2005 Water Balance for the Mount Nansen Mine Tailings Pond, Yukon

Prepared for
Yukon Government, Abandoned Mines Project Office

Submitted by
Gartner Lee Limited

February 2006

Gartner Lee

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1 Gartner Lee Limited

Gartner Lee

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Frank Patch, Project Manager
Energy, Mines and Resources
Abandoned Mines Project Office
Box 2703
Whitehorse, Yukon Y1A 2C6

Dear Mr. Patch:

Re: 50-382 – Water Balance for the Mt. Nansen Tailings Pond - 2005

Gartner Lee is pleased to provide you with a summary report outlining the results of the water balance of the tailings pond at the Mt. Nansen mine, Yukon. This report summarizes the approach to the water balance and the individual components and data used for the modeling. Additional meteorological data and relevant site information are also included to facilitate interpretation and assist in predictive modeling of longer term pond behaviour. We hope the data presented herein can assist the Government of Yukon in understanding the hydrology and hydrogeology of the tailings impoundment site and eventually lead to the development of a scientifically sound approach to site closure and management of the tailings impoundment.

Gartner Lee Limited looks forward to working with you on this important project in the near future.

Yours very truly,
GARTNER LEE LIMITED

Martin Guilbeault, P.Eng., M.Sc.
Senior Hydrogeologist

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1. Background

The mine site at Mt. Nansen, located 60 km west of Carmacks, YT was owned in part or in whole by BYG Natural Resources Inc. from 1985 to 1999. BYG conducted mining and milling operations between October 1996 and February 1999 when environmental concerns forced BYG to cease operation of the mine. An interim receiver, appointed in March 1999, subsequently abandoned the mine in July 1999. Following abandonment, Indian and Northern Affairs Canada, Water Resources Division assumed responsibility for the site and began care and maintenance operations. As part of the devolution of federal government responsibilities in Yukon, the Government of Yukon took over on April 1, 2003 and continued care and maintenance operations and also began the process of closure planning. Gartner Lee Limited (GLL) was retained to assist the Government of Yukon (YG) in developing a water balance for the tailings pond and perform a review of the pond water quality. The water quality review will be presented under separate cover.

2. Tailings Pond Water Balance

In general, the main components of the water balance include direct precipitation onto the pond lake surface, surface runoff from the catchment area, evaporation from the pond lake surface, and net changes in surface water and groundwater inflow/outflow (Figure 1). In addition, water from the pond has been pumped for treatment prior to discharge to Dome Creek, at least during the summer months until 2005. Pond water was pumped from the pond during 2005 and was discharged to Dome Creek without treatment because it met discharge requirements. Groundwater also discharges and accumulates in a seepage pond downgradient of the tailings pond. This discharge is assumed to represent a significant component of tailings pond seepage. Water levels in this pond are maintained relatively constant and seepage water is pumped either back into the pond or discharged to Dome Creek. An important consideration for the water balance of the tailings pond is the incorporation of local meteorological information. Additionally, effects pertinent to a northern setting were also considered. These considerations include the formation of pond surface ice during winter, accumulation of snow within the watershed and the presence of discontinuous permafrost within the study area. Subsequently, these factors affect infiltration rates of precipitation, groundwater flow and hydrology.

To provide accurate estimates for each component of the water balance, pond bathymetry measurements provided by EDI (2005) were essential. In the analysis of the tailings pond water balance, it was also essential to consider the impact of water treatment and de-watering management activities undertaken by government agencies since 1999.

Lack of detailed information and detailed mapping for the immediate area surrounding the tailings pond were limiting factors in determining surficial drainage patterns and catchment areas for the tailings pond.

The absence of groundwater monitoring wells in the vicinity of the tailings pond also makes it impossible to confirm the location of the water table beneath the tailings impoundment. Consequently, this also introduces uncertainty in groundwater seepage estimates and the interaction of tailings pond water with the hydrogeological regime.

3. Background Information

The data used to develop the tailings pond water balance were collected from previous reports, personal communications with individuals familiar with site activities and data collected over two field seasons. The data recorded in 2005 was used to develop the water balance described in this report.

3.1 Previous Site Water Balances

A water balance was first completed for the mine site by Higgs (1994) as part of the Brown-McDade Pit mining project planning process. The Higgs water balance analysis was based on long-term climate data from the Carmacks weather station augmented with a limited amount of site-specific metrological data collected during site exploration actives between 1985 and 1988. Klohn-Crippen (1995) also developed a water balance for the proposed tailings facility as part of the feasibility design work for the main tailings dam.

A water balance model was also developed for the Brown McDade open pit by Gartner Lee (2004) as part of a hydrogeological and geochemical study of the pit. The pit study incorporated site-specific data including post-operational water levels of the pit lake, a 2004 detailed pit survey, digital site mapping, and meteorological data collected from the Mount Nansen Site meteorological station. The present water balance for the tailings pond also uses data from the Mt. Nansen Site meteorological station.

3.2 Piezometer and Groundwater Well Data

Higgs (1994) reports that four groundwater monitoring wells were "established" in September of 1989 in the area of the proposed tailings pond (Site #1) further up valley near the existing camp. These wells confirmed the presence of active groundwater flow in the area upstream of the existing tailings pond. No relevant data from these wells were found in the reviewed materials.

Several pneumatic piezometers were installed by EBA (2002) in boreholes along with thermistors to monitor geotechnical conditions downgradient of the tailings dam. Hydrostatic pressure data from these piezometers were reviewed by EBA (2004) as part of an overall assessment of geotechnical conditions related to the dam. The data reviewed were collected between November 2001 and December 2003 for the main tailings dam #1 and the seepage dam #2 and include hydrostatic pressure measurements from twelve piezometers at five locations within the dam structure (Figure 2). These devices are capable of measuring groundwater pressures, however, they do not allow for collection of groundwater samples.

3.3 Thermistor data

A series of ten boreholes with thermistor strings were installed in the structures downstream of the tailings pond by EBA in 1998. A review of the thermistor data is provided by EBA (2004). Although thermistor and ground temperature data is not used directly for the tailings pond water balance, ground temperatures yield important information about ground conditions within and downgradient of the dam structure. The approximate depth to permafrost can be inferred from these data and is discussed in the following sections.

3.4 Pond level

Intermittent pond water level readings were recorded by BYG, the receiver, and Ketza using direct surveying of water level and staff gauge readings. Levels were recorded manually between 1999 and 2004. EBA (2004) presents a summary of the available measurements prior to 2004. Pond water levels have been recorded continuously since June 2005 by YTG using a level logger. This device was temporarily referenced to a relative benchmark at the site and will be tied into previously known benchmarks at the site by Yukon Government. Environmental Dynamics Incorporated (EDI 2005) completed a bathymetrical analysis of the pond relative to this temporary benchmark. Pond bathymetry has been incorporated for schematic purposes in Figure 2.

3.5 Groundwater Seepage

EBA (2002) and (2004) summarized available records of water pumped from the seepage pond downstream of the main tailings dam. Water from the seepage pond was pumped and re-circulated to the main tailings pond until 2004. In 2005, Yukon Government pumped water from the seepage pond and discharged it to the Dome Creek after water quality monitoring indicated that pond water met discharge requirements. The flow rates available for the seepage re-circulate are summarized in Table 1 and Table 2. As pointed out by EBA (2004) and discussed further in this report, these rates represent only an estimate of the actual groundwater seepage from the tailings pond because the seepage pond does not necessarily capture all seepage, it is not constructed to prevent outflow of seepage and it is subject to surface runoff and direct precipitation (Figure 1).

3.6 Tailings Impoundment Design

3.6.1 Tailings Impoundment and Tailings Distribution

The tailings impoundment was constructed in 1995. The dam was designed with a storage capacity of 300 000 tonnes or 240 000 m^3 of tailings (EBA 2002). The dam crest was set at a width of 6 m and an elevation of 1151.5 m. The maximum elevation of tailings in the impoundment is reported to be 1148.7 m and the estimated volume of tailings within the impoundment is approximately 280 000 m^3.

Following the start of tailings discharge to the impoundment, significant seepage pressures were encountered at the base of the main dam. An emergency toe berm was constructed in July 1997 by the mine operator.

The distribution of tailings is an important factor controlling groundwater movement within and around the impoundment. The thickness of the tailings and relative distribution can also affect pore water residence times, groundwater quality and seepage rates from the pond. Yukon Engineering Services (YES) prepared an estimate of the volume and distribution of tailings at the site in November 2001. The procedure and approach used is discussed by EBA (2002). The interpreted YES tailings survey has been incorporated into Figure 3. At its maximum thickness near the centre of the original valley bottom, the tailings are estimated to have a thickness of approximately 12.5 m. The volume of tailings in the impoundment is estimated at between 250 000 m^3 and 310 000 m^3 (EBA 2001).

The surfice area of the tailings including the tailings pond is approximately 65 000 m^2. This area is bounded on the north and east by a diversion ditch and an access road (Figure 2). The location of the road shown on Figure 2 and Figure 3 has been assumed based on previous mapping and site visits.

3.6.2 Diversion Channel and Spillway

A diversion ditch and spillway were constructed around the tailings impoundment to divert surface water from the upstream catchment area, around the tailings and tailing pond (Figure 2 and Figure 3) This ditch was constructed un-lined with sand and has not been maintained for several years. The ditch was designed to capture most surface runoff from upstream and is reported to not have any breaches in the side berms. However, it is probable that water may leak through the bottom and sides of the ditch, resulting in infiltration to groundwater and perhaps even direct surface flow to the tailings pond. (McAlpine 2006).

