diamond Lake for each Event was 1172.80				

Table 3: TR-20 Stormwater Model Results for Diamond Lake Existing Conditions

Schultz Lake – Existing Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	138	0.6	1,173.60	842
2 – Year	218	1.2	1,173.76	868
5 – Year	412	3.3	1,174.13	931
10 – Year	573	5.0	1,174.42	981
25 – Year	741	7.0	1,174.75	1,039
50 – Year	913	9.1	1,175.09	1,099
100 - Year	1,091	10.4	1,175.42	1,162
Starting Elevation of Schultz Lake for each Event was 1173.25				

Table 6: TR-20 Stormwater Model Results for Schultz Lake Existing Conditions

N. Wheeler Lake – Existing Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	84	4.7	1,173.32	766
2 – Year	124	6.6	1,173.56	809
5 – Year	223	11.3	1,174.09	906
10 – Year	303	14.5	1,174.48	980
25 – Year	388	17.4	1,174.85	1,053
50 – Year	475	20.3	1,175.22	1,125
100 - Year	565	23.0	1,175.59	1,201
Starting Elevation of Diamond Lake for each Event was 1172.80				

Table 7: TR-20 Stormwater Model Results for N. Wheeler Lake Existing Conditions

S. Wheeler and Hubbard Lakes – Existing Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	146	31.5	1,173.51	613
2 – Year	218	49.4	1,173.87	670
5 – Year	381	94.4	1,174.67	802
10 – Year	511	131.9	1,175.25	903
25 – Year	645	173.4	1,175.82	1,007
50 – Year	780	219.5	1,176.46	1,124
100 - Year	918	255.5	1,177.13	1,252
Starting Elevation of S. Wheeler & Hubbard Lake for each Event was 1172.80				

Table 8: TR-20 Stormwater Model Results for S. Wheeler & Hubbard Lake Existing Conditions

Diamond Lake – Design Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	491	18.5	1,173.13	25,314
2 – Year	704	30.6	1,173.26	25,525
5 – Year	1,204	64.3	1,173.56	26,004
10 – Year	1,607	96.4	1,173.79	26,388
25 – Year	2,023	133.1	1,174.03	26,783
50 – Year	2,453	173.8	1,174.27	27,182
100 - Year	2,894	217.1	1174.51	27,577
Starting Elevation of Diamond Lake for each Event was 1172.80				

Table 15: TR-20 Stormwater Model Results for Diamond Lake Design Conditions

Schultz Lake – Design Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	138	0.2	1,173.18	773
2 – Year	218	0.5	1,173.37	804
5 – Year	412	1.8	1,173.82	879
10 – Year	573	3.3	1,174.17	938
25 – Year	741	5.2	1,174.52	999
50 – Year	913	7.4	1,174.86	1,059
100 - Year	1,091	9.8	1,175.20	1,120
Starting Elevation of Schultz Lake for each Event was 1172.80				

Table 16: TR-20 Stormwater Model Results for Schultz Lake Design Conditions

N. Wheeler Lake – Design Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	84	2.0	1,173.28	759
2 – Year	124	3.5	1,173.51	799
5 – Year	221	7.6	1,174.02	893
10 – Year	301	11.0	1,174.39	963
25 – Year	386	14.8	1,174.75	1,032
50 – Year	473	18.1	1,175.11	1,104
100 - Year	564	20.3	1,175.49	1,180
Starting Elevation of Diamond Lake for each Event was 1172.80				

Table 17: TR-20 Stormwater Model Results for N. Wheeler Lake Design Conditions

S. Wheel and Hubbard Lakes – Design Conditions				
Event	Inflow	Outflow	Elevation	Storage
	(cfs)	(cfs)	(feet)	(acre-feet)
1- Year	146	32.3	1,173.52	615
2 – Year	218	50.2	1,173.89	673
5 – Year	381	94.6	1,174.67	802
10 – Year	511	132.1	1,175.25	903
25 – Year	645	173.8	1,175.83	1,008
50 – Year	780	219.9	1,176.46	1,125
100 - Year	918	255.9	1,177.14	1,254
Starting Elevation of S. Wheeler & Hubbard Lake for each Event was 1172.80				

Table 18: TR-20 Stormwater Model Results for S. Wheeler & Hubbard Lake Design Conditions

APPENDIX B

STATE OF MINNESOTA
MIDDLE FORK CROW RIVER WATERSHED DISTRICT

In Re: Diamond Lake TMDL Implementation, Hubbard, Schultz, Wheeler Implementation Activity	RESOLUTION ACCEPTING PETITION, ASSIGNING PROJECT NUMBER AND APPOINTING ENGINEER

Manager Behm offered the following Resolution and moved its adoption, seconded by Manager Wing:

WHEREAS, on August 6, 2013, the Middle Fork Crow River Watershed District (MFCRWD) Board of Managers received the Petition of numerous residents of the District to establish the Diamond Lake TMDL Implementation, Hubbard, Schultz, and Wheeler Implementation Activity.

WHEREAS, the Petition meets the petition requirements of statutes chapter 103D allowing for initiation of a Basic Water Management Project.

WHEREAS, the Board of Managers finds that a proper project petition has been filed, the proposed project promotes the public interest and welfare, is practicable and conforms with the watershed management plan of the watershed district.

THEREFORE, the Board of Managers:

1. Designates the proposed project as the Hubbard, Schultz, Wheeler TMDL Implementation Project and assigns project number 2013-02.
2. Designates the engineering firm of Houston Engineering as the project engineer to make surveys, maps, analyses, and reports for the project as are necessary and consistent with the project as described in the Petition (MS 103D.711).

The question was on the adoption of the Resolution and there were 4 yeas and 0 nays as follows:

	Yea	Nay	Absent	Abstain
BEHM	☑	☐	☐	☐
FLANDERS	☐	☐	☑	☐
HODAPP	☑	☐	☐	☐
SCHAEFER	☑	☐	☐	☐
WING	☑	☐	☐	☐

Upon vote, the President declared the Resolution Passed.

Ruth A. Schaefer

Ruth Schaefer, Secretary

Dated: September 3, 2013

* * * * * * * * * * *

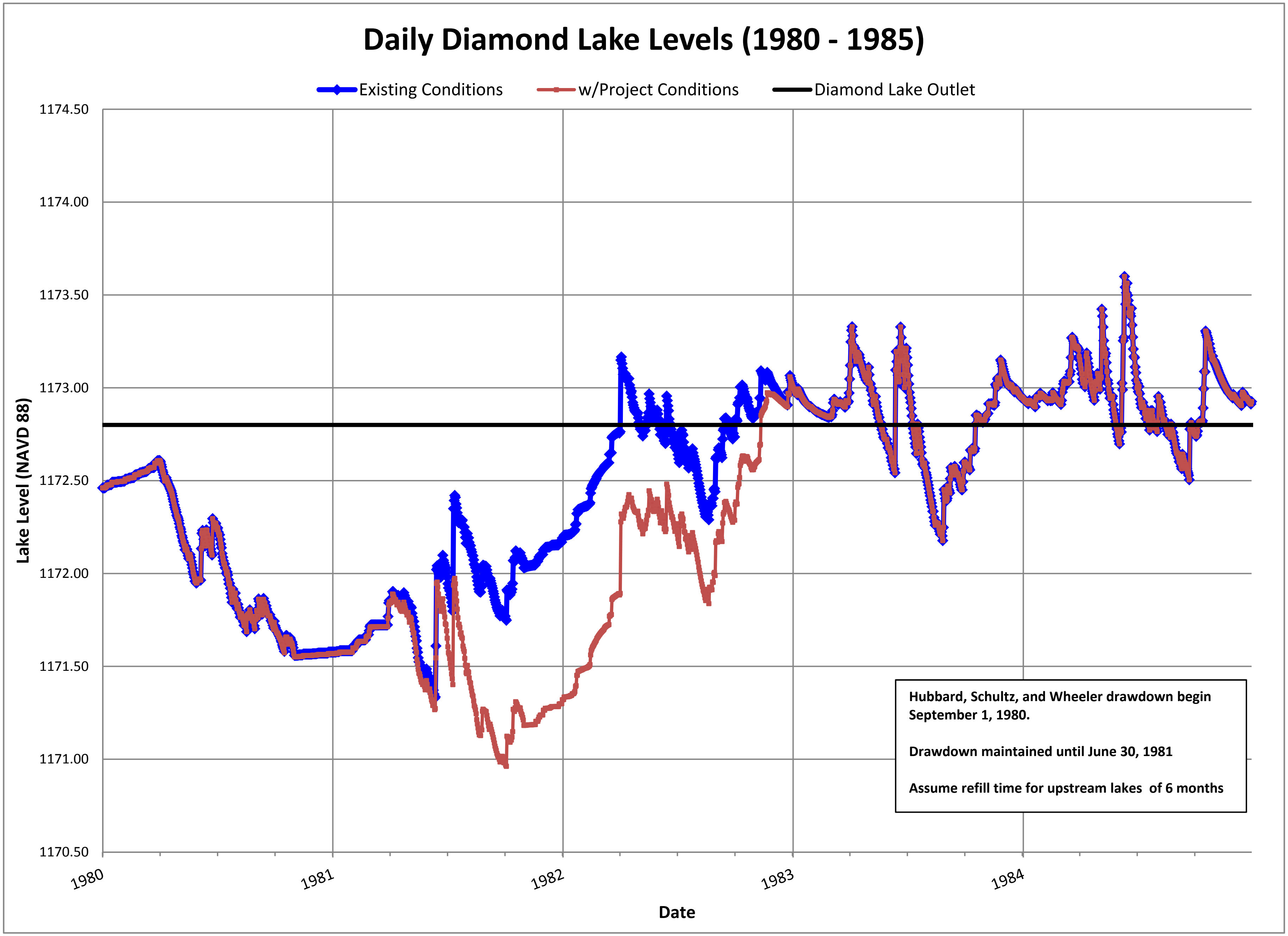
I, Ruth Schaefer, Secretary of the Middle Fork Crow River Watershed District, do hereby certify that I have compared the above resolution with the original thereof as the same appears of record and on file with the District and find the same to be a true and correct transcript thereof.

