Klohn Crippen Berger

January 9, 2014

City of Calgary Water Resources
1646 – 56 Ave. S.W.
Calgary AB T3E 5H1

Steven Dold, P. Eng.
Leader, Project Engineering – Glenmore

Dear Mr. Dold:

Glenmore Dam and Reservoir Improvement
Glenmore Reservoir Dredging

As part of the current work by Klohn Crippen Berger Ltd. (KCB) on the Glenmore Reservoir, the City of Calgary commissioned an evaluation of the possibility of increasing reservoir storage by removing sediment that has been deposited in the reservoir.

Approach

The approach adopted for the evaluation was to assess the potential benefit of dredging the reservoir to regain storage capacity consumed by sediment accumulation. The potential benefit was assessed in terms of both improved flood mitigation and improved winter water supply. The scope of the dredging program was assumed to be sufficient to restore the entire original (1933) storage capacity within the normal reservoir operating range.

The benefits identified below are in comparison to the 2012 reservoir storage, treated for purposes of this assessment as the current condition. Glenmore Reservoir was surveyed in 2012 as part of a regular five-year cycle, and again in the fall of 2013 because of the June 2013 flood event. The surveys found that reservoir storage within in the normal reservoir operating range changed less than 0.4% between 2012 and 2013.

The 2012 and 1933 reservoir capacities are shown on Figure 1, and pertinent elevations are shown on Figure 2. The normal operating range is limited at the top end by the top of the stoplogs on Glenmore Dam Spillway (el. 1076.85 m, 1.5 m above the spillway crest). The bottom of the normal operating range is at elevation 1071.85 m (3.5 m below the spillway crest) because when the reservoir is below that level, reservoir bottom sediment begins to move, creating undesirable turbidity at the water treatment plant intake.

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Between 1933 and 2012, storage in the normal operating range of the reservoir decreased from approximately 17,180 dam^3 to 15,460 dam^3, a reduction of 1720 dam^3 or 10%[1]. Therefore restoring the original capacity in the operating range would require removal of 1720 dam^3 of material.

Flood routing simulations were conducted using the City's reservoir routing spreadsheet model, generally assuming the operating rules currently in use.

Flood Mitigation

When floods occur, reservoir storage can be used to reduce the flood peak, so that the downstream peak discharge is less than the peak inflow. Increasing the reservoir storage would provide a greater reduction in flood peak. The benefit of increased storage was assessed by routing a range of flood events and comparing the flood peak reduction that would occur under current and dredged, and gated conditions.

Pre-flood drawdown was assumed to be in accordance with the drawdown strategy shown on Figure 3. The figure shows the amount that the reservoir would be drawn down below the spillway crest depending on the forecast reservoir inflow. The shape of the flood inflow hydrograph was the design hydrograph shape currently used by the City, taken from the 1983 City of Calgary Floodplain Mapping Study.

The potential benefit of increasing reservoir storage to the 1933 capacity is illustrated on Figure 4. The figures show the flood attenuation (reduction in peak outflow) that can be attained for given inflow floods for the dredged condition compared to the current condition. Lower points relative to the no attenuation line (peak outflow = peak inflow) on the figure indicate greater attenuation benefit.

Figure 4 shows that the largest reduction in peak outflow due to dredging would occur during floods in the range of a 1:50 year event. During that event, the peak inflow of 553 m^3/s would be reduced to a peak outflow of 415 m^3/s under the current condition, or 403 m^3/s under the dredged condition. The effect of dredging is to reduce the outflow peak for that flood magnitude from 75% to 73% of the inflow peak. During larger floods, the benefits of reservoir attenuation decrease because the available flood storage capacity is small relative to the size of the incoming floods. During smaller flood events such as the 1:20 year flood or lower, the additional capacity provides no benefit because of the operating rules that match releases to inflow up to an inflow of 170 m^3/s.

Water Supply

The effect of dredging the reservoir on winter water supply potential is shown on Figure 5. The water supply available in the reservoir was simulated for several historical years to evaluate a range of fall and winter inflows. The Y axis on Figure 5 shows the water supply in ML/day that can be sustained throughout the winter for dredged conditions, against the supply that can be sustained with the current (stoplog) configuration on the X axis. On Figure 5, greater distance above the "no improvement" line indicates a greater benefit.

[1] 1 dam^3 = 1000 m^3

Four selected scenario years were simulated. The figure shows that in moderately dry years like 1937-38 and 1970-71, or in a wet year like 1942-43, the benefit of the increased storage is a water supply increase in the range of 4 to 9 ML/day[2] through the winter, an improvement of 2% to 3%. However, in most years, the water supply is sufficient without the additional storage.

In a very dry year like 1936-37, the benefit of dredging the reservoir is shown as zero on Figure 5 because the reservoir would be depleted by summer demands and the figure shows benefits in terms of winter water supply. The additional capacity due to dredging would in fact provide a benefit of up to 6 ML/day through the winter if the reservoir was managed to prioritize winter over summer demands.

