I. Holubec Consulting Inc.

WATER MANAGEMENT AFTER CLOSURE

Volume II

Of

SEEPAGE AND WATER QUALITY
FOR RECLAIMED
TAILINGS CONTAINMENT AREA
Lupin Operation

Report prepared for:
Kinross Gold Corporation

Report prepared by:
I. Holubec Consulting Inc.
1117 Notley Crescent
Oakville, Ontario
L6M 1H4

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1.0 INTRODUCTION

A closure plan for a Tailings Containment Area (TCA), Lupin Operation, Kinross Gold Corporation, was prepared with the assistance of I. Holubec Consulting Inc., January 2005. A closure design that protects the environment in both continuous permafrost and no-permafrost for the tailings containment is required because climate warming is raising the air temperature at the site. As such, the closure plan was designed for the permafrost conditions that currently exist, as well as for a later period, should permafrost thaw due to climate warming.

Seepage and Water Quality assessment for the reclaimed Tailings Containment Area are given in three volumes, namely: I) Geotechnical, Seepage and Water Balance; II) Water Management after Closure, and III) Geochemistry and Water Quality. Information that is presented in these three reports is:

I) Geotechnical, Seepage and Water Balance
- Description of the tailings containment area (TCA), tailings' physical properties, closure design and water management, after TCA reclamation is completed.
- Seepage analyses through thawed tailings to estimate the volume of unsaturated tailings.

II) Water Management after Closure
- Shows the direction of flows within the TCA after closure
- Estimates the maximum design flows at key points after closure
- Shows the location of discharge channels and provides cross section designs

III) Geochemistry and Water Quality
- Geochemistry and water quality of the present TCA.
- Geochemistry of the unsaturated tailings and seepage water quality.
- Water quality throughout the TCA and prediction of the water quality at the discharge point of the TCA.
- Assessment of the water quality on the downstream aquatic life.

This report represents Volume II of the 3 volumes.

2.0 WATER FLOWS PRE AND DURING MINE OPERATION

2.1 Pre-Mine

The TCA is located about 6km southwest of Contwoyto Lake as shown on Figure 1. It drains in a north westerly direction where it discharges into West Arm of Contwoyto Lake. The pre-mine TCA contained 15 small Lakes shown on aerial photo in Figure 1A in the Appendix.

The lakes drained the TCA watershed through a 'Y' pattern in a westerly direction illustrated in Figure A1. One arm of the 'Y' consisted of lakes 'j', 'k' and 'h' draining into Lake 'd'. The second arm of the Y, lakes 'm' through 'i' also ended up in lake 'd', along with a few other small lakes. The water from all the small lakes within the TCA watershed came together in Lake ‘a’ from where the water was discharged from the TCA by Seep Creek.

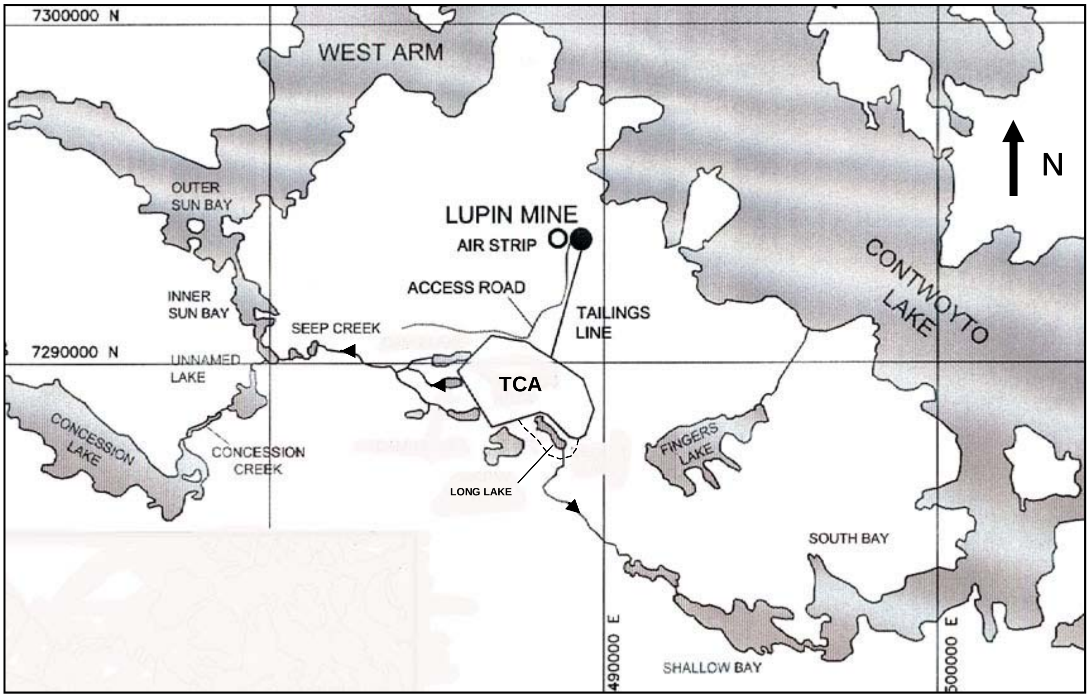


Figure 1. Location of TCA within Contwoyto drainage system

2.2 TCA Watershed after Closure

The TCA was formed by constructing Dam 1A to dam off the outflow from the TCA watershed area and Dams 2, 3 and 4 across saddles to ensure complete containment. Several internal dams were constructed during operation to form cells into which tailings were discharged. Four tailings cells (Cells 1, 2, 3 and 5) were constructed and filled with tailings during the operation of the TCA. The TCA watershed, and the external and internal dams are superimposed on the original topography in Figure 2A. The design, construction and operation of the TCA are given in an earlier Closure Plan Report (Holubec 2005).

Covered tailings cells, ponds and flow of water after closure are illustrated in Figure 2. The flow within the TCA after reclamation will be as follows:

1) Flows will originate in Cell 3. K Dam and natural topography to the south and east causes the water to flow over the covered tailings in Cell 3 towards the L Dam. L Dam will be breached causing the water to flow into Cell 4.
2) Cell 4 was not used to store tailings. The outflow from Cell 4 during operation was towards small Lake ‘p’. A small culvert dike at the east end of Cell 4 was constructed to provide more retention time to lower cyanide concentration, if

necessary. This dike will be breached before closure and the outflow of Cell 4 will be controlled by bedrock topography between Cell 4 and small Lake 'p'.

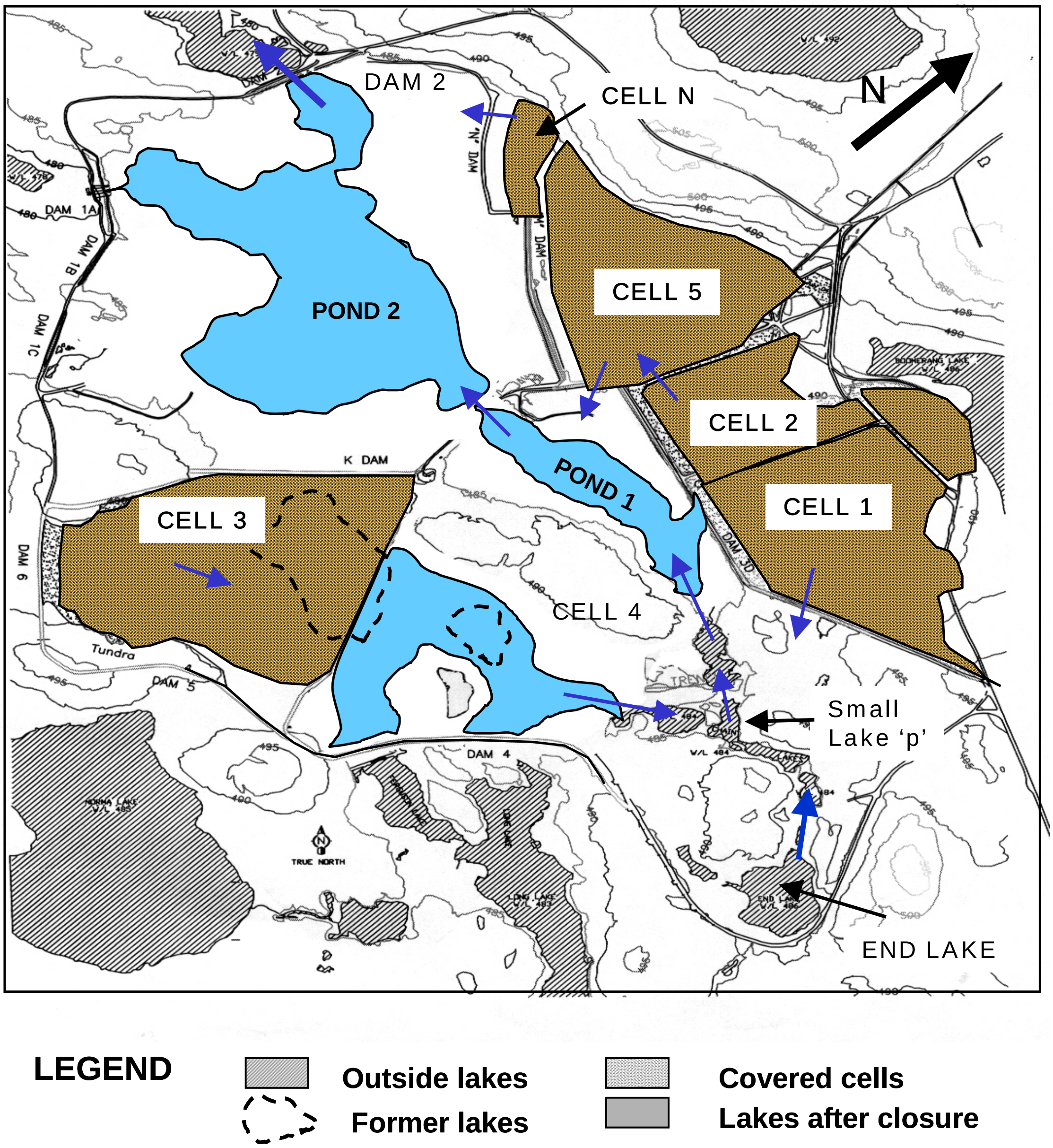


Figure 2. Water flows after TCA closure

3) Water from Cell 4 and natural End Lake will mix in small Lake 'p' and proceed towards Pond 1.
4) Surface water from Cell 1 will be discharged through a discharge channel blasted through bedrock. This water will mix with water from small Lake 'p' and flow into Pond 1.

5) J Dam controlling the present Pond 1 water level will be breached. The water level in Pond 1 will assume the same water level as in Pond 2 after reclamation.
6) Surface water from Cell 2 will be directed into Cell 5. The reason being that there is no shallow controlled bedrock knob along 3D Dam. Constructing a discharge channel through a section of 3D Dam is not desirable because it could be damaged through long-term erosion.
7) Surface water from Cell 5 will be discharged through a discharge channel blasted through bedrock into Pond 1.
8) It is proposed to keep the water level in Pond 2 at El 480.0 by constructing a drainage channel through Dam 2. By keeping Dam 1 in place to act as a saddle, the water from the TCA will flow into the downstream Lake 's' from Dam 2. The breached Dam 2 section will not be eroded with time because the downstream Lake 's' discharge is controlled by bedrock.
9) Discharge from breached Dam 2 will meet up with Seep Creek and finally Contwoyto Lake about 6.5km downstream of Dam 2.