3.6.3 Seepage Dam and Pond

The original seepage dam was rebuilt in November 2000 (EBA 2002). It has a PVC arctic liner keyed into existing permafrost at the time of construction, designed to minimize seepage out of the pond. The crest is at an elevation of 1131 m and has a maximum height of 4m. It is reported that poor water quality seepage was observed in the area of the seepage pond immediately following tailings discharge to the pond (McAlpine 2006) The seepage collected in the pond was re-circulated into the main tailings impoundment until 2004. Seepage which met discharge requirements was discharged downstream to Dome Creek in 2005.

3.7 Management of Tailings Pond Water

The following accounts of pond de-watering activities are based on personal communications with Yukon Government and DIAND personnel and also on historical data collected since mine closure. It is reported that the water intake for pumping from the pond is located 0.5 m above the bottom of the pond. It is not known whether this is at the deepest point in the pond.

4. Physical Characteristics of Tailings Impoundment Site

4.1 Tailings Impoundment Survey and Site Mapping

Several surveys of the tailings impoundment, tailings pond, tailings dam, spillway, seepage dyke and pond have been completed at different times over the past decade. This study utilized the following surveys for development of the water balance model:

- Survey of dam structure, toe berm and seepage pond as reported by EBA (2004)
- Survey of dam spillway
- Pond bathymetry (EDI 2005)
- Tailings thickness and volume survey (EBA 2002)
- Overall site mapping developed by Gartner Lee Limited (2004)

Mapping and surveying data from the above listed sources were combined to generate schematic interpretations of the site layout (Figure 2 and Figure 3).

4.1.1 Pond Bathymetry

Pond bathymetry was reportedly surveyed by Laberge Environmental Services in 1999 for calculations of tailings volumes (EBA 2004). A recent bathymetric analysis of the tailings pond was completed by EDI (2005) (Figure 2). EDI provided a number of pond water levels and their corresponding pond water volume and surface areas (Table 3). Based on these data, pond lake water levels and pond volumes estimated as a function of pond elevation (Figure 4) were used in the water balance calculations.

4.2 Surficial Drainage

The Mt. Nansen mine property is located within the Dawson Range with the surrounding terrain consisting mainly of rounded ridges and shallow valleys with small trees (EBA 1994). The area is drained by the Nisling River to the west, which subsequently drains into the Yukon River via the Donjek and White Rivers. Several small streams drain the area in the immediate vicinity of the tailings impoundment. Dome Creek runs southward in the valley upstream of the tailings pond and is diverted around the tailings impoundment.

The tailings pond is located in the Dome Creek Valley, at an elevation of approximately 1150 m above mean sea level. The natural watershed contributing to the Dome Creek Valley upstream of the pond was estimated to be approximately 2.65 km^2. However, several roads and infrastructure, such as the mining camp and mill complex, located upstream within the drainage basin are assumed to affect surficial drainage patterns. Although a detailed analysis of surface water flow within the drainage basin was not within the scope of this study, it was assumed that ditches along the roads intercept most of the drainage upstream of the mill and mining camp and divert it either into adjacent catchments or allow infiltration to groundwater preventing surface flow from reaching lower areas upstream and ultimately reaching the tailings impoundment.

Figure 5 shows the assumed surficial drainage patterns in the Dome Creek catchment upstream of the pit. The catchment area assumed to contribute overland flow at least in part to the diversion ditch around the tailings impoundment is 1.69 km^2. The efficiency of the diversion ditch in diverting surface runoff from this area is dependent on its integrity. This issue is addressed in previous sections. For the purposes of this water balance, the diversion ditch was assumed to leak a small percentage of surface water from the catchment, directly as overland flow to the pond.

The area within the diversion ditch and access road surrounding the upstream part of the tailings impoundment is approximately 65 000 m^2. This area corresponds to the actual surface area covered by tailings and was calculated based on the tailings thickness survey by Yukon Engineering Services (YES) in

2000 and 2001 (EBA 2004). Precipitation falling on this area is assumed to contribute direct overland flow to the tailings pond.

5. Development of Pond Water Balance

The water balance model developed for the tailings pond is a spreadsheet based model designed to be used as a tool to help provide a better understanding of the various water components and fluxes that affect the behaviour of the pond. These insights can be used in the future to assist in developing a conceptual model and qualitative assessment of pond water chemistry. The conceptual model describing the various components of the pond water budget is presented in Figure 1

Mathematical functions were developed which relate pond lake elevations to pond lake volumes and pond lake surface areas based on pond bathymetry data (Figure 4). To facilitate calculations, the temporary benchmark used by Yukon Government to measure pond levels was assumed to be at an elevation of 100 m as shown in Figure 4. Monthly time steps consistent with the time increment of available meteorological data (i.e. snowfall, evaporation) were selected for the model. The following sections provide details regarding the various components of the water balance model, including information about input data, calibration procedures and overall results.

5.1 Tailings Pond Catchment Areas and Overland Flow

Tailings pond catchment areas were delineated based on 2004 mapping (Figure 5). Inputs of surface runoff to the model are based on the following assumptions:

- Surface runoff (rainfall and snowmelt) from the Zone 1 catchment area of 1.69km^2 is captured by the diversion ditch. A runoff coefficient of 0.2 was assumed for this area based on values recommended by NHC (2004).

- A small percentage (25%) of surface flow from the Zone 1 catchment is assumed to leak from the diversion ditch and flow overland to the tailings impoundment. This assumption is based on the overall water balance calibration.

- Most of the precipitation on the tailings impoundment area (Zone 2) flows as surface runoff to the main tailings pond and does not accumulate in other areas on the impoundment. A runoff coefficient of 0.9 was used in the water balance calculation for runoff along the tailings surface.

- The area of tailings (Zone 2) not covered by the water is a function of the pond elevation and varies according to the pond lake area as described in previous sections.

It should be noted that runoff coefficients usually relate to storm events and therefore, there may be some slight variation between runoff coefficients for heavy rainfall events as opposed to the average values that were used. For the purposes of this study, it was assumed that the runoff coefficients used were representative of average precipitation.

5.2 Meteorological Data

A meteorological station was installed by YG Department of Environment, Water Resources Section at the Mt. Nansen site following closure in 1999 (Figure 5). Available data from the site for the period (2000 to 2004) are summarized in a report by NHC (2004). Additional data used for the water balance calculations are summarized in tables in this report. It should be noted that the water balance was developed for the period of available continuous pond level data (June to October 2005).

5.2.1 Rainfall

Monthly rainfall data for 2000 to 2005 recorded at the site are summarized in Table 4. These site specific 2005 data were used to calibrate the water balance model to the water levels measured in the pond over the corresponding time periods. Daily precipitation values are shown on Figure 6.

5.2.2 Snowmelt

Yukon Government, Water Resources conducts annual snow surveys at the Mt. Nansen site. Snow thickness and corresponding snow water equivalent (SWE) depth available from the end of April 2000 – 2005 for the Mt. Nansen site are provided in Table 5. Based on climatic data, it was assumed that most of the snowmelt occurs at the site during the months of April and May. Therefore, snowmelt, as snow water equivalent, was delivered to the water balance model at this time. This is consistent with observations of snow free conditions at the beginning of May in the spring of 2005. The snow water equivalent data in Table 5 were used in the analysis of pond level behaviour.

5.2.3 Tailings Pond Evaporation

Site specific values for evaporation are not available for the Mt. Nansen site. Tailings pond evaporation rates were estimated from the Pelly Ranch Lake evaporation data record (MET Sta. 2100880). These data show that lake evaporation occurs from May to September, with most evaporation occurring during June and July. Pond evaporation is an important component of the water balance. The effects of evaporation on the runoff components from the tailings impoundment and catchment areas are accounted for by the runoff coefficients used in the water balance. Therefore, mean monthly evaporation rates (Table 6) were applied only to the surface area of the pond.

5.3 Groundwater Seepage

5.3.1 Infiltration

Infiltration rates in tailings are generally low due to the small particle size and fine nature of the tailings. Ponding occurs when infiltration rates are lower than the tailings saturated hydraulic conductivity. This is the case for the Mt. Nansen mine tailings impoundment. In general, these infiltration rates will vary depending on the soil's moisture content and hydraulic conductivity. The infiltration process of surface runoff into the tailings is captured indirectly in the surface runoff coefficients used in calculations.

5.3.2 Permafrost

The site is located in an area of discontinuous permafrost. Previous investigations have shown that permafrost conditions exist within the Dome Creek valley. Boreholes and test pits drilled during dam feasibility, construction and maintenance phases encountered permafrost at depths ranging from ground surface to approximately 11 m below ground surface. Original feasibility and design studies predicted that the zone of thawing in the foundation would extend only one-third of the width of the tailings dam from the upstream toe and would be confined to the upper 1 to 2 m of the foundation soils and up to 5m under the pond. It was also anticipated that ground conditions downstream of the dam would remain frozen (EBA 2002). Frozen ground conditions would provide a barrier to groundwater seepage below the impoundment and below the dam.

A recent review of thermistor data by EBA (2004) indicates that permafrost conditions do exist at the site. However, several meters of unfrozen ground can be found within the tailings impoundment site. Some boreholes down valley from the dam indicated depths to permafrost of up to 11 m. The appearance of seepage downgradient of the dam shortly after tailings deposition also suggests that at a minimum, a shallow zone of active groundwater flow occurs below and downstream of the tailings impoundment. Therefore, groundwater is likely an important component of the water balance and was considered for this water balance model.