Dredging Considerations

Factors that should be considered in planning a dredging program for the reservoir include the following:

- There is little value in dredging material below the minimum operating level, because reservoir capacity below that elevation is not used for water supply.
- Removing material above the winter operating range (i.e. above elevation 1076.85 m) provides benefit only for flood mitigation, not for water supply.
- Based on the information above, the dredging program should focus on areas where the reservoir bed is currently at approximately the elevation of the spillway crest (1075.35 m) and should remove only material above elevation 1071.85 m, for a maximum dredging depth of 3.5 m. Considering those elevation limits and the dredging volume of 1720 dam^3, the area that would have to be dredged would be approximately 0.5 km^2. A square area that size at the appropriate location in the reservoir where the bed is near the required elevation is delineated on Figures 6 and 7.
- Dredging would have a temporary effect, as the dredged area would be expected to fill in again eventually. A more detailed assessment of the expected length of time required to refill the dredged area should be conducted before initiating a dredging program.
- Possible methods of removing material include conventional excavation, hydraulic dredging, and mechanical dredging.
    - Conventional excavation would be difficult because the reservoir is typically only drawn down to elevation 1074.0 m in late winter as shown on Figure 8. The excavation would have to extend down to approximately elevation 1071.85 m, and the working surface would likely be soft. If and when the reservoir is lowered more than usual to facilitate other work such as the dam upgrades, conventional excavation could become more achievable.

[2] ML = megaliter = 1000 m^3

  - If a hydraulic dredge was used, a spoil area would have to be provided where the slurry from the dredge would be allowed to settle and the decanted water returned to the reservoir. The spoil area would have to have containment berms around it. Either the spoil area would have to be sufficiently large to contain all of the removed material (including an allowance for the water), or the spoil material would have to be removed periodically by truck. There is no apparent location for a spoil area in close proximity to the reservoir, so the hydraulic dredging option is considered to be impractical.
  - If a mechanical dredge was used, the material would be barged to shore and loaded into trucks for disposal. This approach seems more achievable than the other two approaches but would also likely be more costly and produce more turbidity in the reservoir.
- Ultimate disposal of the material would likely be a significant issue considering the large volume, the high water content, and the possibility of unknown contaminants.
- Environmental and social issues that would have to be mitigated or addressed include noise (particularly near the Weaselhead Natural Area), disturbance of the aquatic habitat in the reservoir, and creation of large amounts of turbidity.
- A smaller-scale dredging program would be more achievable, but would have correspondingly smaller benefits in terms of flood attenuation and water supply enhancement.

Conclusion

In terms of flood mitigation, restoring the original reservoir capacity through dredging would provide a flood attenuation benefit of 2% of the inflow peak for a 1:50 year flood, with a smaller benefit during larger events.

In terms of winter water supply, dredging would increase the winter water supply available in the reservoir by 2% to 3%. That increase would be beneficial only in years when there was sufficient water supply available to fill the additional storage provided by dredging but not sufficient supply to meet the City’s needs without the additional storage.

Dredging Glenmore reservoir to increase its capacity could provide a small benefit in terms of flood attenuation and water supply enhancement but would have a high cost and limited life, and would face significant environmental, social and logistical challenges. The logistical challenges in particular would be expected to result in very high costs for a dredging program. Based on these considerations, dredging is not recommended.

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of the City of Calgary for specific application to Glenmore Reservoir. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

Yours truly,
KLOHN CRIPPEN BERGER LTD.