3.0 HYDROLOGY

3.1 General

The main purpose for assessing the hydrology at the TCA is to provide design parameters so that the discharge channels can be located appropriately and sized accordingly. Hydrology parameters and hydraulic designs are required at discharge channels at Cells 1, 2 and 5 and for the breaching of dams J and 2.

Three components of the hydrology design are:

1. Select a long-term flood criterion.
2. Estimate the flood flows at the location of each discharge channel and the dam breaches.
3. Design the discharge channel and breach cross sections.

These components are discussed in the following sections.

3.2 Flood criterion

The proposed discharge channels can be considered something in between a ditch/channel and a spillway in a dam. It has to last longer than a ditch/channel and be maintenance free, but its failure is not as critical as a dam that impounds a volume of water (greater than 30,000m^3).

The TCA channel designs are based on an inflow flood event as per the Dam Safety Guidelines (Canadian Dam Safety Association, 1999). The appropriate consequence category is selected as low. Dam Safety Guidelines suggests the inflow flood for this category should have a probability of annual exceedance between 1/100 and 1/1000. For the design of the Lupin TCA an annual exceedance probability of 1/1000 was selected. Note that the annual exceedance probability for a ditch/channel is between 1/25 to 1/200.

3.3 Flood flow estimates

The flood flows at the proposed discharge channels can be estimated from a hydrograph prepared for the 1,000-year exceedance probability at the Lupin site and the watershed above the discharge channel.

Development of a hydrograph is based on extensive analyses of available and comparable stream flows and annual precipitations. For estimating the flood flows at Lupin the hydrographs developed for dam designs at Diavik (Diavik Hydrology, 1998) were used. The two sites have similar climate, although Diavik has slightly 25 % higher mean annual precipitation than Lupin (374mm at Diavik and 299mm at Lupin).

Daily flow hydrographs for various return periods for a typical 1km^2 watershed are given in Figure 3.

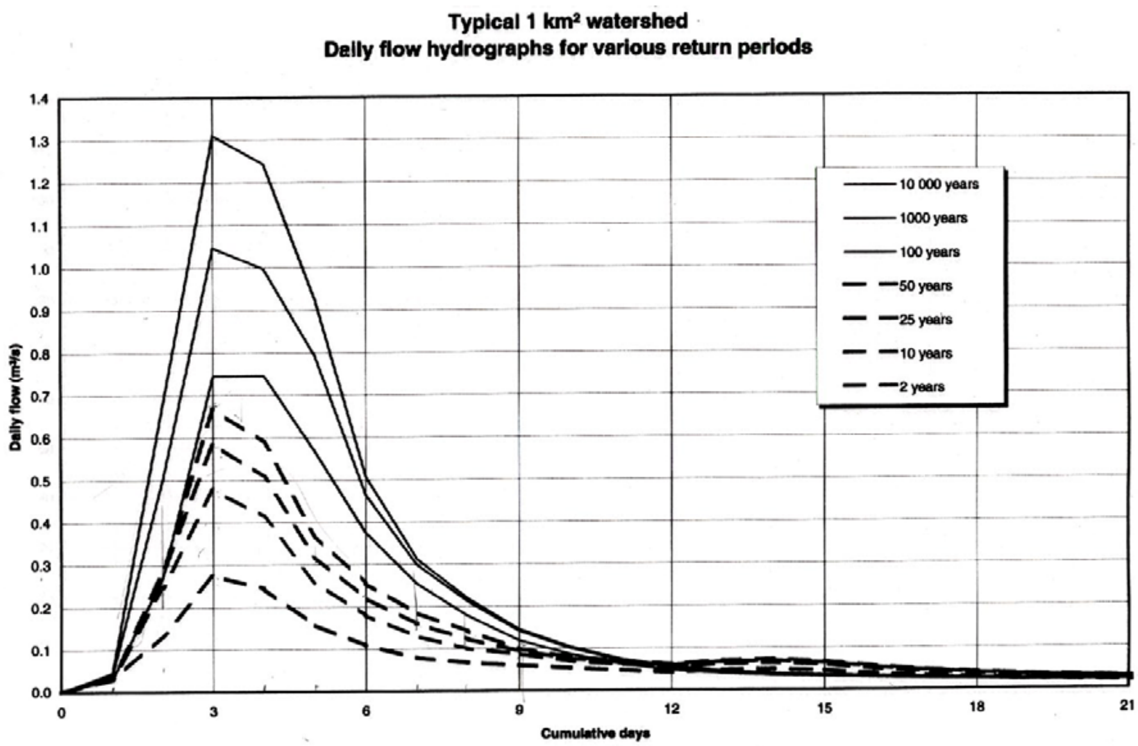


Figure 3. Daily flow hydrographs for various periods

The design flow for a 1km^2 watershed with a probability of 1:1000 for design of the discharge channels at Lupin is 1.04m^3/s. This hydrograph is applicable for watersheds up to about 5km^2.

The maximum design flows were obtained from estimated watershed areas contained by proposed discharge channel locations and the design flow of 1.04m^3/s. The results are given in Table 1.

Table 1. Estimated maximum flows at design discharge points

Area	Total Watershed	Individual Watershed	Cumulative Watershed	Maximum flows Individual Watershed	Maximum flows Cumulative Watershed
	ha	km^2	km^2	m^3/s	m^3/s
Cell 3	67		0.67		0.69
Cell 4	44		1.11		1.16
End Lake	124		2.35		2.44
Cell 1	47	0.47	2.82	0.49	2.93
Cell 2	21	0.21		0.22	
Cell 2 & 5	56	0.77		0.80	
Pond 1	45	0.45	4.04	0.47	4.20
Pond 2	212	2.12	6.16	2.21	6.41
Totals	616				

3.4 Discharge channel cross sections

Two typical discharge channel geometries are proposed for the Lupin TCA. One geometry for discharge channels through bedrock leaving tailings cells 1 and 5 and the other through breached dams J and 2. It is desirable to locate the discharge channels from Cell 1 and 5 through bedrock to ensure that the channels will withstand long-term erosion. The discharge channel from Cell 2 to 5 has been sized to determine its minimum width. There is little concern in regard to erosion in this channel since the cells 2 and 5 are adjacent cells and the flow from Cell 2 will be small.

Design assumptions for the development of discharge channels through bedrock are as follows:

- Minimum base of channel; 2m.
- Side slopes of 2 horizontal to 1 vertical.
- Minimum freeboard of 1m.

Design assumptions for the development of discharge channels through breached dams are as follows:

- Minimum base of channel is 50% larger than required.
- Side slopes of 3 horizontal to 1 vertical.
- Minimum freeboard, greater than 1m.

Maximum water depths were calculated based on selected channel base widths, the design assumptions and design flows developed in Section 3.3. The derived channel base widths and water depths for these design assumptions are given in Table 2.

Table 2. Discharge channels geometrics and resulting capacities (flows)

Flows From	Cumulative Watershed	Maximum flows	Channel base	Channel in bedrock	Water depth	Gradient	Flow for flow depth
	km^2	m^3/s	m	Minimum, m	m		m^3/s
Cell 1	0.47	0.49	2.00	1.50	0.20	0.02	0.45
Cell 2	0.21	0.22	2.00		0.20	0.01	0.32
Cell 2 & 50	0.77	0.80	2.00	1.50	0.30	0.02	0.92
Pond 1	4.04	4.20	8.00		0.50	0.01	5.77
Pond 2	6.16	6.41	12.00		0.50	0.01	8.54

The flows for the selected base width, water depth and gradient in Table 2 were calculated using the Manning Formula for open channel flows. These flows were then compared to the design flows before accepting the design cross section.

Design geometries are shown in Figure 4 for discharge channels in Cells 1 and 5 through bedrock and in Figure 5 for discharge channels through J Dam and Dam 2.

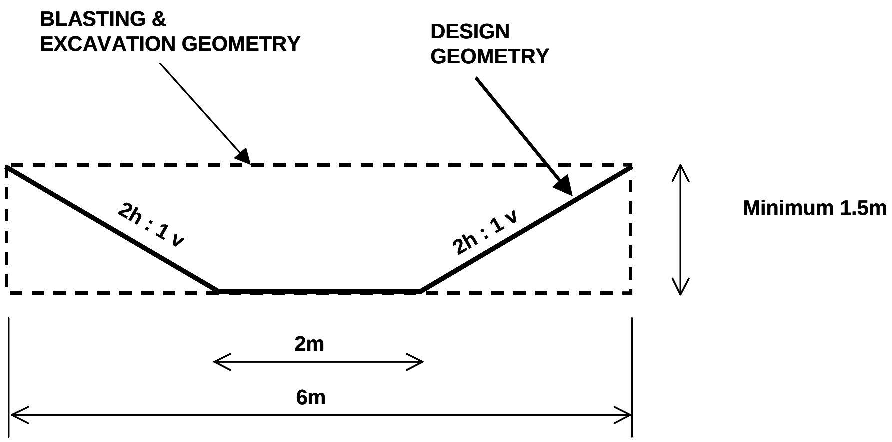


Figure 4. Design cross section for discharge channels through bedrock

While the design cross section shows a discharge channel with 2 horizontal to 1 vertical slope in bedrock, it is proposed to blast rectangular cross sections with 6m width that is based on the design side slopes. The extra base width would accommodate any future sloughing of the bedrock vertical side slopes.

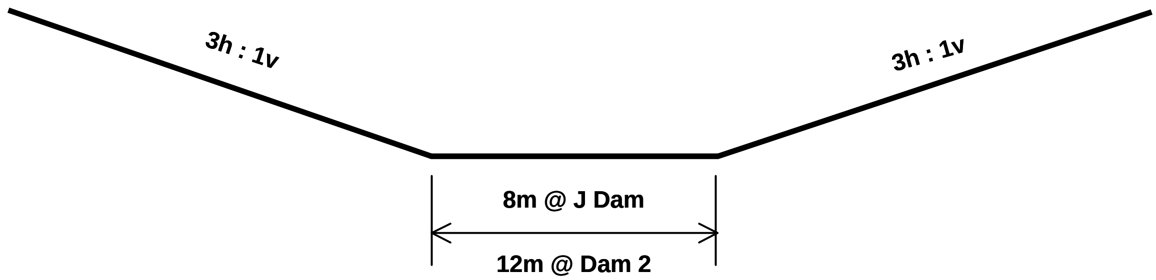


Figure 5. Design cross sections for discharge channels through breached dams

Vertical dimensions are not given for the cross sections through the breached dams since the depth of these channels will be over 6m; this being much greater than required for a freeboard.