IN TESTIMONY WHEREOF, I hereunto set my hand this 3rd day of September, 2013.

Ruth Schaefer

Ruth Schaefer, Secretary

APPENDIX C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Existing Conditions
w/Project Conditions
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1173.50
1173.00
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1171.50
1171.00
1170.50
Lake Level (NAVD 88)
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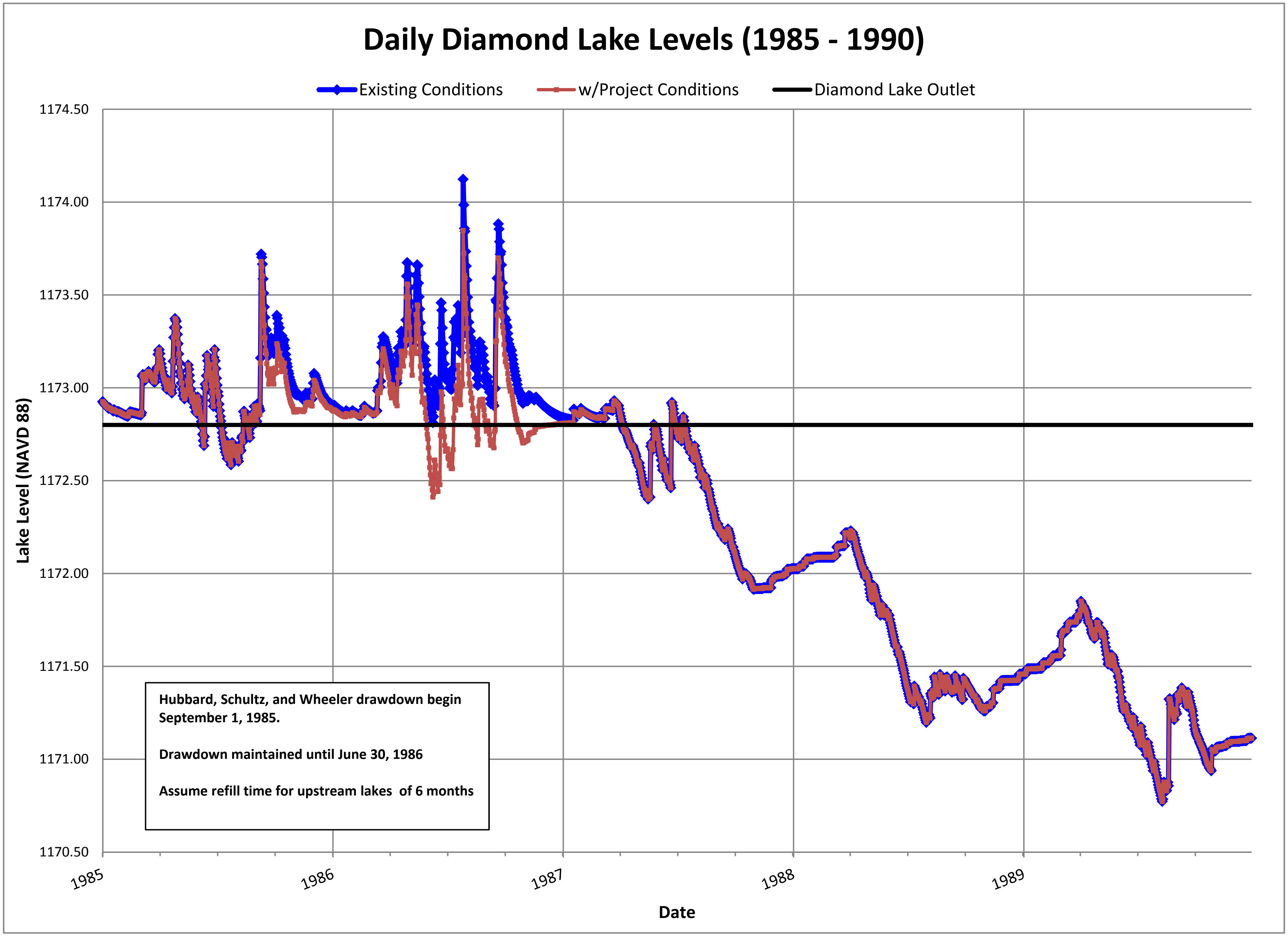
1981
1982
1983
1984
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 1980.
Drawdown maintained until June 30, 1981
Assume refill time for upstream lakes of 6 months



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Existing Conditions
w/Project Conditions
Diamond Lake Outlet
Lake Level (NAVD 88)
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1172.50
1172.00
1171.50
1171.00
1170.50
1985
1986
1987
1988
1989
Date
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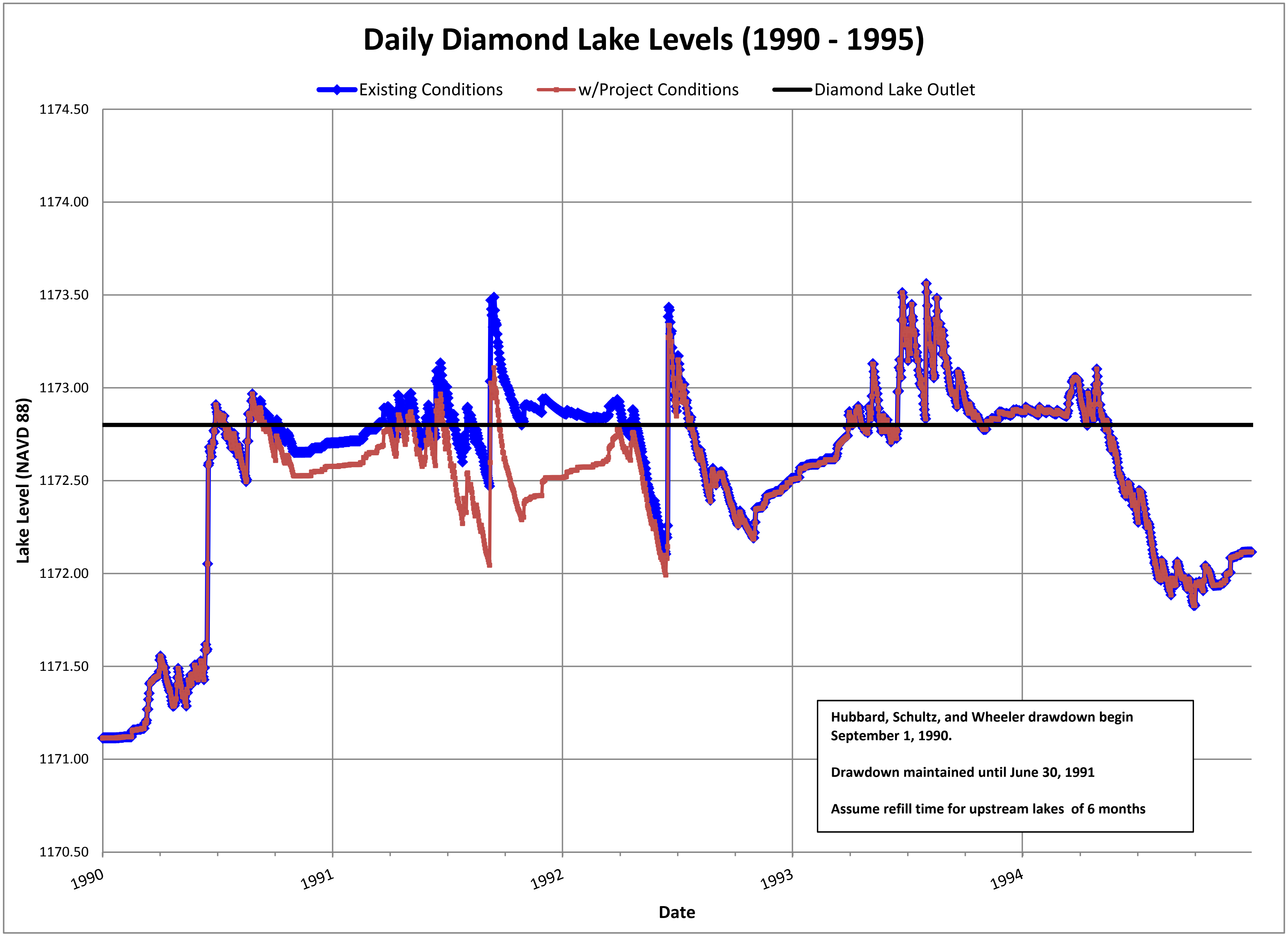
Drawdown maintained until June 30, 1986
Assume refill time for upstream lakes of 6 months