PROFESSIONAL ENGINEER WES DICK ALBERTA

2014-01-09

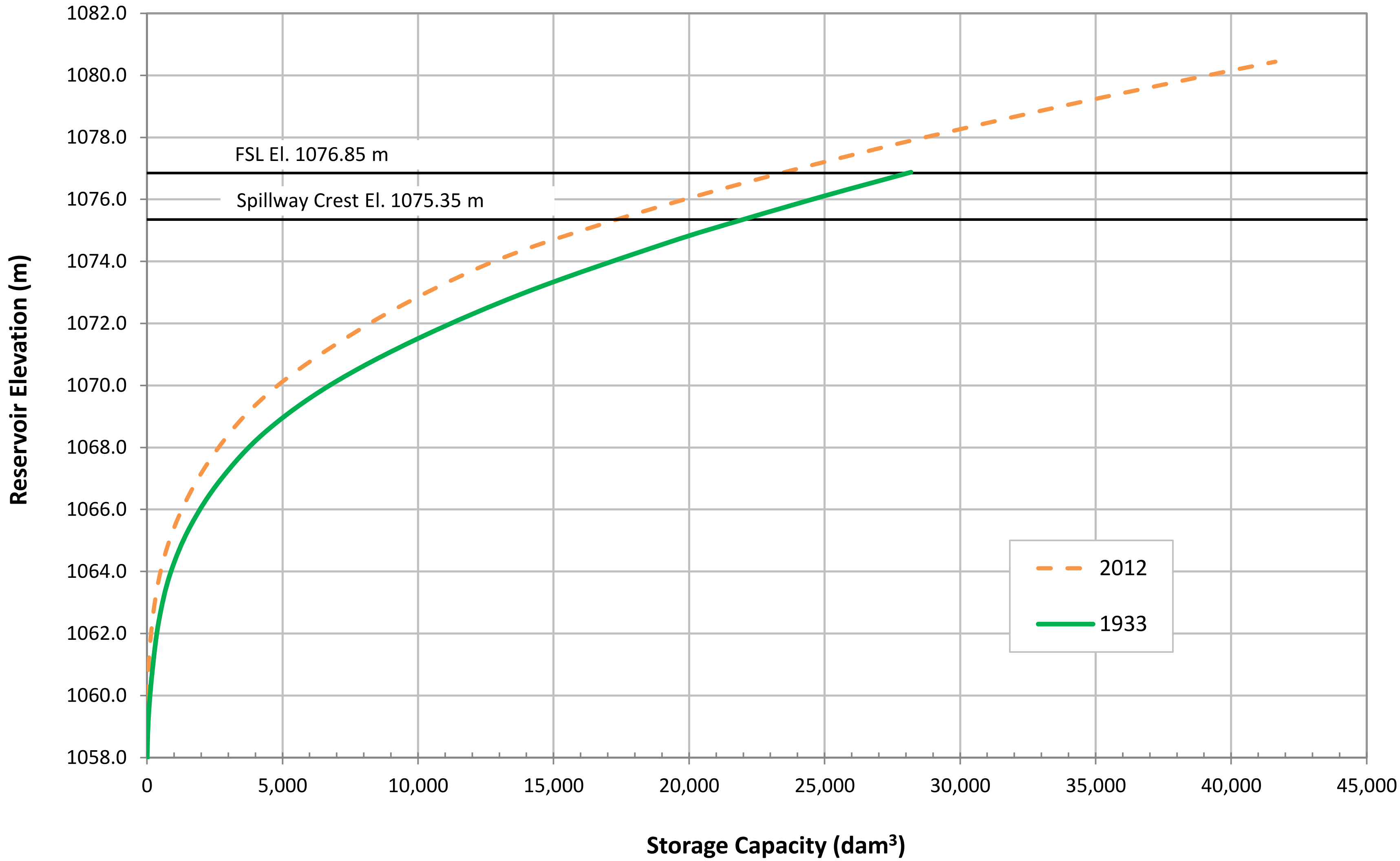
Wes Dick, M.Sc., P.Eng.
Senior Water Resources Engineer