5.3.3 Seepage Data

Seepage from a pond located near the base of the tailings dam is re-circulated to the main tailings pond. As pointed out by EBA (2002), the rates and volumes of seepage re-circulated back into the tailings pond are only estimates of total seepage from tailings impoundment. The seepage pond captures direct rainfall and surface runoff from the tailings dam slope and the north and south abutment slopes. It is also likely that the seepage pond may also not capture all seepage from the dam or retain all the seepage (Figure 1).

Gartner Lee observed shallow groundwater discharge upstream of the tailings within the Dome Creek valley during a groundwater quality investigation related to the Brown McDade pit in 2005. These observations suggest that groundwater is active within an unfrozen zone of overburden and that groundwater likely flows within the catchment area, under the tailings, and potentially discharges to the seepage pond or further downstream within the Dome Creek. Tailings pond water also infiltrates through the tailings and either through the dam material or underlying soils and also discharges downstream either in the seepage pond or further downgradient.

Net groundwater seepage out of the pond was used as a variable for the water balance. An average value of 2.8 L/s, based on pond re-circulate data from 2000 to 2005 (Table 1) was used to guide calculations. It was assumed that the actual net seepage out of the pond would be different than flow rates measured by the pond re-circulate flow meter for reasons discussed above. This assumption is deemed reasonable for most calculations except at low pond levels when the pond surface (and bottom) area are significantly smaller than at high water levels. As a simplification for this model, it was also assumed that groundwater seepage rates out of the pond would not vary with pond level or surface area.

6. Water Balance Results

The tailings pond water balance was calibrated to the available pond water level-elevation data available for June to October 2005 (Figure 7). In combination with the pond volume / pond surface area relationship, and up-valley catchment areas, actual meteorological data collected from the Mount Nansen Mine Site meteorological station was used to calibrate the water balance model. This approach allowed a sensitivity analysis for various water balance components.

Short term rainfall events (often lasting only a few hours or days) caused corresponding responses in the pond level (Figure 7). The monthly time step used water balance did not capture these daily variations and did not capture the maximum level recorded in 2005. In order to capture these changes, a weekly or even daily time-step would be required. For the purposes of understanding the overall components of the pond water balance, a monthly time step was more than adequate.

The relative contribution of individual components to the overall water balance are shown on Figure 8. The calibrated model suggests that groundwater seepage out of the pond is an important component of the overall tailings pond water balance. Tailings impoundments typically have zones with varying degrees of saturation, porosities and grain size distribution as a result of the deposition process. Beaches of fines and slimes have likely formed against the upper face of the dam. These finer grained materials affect the distribution of hydraulic heads and groundwater velocities within the tailings.

For the water balance, values of groundwater seepage out of the pond between 2 and 6 L/s were most suitable to reproduce the observed water level fluctuations. These rates are within the similar range of observed seepage re-circulate rates.

Although groundwater seepage rates represent one of the largest unknown variables in the water balance, a few general observations can be made:

- The distribution of tailings thickness throughout the impoundment also plays an important role in groundwater flow from the tailings pond. Tailings porewater likely infiltrates more quickly along the sides of the tailings impoundment where tailings are thinner than through the thickest part of the tailings (12.5 m) (Figure 3). These different flow paths would result in significantly different travel times for seepage from the bottom of the tailings pond to reach the seepage pond.

- It was noted that pond levels reached minimum levels in December 2005 and that the pond was likely dry (Patch 2006). Seepage rates remained within the same range over this same period. Decreasing water levels in the pond would affect seepage rates from the tailings pond. However, as discussed previously, it is likely that the seepage rates measured in the re-circulate line do not represent only tailings pond water. It is likely that the decrease in pond water level changes the relative contribution of the individual contributors to the seepage pond such as regional groundwater flow, groundwater flow from the valley sides, groundwater infiltrated along the toe of the dam or from the spillway.

- The volume of porewater within the 280 000 m^3 of tailings assuming fully saturated conditions is approximately 140 000 m^3. This is based on a porosity of 0.5 which is an average value for tailings (Blowes et al. 2003). For comparative purposes only, based on the observed average seepage rate of 2.8 L/s, 1.5 years would be required to drain all the porewater from the tailings. Although total draining of the tailings would not occur under current conditions, the calculation highlights the fact that a time lag can be expected between fluctuations in pond level and observed seepage rates at the toe of the dam.

Figure 9 and Figure 10 show how the tailings pond is located approximately 20 m higher than the seepage pond. The cross sections also show how the diversion ditch/spillway is approximately 10 m above the level of the seepage pond as it flows past it. Figure 9 also shows that sources other than direct tailings pond seepage may contribute to the seepage pond. Tailings pond water that infiltrates to groundwater may also flow past without discharging to the seepage pond. As pond levels decrease, although the seepage rates in the seepage pond might not change significantly, the relative contribution of each component (i.e. regional groundwater, groundwater from the sides of the valley, water from the spillway, tailings pond seepage) may change.

7. Conclusions and Recommendations

7.1 Conclusions

The historical review of pond water levels, seepage pond pumping rates, on site observations, meteorological data and the water balance model developed for the tailings pond allowed the following conclusions to be drawn:

- Seepage rates out of the pond are likely a function of water level and pond bottom surface area. These rates can not easily be quantified. Given the current data set, changes in seepage rate out of the pond at higher water levels are unknown at this time.
- Seepage rates calculated from the flow meter in the re-circulation line remained between 2.2L/s and 3.8 L/s from 2000 to 2005.
- Historical pond level measurements indicate that the pond level was decreased to minimal levels in the fall of 2002 and 2005 either naturally or through pumping.
- The spillway is approximately 10 m higher than the seepage pond as it passes cross-gradient. Consequently, there is a possibility that leakage from the spillway/diversion ditch contribute to seepage captured by the seepage pond.
- The tailings are thickest near the center of the valley bottom where they have a maximum thickness of approximately 12.5 m.

- The tailings pond has a maximum depth of 3.5 m below the high water level mark measured by EDI (2005).
- The maximum volume of water in the pond at maximum levels is estimated at 156000 m^3.
- The measured seepage rates in the pond re-circulation line are likely lower than the actual groundwater seepage rates directly from the tailings.
- Pumping from the pond accounts for a large decrease in pond levels. During 2005 pumping rates were approximately two times higher than the seepage rates calculated based on the water balance calibration.
- High intensity short duration rainfall events correlate well with increases in tailings pond levels recorded using the level logger in 2005.
- Pond levels decrease naturally during the winter months.
- Water from the seepage pond was not re-circulated to the tailings pond during 2005.
- The water balance calibration suggests that there is a net rate of groundwater seepage out of the tailings pond throughout the whole year. This rate is on the order of 2.0 to 6.0 L/s.
- The tailings pond level is approximately 20 m higher than the water level in the seepage pond. The seepage pond is located 150 m downgradient.
- Evaporation losses are greater than the direct precipitation to the pond lake during July, August and September 2005.
- Both runoff from the tailings impoundment area and runoff from the catchment area represent larger inputs of water to the pond than direct rainfall to the pit lake.

7.2 Recommendations

Considering the paucity of existing tailings pond water balance component data, especially those related to determining the hydrogeology near the tailings impoundment and estimating groundwater flow beneath the tailings. In order to improve the level of confidence and accuracy of the model, certain data should be validated by field measurements. Additional studies are recommended to better constrain the understanding of the controls on the pond water balance. Accordingly, the following recommendations are offered:

- The exact elevation of the tailings pond water level relative to the elevation of the water level in the seepage pond should be confirmed to establish hydraulic gradients.
- The position of the water table beneath and around the tailings and the direction of groundwater flow should be determined. This can be done with a few strategically placed groundwater wells.
- The amount of flow in the diversion ditch both upstream and downstream of the tailings pond should be measured to help quantify the amount of leakage that may be occurring from the ditch to the groundwater system or from the ditch, directly to the tailings impoundment as surface flow.
- Surficial drainage patterns should be determined to better delineate the extent of catchment runoff zones and the quantify the effect of roads and ditches within the catchment area.
- Continuous monitoring of pond lake water levels using the existing level logger system should be continued as well as the collection of site specific meteorological data.
- An accurate survey of level-logger benchmarks relative to existing surveys should be conducted.
- Continuous monitoring of seepage pond water levels would be beneficial for determining seasonal fluctuations.
- Conduct a visual inspection of the diversion ditch to determine its integrity and whether leakage is occurring either to groundwater or to the surface of the tailings impoundment.
- Collect flow measurements along the length of the ditch upstream of the tailings pond and spillway as well as near the seepage pond to determine if the stream within the ditch is losing or gaining water.

- Perform flow measurements of Dome Creek downstream of the tailings impoundment and diversion ditch discharge to help quantify the overall Dome Creek drainage basin water balance and provide a quantitative check on assumptions of surface runoff coefficients and drainage areas.

- Continue the collection of chemistry data for the different water balance components (tailings pond, seepage pond, Dome Creek, groundwater, tailings porewater, etc.) to help determine the interaction of the different components.

- Key observations of exact timing of snowmelt, ice formation, catchment runoff, and quantitative observations of flow within the diversion ditch seepage rates as well as surface runoff patterns (during and following rainfall events) should be noted, recorded and photographed whenever possible to provide qualitative validation and refinement to the water balance model.

- Use tailings pond pumping rate data since 2000 (if available) to better constrain the water balance model.

- An instrument should be installed at the site to allow direct measurement of pond lake evaporation.

- A site visit should be conducted to determine and better refine the catchment drainage areas and patterns.