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Existing Conditions
w/Project Conditions
Diamond Lake Outlet
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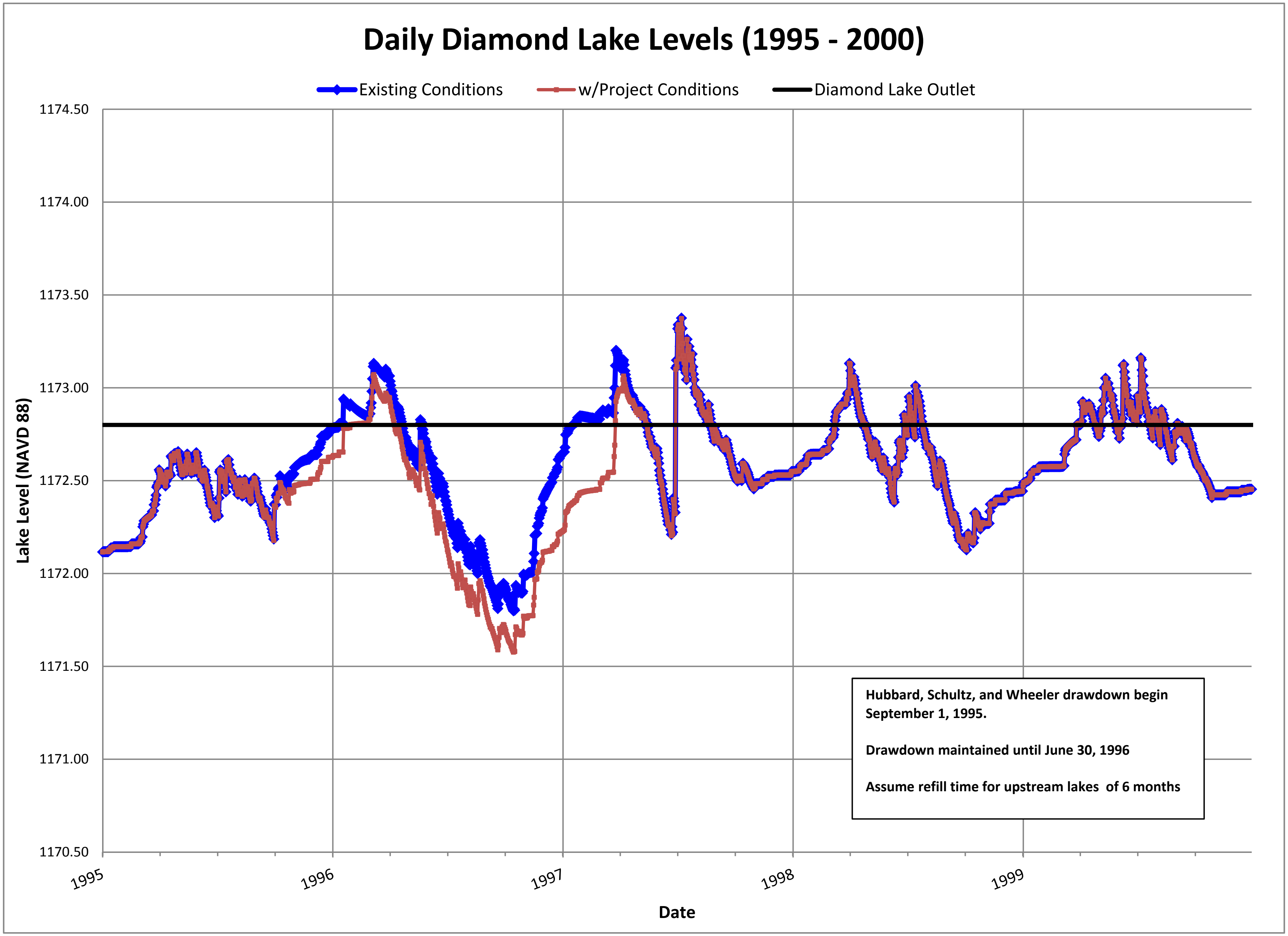
1173.50
1173.00
1172.50
1172.00
1171.50
1171.00
1170.50
Lake Level (NAVD 88)
1990
1991
1992
1993
1994
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 1990.
Drawdown maintained until June 30, 1991
Assume refill time for upstream lakes of 6 months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Existing Conditions
w/Project Conditions
Diamond Lake Outlet
Lake Level (NAVD 88)
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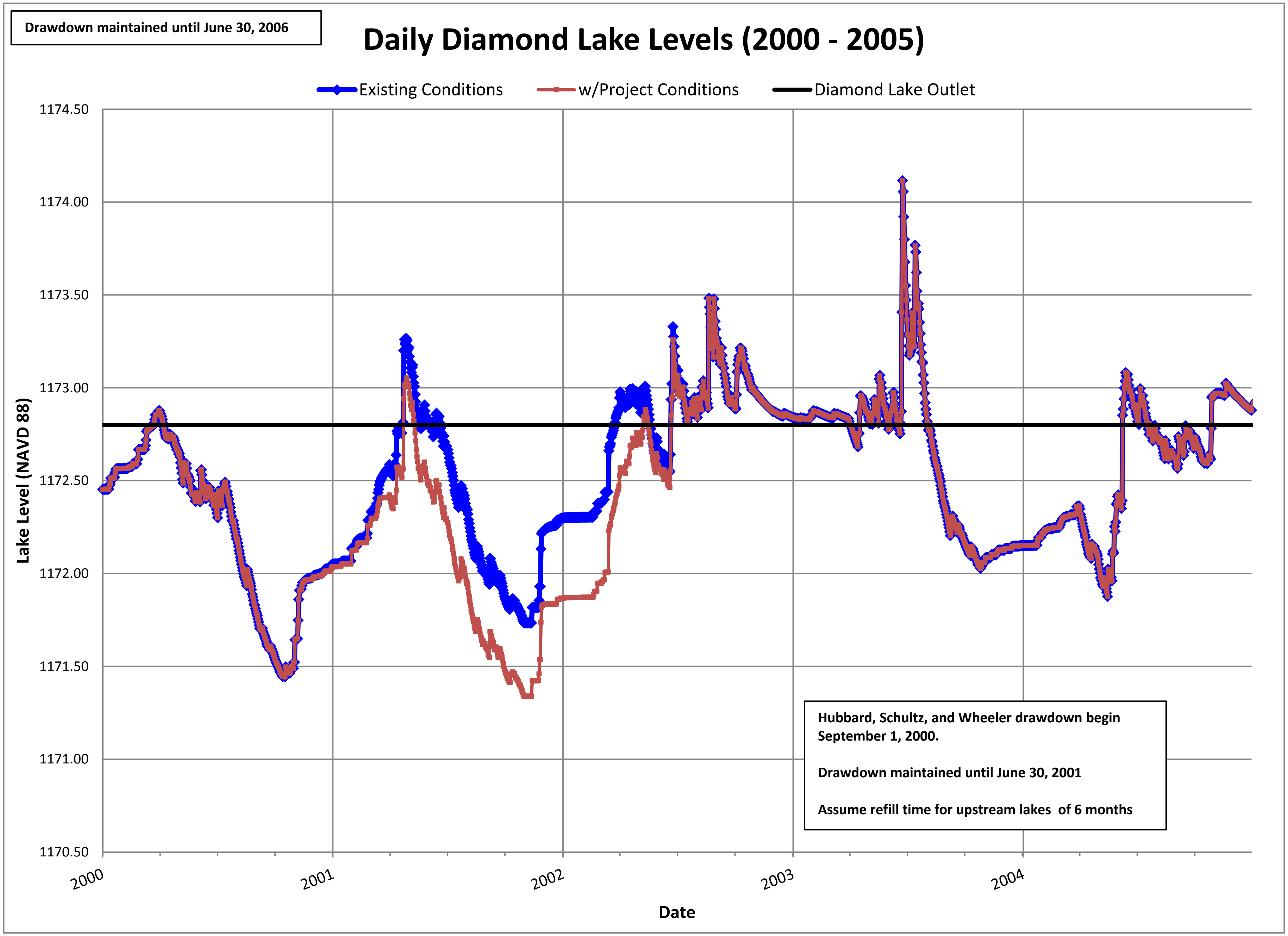
1172.50
1172.00
1171.50
1171.00
1170.50
1995
1996
1997
1998
1999
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 1995.
Drawdown maintained until June 30, 1996
Assume refill time for upstream lakes of 6 months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Existing Conditions
w/Project Conditions
Diamond Lake Outlet
Lake Level (NAVD 88)
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1172.50
1172.00
1171.50
1171.00
1170.50
2000
2001
2002
2003
2004
Date
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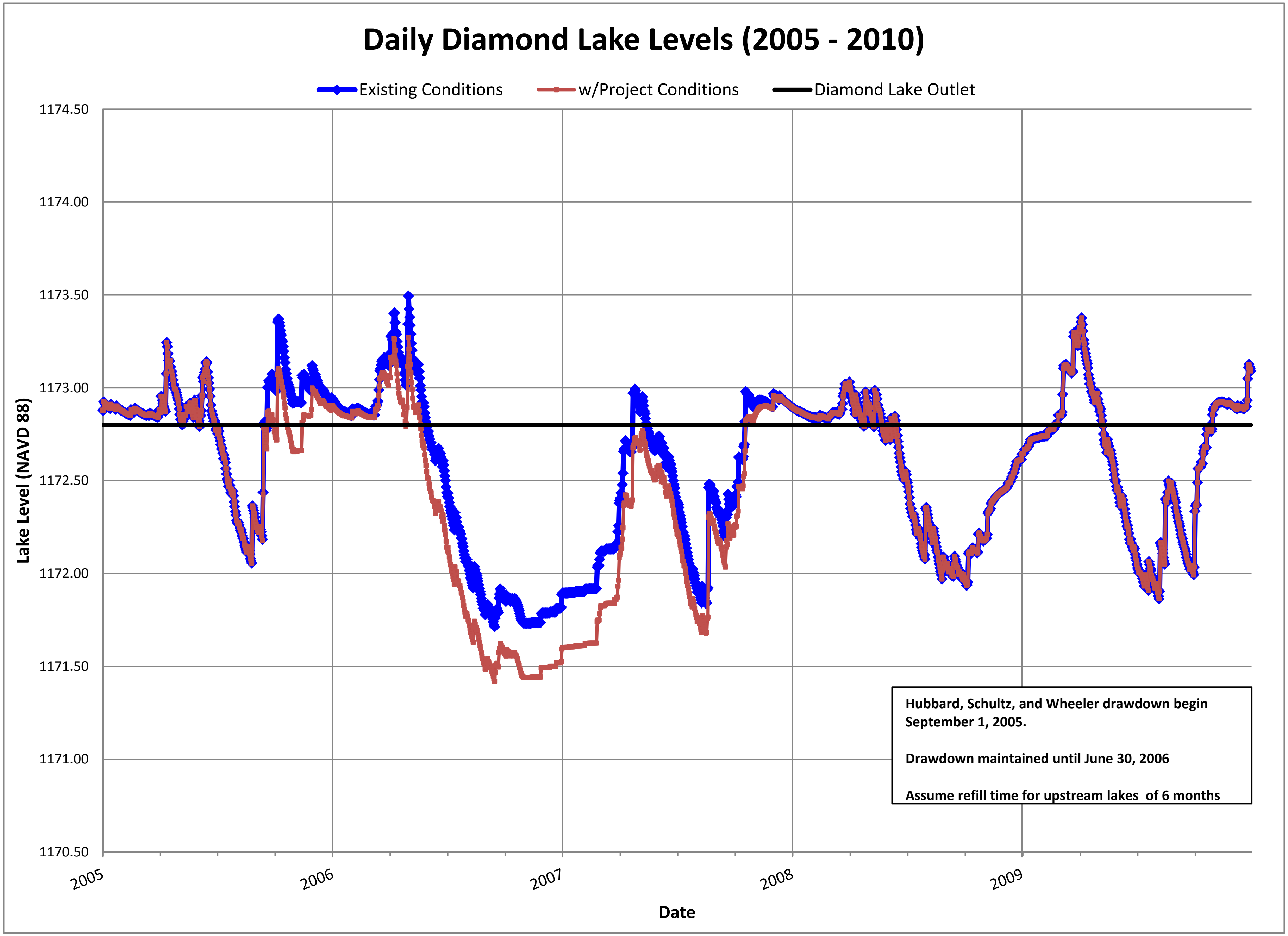
Drawdown maintained until June 30, 2001
Assume refill time for upstream lakes of 6 months