The side slopes of breached dams will be covered with blasted rock harvested from the upstream slopes of the breached dams.

No treatment of breached J Dam base is proposed since at the proposed closure water level at El 480 in Ponds 1 and 2 will be the same.

The base of breached Dam 2 will be covered first with mine rock harvested from the upstream slope of Dam 2 and this in turn with large boulders or quarried rock to form a boulder bed. This treatment is proposed to provide a barrier between the TCA and the downstream stream to aquatic life.

Locations of the discharge channels are discussed in the following chapter.

4.0 WATER MANAGEMENT DESCRIPTION AFTER CLOSURE

4.1 General

This chapter shows flows through the TCA after closure and how these flows will be controlled by either/or both the original and after TCA closure topography. It shows the locations of the discharge channels for Cells 1, 2 and 5. These locations were selected based on known locations where the bedrock will control the flows and thereby minimize long-term erosion.

The discussions are based on the pre-mine and near end-of-mine operation topographies given in the Appendix that were prepared from aerial surveys taken on August 6, 1979 and June 27, 2004 respectively.

Figures located in the Appendix are numbered with a prefix A.

4.2 Cell 3

Tailings Cell 3 was formed by the construction of K and L dams. K Dam provides a divide within the TCA causing water from the earlier Lake ‘h’ to flow northerly towards Pond 1. The pre-mine and 2004 mine operation topographies are shown on Figures A3 and A4.

The figures show that K Dam was constructed on good foundations and the pre-mine Pond 2 edge was a considerable distance from K Dam. The June 2004 water level at El 481.4m shown on Figure A4 will be lowered to El 480.0m at closure. This will cause the Pond 2 edge to retreat from the toe of K Dam.

L Dam containing the tailings in Cell 3 will be breached, if necessary, during reclamation. Cell 4 will control water level of any pond remaining in Cell 3.

4.3 Cell 4

Cell 4 was not used to store tailings. However, its flows were changed by the construction of Cell 3. Flows from small Lakes ‘j’ and ‘k’ were directed towards the small Lake ‘p’ (Figure A1). The pre-mine water elevations in these lakes are shown on Figure A5.

Presently, surface waters from Cell 3 flow into Cell 4 and then to small Lake ‘p’ (Figure A6). A small culvert dike in Cell 4 provided minor water level control in Cell 4. The culvert dike will be breached and the discharge control on the downstream un-named small lake will control the water level in Cell 4 after closure.

It is noted that there are some discrepancies in the water elevations in the undisturbed small lake north of Cell 4 given in Figures A5 and A6. Water elevations determined from the 2004 survey indicated that the water level in Cell 4 after closure will be at El 485.7m; controlled by the small lake north of the culvert dike. Therefore, the future water level in Cell 4 will be less than 1m lower than the 2004 level.

4.4 Pond 1

Pond 1 accumulates surface water from Cells 3 and 4, as well as from End Lake and several smaller lakes along the path from End Lake to Pond 1 and Cell 1; not shown in Figure A6. The flows from Cell 4 and End Lake to Pond 1 are all controlled by bedrock topography along the stream path.

4.5 Cell 1 Discharge Channel

This discharge channel will be located in an area where the bedrock surface is at the 3D Dam crest (Figures A7 and A8). A slight depression in Cell 1 presently directs any excess surface runoffs in Cell 1 to a culvert in the 3D Dam crest. The culvert is located about 50m north of the proposed discharge channel. The surface water from Cell 1 will discharge into Pond 1.

It is proposed to blast a discharge channel through the shallow bedrock with a design shown on Figure 4. The location of this channel will be surveyed in the field before construction.

4.6 Cell 2 Discharge Channel

There does not appear to be any suitable shallow bedrock along 3D Dam adjacent to Cell 2. Considering that Cell 2 is a smaller cell and that it is adjacent to Cell 5, it is proposed to direct the surface water from Cell 2 into Cell 5 as shown in Figure A9. A channel will be excavated through the road/dike separating Cells 2 and 5 to allow this flow. The design of this channel will be field developed to ensure that adequate erosion control is provided for the tailings. It is likely that the width of this channel will be about twice the width shown in Figure 4 to reduce the height of water during the maximum flow.

4.7 Cell 5 Discharge Channel

This discharge channel will drain a watershed of about 75ha and therefore has to be erosion durable for the long-term. It is located in an area where the bedrock surface is higher than the surface of the tailings and final cover. A general location is shown in Figure A10. Again the final location and its routing will be field determined.

4.8 J Dam Breach

J Dam separates Ponds 1 and 2. The pre-mine, June 2004 and proposed water levels in these two ponds are given in Figure A11. J Dam will be breached to lower the water level to El 480.0m to be the same as in Pond 2.

The breach geometry is shown in Figure 5. The base of the breach is considerably wider than necessary to handle the maximum design flow and the slopes of the breach are shallow at 3 horizontal to 1 vertical. The reason for more conservative cross-section design is that this channel is located within dam fill.

It is proposed to harvest the mine rock from the slopes of the dam and apply them to the channel slopes.

4.9 Pond 2

The discharge from the TCA will be directed through a breach in Dam 2. Dam 2 was selected because it has a slightly higher discharge control than is present at Dam 1A. The discharge control is located at the downstream end of small Lake ‘s’ by the surface bedrock at this location. The pre-mine and the 2004 topographic contours at Dam 2 are shown on Figures A12 and A13 respectively. The breach will be constructed as per Figure 5.

As mentioned earlier, the base of breached Dam 2 will first be covered with mine rock harvested from the upstream slope of Dam 2 and then with large boulders or quarried rock to form a boulder bed. This proposed treatment is to provide a barrier aquatic life.

Dam 2 was selected as the discharge point for water from the TCA after closure because the water level in Pond 2 will remain about 2m above the original water level. The pre-mine Pond 2 water level was controlled and drained by the depression at Dam 1A. It is likely that when foundations thaw in Dam 1A due to climate warming, some seepage may occur through Dam 1A.

The location of the discharge channel at Dam 2 is preferred because it will minimize exposing any sediment that may have settled within the increased perimeter shoreline in Pond 2 due to the higher water level (original water level at El 477.8 and proposed El 480.0). It is noted that the proposed final water level in Pond 2, at El 480.0, is similar to the operating level in Pond 2 between 1986 and 2002 (Holubec 2005).

4.10 Downstream Seep Creek

Water discharged from Dam 2 will reach the original Seep Creek route in a short distance, as illustrated in Figures A14 and A15.

5.0 CLOSURE

This report was prepared to provide the location and design of water management of the TCA after closure and basis for evaluation of the present water quality within the TCA and to predict the future water quality, as discussed further in Volume III.

I. Holubec Consulting Inc.

Igor Holubec, Ph.D., P. Eng. (NT & ON)
Geotechnical Specialist

6.0 REFERENCES

Canadian Dam Association, 1999. Dam Safety Guidelines.

Diavik Hydrology, 1998. Used in the design of on-land ditches and ponds.

Holubec, I. 2005. Closure plan for tailings containment area, Lupin Operation, Contribution to 2004 Final Abandonment and Restoration Plan. Prepared for Kinross Gold Corporation. January 2005. pp 43.

McElhanney 1979. Topographic Map Area No 2. Prepared from aerial photographs taken in Aug 9, 1979. Scale 1:5000; Contour intervals 2.5m.

Topographic Map prepared from aerial photographs taken in June 27, 2004.

