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for the Minnesota Pollution Control Agency

Malmedal Lake Drawdown Plan

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water | ecology | community

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1 BACKGROUND

A Draft Total Maximum Daily Load (TMDL) and a draft implementation plan was prepared for Malmedal Lake as part of the Pope county 8 Lakes TMDL study for Lake Emily, Malmedal, Gilchrist, Pelican, Strandness, Ann, Reno, and Leven located in Pope County, Minnesota. The lakes are all listed on the State of Minnesota's 303d list for aquatic recreation impairment due to nutrients/eutrophication. Through the development of the TMDL for Malmedal Lake it was determined that water quality is primarily driven through in lake processes; therefore, the implementation plan for Malmedal primarily focuses on reducing internal loading. In the Pope County 8 Lakes TMDL report it states a reduction of 1,052 lb/yr of Total Phosphorus (TP) is needed in the load of Malmedal Lake. The TMDL estimates that the internal loading to Malmedal Lake is 124 – 816 lb/yr with the low end of the range occurring after a recorded winterkill of Malmadal Lake. It is estimated that a drawdown of Malmedal Lake could result in a reduction of 75% of the TP reduction needed for the TMDL. This reduction will further benefit Strandness Lake because in the TMDL report 45% of the annual TP load coming into Strandness Lake is coming from Malmedal Lake. In both the draft TMDL and implementation plan for Malmedal Lake a lake drawdown and installation of fish barriers are identified as an approach to reestablish the macrophytes, control the benthic fish, and consolidate sediments.

2 DATA COLLECTION

During the Phase I part of this effort all structures connecting to and both Malmedal Lake Strandness Lake and found in the flowage area of Trappers Run between both lakes were identified, located by GPS using Pope County coordinates and associated elevation data was gathered. All inlets and outlets to Malmedal Lake and Strandness Lake were located by GPS using Pope County coordinates and associated elevation data was gathered including centerline channel information and channel cross section information for each. The entire channel of Trappers Run between Malmedal Lake and Strandness Lake was surveyed with a center line profile taken and regular cross sections taken. Present habitat conditions were observed and any stability issues were identified. Bathymetry data was gathered both on Trappers wetland and a connected shallow unnamed waterbody connected to Malmedal Lake.

3 FLOW ANALYSIS

Trapper's Run flows were analyzed in the area of Malmedal Lake and Strandness Lake by using an XP-SWMM model and all available hydrologic data.

3.1 Model Description

The hydrologic and hydraulic investigations of Malmedal Lake were conducted in XP-SWMM modeling software. This model was chosen for its flexibility and versatility. The hydrologic portion of this model was created using Green-Ampt methodology to facilitate design storms, continuous simulation and snowmelt modeling. This software also allows the flexibility of modeling pumps, siphons, natural channels and culverts utilizing the fully dynamic energy-momentum equations. The creation of this model was supported by:

- Topographic Survey (see data collection section)
- Bathymetric Survey
- Pope County LIDAR
- Soil Survey
- 2008 Aerial Photography

3.2 Monitored and Observed Flows

The Trappers Run Watershed Project monitored flows in 1994 and 1995 both at the outlet of Malmedal Lake and the outlet of Pepple's Slough. Flows were again monitored in July- October, 2009 at locations downstream of Strandness Lake near Highway 15.

The 1994-95 monitoring period shows similar flows at the Malmedal and Pepple's locations. Recorded flows vary between 1 and 15 cfs throughout the monitoring period. The peak flow of ~15 cfs was recorded on 7/11/1994 following a 5-day period with 3.4" of rain.

The 2009 monitoring period recorded very little flow. Recorded flows vary between 0.7 and 3.5 cfs throughout the monitoring period. A steady baseflow signature is seen during this monitoring period at 0.7 cfs at this location. The peak flow of 3.5 cfs was monitored on 10/6/2009 following a 1.0" rainfall.

3.3 Drawdown Volume

A primary parameter of a lake drawdown is to calculate the volume that will need to be removed to complete the drawdown. This must take into account not only the existing volume of water in the lake but inputs the lake will receive during the estimated drawdown period. Table 1 summarizes the hydrologic inputs to Malmedal Lake over a 2-month fall drawdown period. Figure 1 shows the estimated drawdown time given a flow rate and can be used to select a drawdown flow rate that balances channel capacity with drawdown time.

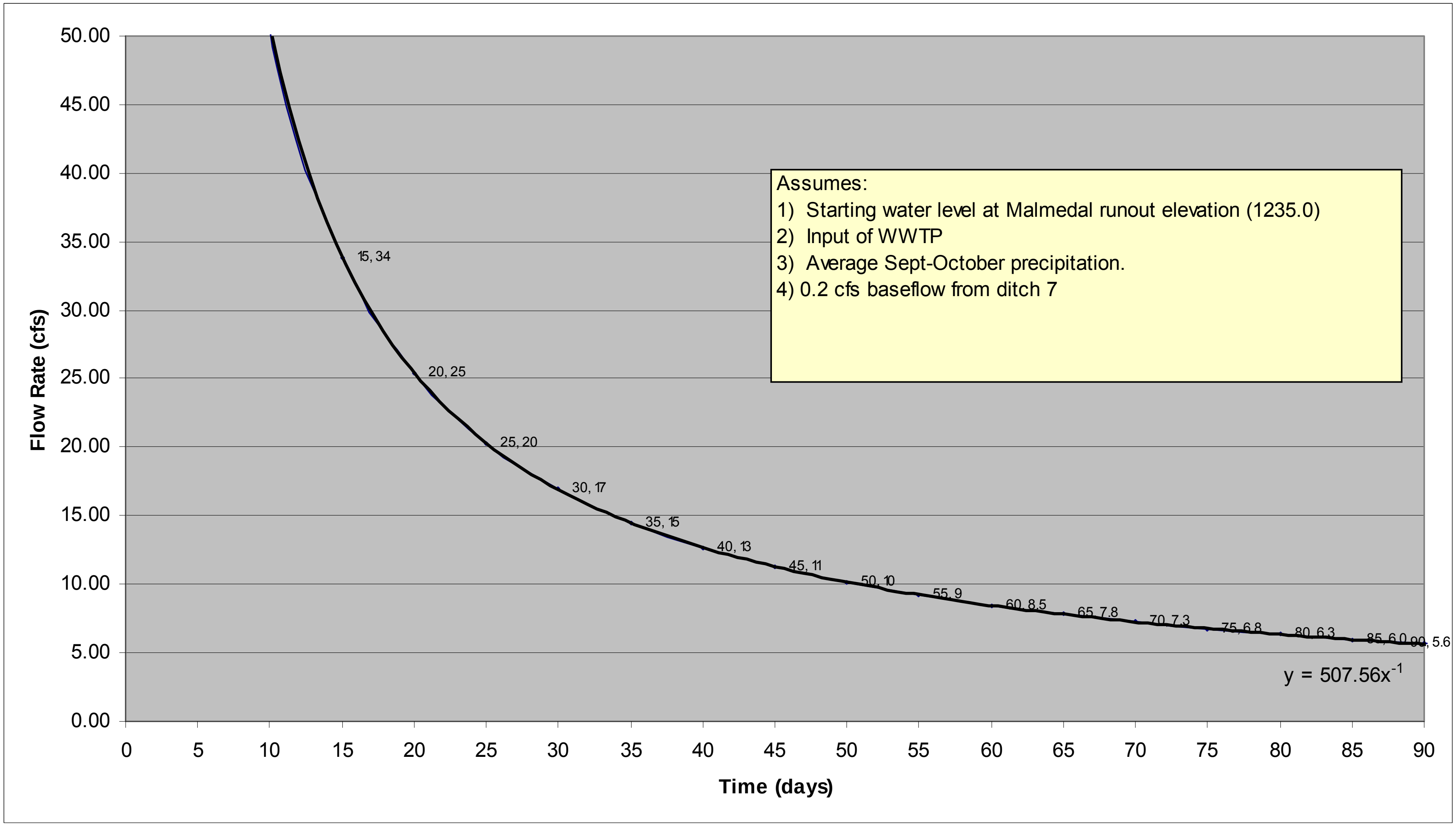

Figure 1. Malmedal Lake Drawdown Curve

Table 1. Malmedal Lake drawdown volumes (2-months of drawdown)

	Volume (ac-ft)	Fraction of Total Volume (%)	Source
Malmedal Volume at Outlet (1235.01)	858	85%	Bathymetric Survey
Average Runoff Volume Sept-Oct	78	8%	XP-SWMM
Lowry Discharge	13	1%	Monitored Average
Potential Ditch 7 Baseflow	26	3%	Trappers Run Watershed Study
Malmedal East Pond Volume	31	3%	Bathymetric Survey
Total	**1007**	**100%**	

Lake Volume

The volume of the lake was calculated by bathymetric survey. The depth-area curve was input into XP-SWMM and the volume was calculated. The volume at the primary outlet of the lake (1235.01) is 858 ac-ft.