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Existing Conditions
w/Project Conditions
Diamond Lake Outlet
Lake Level (NAVD 88)
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1173.50
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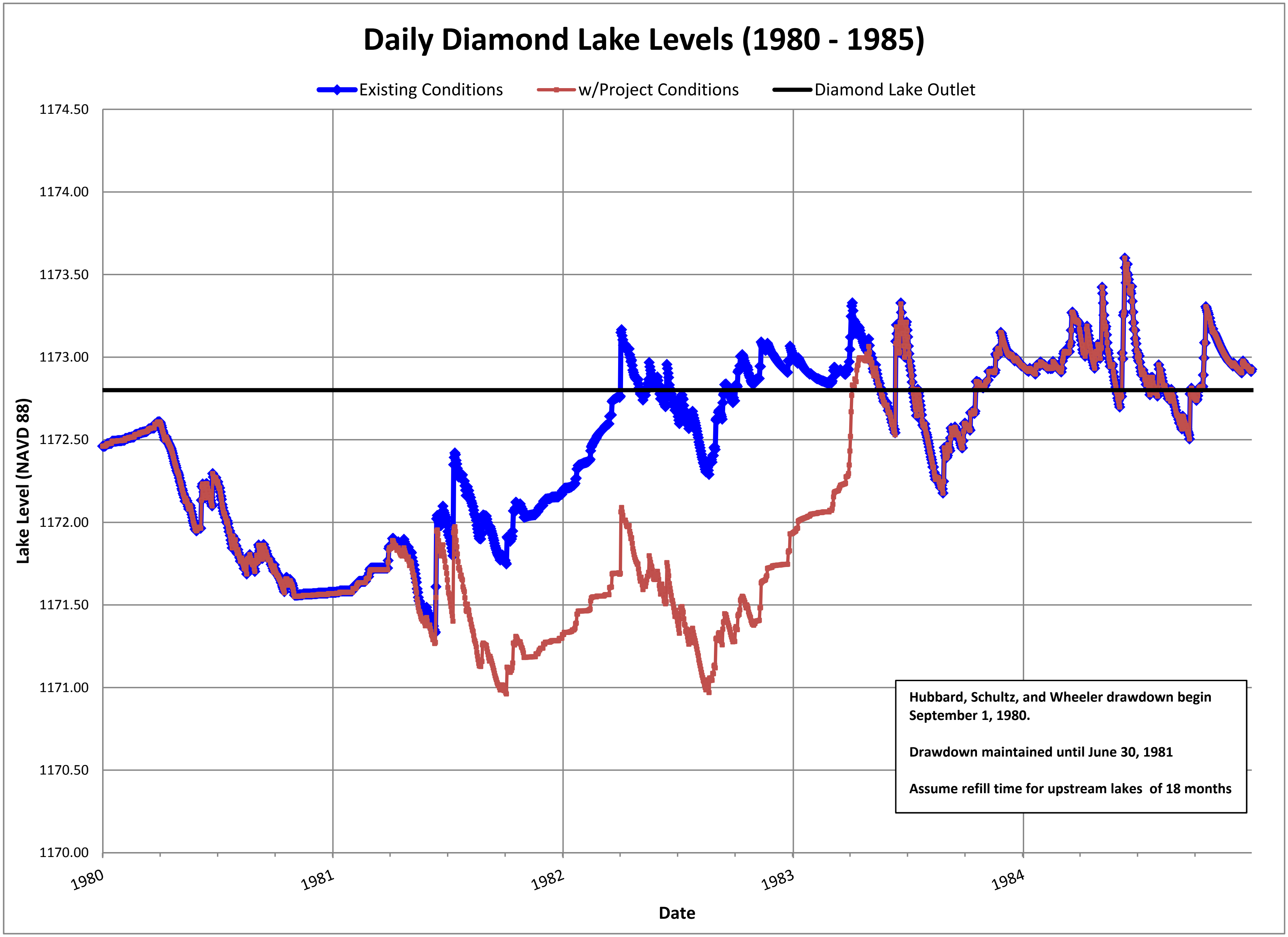
1172.50
1172.00
1171.50
1171.00
1170.50
2005
2006
2007
2008
2009
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 2005.
Drawdown maintained until June 30, 2006
Assume refill time for upstream lakes of 6 months

APPENDIX D



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Existing Conditions
w/Project Conditions
Diamond Lake Outlet
Lake Level (NAVD 88)
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1174.00
1173.50
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1172.50
1172.00
1171.50
1171.00
1170.50
1170.00
1980
1981
1982
1983
1984
Date
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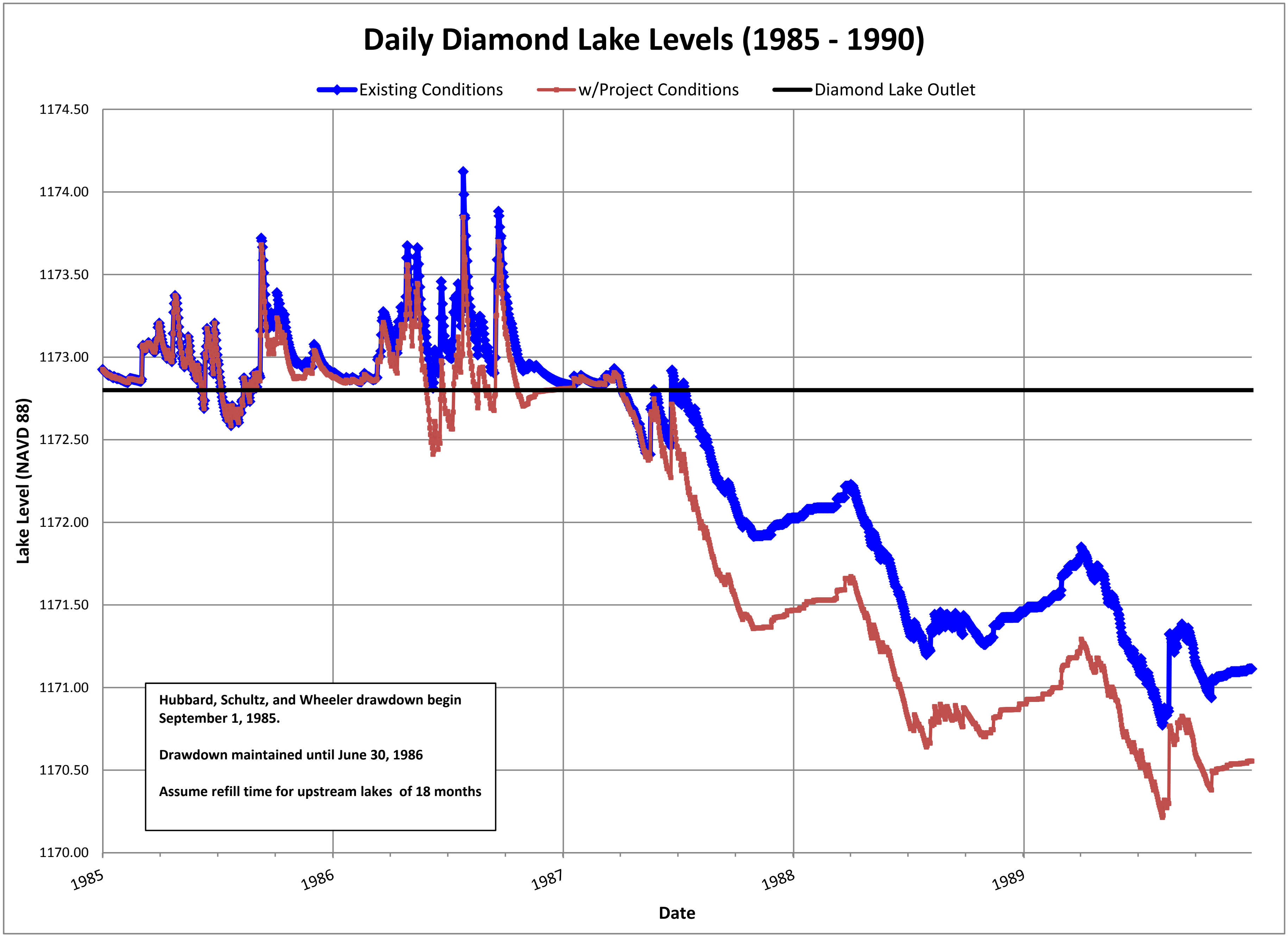
Drawdown maintained until June 30, 1981
Assume refill time for upstream lakes of 18 months