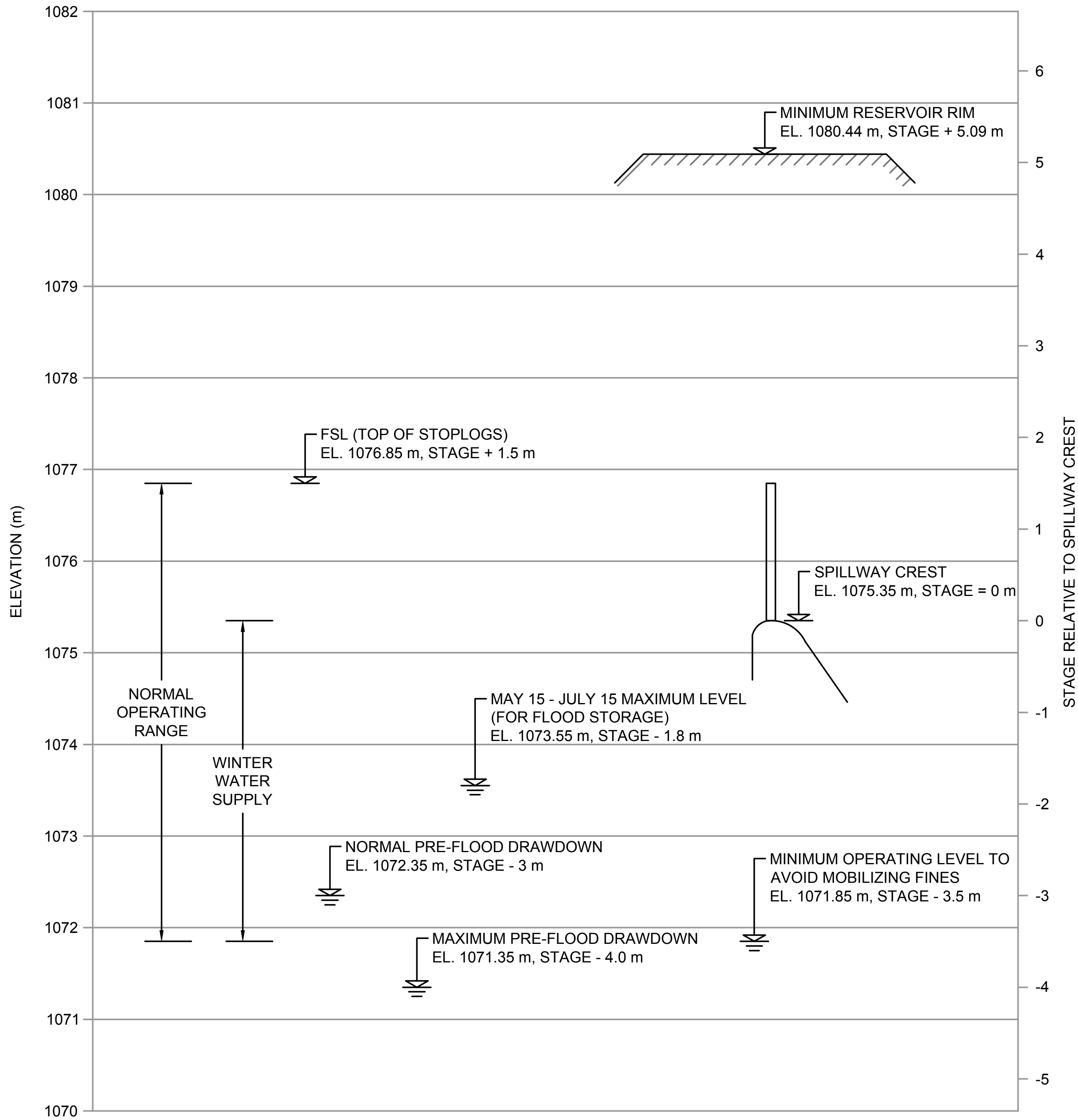
APEGA Permit to Practice P9196

wd :wd

Attachments:
- Figures 1 – 8

Figure 1
Glenmore Reservoir
Comparison of 1933 and 2012 Storage Capacity





CLIENT	PROJECT
THE CITY OF CALGARY WATERWORKS	GLENMORE DAM & RESERVOIR
	TITLE: IMPORTANT ELEVATIONS
Klohn Crippen Berger	PROJECT No. A03018A20 — FIGURE No. FIGURE 2