Precipitation

Historic precipitation patterns were reviewed by using the University of Minnesota Climatology website at the Target location: lat 45.68180 lon 95.46157 and default retrieval settings. The average annual rainfall for the period of record (1886-2010) is 23.8" at this location. (Figure 1) Data for the period 1950-2011 were reviewed and monthly totals arranged into a matrix. (Tables 2 and 3) Table 1 shows that ideal drawdown would take place during the fall or early winter. Due to the likelihood of freeze-up by early December, the target drawdown time was set for September and October. The average fall (Sept-Oct) period was then chosen as 1954, the latest year where both months total precipitation was within 20% of the average monthly precipitation. The daily fall precipitation pattern for 1954 was used in the XP-SWMM model as the probable precipitation for the drawdown period. The 2-month total input to the lake is 78 ac-ft.

Table 2. Average Monthly Precipitation

Month	Average
Jan	0.60
Feb	0.54
Mar	1.03
Apr	2.18
May	3.19
Jun	3.88
Jul	3.34
Aug	3.17
Sep	2.52
Oct	1.84
Nov	0.99
Dec	0.56

Table 3. 1950-2011 Monthly Precipitation Summary

Month	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Jan	1.38	1.14	2.42	0.57	0.27	0.23	0.85	0.19	0.28	0.12	0.42	0.06	0.58	0.25	0.13	0.22	0.54	1.17
Feb	0.13	0.32	1.06	0.81	1.19	0.37	0.12	0.44	0.14	0.39	0.02	0.08	1.08	0.28	0.50	0.42	0.43	0.77
Mar	1.67	3.19	1.32	1.56	1.06	0.16	0.86	1.17	0.23	0.07	0.75	0.41	0.59	1.16	1.09	3.30	1.75	0.16
Apr	3.75	2.05	0.73	2.88	5.39	2.12	2.33	1.56	2.89	0.61	2.51	2.24	0.92	2.01	3.20	3.29	1.54	1.51
May	4.16	3.66	2.71	3.41	2.39	2.53	2.40	4.82	2.07	7.15	2.11	2.35	5.81	3.62	0.97	5.89	1.25	0.93
Jun	1.59	6.00	4.34	7.04	3.48	2.42	2.17	8.12	2.48	4.96	2.85	0.98	2.97	4.17	2.06	2.67	3.00	5.14
Jul	3.73	3.21	4.99	1.30	1.78	4.06	3.05	4.46	3.70	1.62	2.14	3.39	8.90	3.20	1.66	5.09	1.56	1.06
Aug	1.19	4.04	5.06	3.64	2.32	3.38	3.80	5.98	2.72	4.55	5.31	2.19	1.60	2.59	6.09	3.11	5.72	0.75
Sep	2.10	1.23	0.55	0.56	2.90	1.31	0.91	3.24	2.43	1.73	2.03	4.16	5.53	2.90	5.19	5.80	2.28	1.58
Oct	1.80	2.92	0.02	0.65	1.63	0.57	1.12	2.46	0.53	1.86	1.25	0.91	0.44	0.85	0.04	2.06	2.82	0.83
Nov	1.01	2.39	0.54	0.82	0.08	0.37	2.48	0.94	2.14	0.15	1.04	0.55	0.37	0.71	0.35	1.21	0.76	0.04
Dec	1.89	1.66	0.10	0.93	0.05	0.81	0.19	0.71	0.07	0.75	0.21	0.49	0.05	0.48	0.29	0.47	0.59	0.51

Month	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Jan	0.31	3.22	0.09	0.92	0.41	0.12	0.05	1.32	0.91	0.73	0.14	1.59	0.56	0.04	0.90	0.52	0.87	0.09
Feb	0.13	1.12	0.12	1.72	0.51	0.40	0.86	0.45	0.55	1.04	0.29	1.33	0.89	1.33	#DIV/0!	0.10	0.28	0.13
Mar	1.00	0.46	0.24	0.39	1.61	1.63	0.46	1.66	1.77	3.03	0.48	1.57	0.74	0.69	1.42	1.05	0.54	3.04
Apr	5.71	2.39	1.62	1.14	2.51	1.09	1.29	2.54	0.59	3.87	3.52	1.46	0.10	1.60	0.90	0.37	2.33	2.05
May	2.11	3.97	2.62	2.63	6.26	4.01	3.62	3.81	0.71	7.70	2.95	2.06	2.54	4.96	2.63	2.05	2.69	4.99
Jun	3.57	1.98	2.84	5.22	2.12	0.83	2.49	5.65	2.45	3.12	4.55	7.73	5.15	5.12	4.08	4.39	6.39	2.83
Jul	1.10	3.27	2.23	1.49	7.38	4.45	2.08	2.20	2.16	4.58	1.72	2.20	3.93	2.20	2.93	3.65	1.14	1.97
Aug	2.84	0.15	0.39	3.54	3.51	3.25	3.27	3.99	0.79	3.87	1.84	1.66	4.91	5.91	2.84	3.17	3.17	3.31
Sep	3.45	2.95	1.63	1.28	0.96	1.33	1.52	1.56	0.33	3.75	4.28	0.00	3.65	1.33	2.38	1.99	2.97	4.14
Oct	4.45	2.70	3.75	8.61	1.81	2.07	0.86	1.05	0.26	1.27	0.00	4.34	1.44	2.97	4.84	2.43	7.05	1.31
Nov	0.45	1.32	4.79	2.03	1.43	1.13	1.32	1.62	0.17	4.06	2.18	0.19	0.11	0.53	0.94	2.82	0.00	2.16
Dec	2.84	1.09	0.28	0.32	1.56	0.82	0.40	0.00	0.29	1.69	0.47	0.18	0.07	0.38	0.29	0.43	0.93	0.30

Month	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Jan	1.84	0.24	0.65	0.41	0.04	0.20	0.72	0.54	0.72	0.59	0.90	1.63	0.90	0.84	0.32	0.62	0.09	0.12
Feb	0.93	0.12	0.06	0.38	0.23	0.58	0.17	0.18	0.51	0.50	0.30	0.18	0.47	0.11	1.18	1.08	0.65	0.15
Mar	0.37	1.39	0.92	1.67	2.20	1.31	1.78	1.69	0.64	2.86	0.48	1.15	0.94	1.19	1.15	0.21	0.63	0.51
Apr	6.07	0.25	0.50	2.01	1.88	5.32	2.66	2.04	3.74	2.98	0.62	1.23	1.18	1.17	0.60	6.35	2.36	0.82
May	4.29	4.85	1.41	2.57	2.07	2.40	2.64	4.79	2.01	3.19	3.53	1.54	3.09	4.70	4.41	2.15	2.30	3.24
Jun	5.38	1.79	0.63	2.37	6.54	7.43	4.04	4.64	3.46	4.40	3.17	3.99	4.77	4.06	2.83	4.47	3.08	6.88
Jul	5.50	2.74	1.58	1.76	1.76	3.43	4.29	4.75	5.16	4.64	1.71	5.28	4.86	2.67	5.74	3.98	9.55	3.13
Aug	4.53	1.06	6.58	6.53	2.95	2.66	1.78	1.81	2.08	5.06	1.72	4.36	2.43	3.79	1.94	1.07	4.10	0.26
Sep	5.65	2.69	4.62	1.49	2.11	4.10	1.64	1.84	2.40	3.44	4.64	1.82	1.00	3.55	1.41	2.95	1.29	2.64
Oct	0.23	0.20	0.55	1.72	3.71	0.51	0.45	0.50	4.66	3.72	3.45	1.81	5.64	0.24	1.80	1.28	3.01	1.22
Nov	1.41	0.74	0.81	0.61	0.10	0.96	1.34	1.89	1.02	0.27	2.14	0.38	0.95	0.02	4.46	1.52	0.52	0.26
Dec	0.00	0.48	0.42	0.17	0.22	0.36	0.50	0.58	0.30	1.01	0.39	0.23	0.33	0.09	0.39	0.26	0.25	0.19