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Existing Conditions
w/Project Conditions
Diamond Lake Outlet
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1173.50
1173.00
1172.50
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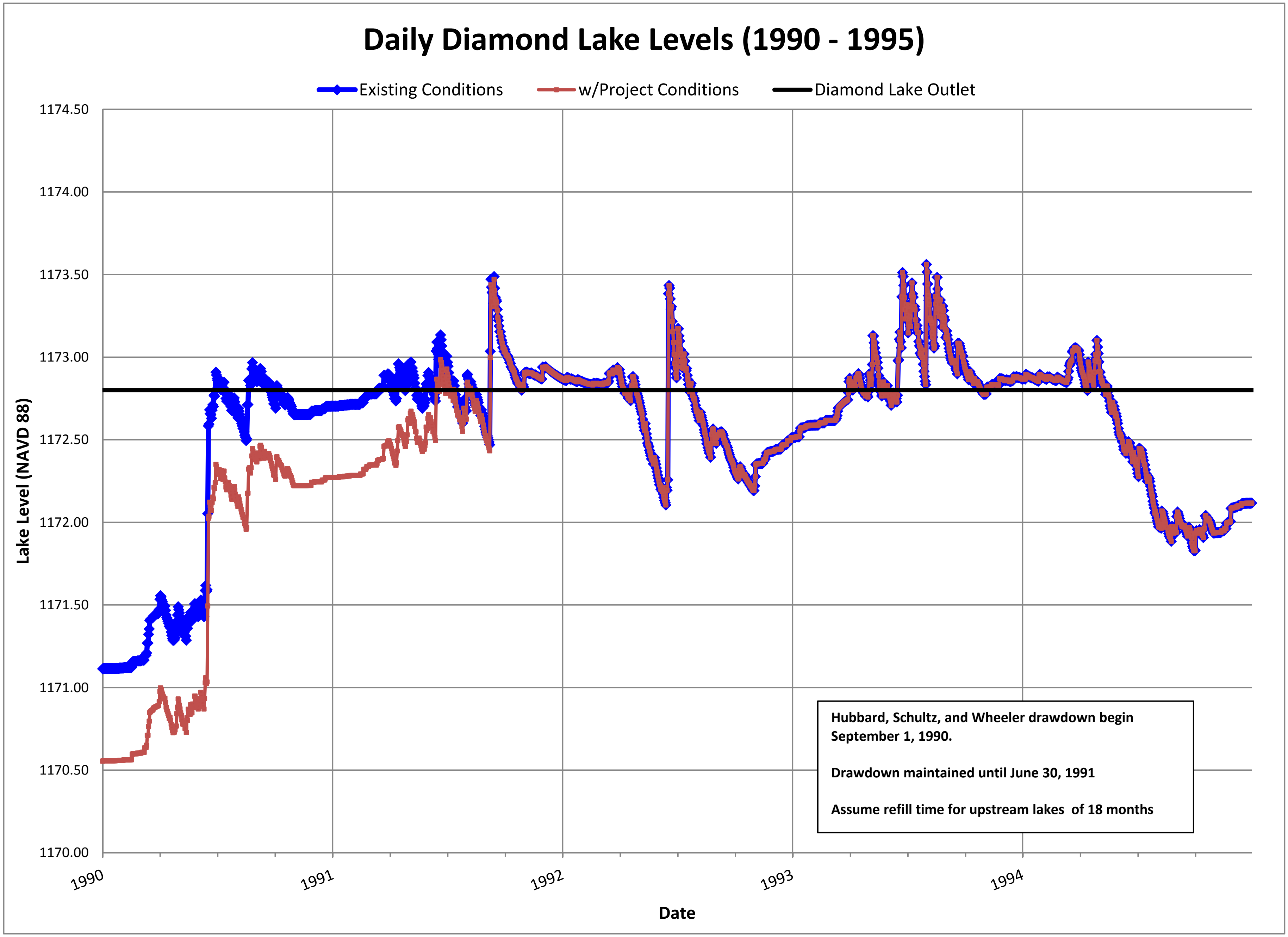
1171.50
1171.00
1170.50
1170.00
Lake Level (NAVD 88)
1985
1986
1987
1988
1989
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 1985.
Drawdown maintained until June 30, 1986
Assume refill time for upstream lakes of 18 months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Existing Conditions
w/Project Conditions
Diamond Lake Outlet
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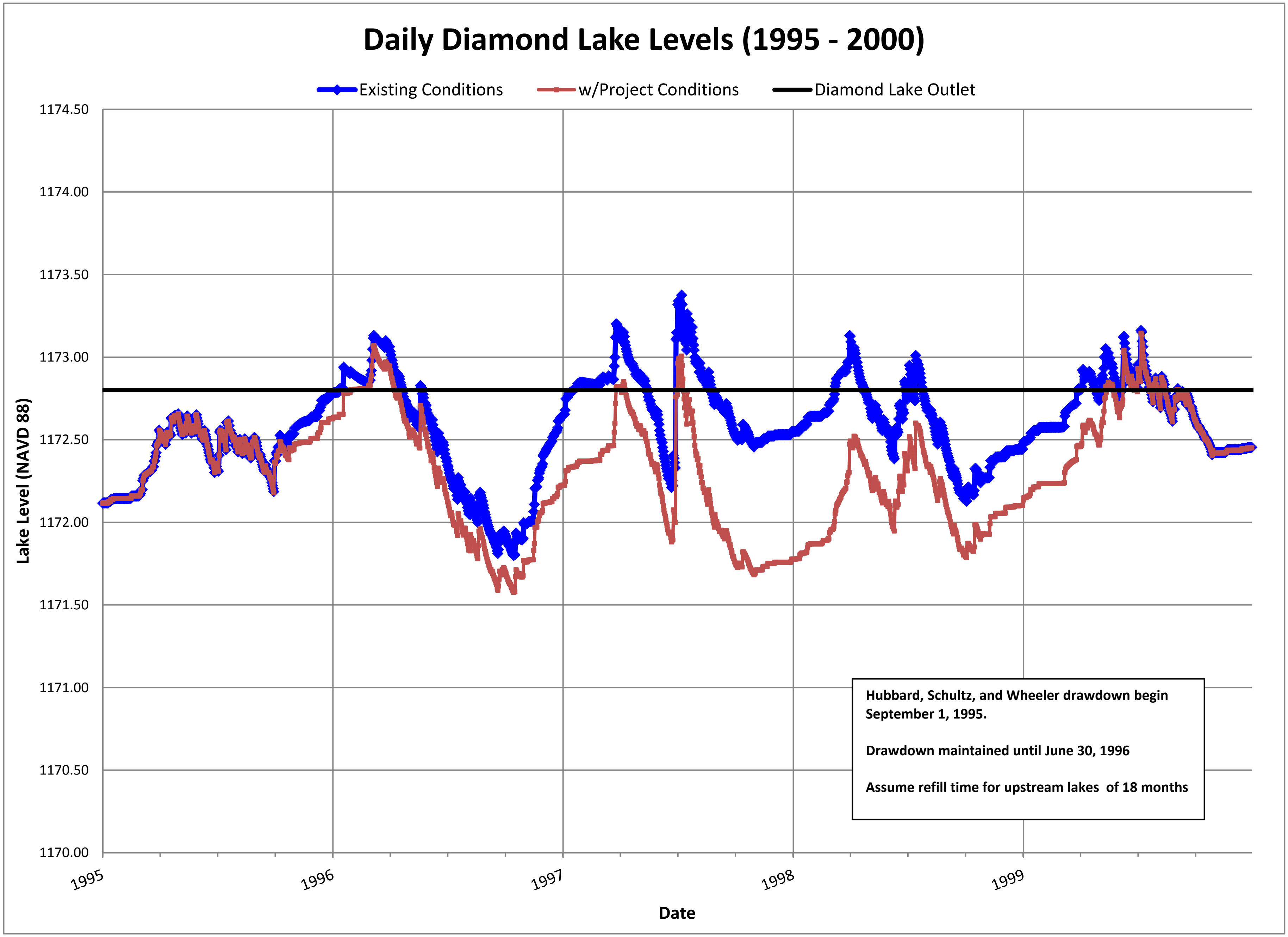
1171.50
1171.00
1170.50
1170.00
Lake Level (NAVD 88)
1990
1991
1992
1993
1994
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 1990.
Drawdown maintained until June 30, 1991
Assume refill time for upstream lakes of 18 months