APPENDIX – FIGURES

List of Figures

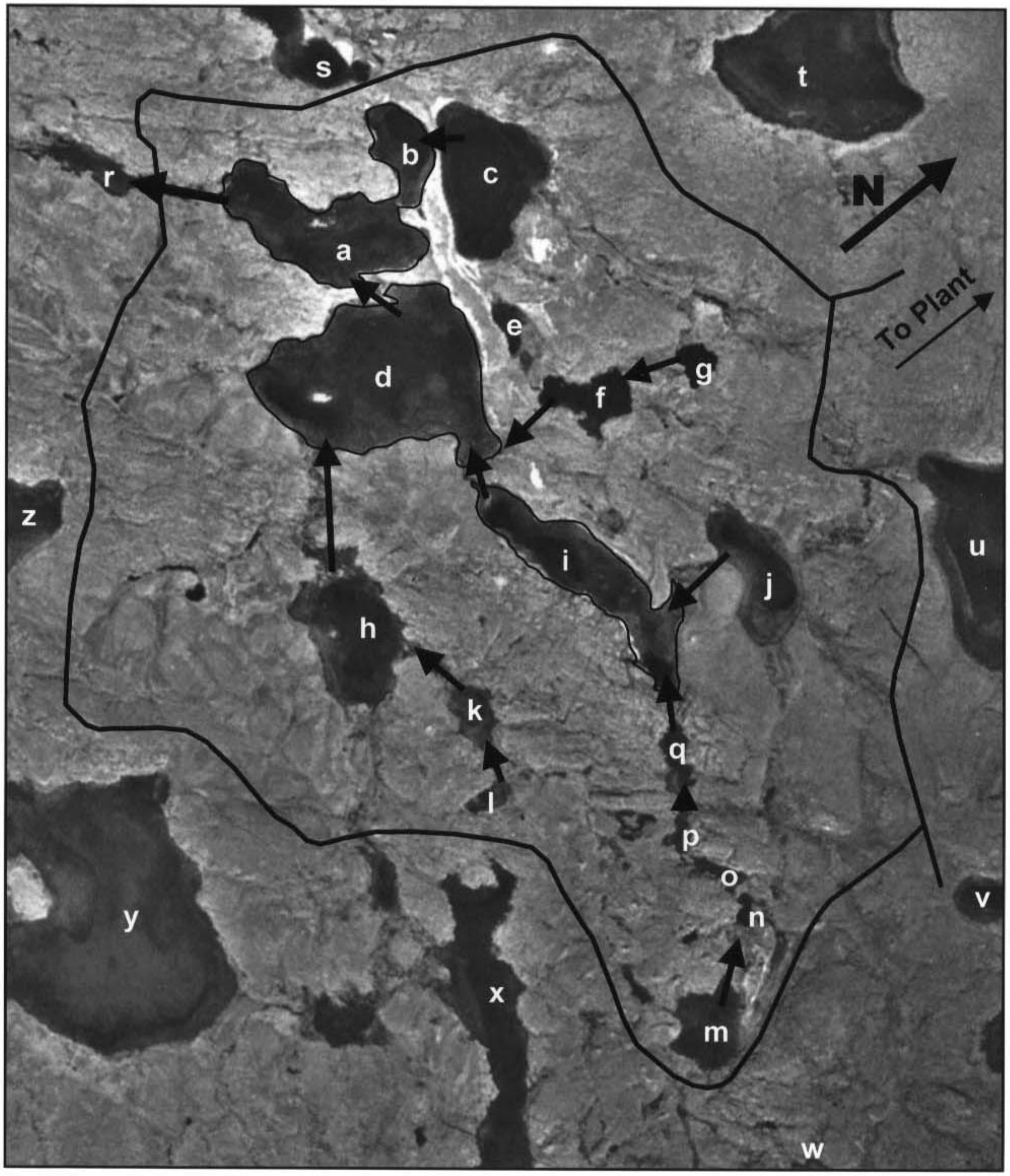


Figure A1. Pre-mine lakes and water flow within tailings area watershed

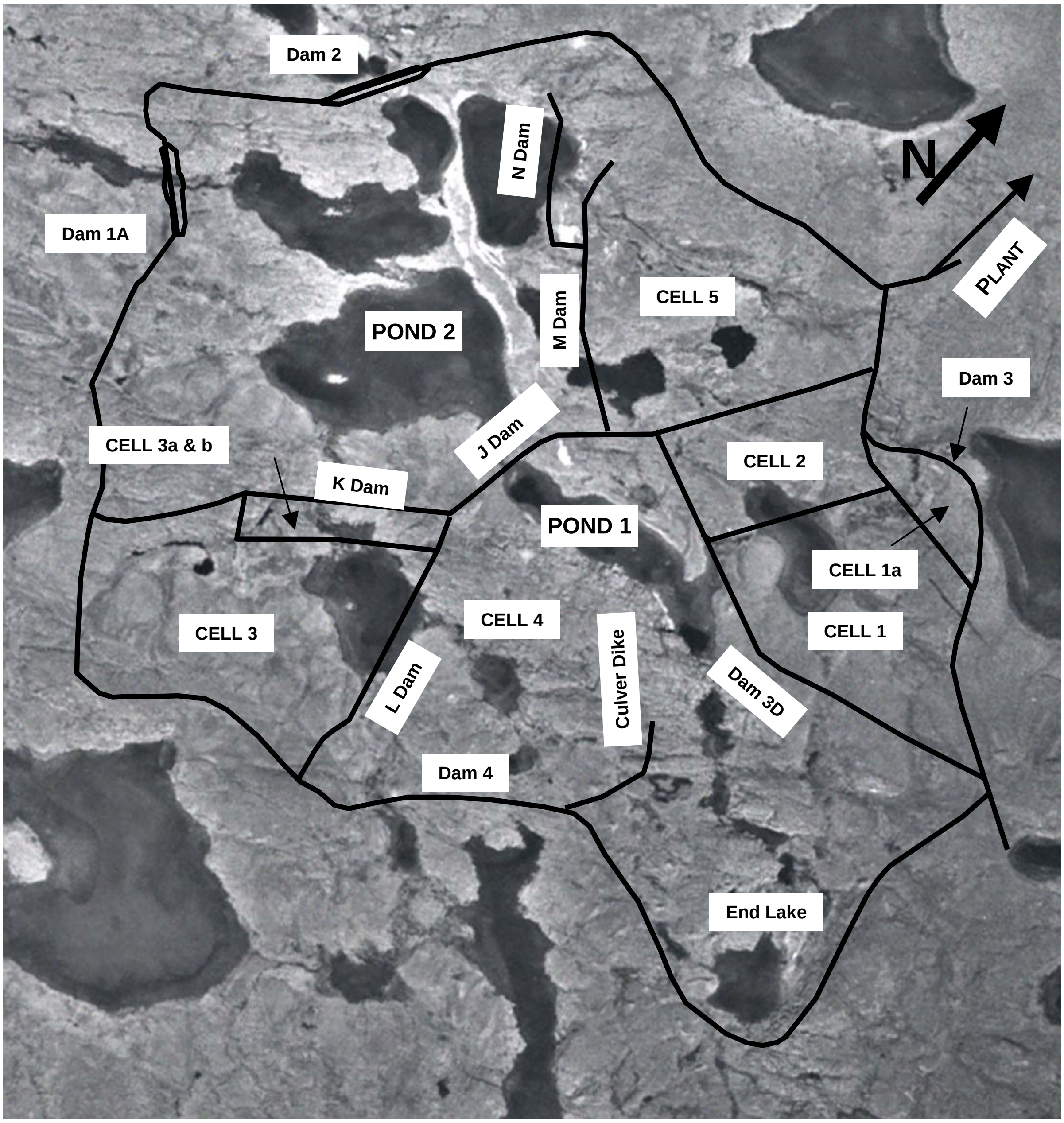


Figure A2. Location of dams and cells at TCA

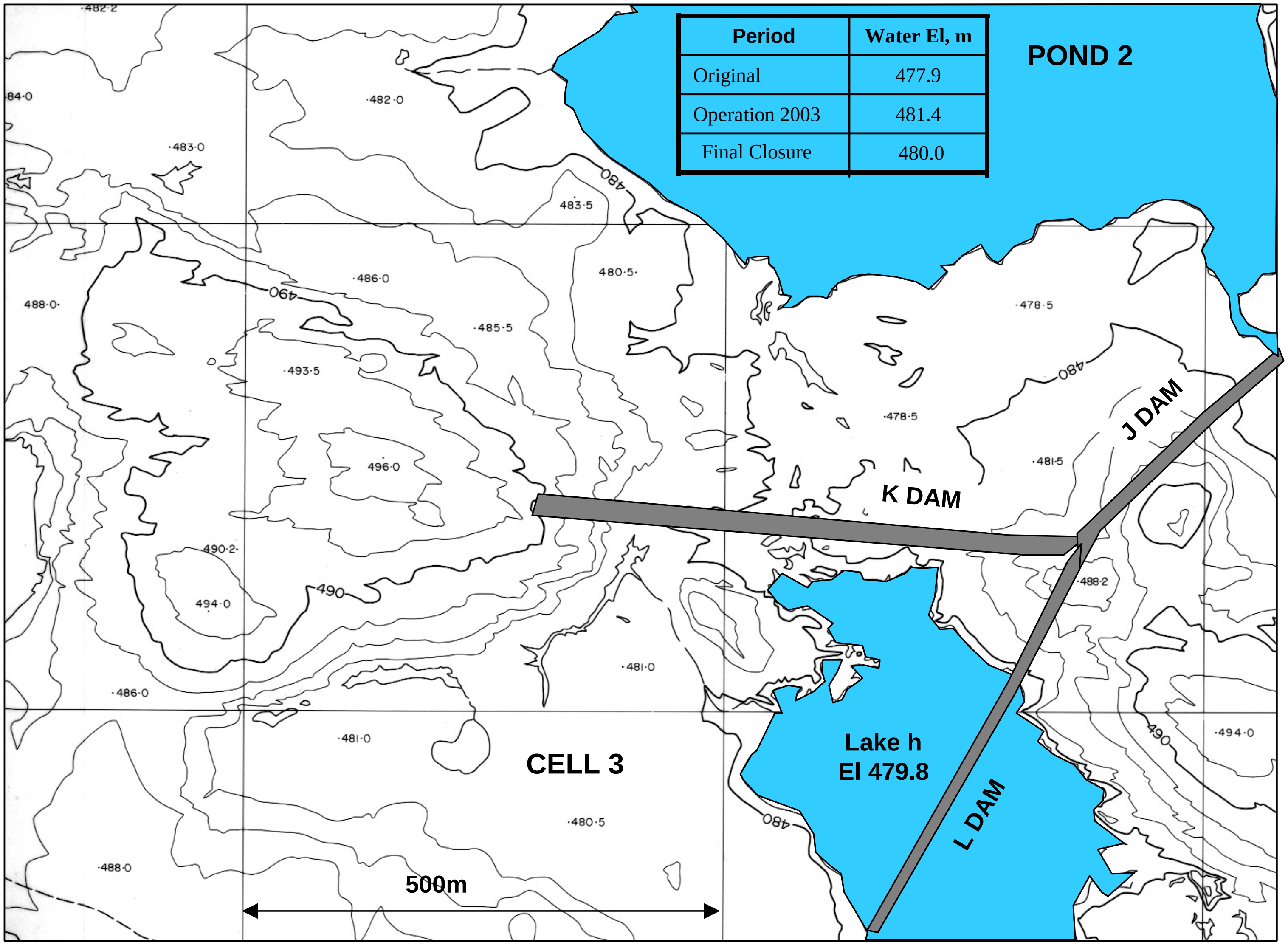


Figure A3. Pre-mine topography & general location of J, K and L Dams