Table 3 – continued

Month	2004	2005	2006	2007	2008	2009	2010	2011
Jan	0.38	1.20	0.08	0.10	0.06	0.34	1.02	0.69
Feb	0.50	0.88	0.33	1.24	0.11	0.69	0.55	0.40
Mar	1.08	0.70	0.90	1.68	1.05	0.43	0.86	1.40
Apr	2.20	2.66	2.65	3.25	1.85	1.01	1.00	1.84
May	4.10	4.03	1.97	2.69	2.71	0.22	2.47	5.35
Jun	4.22	5.83	1.35	2.28	3.28	4.34	3.68	1.83
Jul	4.18	2.16	1.07	0.46	2.86	1.90	6.33	8.92
Aug	3.40	5.25	3.15	1.89	2.43	3.08	6.60	
Sep	4.83	4.04	6.13	6.61	3.15	2.52	5.97	
Oct	1.62	2.49	0.64	4.06	4.45	7.10	2.81	
Nov	0.45	2.05	0.50	0.00	2.45	0.17	0.87	
Dec	0.22	1.50	1.07	0.61	0.93	1.10	1.74	

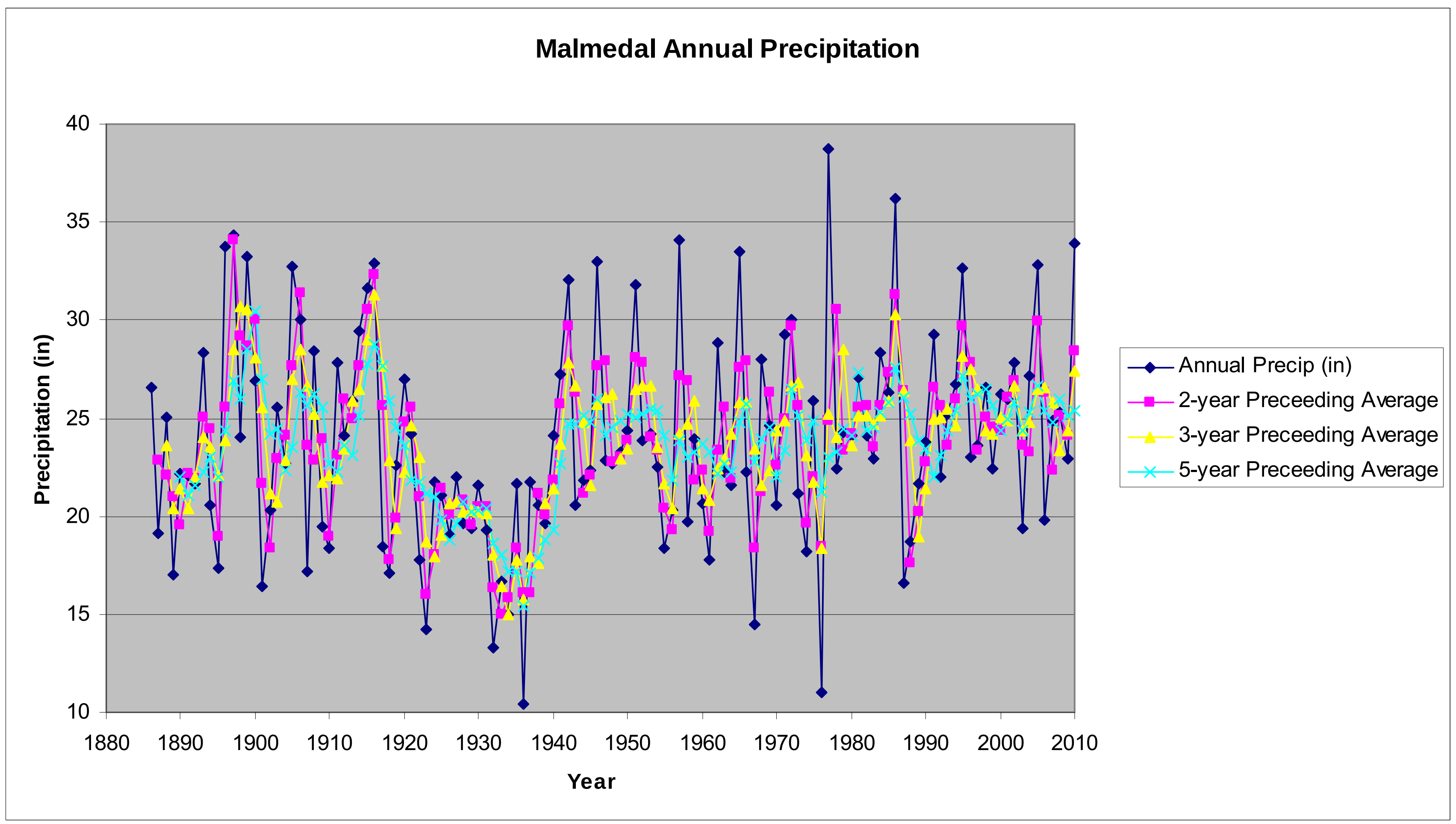

Figure 2. Annual Malmedal Precipitation

Lowry Wastewater Treatment Plant (L-WWTP)

The current L-WWTP was finalized and went on line in 2010 replacing the waste water treatment plan that was put into operation in 1998. The new waste water treatment plant, like previous plants discharges into Ditch 7 which discharges to Malmedal. Reviewing the flow and permit records show that although the L-WWTP is permitted to discharge April-June and September-December 15th, it only has discharged for 2 months of the year since 2008. One spring (either May or June) discharge and one Fall discharge period (October or November) occur each year with the Fall discharge averaging 13 ac-ft of flow over a 30-day period. (Table 4)

Table 4. Lowry WWTP discharge summary 2008-2010

Spring Flow	
Average Spring Flow (May or June) [MG]	5.5
Total Average Spring Flow [CF]	735,243
Total Average Spring Flow [AF]	17
Average Spring Flow (May or June) [mgd]	0.18
Average Spring Flow (May or June) [days]	30
Average Fall Flow (May or June) [cfs]	0.28

Fall Flow	
Average Fall Flow (October or November) [MG]	4.25
Total Average Fall Flow [CF]	568,142
Total Average Fall Flow [AF]	13
Average Fall Flow (May or June) [mgd]	0.14
Average Fall Flow (May or June) [days]	30.6
Average Fall Flow (May or June) [cfs]	0.22

Groundwater

To anticipate the impact of a Malmedal Lake drawdown on the area groundwater table and potential for groundwater inflow into the lake, the Pope County geologic atlas was reviewed. This review shows that groundwater is likely a small hydrologic input to Malmedal Lake and that a drawdown would not be hampered by groundwater inflows.

The geologic atlas shows no surficial aquifers in this area and two buried aquifers. The surficial geology is composed of primarily confining till extending 30-80 feet from the lake bottom. The tops of the two buried aquifers (CW and BROW aquifers) are identified at this same depth. The potentiometric elevation of the CW aquifer is the same as the top of the aquifer. The potentiometric elevation of the BROW aquifer is approximately 50 feet above the lake elevation at 1280 feet. This indicates that the BROW aquifer has potential to contribute groundwater to the lake, although with 30-80’ of confining layer (heavy till) it is unlikely.

The County Well Index was also reviewed for further information regarding the likelihood of groundwater inputs. The review of wells in the area of Malmedal Lake show that the static water elevation below the elevation of the lake and that the only well located on a lakeshore property has a static groundwater elevation of 1,188’, approximately 40’ below the lake’s lowest elevation.

Potential for groundwater discharges to Ditch 7 exists due to elevated groundwater potential in the area of the L-WWTP. The Trappers Run watershed report was reviewed for flow data on

Ditch 7 near the discharge point to Malmedal Lake. This flow data shows that during a dry period in June that flow in Ditch 7 drops to approximately 0.2 cfs. This flow rate will be used as a conservative fall baseflow rate in this creek.

3.4 Channel Capacity

The XP-SWMM model incorporated surveyed cross sections to determine the bankfull discharge of the existing natural channels between Malmedal and Strandness. A user defined hydrograph was used to ramp up the discharge from Malmedal Lake from 0-55 cfs and cross sections with water profiles were reviewed to determine the limiting capacity cross section of each reach. The most restrictive reach in the existing channel between Malmedal and the Pepple's Slough can pass approximately 45 cfs and the channel between Pepple's Slough and Strandness can pass approximately 50 cfs.