Daily Diamond Lake Levels (1995 - 2000)
Existing Conditions
w/Project Conditions
Diamond Lake Outlet
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1173.50
1173.00
1172.50
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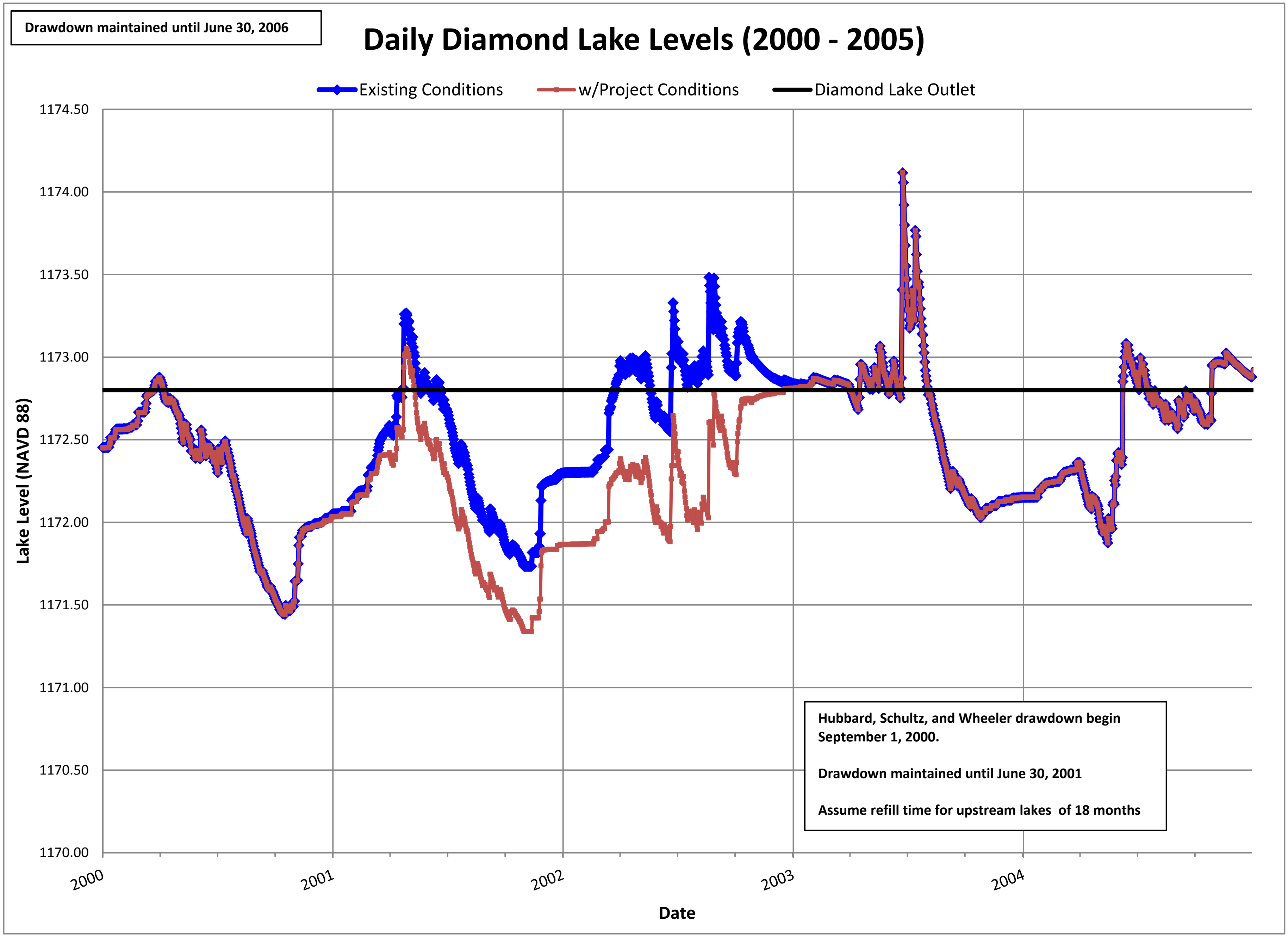
1171.50
1171.00
1170.50
1170.00
Lake Level (NAVD 88)
1995
1996
1997
1998
1999
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 1995.
Drawdown maintained until June 30, 1996
Assume refill time for upstream lakes of 18 months



Drawdown maintained until June 30, 2006
Daily Diamond Lake Levels (2000 - 2005)
Existing Conditions
w/Project Conditions
Diamond Lake Outlet
1174.50
1174.00
1173.50
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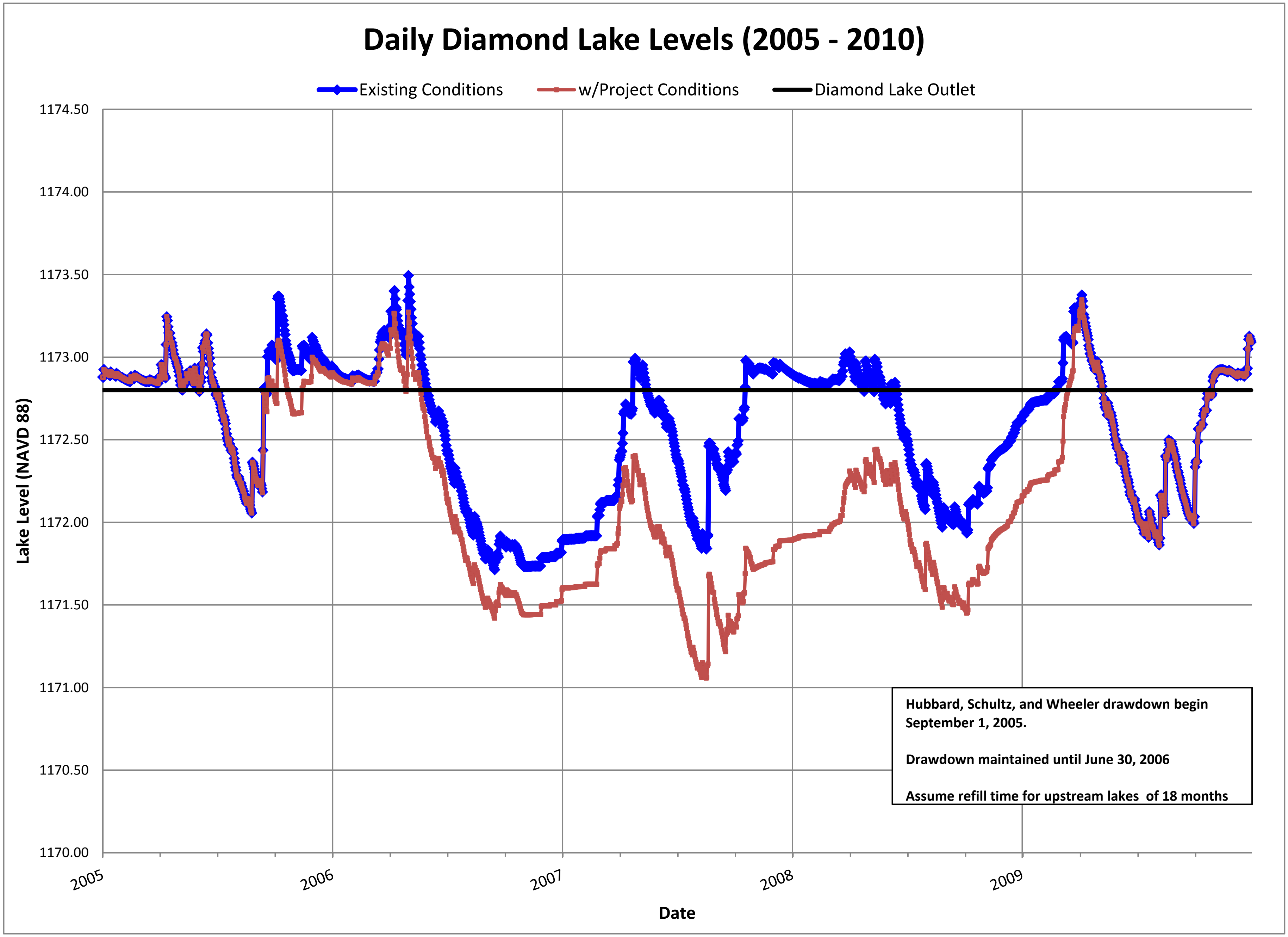
1172.50
1172.00
1171.50
1171.00
1170.50
1170.00
Lake Level (NAVD 88)
2000
2001
2002
2003
2004
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 2000.
Drawdown maintained until June 30, 2001
Assume refill time for upstream lakes of 18 months



Daily Diamond Lake Levels (2005 - 2010)
Existing Conditions
w/Project Conditions
Diamond Lake Outlet
1174.50
1174.00
1173.50
1173.00
1172.50
1172.00
1171.50
1171.00
1170.50
1170.00
Lake Level (NAVD 88)
2005
2006
2007
2008
2009
Date
Hubbard, Schultz, and Wheeler drawdown begin September 1, 2005.
Drawdown maintained until June 30, 2006
Assume refill time for upstream lakes of 18 months

APPENDIX E

Appendix E

Evaluation of Additional Water Quality Monitoring Data since TMDL

As discussed in Section 4.3.1 of this Engineer's Report, additional water quality monitoring data since 2009 was evaluated to determine if water quality has changed significantly or has remained unchanged. The locations of In-lake monitoring stations providing water quality data used in the 2011 Diamond Lake TMDL are shown in Error! Reference source not found. of the report.