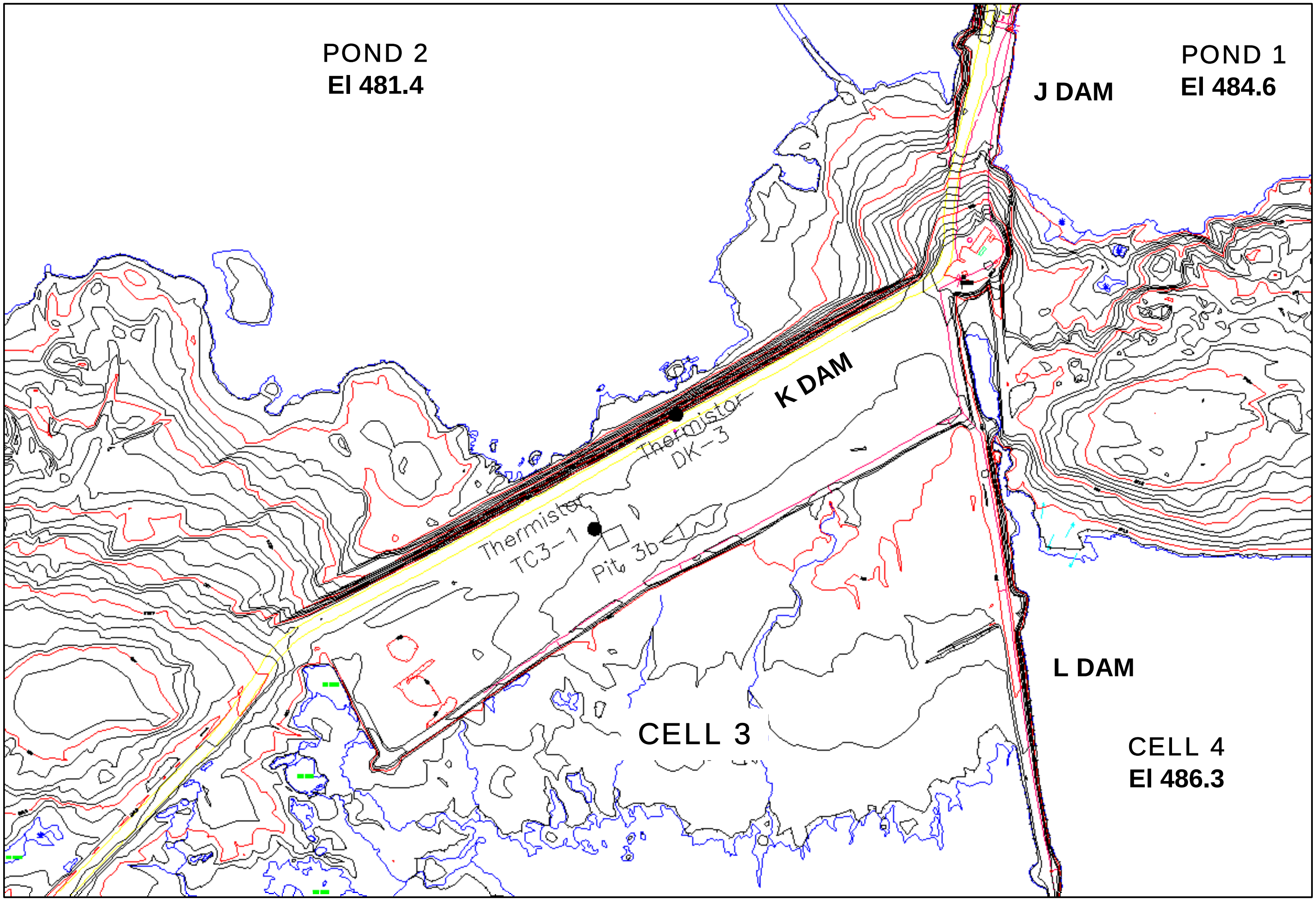


Figure A4. June 27, 2004 topography at Cell 3 and J, K and M dams

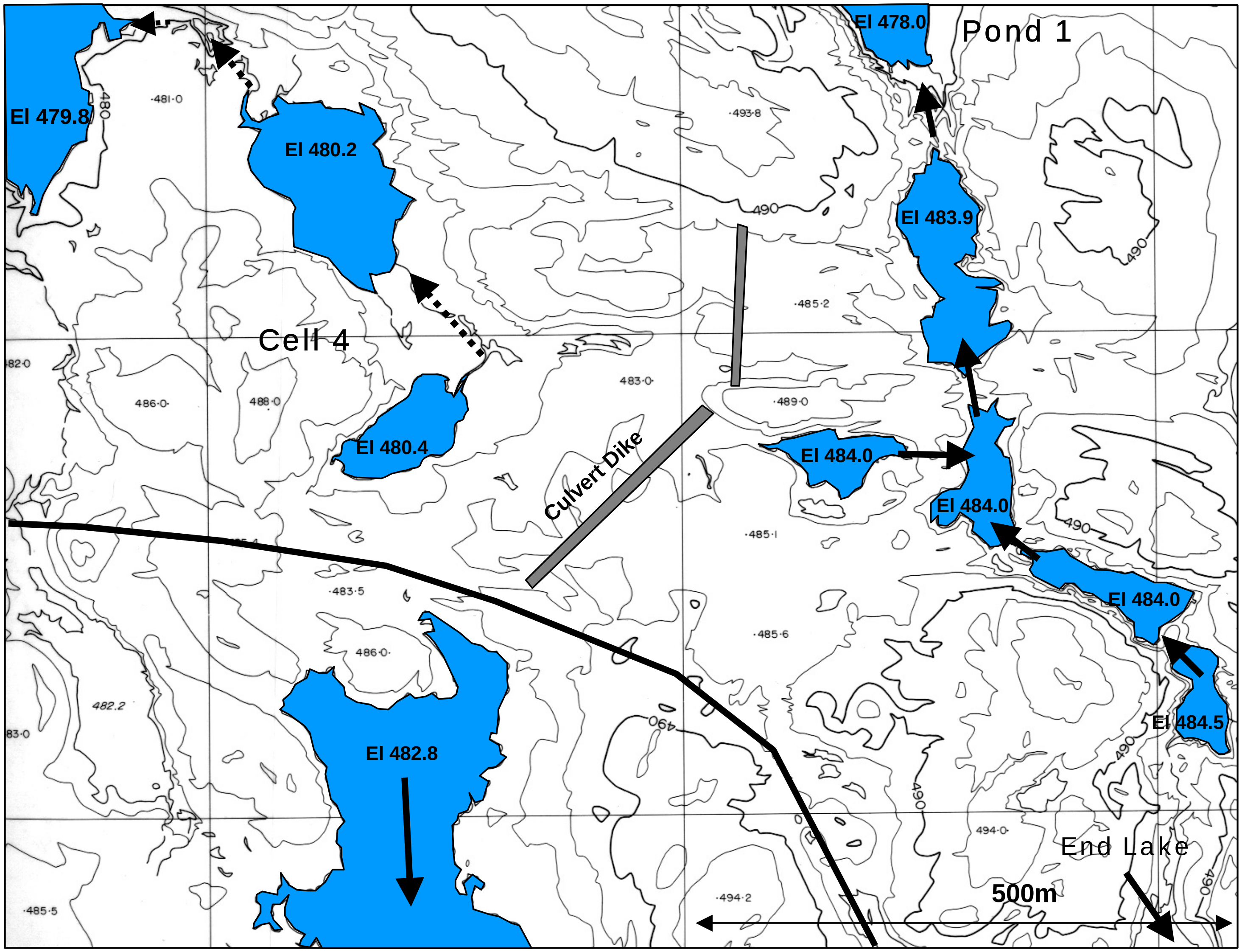


Figure A5. Pre-mine topography and water flows in Cells 3 and 4 and Pond 1 area

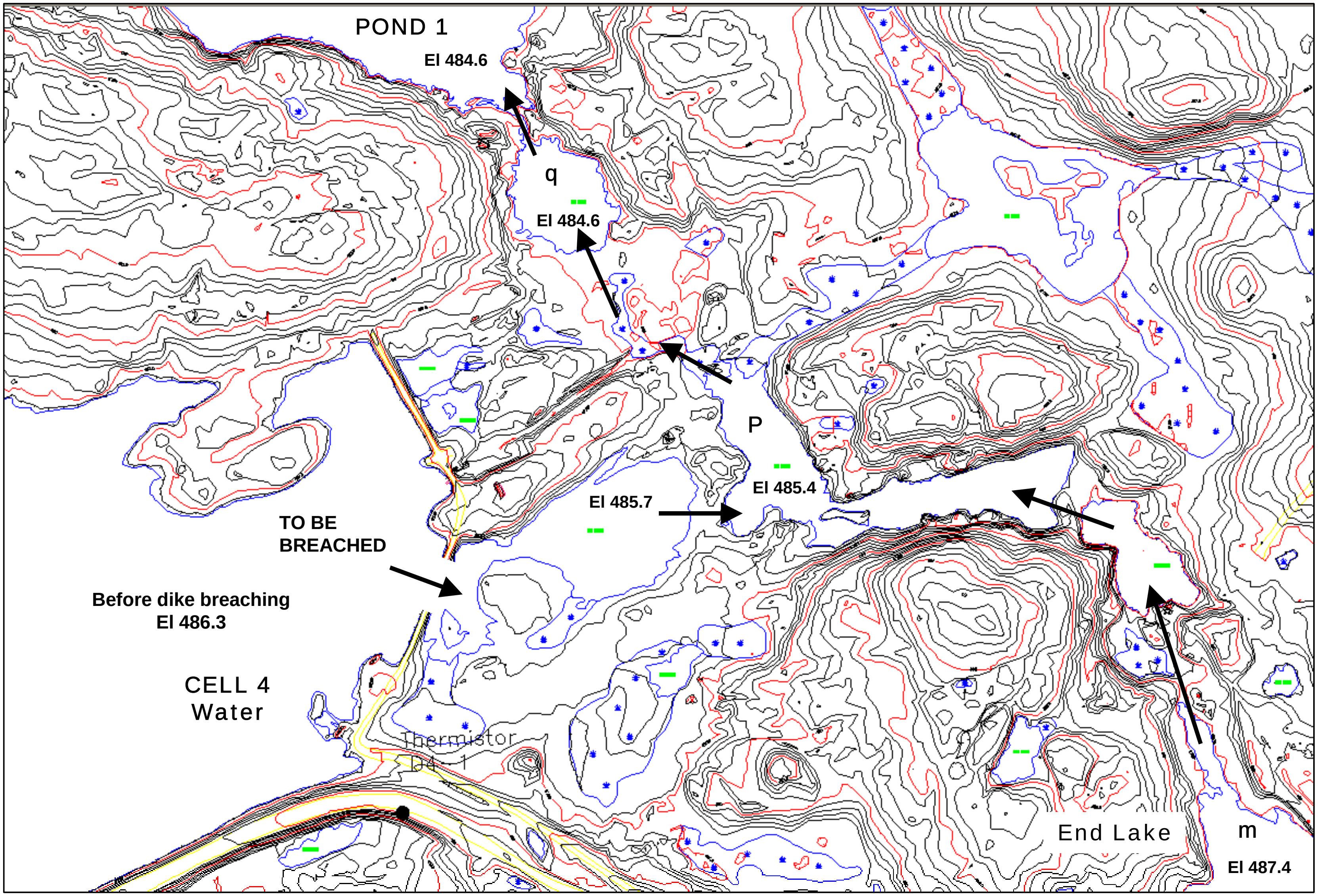


Figure A6. Water flows in Cell 4 area after reclamation