3.5 Lake Water Elevation Recovery

Following a drawdown, the lake will take a period of time to recover to pre-drawdown water elevations. This recovery is highly determined by climatic conditions but an estimated rate water recovery can be estimated from regional runoff values and historic precipitation records.

Using the annual runoff method, as described in chapter 7 of the Hydrology Guide for Minnesota, shows that the annual runoff from this watershed is 3.5 inches/year. Multiplying this across the area of the watershed (6,781 acres) shows an average annual runoff volume of 1,978 ac-ft. This calculation shows that the average annual runoff volume of the watershed equals 2.3 times the volume of the lake, indicating the lake should refill the next spring/summer following a drawdown given a normal precipitation year.

Additionally, the annual runoff having a 90 percent chance of occurrence was calculated. This analysis shows that in any given year there is a 90 percent chance the runoff will equal or exceed 1.75 inches. There is a 10 percent chance that the runoff will be less than 1.75 inches. The runoff volume for this 90% occurrence is 989 ac-ft, 1.2 times the volume needed to refill Malmedal Lake to the outlet. This indicates that there is a greater than 90 percent chance that the lake will be completely refilled in the year following the drawdown.

4 FISH BARRIER

A fish barrier is recommended to prevent rapid rough fish repopulation of Malmedal Lake following a drawdown.

4.1 Hydraulic Assessment

Design storms (1, 2, 5, 10, 25, 50, and 100-year) were modeled in XP-SWMM and the return period of flooding in each of the reaches was determined. The graph below shows the hydrographs for the flows through the channel between Pepples Slough and Strandness Lake. The relatively high flows affect the type and size of fish barrier that can be utilized. A typical screen type barrier would need to be very large and would be subject to frequent clogging, therefore the recommended design (as discussed below) would need to be configured in such a way that large flows could be passed.

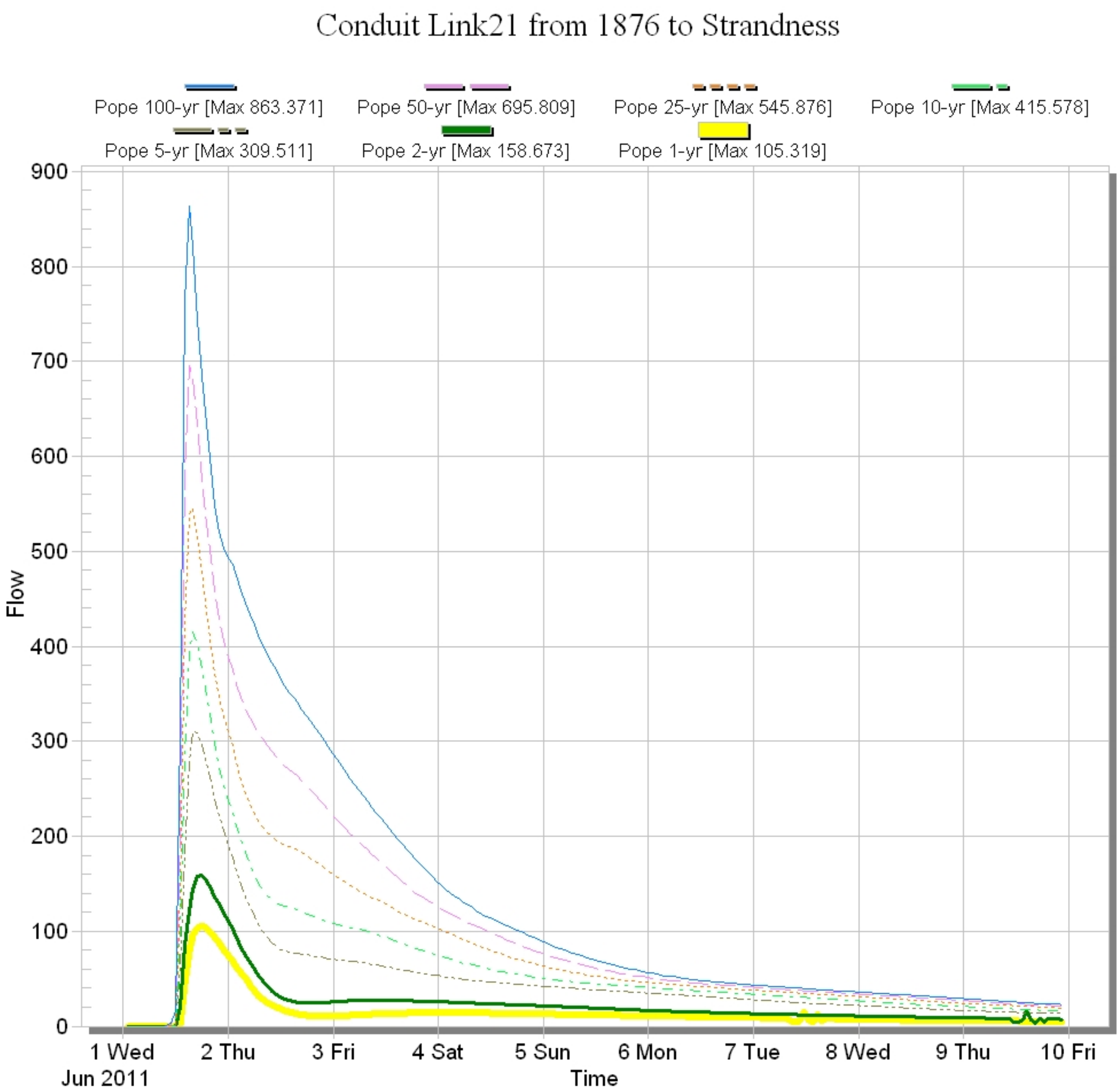

Figure 3. Hydrographs at Pepple Slough Outlet

4.2 Options

Fish barriers come in a variety of different options and configurations. Barriers can be either physically constructed barriers such as screens or grates or the barriers can result from design configurations that produce high velocities or hydraulic drops that prevent fish migration upstream. Electric shock barriers are another option; however the cost and maintenance of this type of barrier are quite high and are only occasional implemented in areas where physical barriers are not feasible.

Traditional grate structures were assessed for both the outlet of Malmedal Lake and Pepple's Slough. Due to the magnitude of the flows that would need to be passed, clogging was a particular concern at both locations and would require frequent maintenance in order to be effective and not affect upstream water levels. An electric barrier was also considered, however the cost for a barrier at these locations would be very high and would require ongoing maintenance and electrical cost. Therefore a physical barrier that reduces clogging and frequency of maintenance is recommended.

As discussed in the drawdown plan it is recommended that both Malmedal Lake and Pepple's Slough be drawn down to consolidate sediment and provide for fish kills over the winter. Therefore, it is recommended that a fish barrier be placed at the outlet of Pepple's Slough to eliminate fish passage upstream. The proposed location is identified in the figure below.

Figure 4.

It is recommended that the existing berm outlet of Pepple's Slough, currently in disrepair, be improved to provide a more stable outlet. The recommended repair is a sheet pile weir approximately 20-feet wide be installed to mimic the existing outlet of the wetland. At the time of the installation it is recommended that approximately 100-feet of channel downstream of the outlet be maintained such that there will be a hydraulic drop of approximately 3-feet under typical flow conditions. Additional clean out of any deadfalls or obstructions in the channel further downstream should also be removed to ensure free flow. This weir by its self will provide an impediment to fish passage. However, some passage of fish would still likely occur due to fish jumping and loss of the hydraulic drop due to high tailwater occurrences during high flow events.

To address the fish jumping issue and further restrict passage, horizontal bars could be attached to the face of the weir. These bars should project out close to the top of the structure and out over the downstream water level. As fish attempt to jump up through the falling water they will hit the bars and fall back down below.

To provide an additional safety factor in preventing fish passage during high water flow, hanging vertical bars could be incorporated. A small bridge or overhanging bar would need to be constructed above the weir. The overhanging vertical bars would need to have the ability to swing out to pass large debris. This would help prevent fish passage upstream during high flows when the weir is completely submerged. Below is an example of a design that incorporates this type of barrier.

The proposed design would be intended to prevent passage of all sizes of fish under the majority of flow conditions. However, fish barriers are never 100% effective and things such as large storm events, human transport, high tail-water conditions and lack of maintenance can all lead to occasional fish passage. The fish barrier should be considered as one tool in preventing rapid re-colonization of Malmedal Lake and Pepple's Slough. Future management of rough fish in the upstream lakes will likely be required at some point in the future.