- Manual measurements of pond staff gauge readings should be collected periodically to validate level-logger data.

- A transect of groundwater monitoring wells allowing collection of depth-discrete samples, installed downgradient of the dam would allow determination of groundwater quality in the vicinity of the seepage pond and facilitate the interpretation of groundwater – surface water interaction downstream of the dam.

- Geological data collected to date from test pits and boreholes should be reviewed to refine the conceptual model for geology and hydrogeology by determining soil types, soil thicknesses, grain size of the materials, depth to permafrost, depth to bedrock and the lateral extent of geological units.

8. Acknowledgements

Gartner Lee Limited would like to thank Frank Patch and Hugh Copland of Energy, Mines and Resources, Yukon Government and Bud McAlpine of the Department of Indian and Northern Affairs, Government of Canada for assisting with the project and providing useful discussions.

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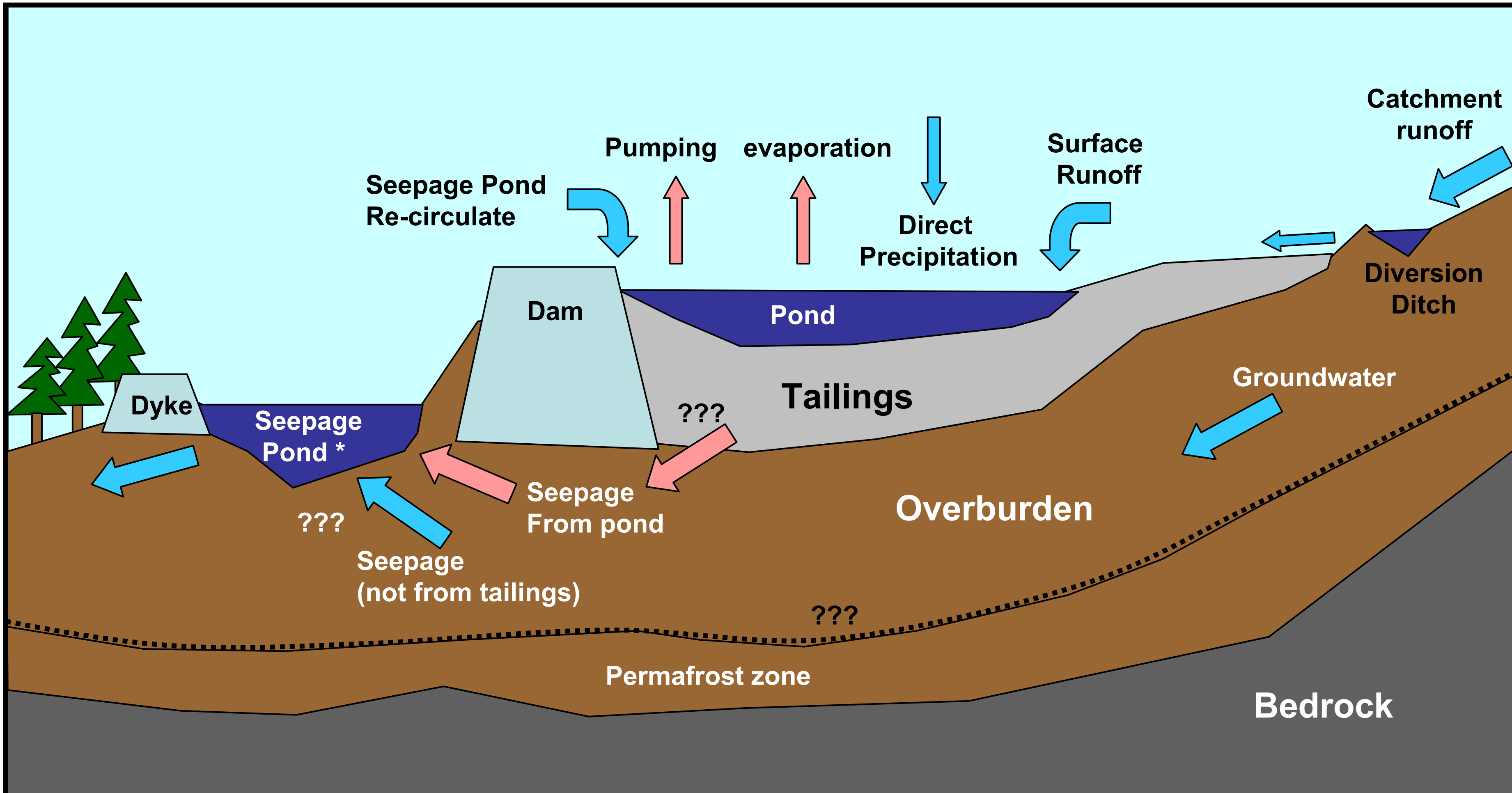
Figures



* Seepage pond also subject to surface runoff, precipitation and evaporation

Tailings Pond Water Balance, Mt. Nansen Mine - Gartner Lee Limited

Figure 1. Conceptual Model of Tailings Pond Water Balance, Mt. Nansen Mine, YT

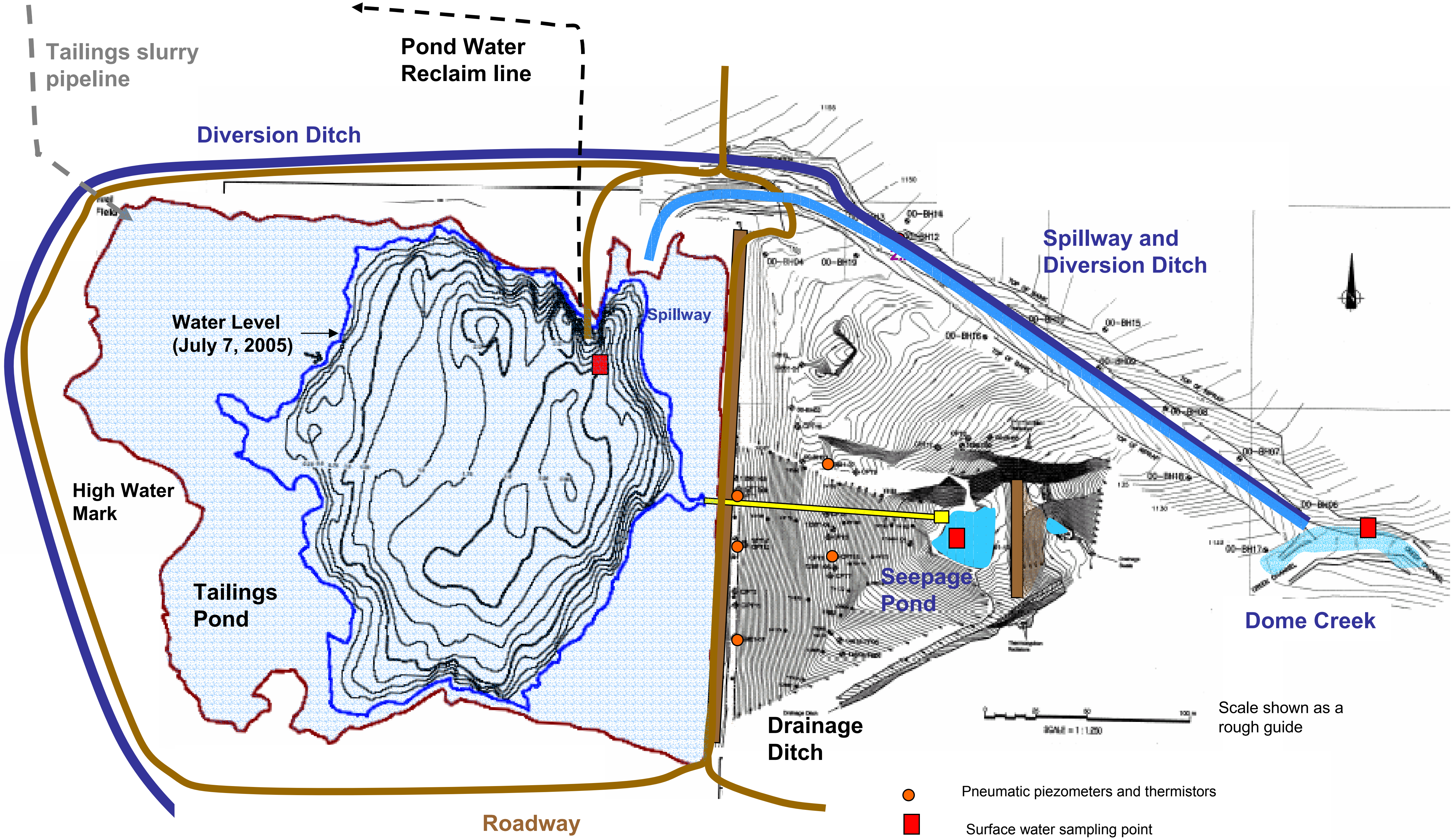


Figure 2. Schematic Layout of the Mt. Nansen Mine Tailings Impoundment Showing Tailings Pond Bathymetry (not to scale)
Composite diagram incorporating 1) Pond Bathymetry (EDI, 2005), 2) Tailings Dam Survey (EBA, 2004), 3) Spillway Survey