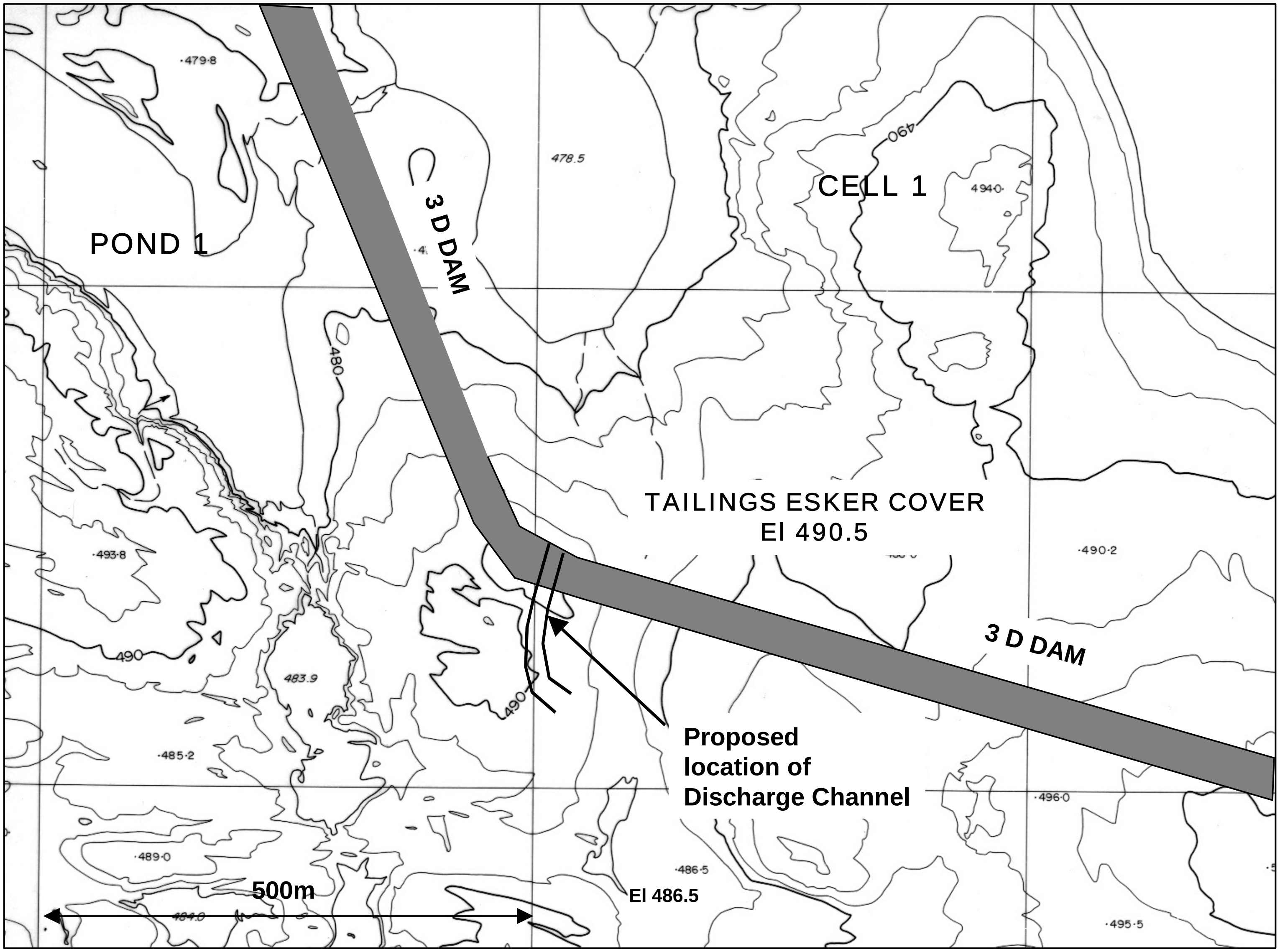


Figure A7. Pre-mine topography at proposed Cell 1 discharge channel location

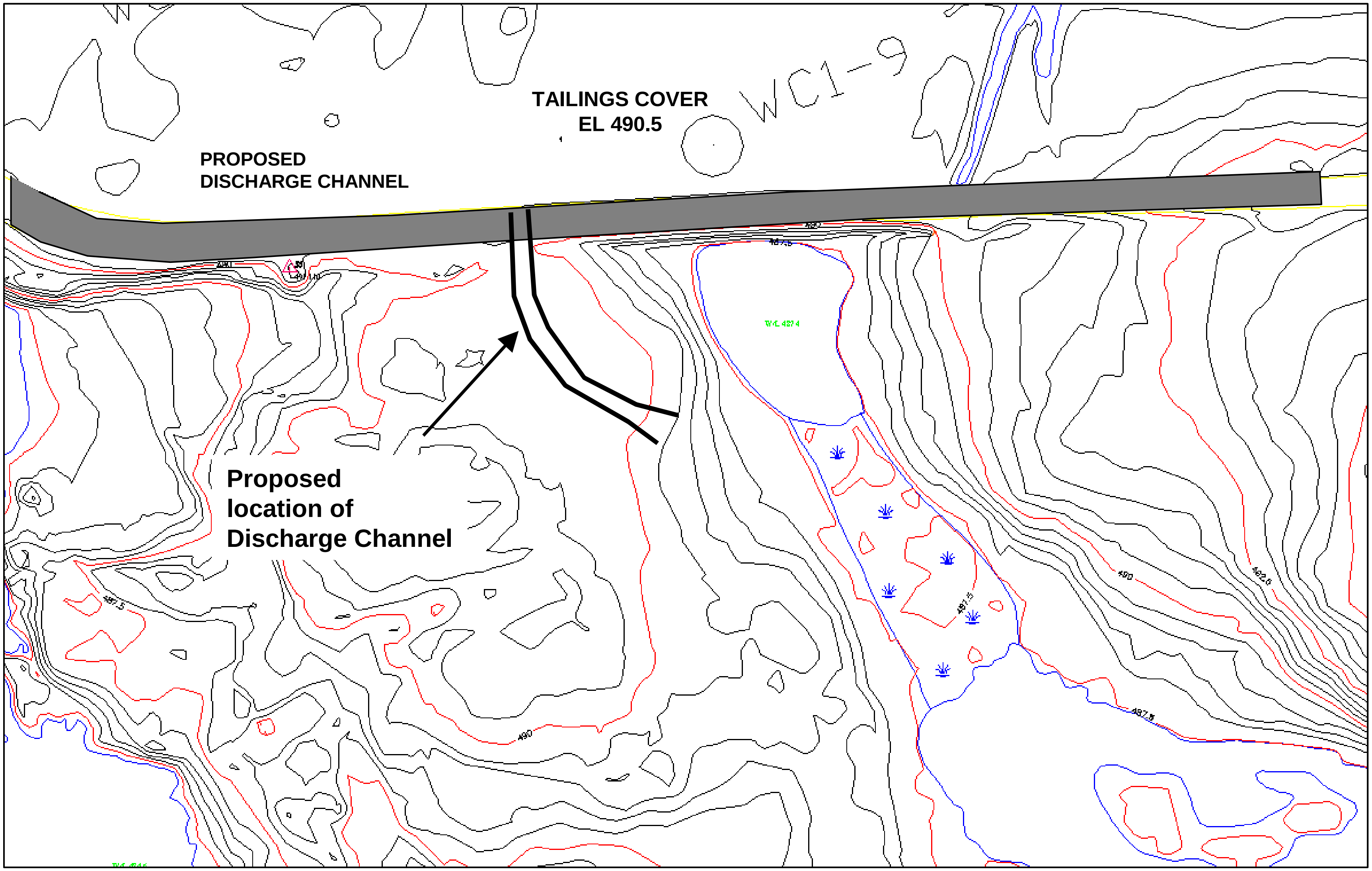


Figure A8. Cell 1 discharge channel location

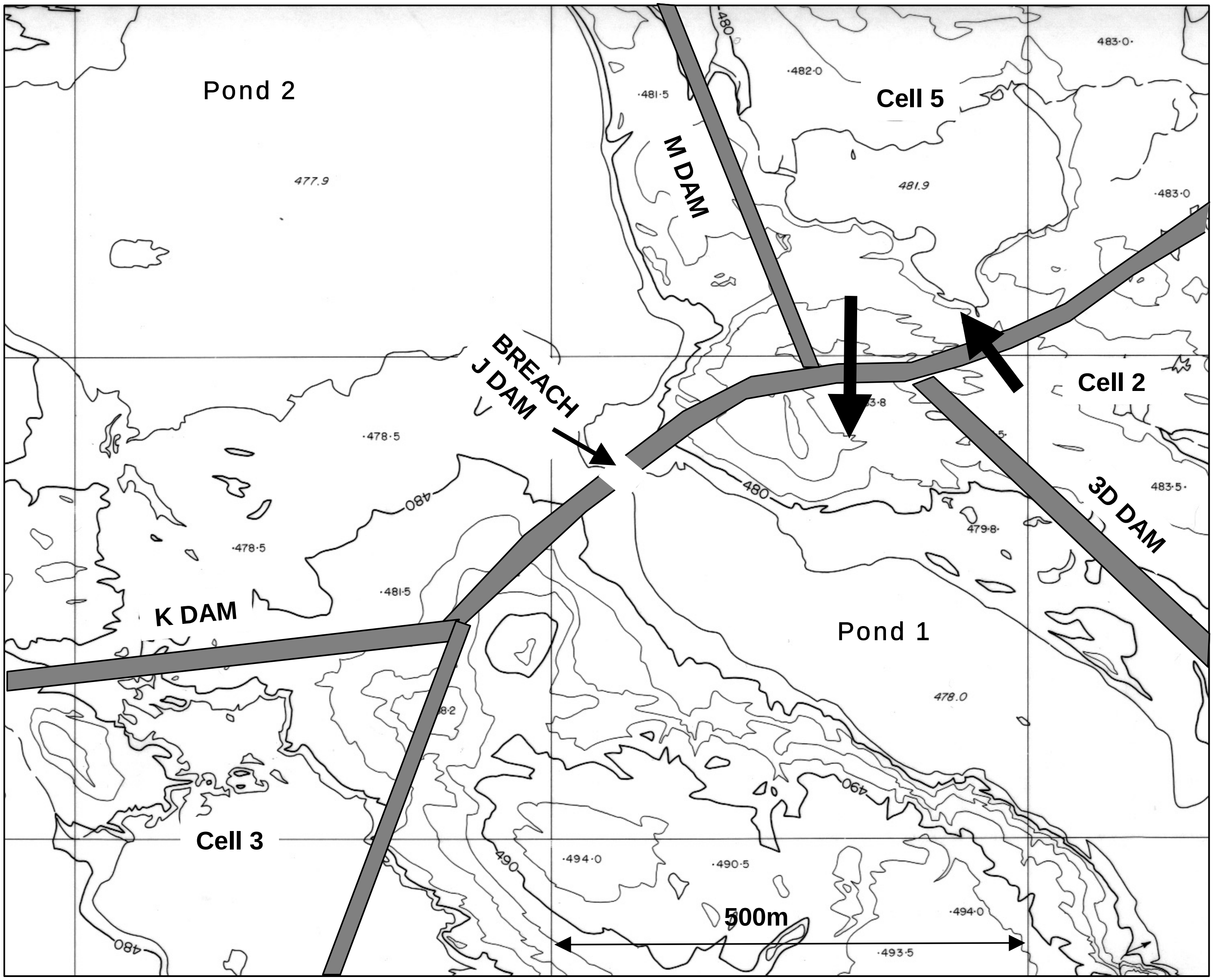


Figure A9. Pre-mine topography at J Dam and location of Cell 2 and 5 discharge channels