Figure 3
Glenmore Reservoir
Assumed Pre-Flood Drawdown Strategy

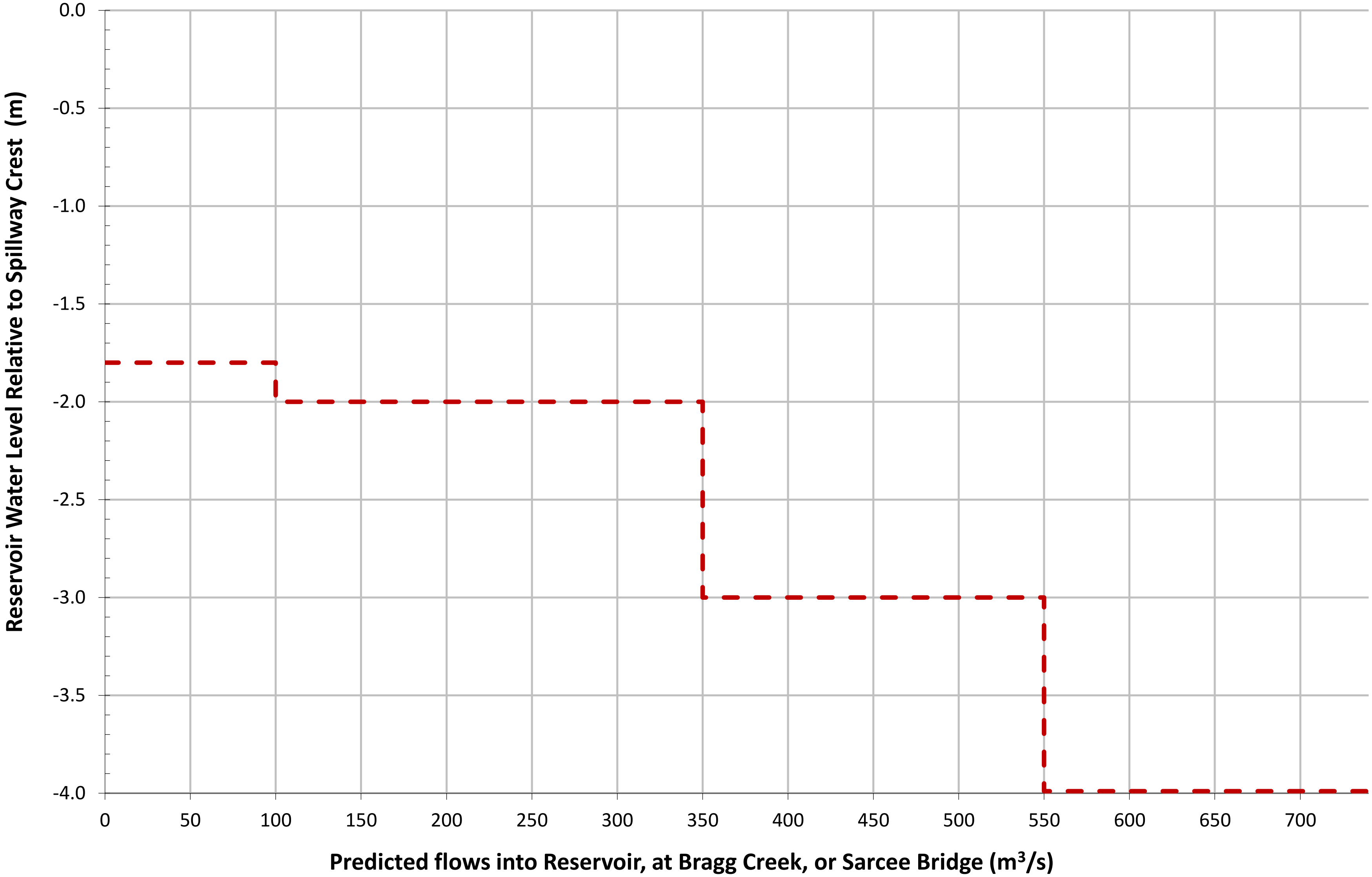


Figure 4
Flood Attenuation in Glenmore Reservoir

