CANADIAN ZINC CORPORATION

# PRAIRIE CREEK MINE
# DEVELOPERS ASSESSMENT REPORT

# ADDENDUM

**SUBMITTED IN SUPPORT OF:**

Environmental Assessment of
Prairie Creek Mine EA 0809-002

**SUBMITTED TO:**

Mackenzie Valley Review Board
Yellowknife, NT  X1A 2N7

**SUBMITTED BY:**

Canadian Zinc Corporation
Vancouver, BC  V6B 4N9

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# 1.0 INTRODUCTION

Canadian Zinc Corporation ("CZN") submitted a Developer's Assessment Report ("DAR") for Prairie Creek Mine operations to the Mackenzie Valley Review Board on March 25, 2010. The project is currently the subject of environmental assessment EA0809-002. In a letter to CZN dated April 23, 2010 (Appendix A) the Review Board noted a number of deficiencies in the DAR compared to the Terms of Reference dated June 26, 2009. This DAR Addendum report seeks to address the noted deficiencies, and provides some additional information generated since the DAR was submitted.

# 2.0 TEMPORARY STORAGE OF TAILINGS IN WATER STORAGE POND

CZN is proposing to temporarily store up to 50,000 tonnes of tailings in the water storage pond ("WSP") during the early phase of mine operations when the mill is operating but sufficient mine openings are not yet developed, hence are not available for backfill. This is because the mine will be undergoing intensive underground development during the early production phase, and mined-out stopes along with mine infrastructure may not be available. CZN had previously intended to temporarily store the tailings on a pad upslope from the WSP. The decision was made to move the temporary storage location into the pond because it represents a superior solution, as will be described below. CZN's plan is still not to have tailings permanently stored on the Prairie Creek floodplain. All tailings will be placed underground before or during mine closure, and the WSP area can then be reclaimed.

As described in Section 6.3.7 of the DAR, the former tailings pond (which never received any tailings) will be converted into a water storage pond. The capacity of the WSP will be approximately 450,000 $m^3$. The pond will receive water primarily from the mine (mine drainage) and mill (used process water). The pond will feed process water to the mill. A pond water balance will be maintained by controlling the proportions of mine and mill water inflows. Mine and mill water not sent to the WSP will be sent directly to the Water Treatment Plant for treatment and discharge.

During operations, mine water will be pumped up successive levels within the mine through a series of sumps. While sediment will settle out in the sumps, the mine water is expected to retain some suspended sediment upon leaving the mine. This suspended sediment within the mine water sent to the WSP will gradually settle out within the WSP.

At the end of the milling process, used process water will be separated from the final tailings through filtration. The filtered tailings will be sent to the backfill plant. After filtration, the used process water will retain some finely suspended sediment, which will settle out in the WSP from that portion of the water sent to the pond.

It is apparent from the above discussion that the WSP will accumulate sediment over its life as a result of settling from mine and mill water. While this accumulation is not expected to be a significant operational issue in terms of water storage capacity reduction, the sediment will need to be managed after mine closure. CZN intends to drain the pond and recover the sediment as part of the pond reclamation process. The sediment will be delivered to the backfill plant and then underground to fill mine voids.

The volume of tailings for temporary storage will be approximately 32,000 $m^3$. This represents only 7% of pond capacity. Thus, the quantity of tailings involved is small by comparison. CZN believes temporary storage of the tailings in the pond as opposed to on an adjacent pad is a superior approach for the following reasons:

- Placement of the tailings in the WSP under water avoids the issues of tailings oxidation and leaching, dust dispersal and runoff control if exposed on surface;
- There are no significant negative environmental issues because the WSP will contain similar sediment in any event, water quality would not be significantly impacted by tailings storage, all pond water will be recycled to the mill in any event, and all sediment will be removed from the WSP during mine closure;
- The tailings can be placed against the pond backslope, and in so doing, the stability of the backslope will be further enhanced because the weight of the tailings will be greater than water; and,
- The tailings could be recovered during any season whereas recovery from a surface pad in winter would be difficult due to freezing.

Figure 1 shows the intended location of tailings deposition. The tailings would be delivered to the WSP through an existing tailings pipeline. A suitable pipeline currently exists on the flood protection berm adjacent to Prairie Creek. The pipeline will be relocated to the north side of the pond. The line would deliver the tailings as a pumped slurry to below the pond water level. The discharge point would be moved periodically to deposit tailings evenly along the submerged slope. The line would be independent of the lines normally carrying mine water and used mill water to the WSP. The tailings will be contained within the intended placement location by the use of a strategically positioned baffle to the west, and the fill apron for slope stabilization to the east. On the west and south sides, a 2 m high toe berm will be built to assist with tailings containment (see cross-sections in Figure 2). As shown on the figure, the direction of pond water flow in the tailings location will be from south to north, and this will further contain the tailings within the proposed location.

The base of the WSP is approximately at elevation 869 m. The tailings will be placed to create a layer up to 5 m thick to elevation 874 m, the same elevation as the planned adjacent fill apron. Elevation 874 m will be 3 m lower than the minimum pond water level. While the fill apron and tailings toe berms will be below a new geosynthetic liner to be installed, the tailings will be deposited on top of the liner.