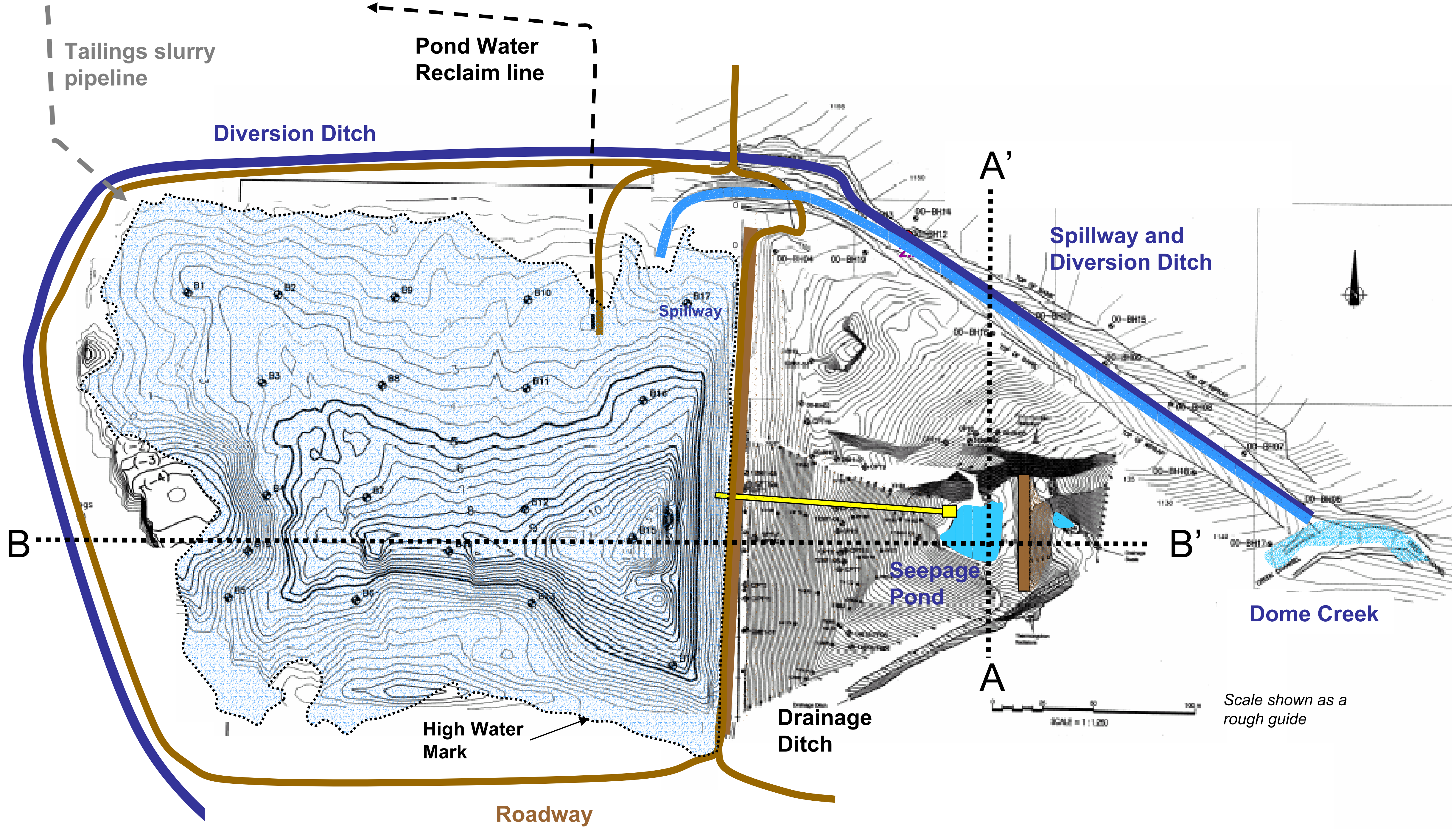


Figure 3. Schematic Layout of the Mt. Nansen Mine Tailings Impoundment Showing Tailings Thickness and Location of Interpretive Cross Sections. (not to scale) Composite diagram incorporating 1) Tailings Thickness (YES, 2002), 2) Tailings Dam Survey (EBA, 2004), 3) Spillway Survey

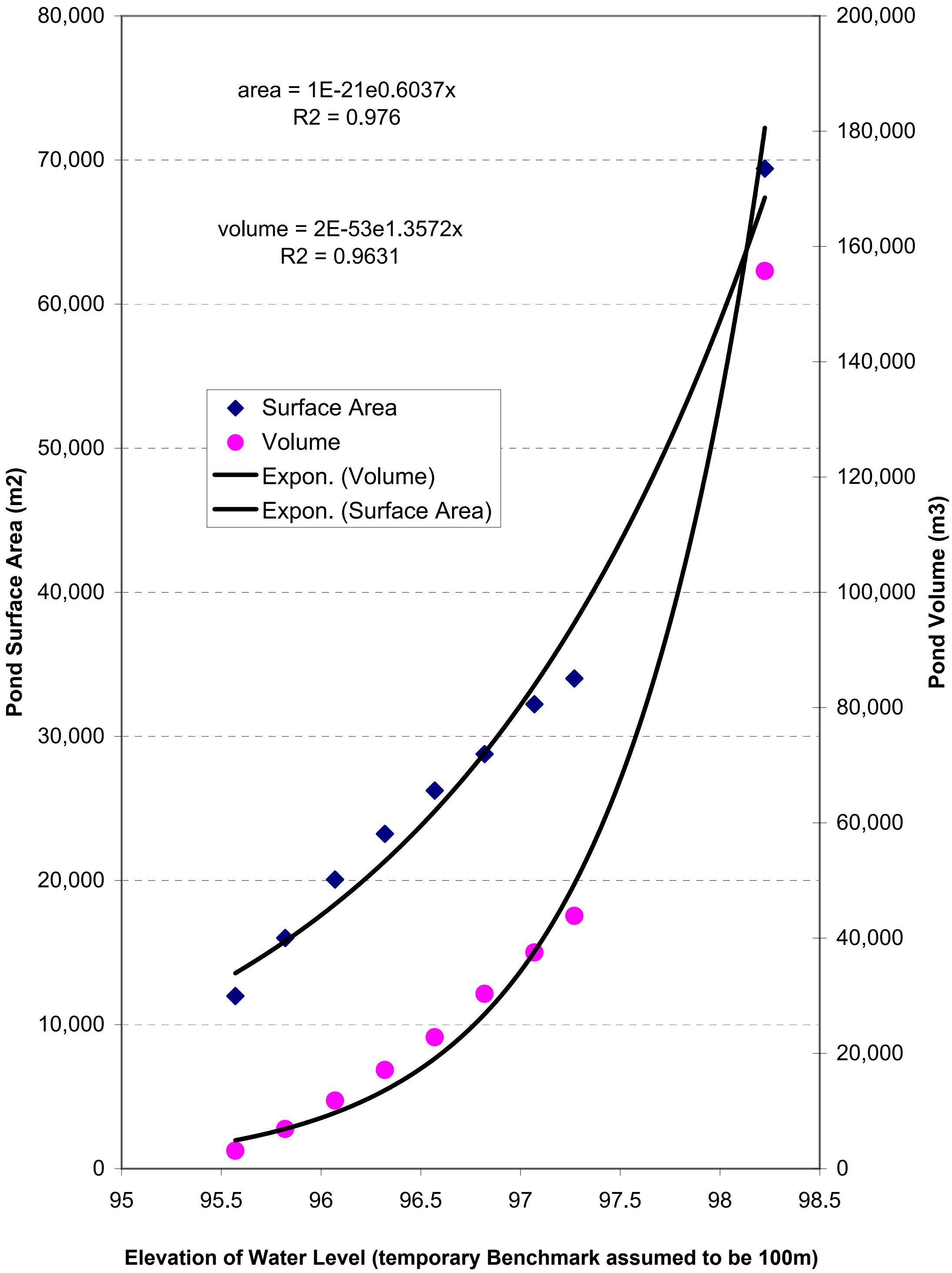
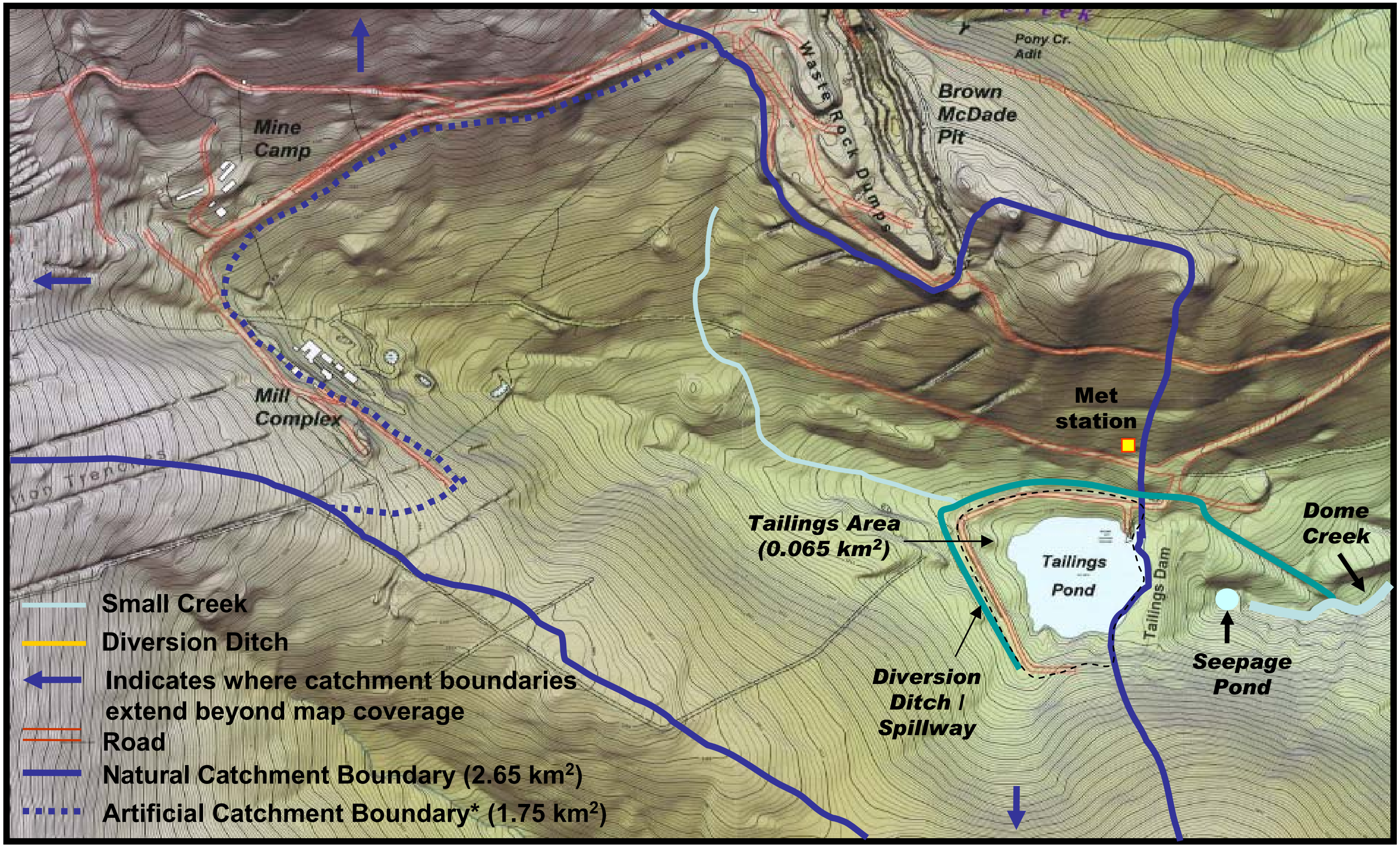