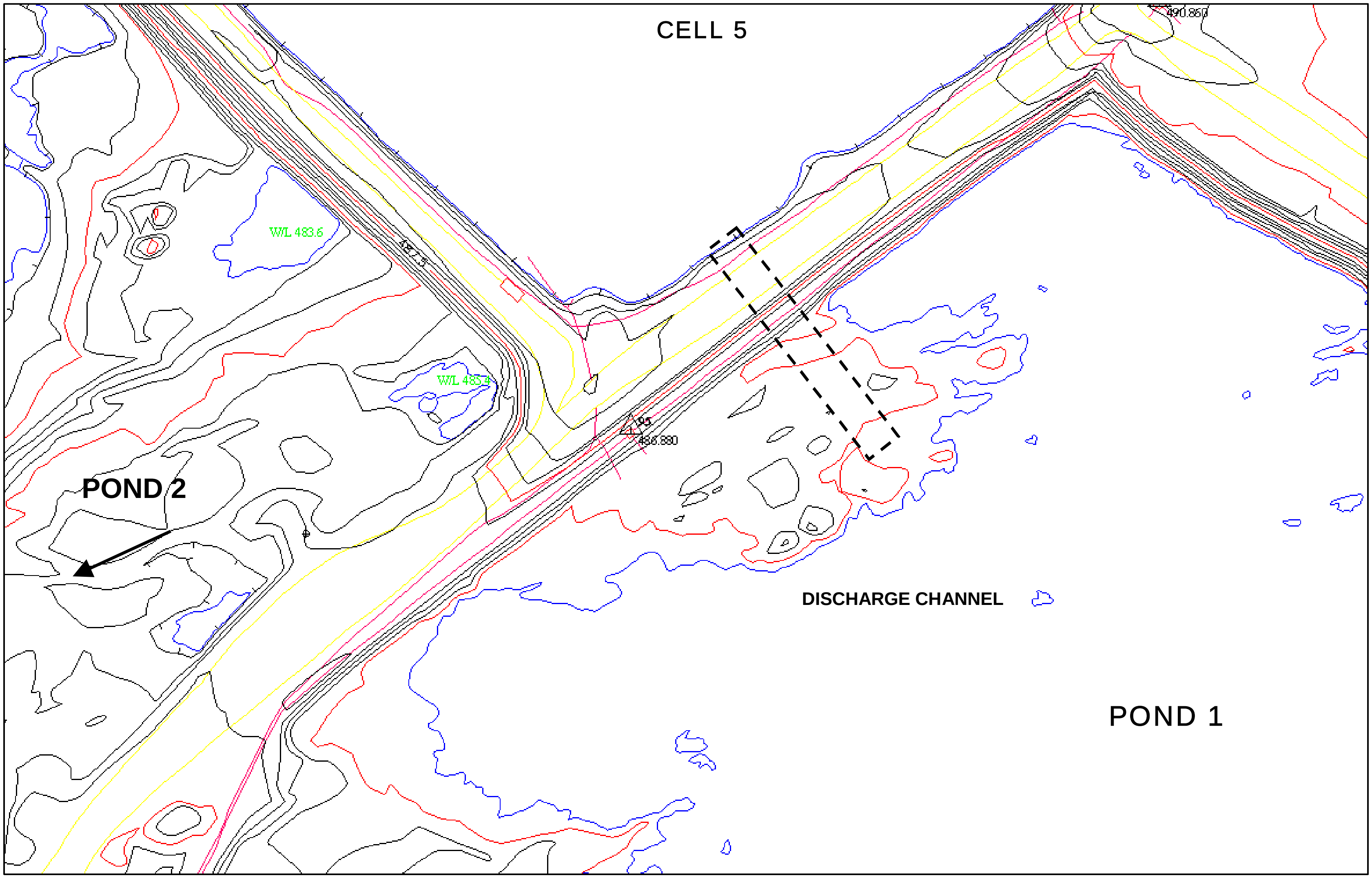
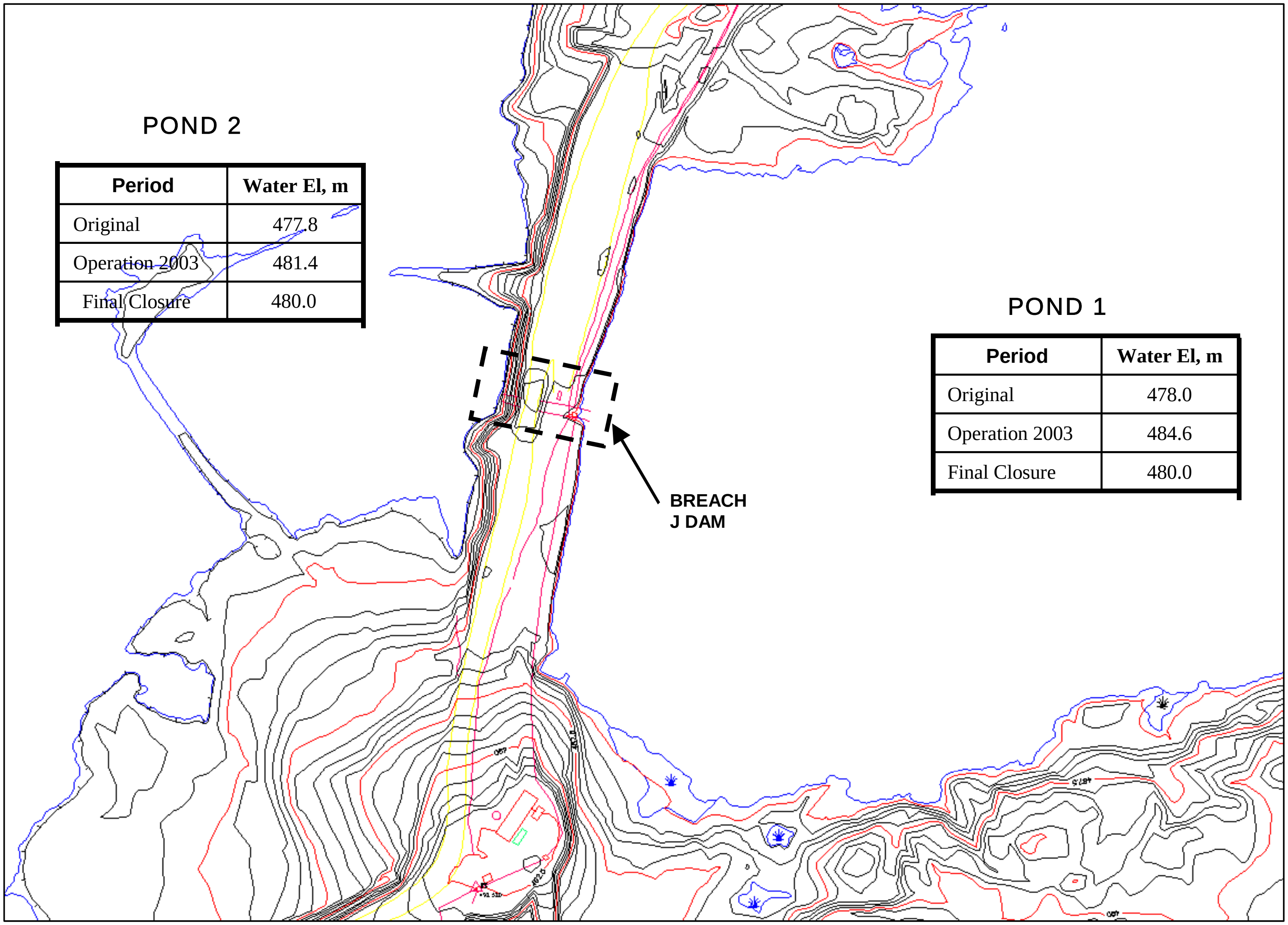