Hubbard / South Wheeler Lake

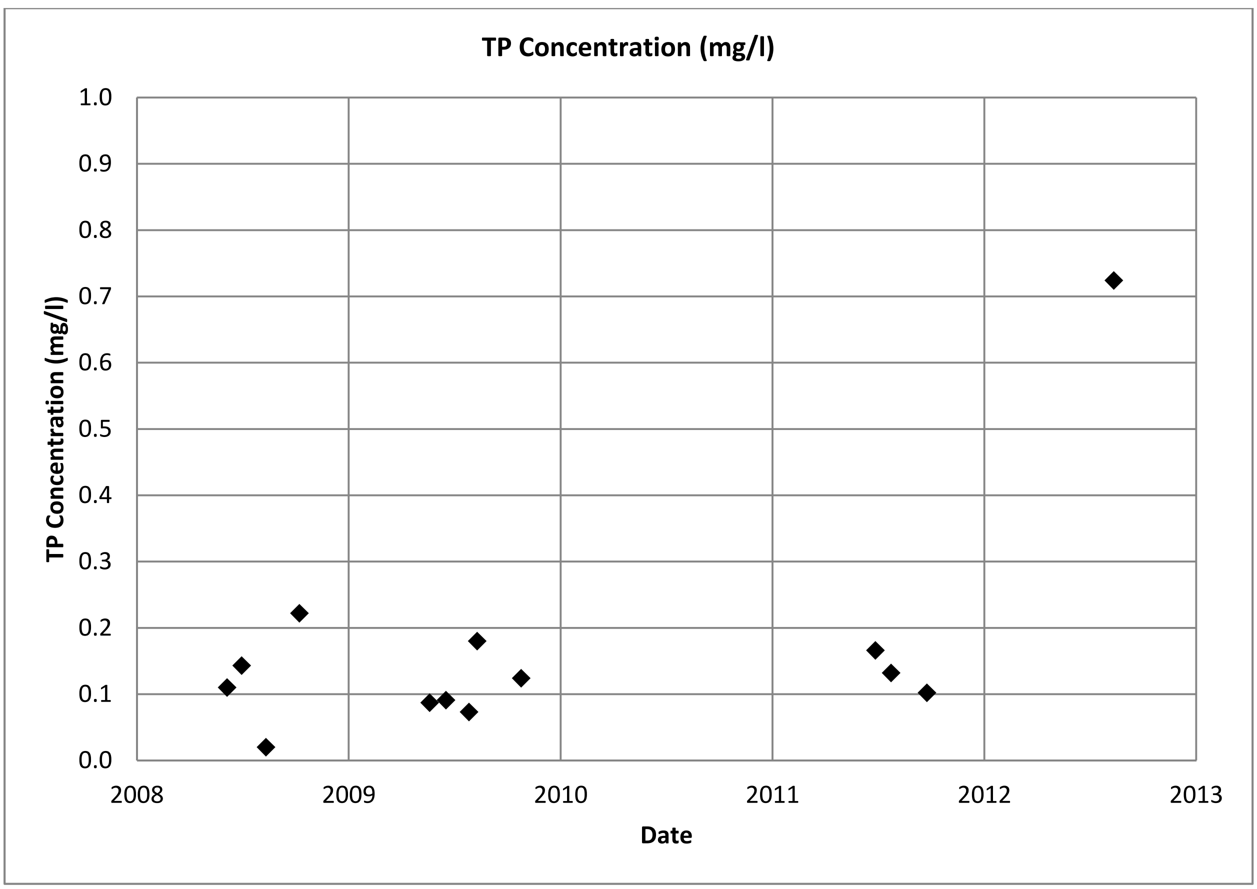
At the in-lake monitoring station HL1 on South Wheeler, there has been no further data collected after 2009. However, there were samples taken at another location in Hubbard Lake (see Error! Reference source not found.) which are reported on the EDA website and listed in Table 1 and shown in **Figure 2**. The mean value of all of the TP concentration measurements of 0.167 mg/l, which is higher than the mean value for 2008 and 2009 of 0.117 mg/l. For the purposes of estimating the water quality benefits of the proposed project, as well as water quality impacts to CD 28 (see **Section** Error! Reference source not found. and **Section** Error! Reference source not found.), the value of 0.167 mg/l will be assumed as the existing in-lake TP concentration.

Figure 1: Location of In-lake Monitoring Station in Hubbard Lake (EDA Station 34-0054-00-202)

Table 1: Water Quality Samples in Hubbard / South Wheeler Lake Subsequent to 2009 (MPCA)

Date	Location	TP (mg/L)	TSS (mg/l)
06/05/08	HL1	0.110	3
06/30/08	HL1	0.143	2
8/11/2008	HL1	0.020	2
10/8/2008	HL1	0.222	22
5/21/2009	HL1	0.087	8
6/18/2009	HL1	0.091	1
7/28/2009	HL1	0.073	7
8/11/2009	HL1	0.18	29
			40
10/26/2009	HL1	0.124	10
6/30/2011	34-0054-00-202	0.166	
7/27/2011	34-0054-00-202	0.132	
9/27/2011	34-0054-00-202	0.102	
8/15/2012	34-0054-00-202	0.724	
Mean		**0.167**	**12.4**

Figure 2: Total Phosphorus Measurements in South Wheeler and Hubbard Lakes



North Wheeler Lake

At the in-lake monitoring station WL1 on North Wheeler, there has been no further data collected after 2009. However, there were samples taken at two other locations in North Wheeler (see **Figure 3**and **Figure 4**) which are reported on the EDA website and listed in **Table 2** (also see Figure 5). Note that the mean of all the TP concentration readings of 0.333 mg/l is slightly lower than the mean concentration based on just 2008 and 2009 data of 0.354 mg/l.

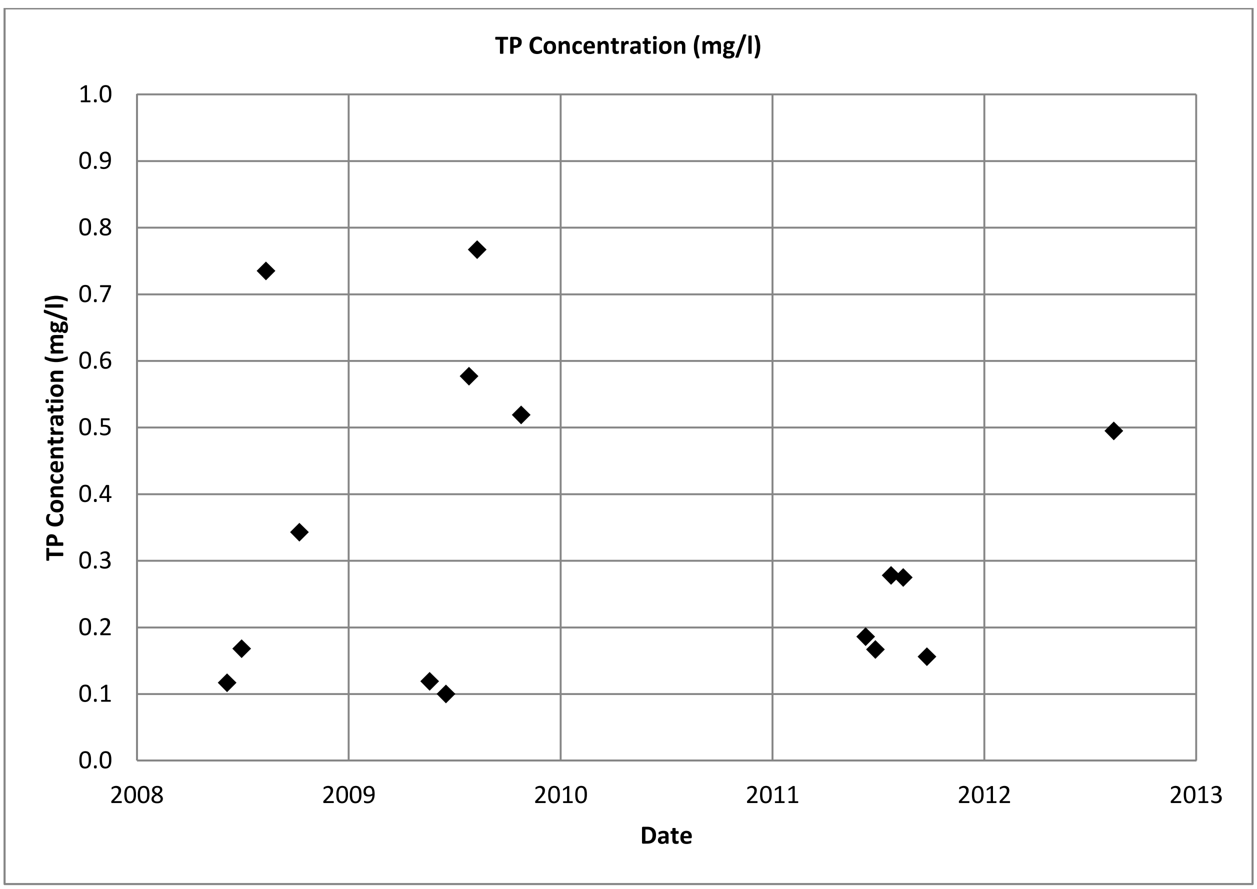
Figure 3: Location of In-lake Monitoring Station in North Wheeler Lake (EDA Station 34-0051-00-201)