Figure 4. Pond Surface Area, Volume and Water Level Relationships



* The artificial catchment boundary is due to a diversion ditch that captures all runoff up-valley from entering the Tailings Pond.

Figure 5. Tailings Pond Catchment Areas and Surficial Drainage (Mt. Nansen Mine, YT)

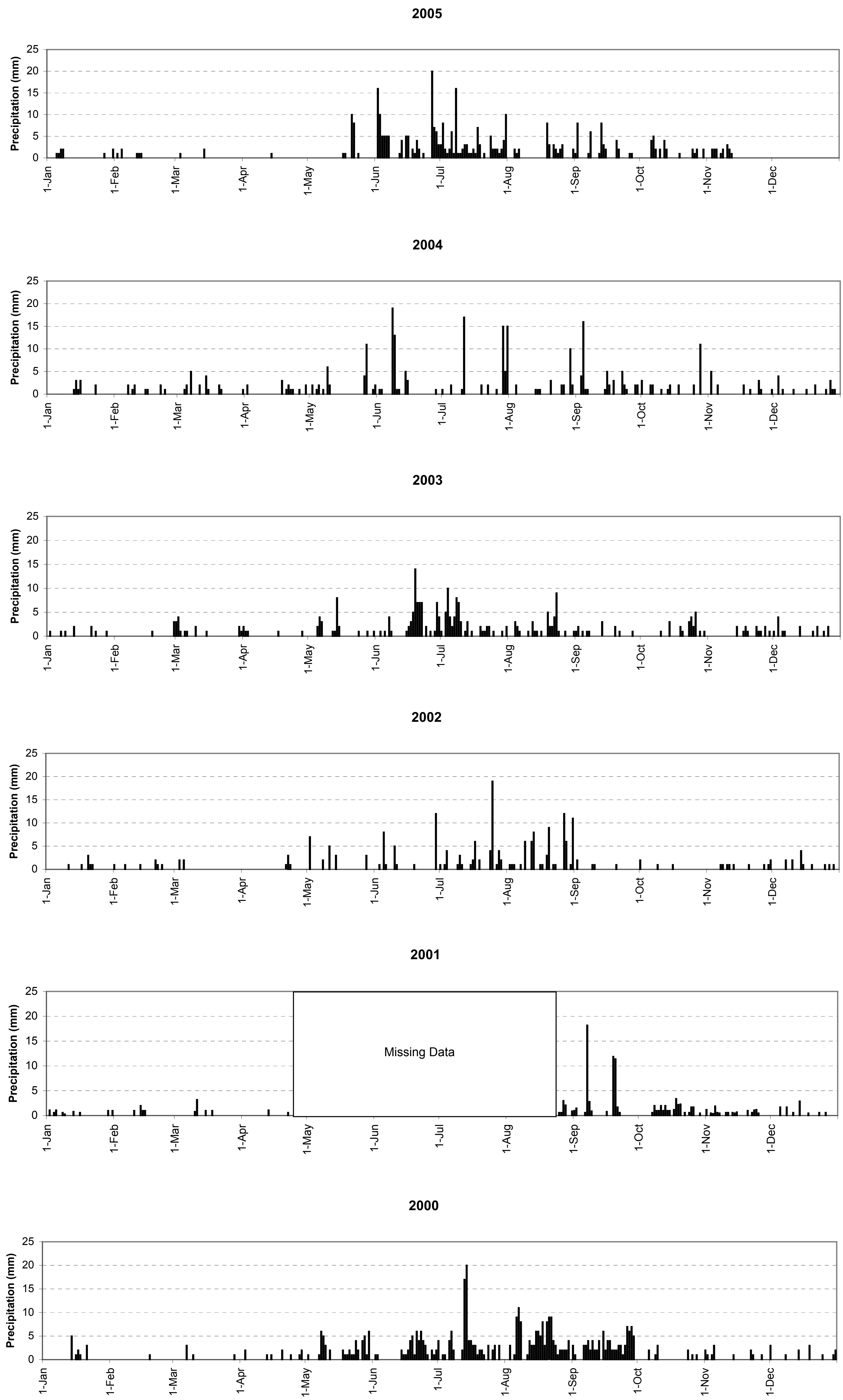


Figure 6. Daily Precipitation at Mt. Nansen Site (2000 - 2005)

Figure 7. Calibrated Water Balance Results, Observed Water Levels and Daily Precipitation (2005)