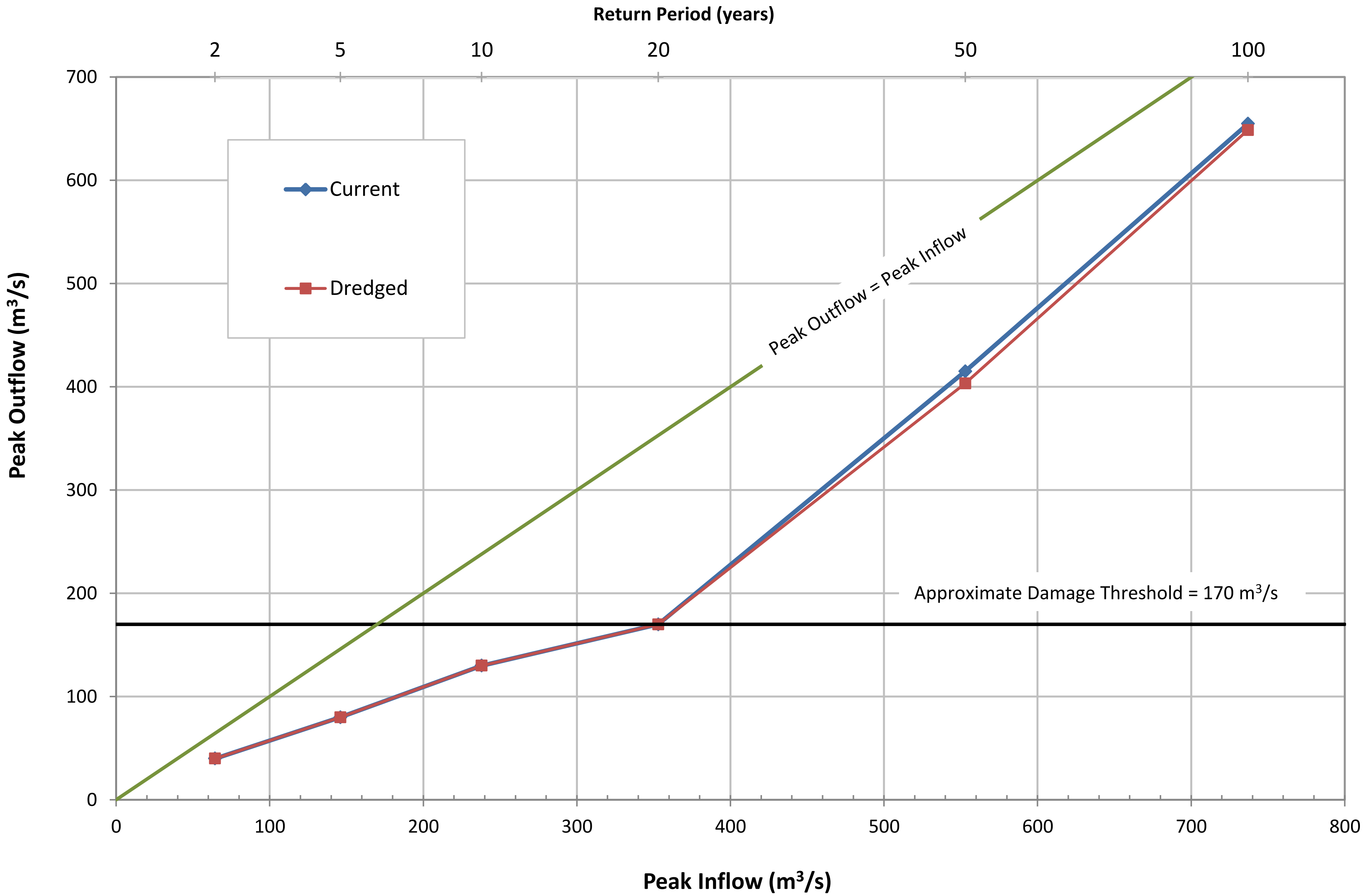
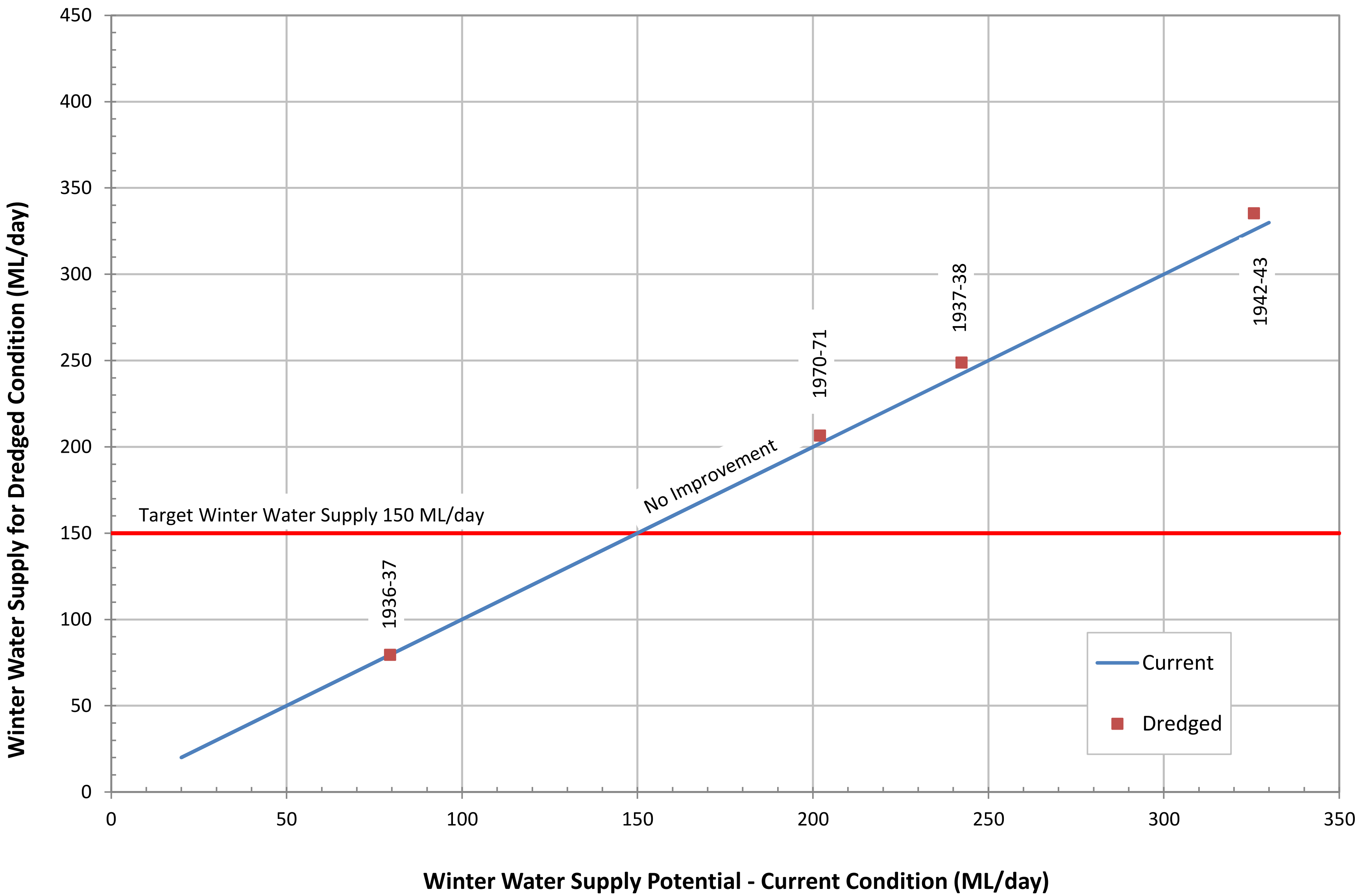
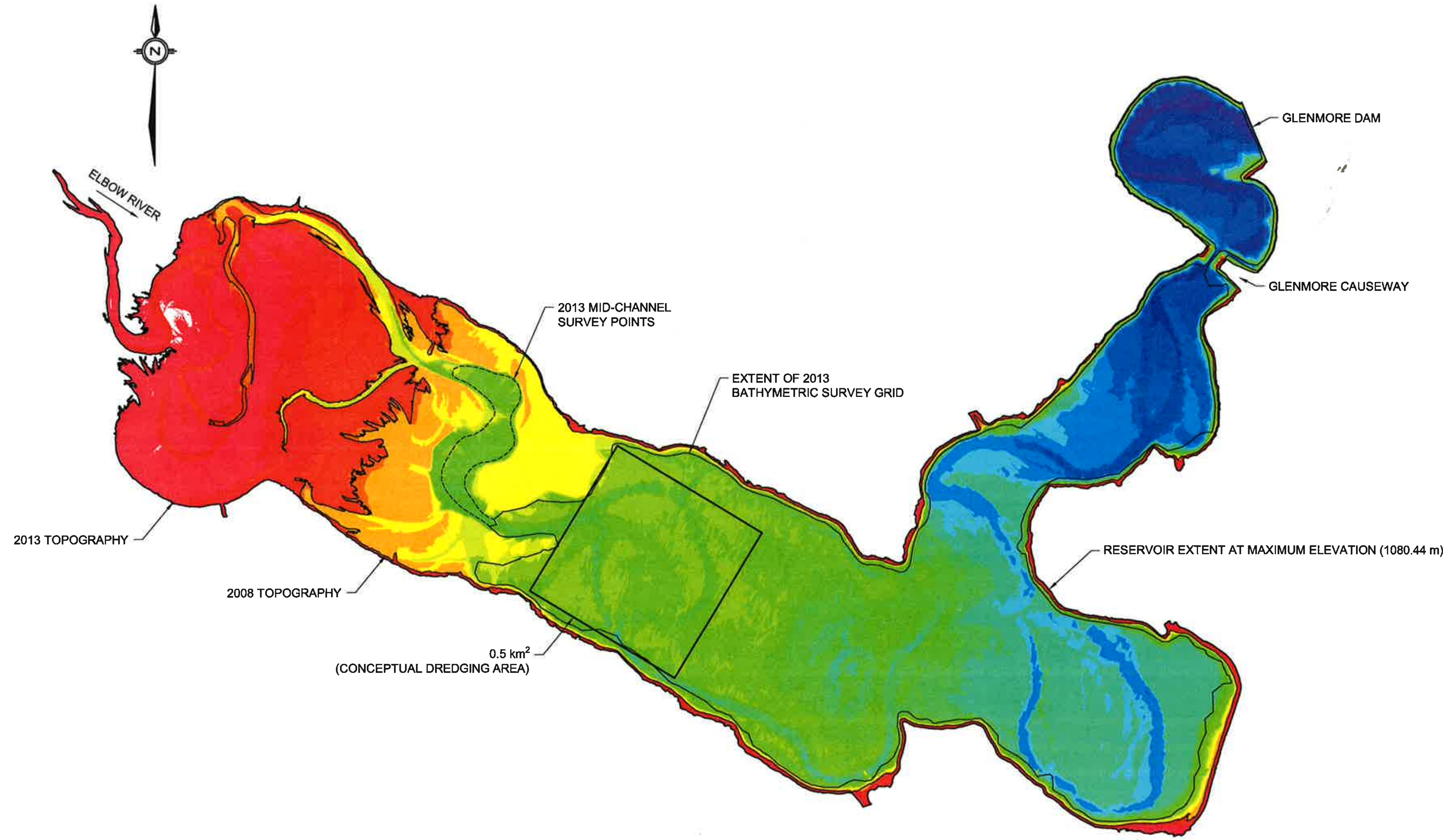