Figure 4 Location of In-lake Monitoring Station in North Wheeler Lake (EDA Station 34-0051-02-201)

Table 2: Water Quality Samples for North Wheeler Lake Subsequent to 2009 (MPCA)

Date	Location	TP (mg/L)	TSS (mg/l)
06/05/08	WL1	0.117	4
06/30/08	WL1	0.168	9
8/11/2008	WL1	0.735	61
10/8/2008	WL1	0.343	37
5/21/2009	WL1	0.119	9
6/18/2009	WL1	0.100	7
7/28/2009	WL1	0.577	57
8/11/2009	WL1	0.767	55
10/26/2009	WL1	0.519	58
6/13/2011	34-0051-00-201	0.186	
6/30/2011	34-0051-02-201	0.167	
7/27/2011	34-0051-02-201	0.278	
8/17/2011	34-0051-02-201	0.275	
9/27/2011	34-0051-02-201	0.156	
8/15/2012	34-0051-02-201	0.495	
Mean		**0.333**	**30.5**

Figure 5: Total Phosphorus Measurements in North Wheeler Lake



Schultz Lake

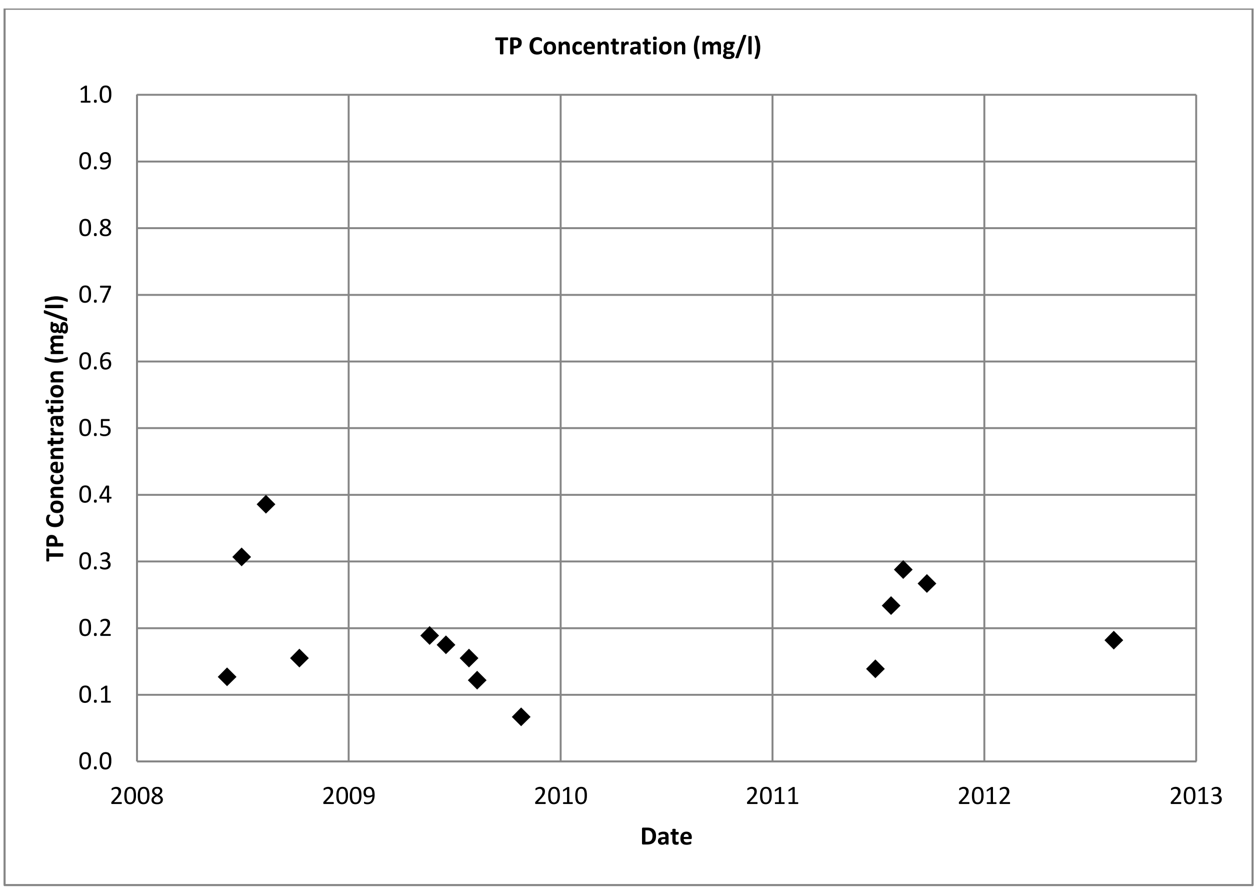
At the in-lake monitoring station SL1 on Schultz Lake (see Error! Reference source not found.), there has been one further data collected after 2009. There were also samples taken at another location in Schultz Lake (see **Figure 6**) which are reported on the EDA website and listed in Table 3 and shown in **Figure 7**. Note that the mean of all the TP concentration readings of 0.200 mg/l is slightly higher than the mean for just 2008 and 2009 of 0.187 mg/l.

Figure 6: Location of In-lake Monitoring Station in Schultz Lake (EDA Station 34-0049-00-202)

Table 3 Water Quality Samples for Schultz Lake Subsequent to 2009 (MPCA)

Date	Location	TP (mg/L)	TSS (mg/l)
06/05/08	SL1	0.127	54
06/30/08	SL1	0.307	130
8/11/2008	SL1	0.386	164
10/8/2008	SL1	0.155	54
5/21/2009	SL1	0.189	40
6/18/2009	SL1	0.175	11
7/28/2009	SL1	0.155	10
8/11/2009	SL1	0.122	16
10/26/2009	SL1	0.067	48
6/30/2011	SL2	0.139	
7/27/2011	34-0049-00-202	0.234	
8/17/2011	34-0049-00-202	0.288	
9/27/2011	34-0049-00-202	0.267	
8/15/2012	34-0049-00-202	0.182	
Mean		**0.200**	**53.7**

Figure 7: Total Phosphorus Measurements in Schultz Lake



Diamond Lake

TP data collected since the Diamond Lake TMDL has also been evaluated because it is important in the assessment of downstream water quality impacts. There are two in-lake monitoring stations in Diamond Lake, DL3 and DL4. Both surface and bottom water quality data was monitored in 2008 and 2009 for stations DL3 and DL4, however, the surface TP is only used in this analysis since it will be more likely represent the outflow from the lake to CD 28. **Table 4** shows all data collected for these two stations. The mean TP concentrations for 2008 and 2009 are 41 ug/l and 36 ug/l for DL3 and DL4, respectively. No further data was collected at station DL4 subsequent to 2009. However, there is data through 2012 for DL3. The mean in-lake TP concentration for the entire data collection period is 58 ug/l, well exceeding the total phosphorus water quality numeric standard of the MPCA of 40 ug/l.

Table 4: Diamond Lake Monitoring Data from 2008 to Present

Date	Total Phosphorus (μg/l)		Total Suspended Solids (mg/l)	
	DL3	**DL4**	**DL3**	**DL4**
02/05/08	18	15	2	1
03/18/08	25	19	0	0
05/05/08	29	32	2	2
05/22/08	30	30	7	4
06/04/08	91	32	4	1
06/18/08	38	33	3	3
07/08/08	36	34	6	8
07/22/08	24	33	3	2
08/06/08	62	65	9	7
08/20/08	54	40	10	5
09/03/08	72	70	14	12
09/24/08	46	42	3	4
10/08/08	43	40	5	5
05/21/09	38	35	7	9
06/17/09	39	25	0	0
07/27/09	24	27	2	3
08/31/09	36	35	6	7
10/14/09	33	39	11	10
05/07/10	41		2	
05/17/10	44		5	
05/31/10	34		3	
06/21/10	89		11	
06/28/10	63		6	
07/11/10	57		8	
07/25/10	127		17	
08/08/10	93		13	
08/22/10	209		41	
09/06/10	136		18	
09/21/10	98		14	
05/15/11	32		4	
05/22/11	43		5	
06/19/11	31		4	
06/26/11	31		12	
07/11/11	26		4	
07/24/11	44		6	
08/07/11	58		7	
08/21/11	114		8	
09/12/11	86		10	
09/26/11	97		10	
05/15/12	20		1	
05/20/12	28		2	
06/03/12	41		3	
06/18/12	70		3	
07/01/12	23		3	
07/15/12	28		1	
07/29/12	65		7	
08/19/12	100		21	
08/26/12	74		11	
09/09/12	100		13	
Mean	**58**	**36**	**7.5**	**4.6**