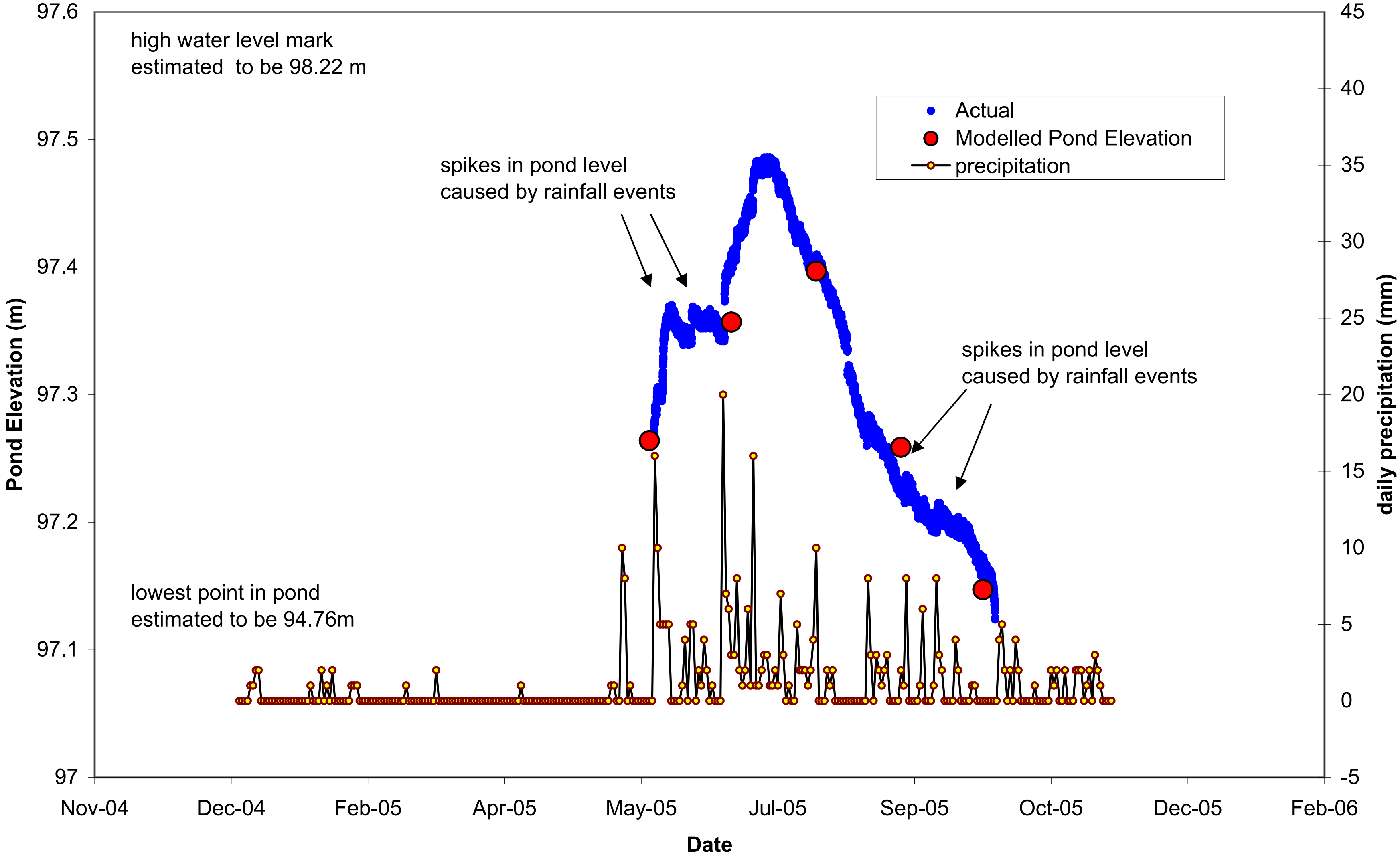
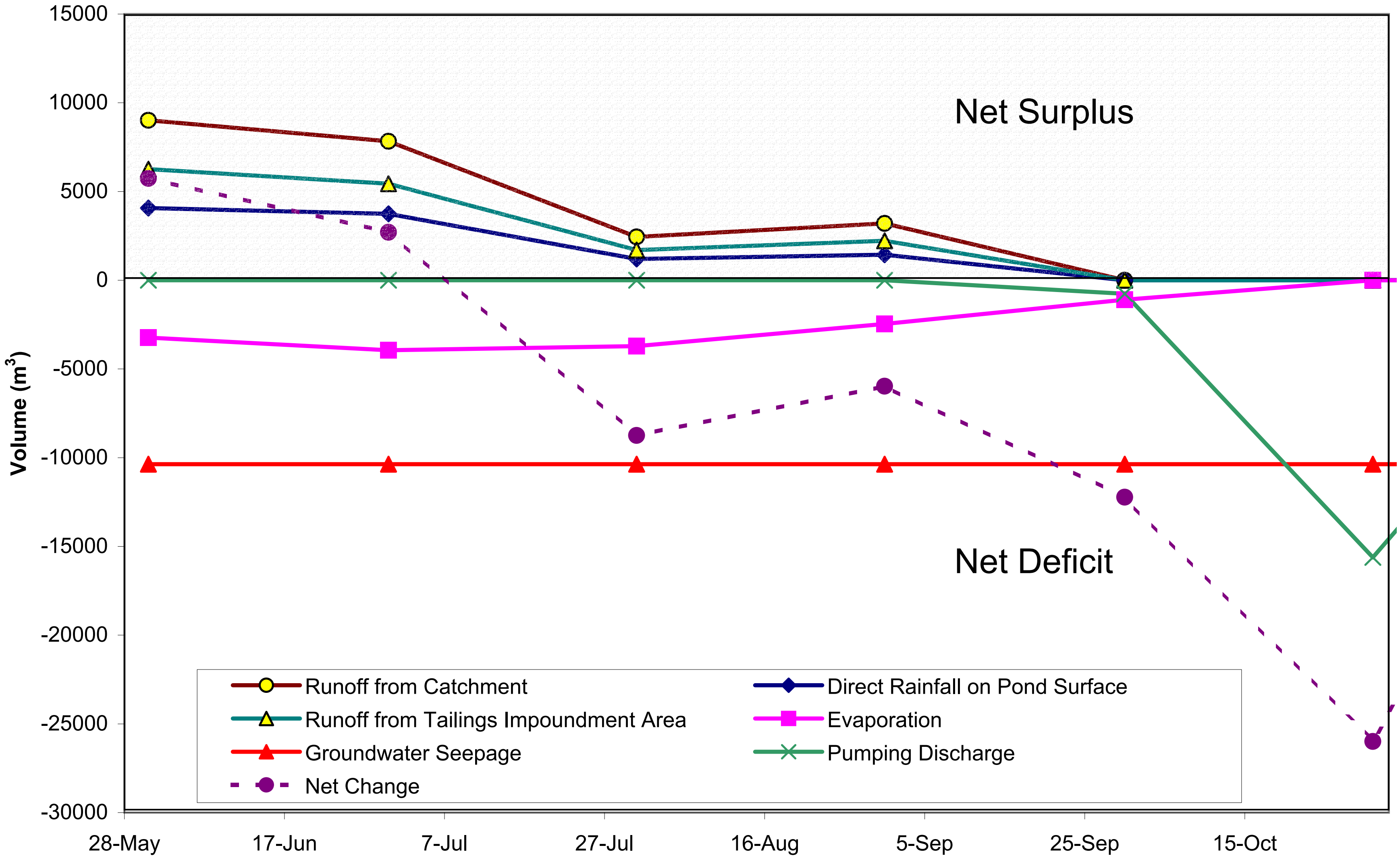


Figure 8. 2005 Water Balance Components, Mt. Nansen Mine, YT



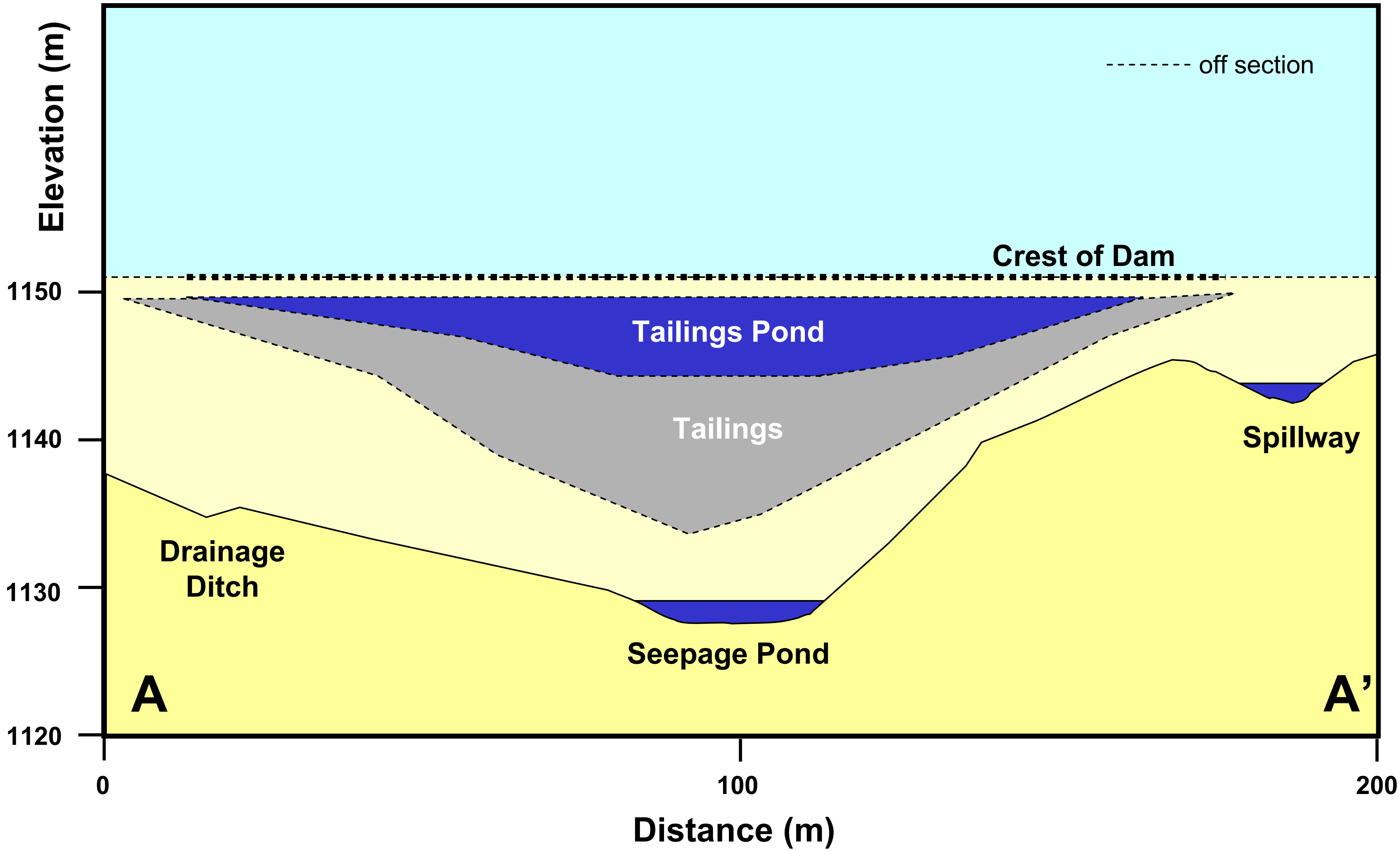


Figure 9. Schematic Interpretation of Longitudinal Section A – A' Profile of Tailings Pond Area.