A permit will be required from DNR waters for placement of the fish barrier. Coordination with DNR during design is recommended to ensure that the project goals are being satisfied while complying with DNR regulations.

Figure 5. Highway 13 Wetland Fish Barrier (Prior Lake Spring Lake Watershed District, located in Scott County)

4.3 Concept Design

The concept design for the sheet pile weir is provided below. If desired the weir could incorporate stop logs that could be removed for future drawdowns. A preliminary planning estimate for construction cost is $50,000 for the weir without the additional fish barrier components. The cost of this structure would be highly dependent on the depth to mineral soils. The piles would need to be driven to a depth that provides structural stability. Soil borings and a structural analysis would be required. It is also recommended that the XP-SWMM model be further refined during the design process as the existing model may be over predicting peak flows due to upstream storage not being fully accounted for. It will be important to mimic the existing outlet as to not increase downstream flows, but at the same time make sure that the structure will be able to pass the larger storm events.

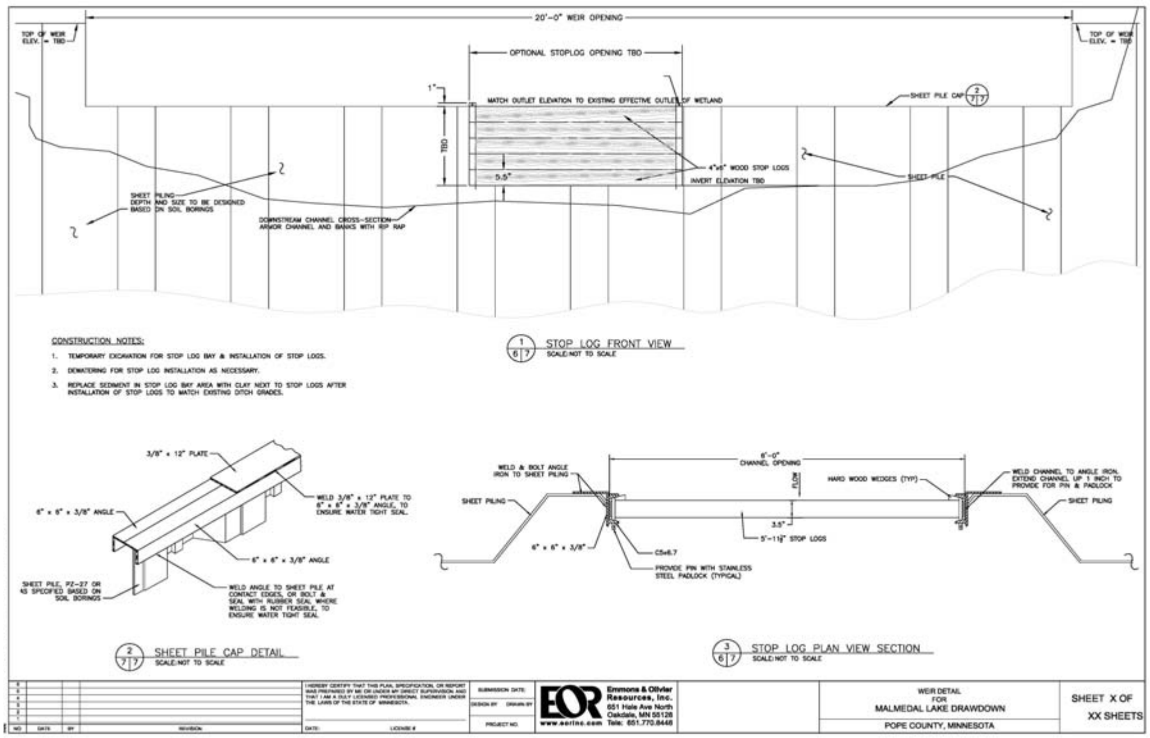

Figure 6. Sheet Pile Weir Concept Design

A concept design for incorporating the horizontal and/or vertical bars to further prevent fish passage is illustrated below. The spacing of the bars would need to be discussed with the DNR and balanced with the ability and the ability for regular maintenance of the structure. The tighter the spacing the less potential for fish passage, however the tighter spacing increases the need for regular maintenance. For planning purposes the estimated additional construction cost for the additional fish barrier components (horizontal and vertical bars with footbridge) is $20,000.

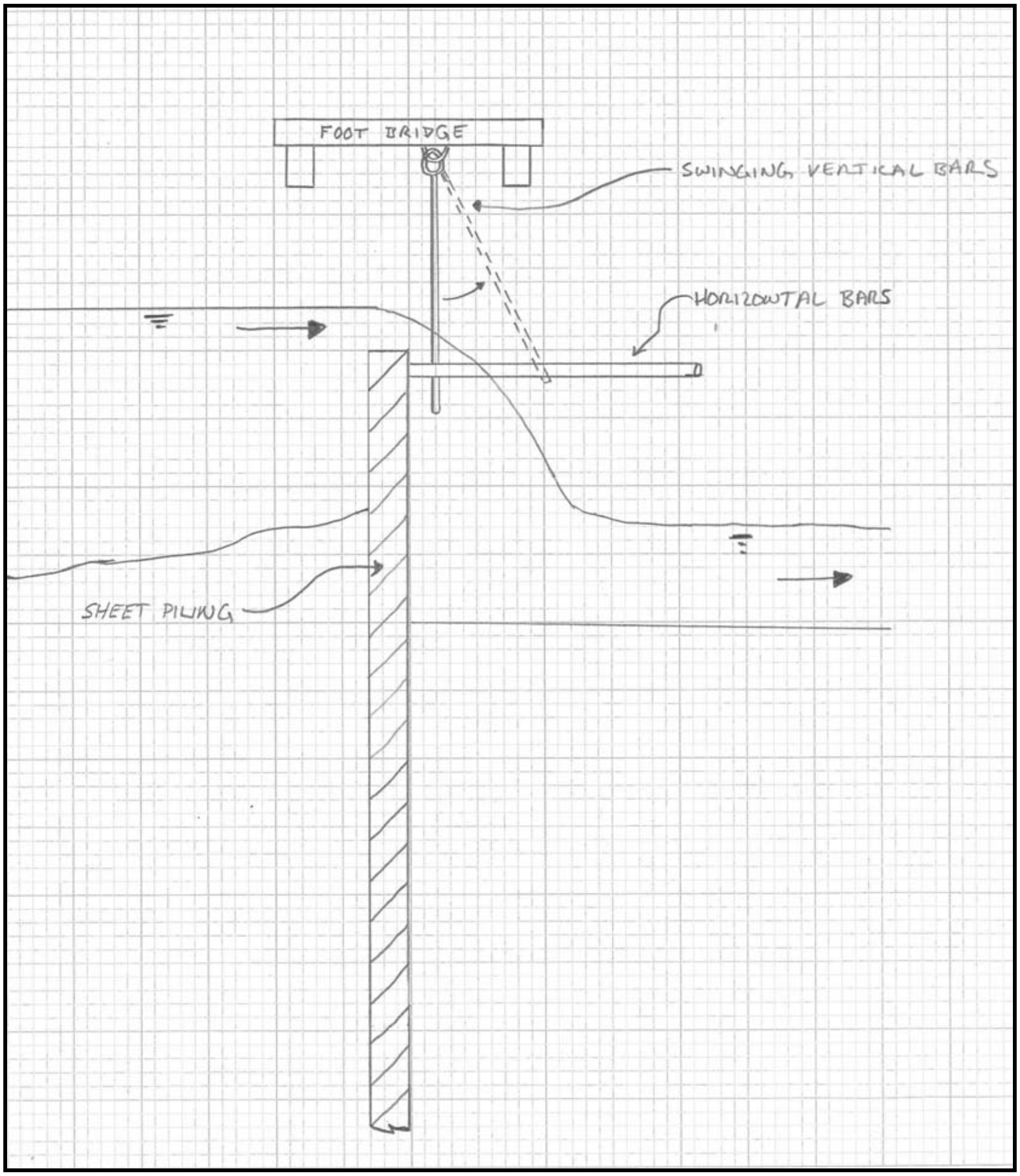

Figure 7. Fish Barrier Concept Design

5 DRAWDOWN OPTIONS

Many options to complete a drawdown were reviewed to determine the most beneficial method for drawing down Malmedal Lake. Primary objectives were cost-effectiveness and risk. The following 10 options were selected for final consideration and are organized by the primary drawdown method. Although some pumping is necessary with all the options, the items categorized under "pump" exclusively use a pump to complete the drawdown while the other options utilize other methods as well. Table 5 shows the costs of each option. Figures 10-12 show the two potential alignments considered. Figures 8-12 show all of the project components of Options 1-10.