Figure 5
Winter Water Supply Potential in Glenmore Reservoir





ELEVATIONS TABLE

MINIMUM ELEVATION (m)	MAXIMUM ELEVATION (m)	AREA (ha)	COLOR
1057.60	1059.00	0.58	
1059.00	1060.00	3.33	
1060.00	1061.00	3.03	
1061.00	1062.00	3.71	
1062.00	1063.00	5.93	
1063.00	1064.00	9.74	
1064.00	1065.00	12.77	
1065.00	1066.00	12.62	
1066.00	1067.00	14.03	
1067.00	1068.00	15.40	
1068.00	1069.00	20.75	
1069.00	1070.00	38.03	
1070.00	1071.00	26.02	
1071.00	1072.00	25.95	
1072.00	1072.50	16.91	
1072.50	1073.00	18.66	
1073.00	1073.50	20.35	
1073.50	1074.00	21.46	
1074.00	1074.50	54.28	
1074.50	1075.00	38.64	
1075.00	1075.35	7.63	
1075.35	1075.50	5.74	
1075.50	1076.00	29.18	
1076.00	1076.50	17.92	
1076.50	1076.85	13.73	
1076.85	1077.00	7.47	
1077.00	1077.50	19.36	
1077.50	1078.00	20.18	
1078.00	1079.00	36.29	
1079.00	1080.00	42.49	
1080.00	1080.44	13.15	

NOTES:

1. BATHYMETRY BASED ON SURVEY BY CHALLENGER GEOMATICS, SEPT. 16 TO 24, 2013.
2. 2008 TOPOGRAPHY BASED ON CONTOURS PROVIDED BY THE CITY OF CALGARY BASED ON AERIAL PHOTOGRAPHY.
3. 2013 TOPOGRAPHY BASED ON LIDAR DATA COLLECTED SEPTEMBER 2013 AND PROVIDED BY THE CITY OF CALGARY.