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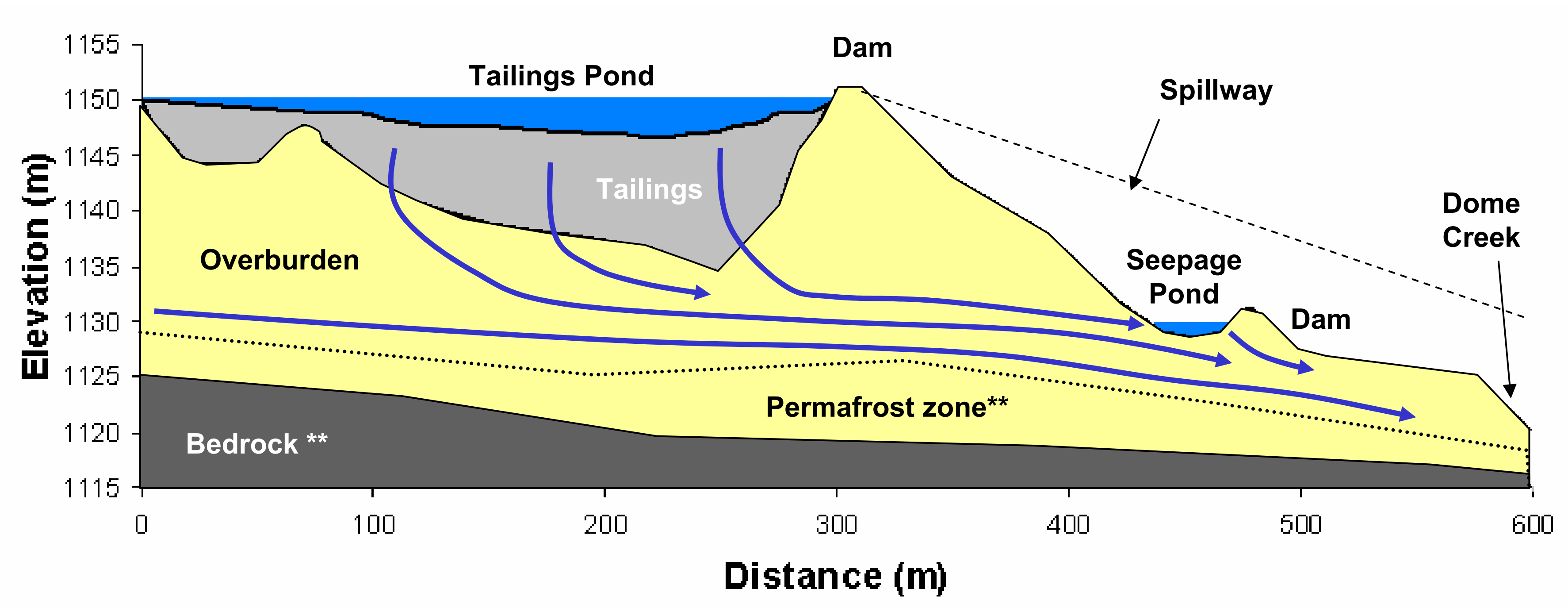

Note: ** Bedrock and Permafrost Surfaces Interpreted for Schematic Purposes Only

Figure 10. Schematic Interpretation of Longitudinal Section B – B' Showing Elevation of Tailings Pond and Tailings Relative to Seepage Pond. (note vertical exaggeration) and Interpreted Groundwater Flow

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Tables

Table 1. Seepage Data from Flowmeter (1999 - 2003)

	1999	2000	2001	2002	2003
January		2.5	2.8	3	
February		2.4	2.8	2.9	
March	5.2 *	2.3	2.7	2.9	2.7
April	4.4 *	2.4	2.7	2.7	2.5
May	2.9 *	3	3.1	3.1	2.6
June	2.4 *	2.8	2.8		3
July	3.7 *	3	2.9	3.1	2.8
August	unknown	3.8	2.6	2.8	2.5
September	1.6 *	4.1	2.6	2.8	2.3
October	2.8 *	3.8	3.2	2.9	2.2
November	2.6	2.6	3.2	2.9	2.7
December	2.8	2.9	3.2	2.9	

Data from EBA (2004)

note: * manual measurements
all other measurements from flow meter

Table 2. Mt. Nansen Mine, Tilings Pond / Seepage Pond Flowmeter Readings 2005

Date	Time period		Pumping of Water from Seepage Pond to Dome Creek (USG)			Pumping of Water from Tailings Pond to Dome Creek (USG)			Notes
	from	to	Flow Meter Reading	Incremental Volume	Cummulative Volume	Flow Meter Reading	Incremental Volume	Cummulative Volume	
15-Jul-05	15-Jul-05	15-Jul-05	23331847		0				Start of Direct Discharge from Seepage Pond to Dome Creek
16-Jul-05	15-Jul-05	16-Jul-05	23586200	254353	254353				
31-Jul-05	16-Jul-05	31-Jul-05	24712068	1125868	1380221				
7-Aug-05	31-Jul-05	7-Aug-05	25307166	595098	1975319				
14-Aug-05	7-Aug-05	14-Aug-05	25904887	597721	2573040				
21-Aug-05	14-Aug-05	21-Aug-05	26552926	648039	3221079				
28-Aug-05	21-Aug-05	28-Aug-05	27195498	642572	3863651				
4-Sep-05	28-Aug-05	4-Sep-05	27785594	590096	4453747				
11-Sep-05	4-Sep-05	11-Sep-05	28491840	706246	5159993				
18-Sep-05	11-Sep-05	18-Sep-05	29134583	642743	5802736				
25-Sep-05	18-Sep-05	25-Sep-05	29809432	674849	6477585				
27-Sep-05	25-Sep-05	27-Sep-05	29991500	182068	6659653	2183527		0	Start of pumping from pond and discharge to Dome Creek (5 hours)
27-Sep-05						2203633	20106	20106	
2-Oct-05	27-Sep-05	2-Oct-05	30404030	412530	7072183				
4-Oct-05						2316646			Start of pumping from pond
8-Oct-05	4-Oct-05	8-Oct-05	30989890	585860	7658043	2947932	631286	651392	
9-Oct-05	8-Oct-05	9-Oct-05	31087860	97970	7756013	3119111	171179	822571	
12-Oct-05	9-Oct-05	12-Oct-05	31347776	259916	8015929	3582564	463453	1286024	
16-Oct-05	12-Oct-05	16-Oct-05	31721127	373351	8389280	4240472	657908	1943932	
23-Oct-05	16-Oct-05	23-Oct-05	32357750	636623	9025903	5324288	1083816	3027748	
30-Oct-05	23-Oct-05	30-Oct-05	33016683	658933	9684836	6443242	1118954	4146702	
6-Nov-05	30-Oct-05	6-Nov-05	33545798	529115	10213951	7394908	951666	5098368	
9-Nov-05	6-Nov-05	9-Nov-05	33882132	336334	10550285	8008809	613901	5712269	
10-Nov-05	9-Nov-05	10-Nov-05	33969077	86945	10637230	8124915	116106	5828375	stop pumping from pond
13-Nov-05	10-Nov-05	13-Nov-05	34238442	269365	10906595				
20-Nov-05	13-Nov-05	20-Nov-05	34826410	587968	11494563				
27-Nov-05	20-Nov-05	27-Nov-05	35392140	565730	12060293				
4-Dec-05	27-Nov-05	4-Dec-05	35955585	563445	12623738				
6-Dec-05	4-Dec-05	6-Dec-05	36102209	146624	12770362				
7-Dec-05	6-Dec-05	7-Dec-05	no reading *	73300	12843662				
8-Dec-05	7-Dec-05	8-Dec-05	no reading *	73300	12916962				
9-Dec-05	8-Dec-05	9-Dec-05	210124	73300	12990262				flow meter re-calibrated on Dec. 9
10-Dec-05	9-Dec-05	10-Dec-05	279329	69205	13059467				
11-Dec-05	10-Dec-05	11-Dec-05	401234	121905	13181372				
12-Dec-05	11-Dec-05	12-Dec-05	517470	116236	13297608				
13-Dec-05	12-Dec-05	13-Dec-05	637315	119845	13417453				

* flow meter not working, assume rate of 73300 USG / day

Table 3. Water Levels and Corresponding Pond Volume and Pond Lake Area

Water Level Below Benchmark (m)	1.775	2.73	2.93	3.18	3.43	3.68	3.93	4.18	4.43
Water Level Compared to July 7, 2005 (m)	0.955	0	-0.2	-0.45	-0.7	-0.95	-1.2	-1.45	-1.7
Volume (m^3)	155739	43867	37524	30328	22793	17121	11815	6881	3126
Area (m^2)	69400	34020	32230	28770	26240	23240	20070	16010	11980

Note: data provided by EDI (2005)

Table 4. Monthly Rainfall Data Available for Site (Mt. Nansen Meteorological Station)

	Rainfall (mm)					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
January						
February						
March						
April	10	2	5	6	13	1
May	48	n/a	20	24	32	21
June	47	n/a	29	68	45	107
July	88	n/a	52	61	61	93
August	117	7	70	38	24	29
September	85	51	5	13	45	38
October						
November						
December						

note: *n/a data not available*

all precipitation from October to March assumed to be snow

Table 5. Snow Water Equivalent (SWE) at the End of March for Mt. Nansen

Year	Depth (cm)	SWE (mm)
2000	38	68
2001	36	52
2002	45	71
2003	31	50
2004	n/a	105
2005	41	71

Notes: Summary of data (by North West Hydraulics) supplied by Rick Janowicz of Yukon Environment, Hydrology)

Table 6. Estimated Mean Annual to 100-Year Lake Evaporation for Tailings Pond at Mt. Nansen

Return Period	Pit Evaporation	Monthly Mine Pit Evaporation (mm)				
years	(mm)	May	June	July	August	September
Percentage Distribution		**23.0**	**26.5**	**24.5**	**17.6**	**8.3**
Mean annual	369	85	98	90	65	31
5	38	89	103	95	68	32
10	39	92	106	98	70	33
20	408	94	108	100	72	34
50	419	96	111	103	74	35
100	426	98	113	104	75	35

Notes: Estimates from LogNormal frequency analysis (by North West Hydraulics) of Pelly Ranch (MET Sta. 2100880) lake evaporation data of 1965-1995 and reduced by 19% to account for the 800 m higher elevation of the Brown McDade Pit and Mt. Nansen