5.1 Pump (Options 1-2)

These options involve pumping the lake in its entirety using the existing outlet channel on the west side of Highway 114 or pumping to the east pond and allowing the water to gravity drain from that point.

5.2 Siphon (Options 3-4)

The option of drawing down Malmedal Lake by siphon was vetted. Due to elevations and water levels of the lakes, the only practical route for a siphon was from the lowest point in Malmedal through the east pond and over the small hill down to Strandness Lake. (Figure 4) This route was analyzed using the energy equation and guidance on aquaculture design from the Food and Agriculture Organization of the United Nations (Kövári 1984). This analysis shows that an 18 inch siphon is required to pass the minimum goal flow of 5 cfs. At this diameter the velocity of flow is 0.865 m/s, less than half the minimum recommended velocity in siphons of 1.8 m/s. In short, it is not possible to overcome the frictional forces of the pipe with the available hydraulic head between the lakes and the siphon option was not further evaluated.

5.3 Gravity (Options 5-6)

Many options exist to drawdown Malmedal Lake and Pepple's Slough without using pumps. The drawback of this method is that the practical lower level that could be reached is 1230.5, the current control elevation of the HWY 114 culvert. This leaves ~ 2 feet of water in Malmedal Lake and approximately 109 acres with standing water. Although this would likely result in a fish kill, the additional benefits of sediment consolidation and seed germination may not be realized.

Option 5 utilizes a weir with a flow control device and Option 6 uses a piped outlet. Because the elevation of the outlet of Pepples Slough causes backwater effects to 1232.0 feet, the Pepples Slough drawdown would need to be conducted simultaneously with either gravity drawdown option.

Additionally, any gravity drawdown option would require a small pumping operation to lower the water elevation on the east pond to ensure a winterkill.

5.4 Gravity and Pumping (Options 7-10)

These options involve removing a large volume of water by gravity and utilizing pumps to complete the drawdown. Because of the bathymetry of Malmedal lake it is possible to remove a approximately ½ of the drawdown volume by lowering the outlet elevation by 2 feet to 1233.0. Options 7 includes a small amount of excavation at the existing overflow outlet to accomplish this, followed by a pumping operation to complete the drawdown. Option 8 is this same option with reconstruction of the Pepples Slough outlet to repair existing overflow and also allow for its drawdown.

Option 9 includes dredging of a channel into lake, construction of a sheet pile weir (with stoplogs) at the lake outlet and improvement of existing channel to allow drawdown of Malmedal Lake to elevation 1230.5 ft by gravity. The remaining 2.5 feet of Malmedal would be pumped to complete the drawdown. Reconstruction of the Pepples Slough outlet would also be required for this option. Implementation of Option 9 would result in a significant reduction in the volume of water pumped to complete the drawdown. As additional benefit of this option is the ability for future gravity only drawdowns of Malmedal for rough fish control. Future drawdowns would only require some dredging to re-establish the channel into the lake and removal of stoplogs from weirs at Malmedal Lake and Pepples Slough outlets.

Option 10 is the same as Option 9 except that a pipe (with a valve to control flows) is used for the outlet structure of Malmedal Lake instead of a sheetpile weir.

Table 5. Malmedal Drawdown Options

Primary Device	Alternative ID	Alternative Description	Malmedal Outlet Construction Cost	Pumping Cost	Pepples Slough Construction Cost	Additional Fish Barrier Cost****	Contingency (20%)	Total Capital Costs	Engineering Cost**	Permitting Cost	Total Cost***	Cost of repeat drawdowns*	Number of Structures to be maintained
Pump	1	Pump Malmedal and Pond at 10 cfs for 50 days, Fish barrier at Hwy114	$ -	$168,000	-	$30,000	$39,600	$237,600	$24,000	$5,000	$266,600	$237,600	0
	2	Pump Malmedal to Pond and allow gravity drain from pond	$ -	$168,000	$ -	$30,000	$39,600	$237,600	$24,000	$5,000	$266,600	$237,600	0
Siphon	3	Siphon direct to strandness - Permanent	Not Estimated, See Description in Text										
	4	Siphon direct to strandness - Temporary											
Gravity	5	Construct Weir Outlet, Gravity drain to 1230.5', dredge channel in Lake, Pepples outlet reconstruction	$59,000	$20,000	$32,000	$ -	$22,200	$133,200	$27,000	$5,000	$165,200	$15,000	2
	6	Pipe with valve at 1230.5 in lake to channel downstream of 24" pond outlet. Pepples Outlet Construction	$70,000	$20,000	$32,000	$ -	$24,400	$146,400	$29,000	$5,000	$180,400	$5,000	2
Gravity and Pump	7	Gravity drain 2 feet of Malmedal (to 1233.0'), then pump Malmedal and Pond	$9,000	$115,000	-	$30,000	$30,800	$184,800	$37,000	$5,000	$226,800	$184,800	0
	8	Gravity drain 2 feet of Malmedal (to 1233.0'), then pump Malmedal and Pond. Pepples outlet reconstruction	$9,000	$115,000	$ 32,000	$ -	$31,200	$187,200	$37,000	$5,000	$229,200	$187,200	1
	9	Construct Weir Outlet, Gravity drain to 1230.5', dredge channel in Lake, Pepples outlet reconstruction	$59,000	$66,000	$32,000	$ -	$31,400	$188,400	$38,000	$5,000	$231,400	$15,000	2
	10	Pipe with valve at 1230.5 in lake to channel downstream of 24" pond outlet. Pepples Outlet Construction	$70,000	$66,000	$32,000	$ -	$33,600	$201,600	$40,000	$5,000	$246,600	$15,000	2

*Cost of repeat drawdowns includes dreging material in Lake Channel

**Engineering cost is 10% for pumping only options, 20% for gravity and pumping

***Cost to acquire permanent easements for structures and temporary construction easements are not included

****Additional Fish Barrier Cost is additional cost for undefined fish barrier if Pepples Slough outlet is not reconstructed to act as barrier