Figure A 10. Discharge channel from Cell 5



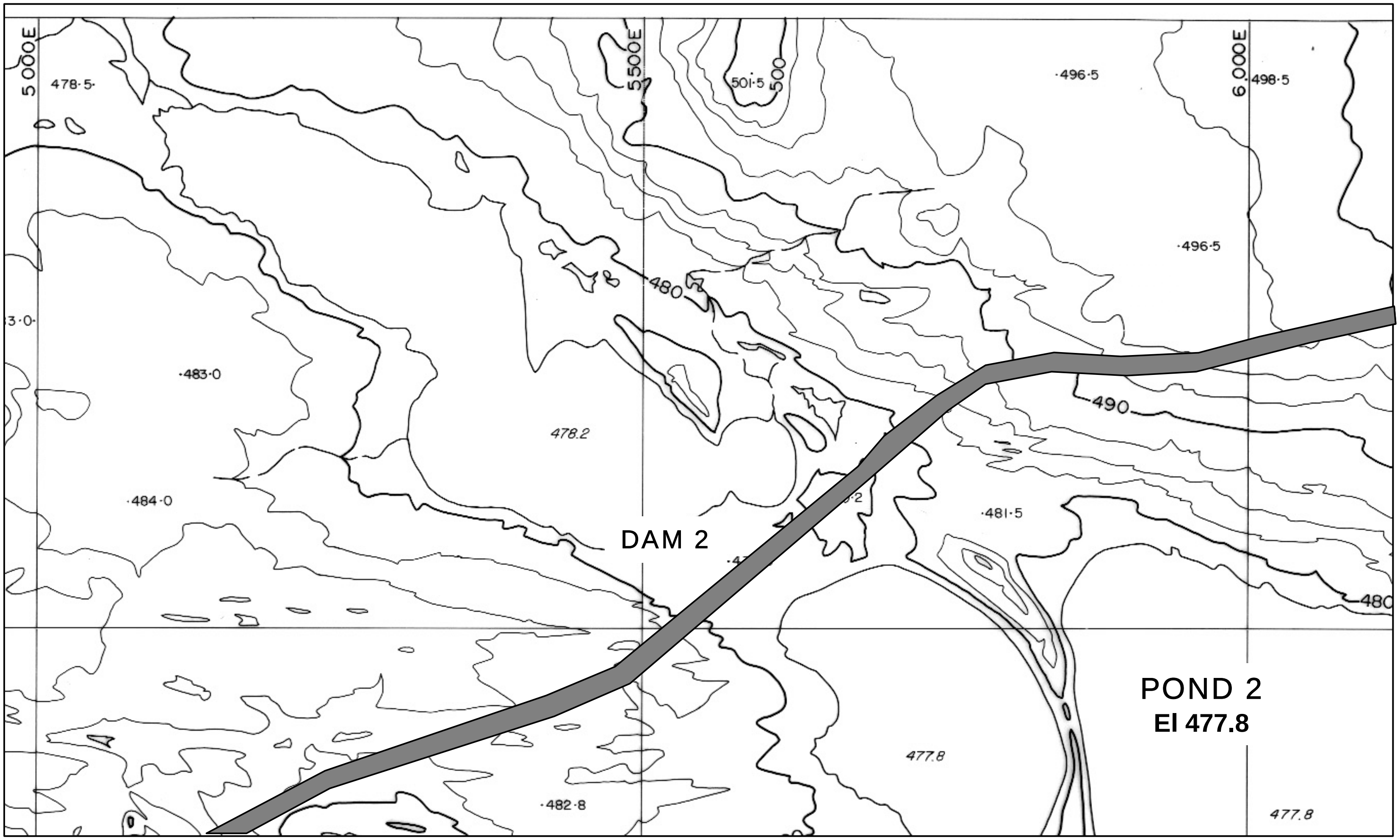
POND 2

Period	Water El, m
Original	477.8
Operation 2003	481.4
Final Closure	480.0

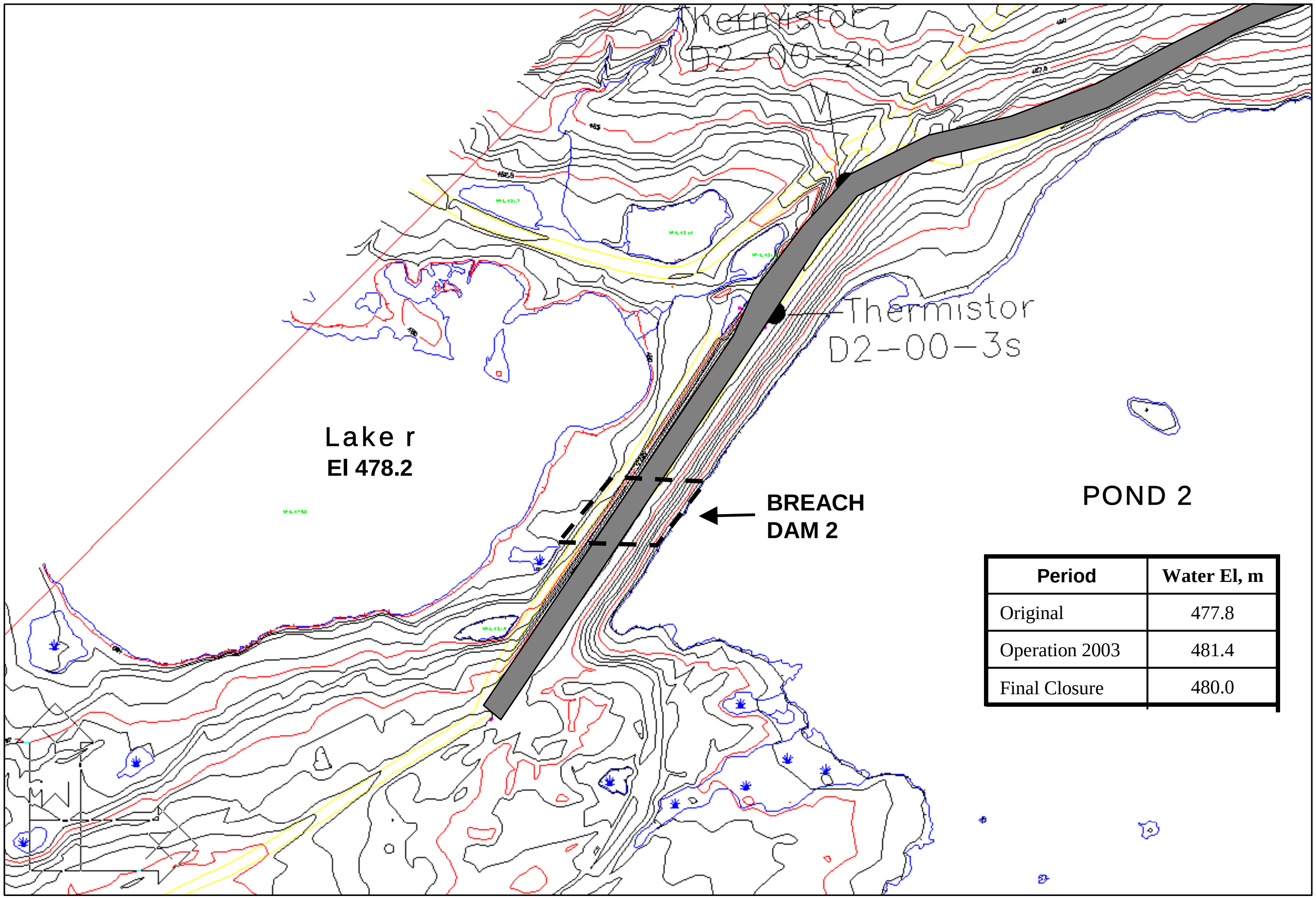
POND 1

Period	Water El, m
Original	478.0
Operation 2003	484.6
Final Closure	480.0

Figure A11. Breaching of J Dam and water levels at different periods



FigureA 12. Pre-mine topography at Dam 2



Period	Water El, m
Original	477.8
Operation 2003	481.4
Final Closure	480.0

FigureA 13. Dam 2 breach area and water levels in different periods

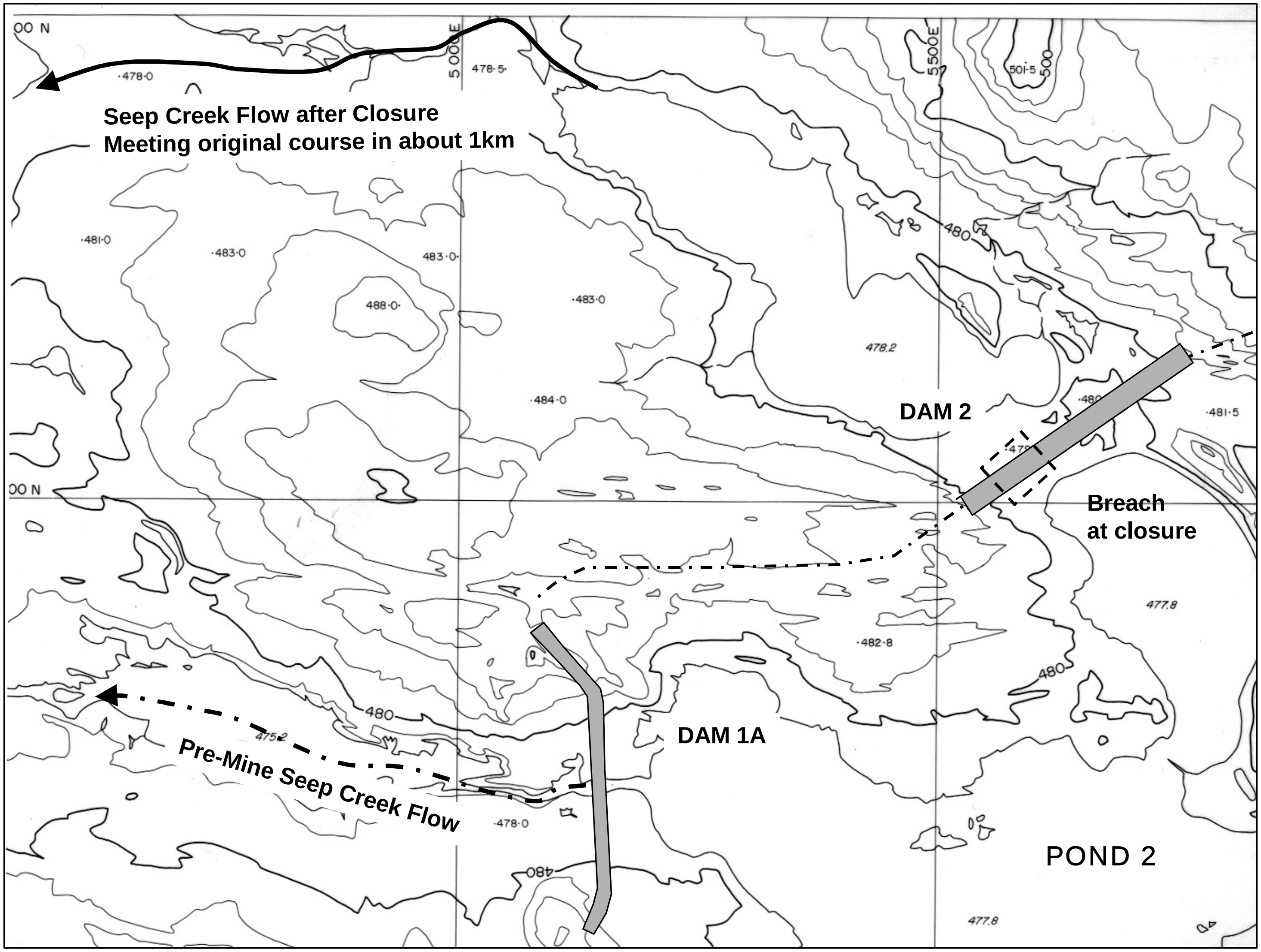


Figure A14. Pre-mine & after closure discharge course from Pond 2

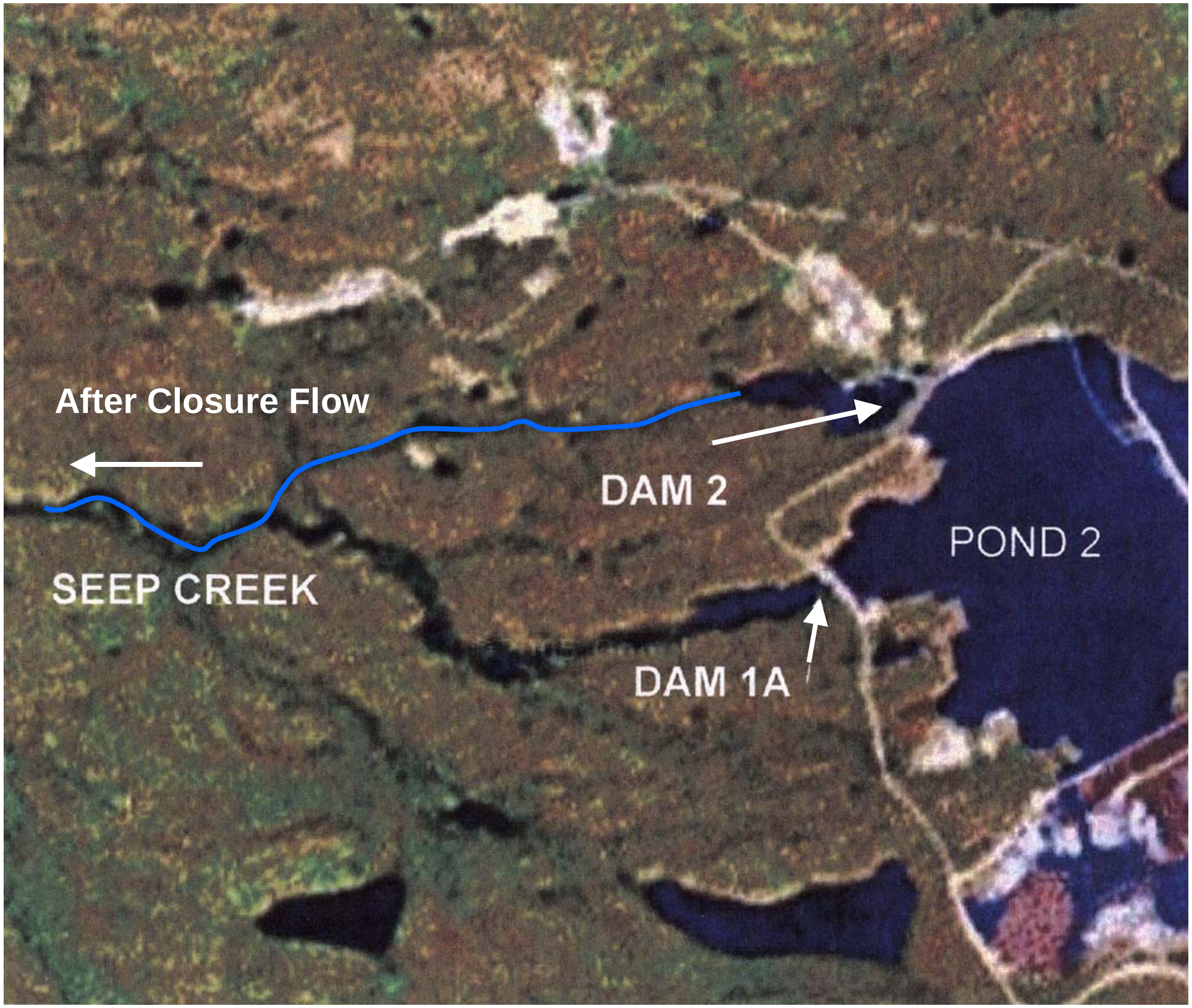


Figure A15. TCA discharge Creek after Closure