1:20 000 0 200 400 m

CLIENT: THE CITY OF CALGARY WATERWORKS

Klohn Crippen Berger

PROJECT: GLENMORE DAM & RESERVOIR

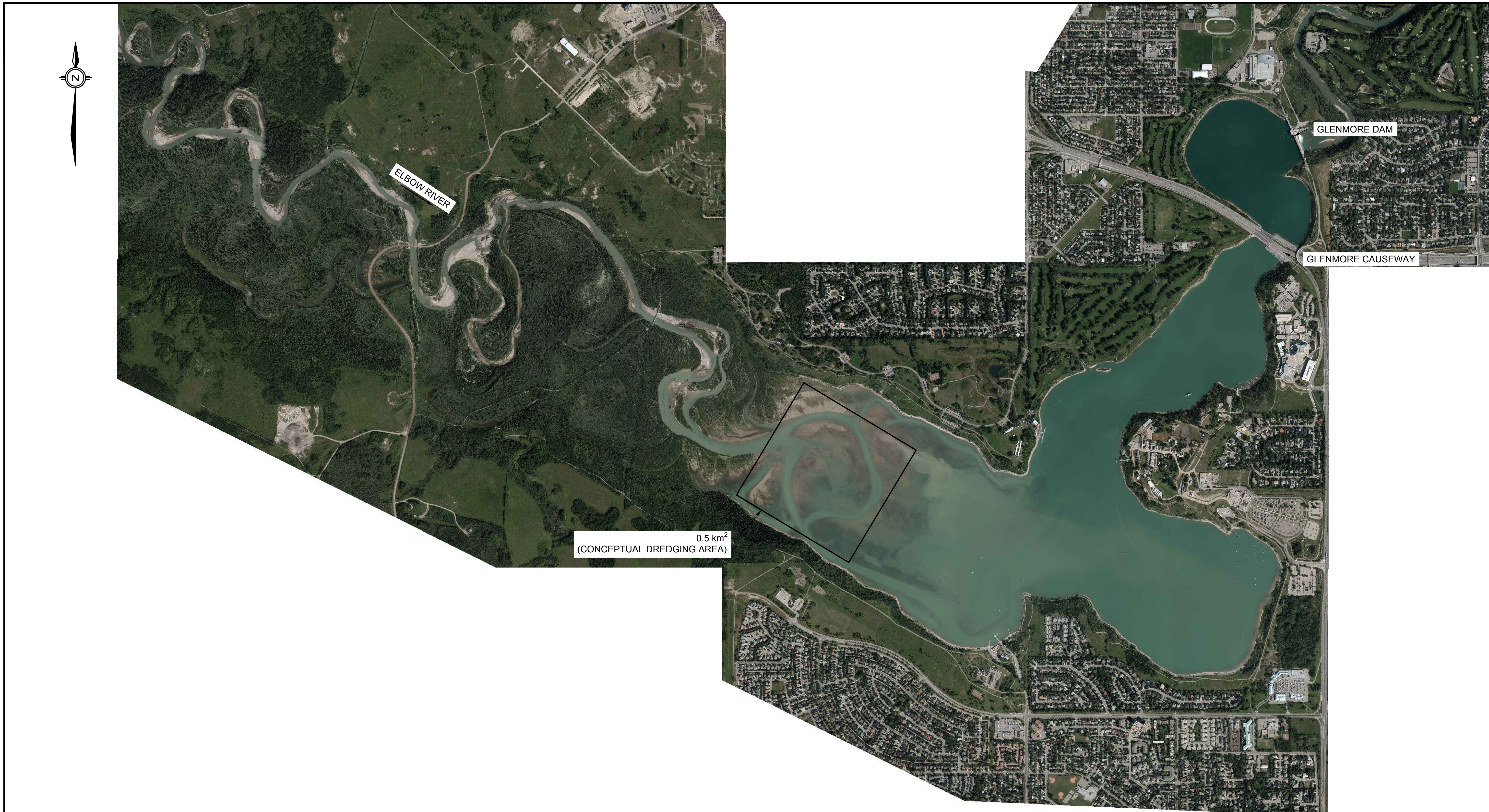
TITLE: 2013 RESERVOIR PLAN

PROJECT No. A03018A20

FIG. No FIGURE 6

KCC-F-B-M

Z:\A\CGY\Alberta\A03018A20 - Glenmore Dam & Reservoir Improvements\400 Drawings\Bathymetry Comparison\ 2013 Surface (Figure 6).dwg Layout=FIGURE 6 Monday, January 06, 2014 4:41:15 PM



NOTES:

1. AERIAL PHOTOGRAPHY TAKEN AUGUST 11, 2013 PROVIDED BY THE CITY OF CALGARY.

1:20 000 0 200 400 m

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PROJECT
GLENMORE DAM & RESERVOIR

TITLE
2013 RESERVOIR AIRPHOTO

PROJECT No.
A03018A20

FIG. No.
FIGURE 7

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Figure 8
Glenmore Reservoir Historical Water Levels