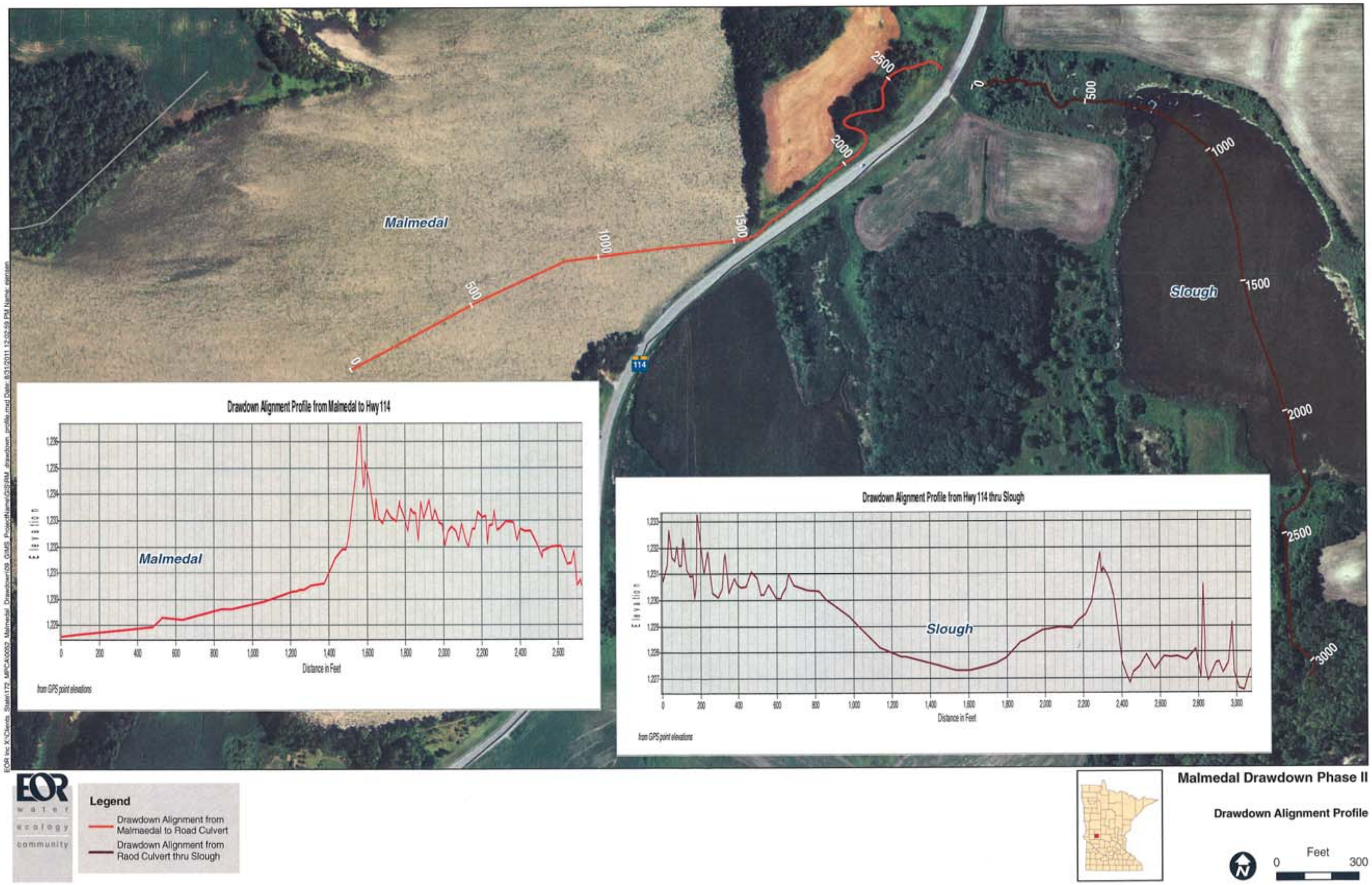

Figure 8. Channel Profile

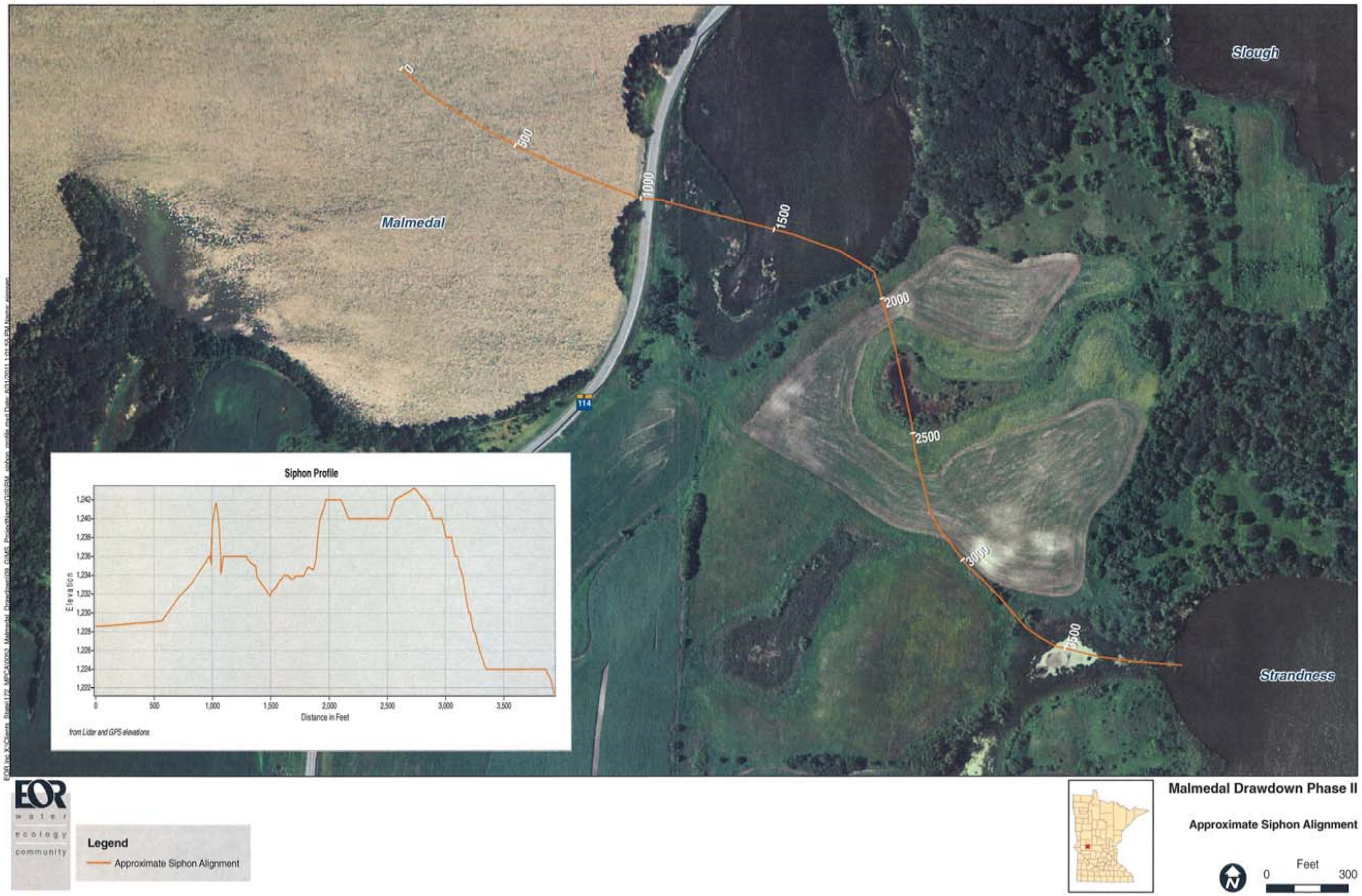

Figure 9. Siphon Profile

Figure 10. Malmedal Channel Improvement Alignments

Figure 11. Malmedal Pumping Alignments

Figure 12. Pepples Slough Outlet Alignment

6 RECOMMENDED DRAWDOWN PLAN

6.1 Recommended Drawdown Option

Option 9, with a preliminary estimated cost of $231,000 is the recommended drawdown option. This option includes construction of a sheet pile weir, with stop-logs (refer to Figure #), the dredging of a channel into the low point of lake to elevation 1230.0 ft, and improvement of existing outlet channel to allow drawdown of Malmedal Lake to elevation 1230.5 ft by gravity. Reconstruction of the Pepples Slough outlet berm/weir to match original design hydraulics, with an added sheetpile weir and stop-log structure for controlled drawdown's, will also be required for this option. A channel will also need to be dredged for Pepples Slough to the low point elevation of 1228.0 ft. Pepples Slough outlet will require some cleaning and removal channel high points. A fish barrier should be incorporated into the reconstruction of the Pepples Slough outlet weir (Figure 7). Following the gravity drawdown the remaining 2.5 feet of Malmedal will be pumped to complete the drawdown. Even though most of the water volume is removed via gravity the lake still needs to be pumped, to entirely drawdown the lake and achieve sufficient consolidation of bottom sediments necessary to realize the reductions in internal phosphorus loadings desired. Once Malmedal pumping is complete the inlet piping would need to be moved to pump down the water elevation of the east pond to help ensure a winterkill in this pond.

The concept for the temporary pumping system configuration was previously identified in Figure 11. The pumping system will need to have a capacity of at least 5 cfs (2,250 gpm) to complete pumping down Malmedal Lake within a 60-day time period.

Implementation of Option 9 results in a significant reduction in the volume of water pumped to complete the drawdown. An additional advantage of this option over the others considered is the future operational capabilities it provides in allowing the ability for future gravity only drawdown of Malmedal for rough fish control. Future drawdowns would then only require some maintenance dredging to re-establish the channel into the lake and removal of stoplogs from weirs at Malmedal Lake and Pepples Slough outlets.

Prior to construction and implementation of the drawdown plan, ownership of the drawdown system needs to be determined. Ownership will need to include the responsibility for future operation and maintenance of the drawdown system.

6.2 Estimated Project Timeline

The project is estimated to take a minimum of 2-yrs to construct, complete drawdown and ultimately refill the lake. Both drawdown and refilling of lake and slough will be dependent on precipitation during and after project. The actual construction schedule and methods will be determined by the contractor. The following is the estimated project timeline:

- **Year 1:**
  - Assume final design, plans and bidding are completed so that project is awarded by March of Year 1.
  - Construction start date of June 1, Year 1 starting with outlet channel cleaning and stabilization for both Mamedal Lake and Pepples Slough outlet channels.
  - Construction of Pepples Slough outlet structure, channel dredging and start of Slough drawdown complete by July 15, Year 1.

   - Construction of Malmedal Lake outlet structure, channel dredging and start of gravity drawdown complete by August 1, Year 1. (See Detailed Drawdown Curve on Figure 13.)

   - Completion of gravity drawdown of Malmedal Lake by September 15, Year 1.

   - Mobilization of pumping contractor starting September 1, of Year 1 and start of pumping operation by September 15, Year 1.

   - If needed manually remove accumulations of dead fish as basins are dewatered. (Owner should also consider allowing harvesting of fish, as they are concentrated into small pools during the dewatering process).

   - Substantial Completion of pumping operation by November 15, Year 1 with some likely maintenance pumping until freeze-up.

   - Evaluate dewatered basin for any remaining pools containing fish upon completion of pumping operation. Remaining fish should be manually removed.

- **Year 2:**

   - Replace stoplogs in Malmedal Lake and Pepples Slough outlet structures prior to spring runoff event for Year 2.

   - Implement post drawdown monitoring plan described in section 6.4.

   - Complete channel restoration to address any issues that occurred during drawdown.

- **Years 3 to 5:**

   - Implement channel and vegetation maintenance plan to ensure channel is stabilized.

   - Implement post drawdown monitoring plan described in section 6.4.

- **Years 5 and beyond:**

   - Implement regular on-going maintenance plan.

   - Implement post drawdown monitoring plan described in section 6.4.

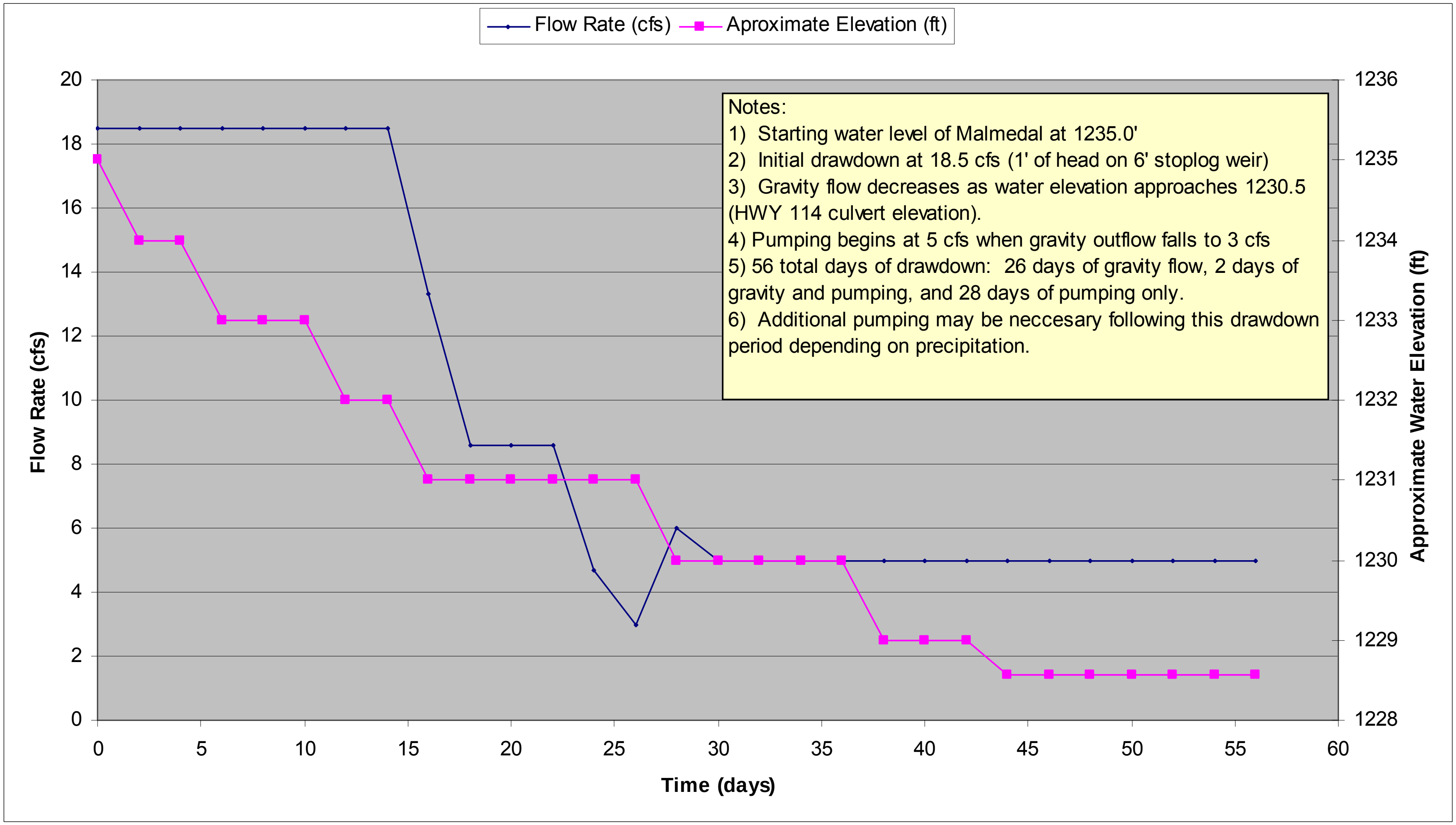

Figure 13. Option 9 Detailed Drawdown Curve

6.3 Project Permit Requirements

The required permits for this project are listed below:

- U.S. Army corps of Engineers: Section 404 Permit.
- MN Dept. of Natural Resources: Work in Public Waters Permit and potentially a permit for aquatic vegetation management.
- MN Pollution Control Agency: 401 certification (discharge to navigable waters); NPDES Construction Permit and a Notification for disposal of dredge materials.
- MN Dept. of Transportation: Work in ROW Permit.
- Pope Co. Soil and Water Conservation District: Wetlands Conservation Act Permit for any impacts to wetlands outside of DNR jurisdiction (i.e. above OHW).

Pope County: Conditional Use Permit for work inside the shoreland zone.

6.4 Recommended Monitoring Plan

The following monitoring plan has been developed to evaluate the effectiveness of the lake drawdown in accomplishing its primary objectives. Those objectives are:

- Improved Lake Water Quality
- Reduction in Rough Fish (Carp) Population
- Consolidation of Lake Sediment
- Increased Diversity and Density of the Aquatic Macrophyte Community

In-Lake Water Quality

Water quality in Malmedal Lake will be assessed through use of a standard in-lake monitoring program. Monitoring will be conducted for two years following the drawdown at which time the data will be evaluated and the need for additional monitoring will be determined. The monitoring will be conducted twice a month during the growing season (April – October) at the deepest point within the lake. Monitoring will be conducted for the following parameters:

- Secchi Depth (SD)
- Total Phosphorus (TP)
- Chlorophyll A (ChlA)

The TP and ChlA samples will be taken from a composite sample of the top 1 meter of lake water.

Rough Fish

The presence of rough fish within the lake will be evaluated through a simple observational methodology for the first year following the drawdown and construction of the fish barrier. It is quite unlikely that rough fish will still be present. After observing the lake if it is determined that there may be rough fish present a fish trapping would be done in October of the following year.

Lake Sediment Consolidation

Lake sediment measurements will be taken prior to the drawdown and then again in the spring following the drawdown. Sediment measurements will be done at approximately 25 points throughout the lake. Measurements will include elevation and a simplified in-field compaction test. Elevation will be surveyed to a known local benchmark and pre to post project comparison will be made to determine if the lake sediment consolidated to a degree where the elevation was lowered. The compaction testing will be done by setting a weight onto the sediment and measuring the distance the weight settles into the sediment. The measurements will be replicated in approximately the same location before and after the drawdown.

Aquatic Macrophytes

An aquatic macrophyte survey will be conducted in the second year following the drawdown. The survey will consist of two sampling dates; one in mid spring and one in late summer, in an effort to quantify the macrophytes that are present at varying levels dependent upon the time of year. The point intercept methodology as developed by the Corps of Engineers (http://el.erdc.usace.army.mil/elpubs/pdf/apcmi-02.pdf) will be used.