The tailings placed in the WSP will be stored until sufficient mine openings are available for backfill. At that point, the majority of the tailings will be dredged out and pumped to the backfill plant. After mine closure, any remaining tailings in addition to accumulated sediment will be completely removed by using a high-pressure water stream to mobilize the solids remaining on the underlying liner, followed by collection in a sump and pumping to the backfill plant.

# 3.0 WATER STORAGE POND CAPACITY

A water level-storage capacity relationship has been developed by Golder Associates for the WSP (see Appendix B). With a WSP uniform crest height at 881 m elevation, the maximum operating pond water level will be 880 m providing for a 1 m freeboard. Preliminary slope stability analyses call for a minimum water level elevation of 877 m (water acts as an additional buttress to the backslope). The storage volume from 877 m to 880 m is approximately 220,000 $m^3$. In the WSP water balance for operations (DAR Appendix 9), the maximum cumulative volume fluctuation due to seasonal water treatment variations was estimated at ~90,000 $m^3$. As such, seasonal water level fluctuations can be readily managed within the minimum and maximum water level range.

# 4.0 STORAGE OF OVERBURDEN AND ORGANIC MATERIAL REMOVED FROM WASTE ROCK PILE SITE

As noted in the Golder Associates report (Appendix 11 of the DAR), the toe area (935 m to 975 m elevation) of the proposed Waste Rock Pile (WRP) would require the removal of organics and colluvial soil. Colluvial materials are estimated to be 3-5 m thick in this area, and it is estimated that approximately 50,000 to 80,000 $m^3$ of material would need to be stripped to bedrock. This would be carried out by Cat blading.

The seepage collection pond will be located immediately down-gradient from the WRP. The berm for the pond will require up to 30,000 $m^3$ of material. The colluvial material stripped from upslope will be used to construct the berm after screening out organics. The remaining colluvial and organic material will be stored nearby to be available for progressive reclamation of the WRP main slope. The preferred storage location is immediately below the WRP toe, but within the capture zone of the seepage collection pond for the collection of runoff (Figure 3). If this storage location is insufficient, a location within the upper elevations of the WRP footprint will be used for any excess. The exact locations of the colluvial/organics storage piles will depend on site-specific factors during WRP site preparation.

# 5.0 AGGREGATE SOURCES

Aggregate will be required for three uses in the mine project, as follows:

- Roads and the airstrip at the mine site;
- Foundation material for the Tetcela Transfer Facility (TTF); and,
- Foundation material for the Liard Transfer Facility (LTF).

Aggregate may also be required for certain sections of the access road. Each of these uses, and their aggregate sources, are discussed below.

## *5.1 Mine Site*

The airstrip is in need of a new surfacing layer. Existing site roads and traffic areas also require new surfacing, and a limited number of new roads may need aggregate surfacing, in and around the Waste Rock Pile and Solid Waste Facility for example. The exact aggregate requirement for the life of the mine is difficult to estimate, but based on a 150,000 $m^2$ area including the airstrip, mine site yard and adjacent roads and a 'life of mine' aggregate thickness of 0.1 m, the mine aggregate requirement is expected to be in the order of 15,000 $m^3$. The most likely aggregate source is the existing quarry at the north end of the airstrip.

## *5.2 TTF*

The TTF will include 2 and possibly 3 structures for temporary concentrate storage. Although the structures will only be used in winter and will not be heated, foundation material is required for stability because of the high traffic and weight of trucks. Facility roads linking the structures to the access road may similarly require foundation material. Approximately 6,000 $m^3$ of aggregate will be required. CZN's preference is to acquire this aggregate from the scree slopes traversed by the access road between kilometre markers Km 24 and Km 38 in the Sundog Creek valley. In particular, the road bed between Km 24 and Km 28 is cut into scree slopes, and material is readily available upslope to the north. There are also extensive scree slopes adjacent to the road upslope on the southern side between Km 32 and Km 38. If the use of scree material is not acceptable, aggregate would be sourced from the mine site quarry.

### *5.3 LTF*

The LTF will be used almost year round, and the facility will require foundation material similar to the TTF. Approximately 8,500 $m^3$ of aggregate will be required. CZN's preference is to acquire this aggregate locally. Possible sources are the Nahanni Butte Dene Band, or borrow pits along the Liard Highway. Failing this, aggregate could be sourced from more distant commercial ventures, or the mine site quarry.

### *5.4 Access Road*

As stated in the DAR, the access road will be essentially a frozen road bed at grade with limited use of snow fill and ice. A level bed is required. Re-alignments have been proposed to avoid sensitive or difficult terrain. A limited amount of cat blading will be required to form a level surface. The existing access road alignment was formed without the use of aggregate. The same may be true for the re-alignments. However, CZN's terrain consultant (Golder Associates) has indicated that soft soils may be encountered along the Polje and Silent Hills re-alignments, and that good drainage is required to avoid small slope failures. Therefore, there may be a need for aggregate in problematic areas. The quantity required cannot be estimated at this time, but is unlikely to be as much as the transfer facility requirements. Whatever the needs are, it is likely to be a one-time requirement, unless particular areas show annual instability and require aggregate addition for every operating season. The Sundog Creek scree slopes are again the preferred aggregate source, or alternatively the mine site quarry.

## 6.0 ACCESS ROAD IMPROVEMENTS

In Section 6.2 of the DAR (Access Road Alternatives, Polje Creek By-Pass, Km 48-59), reference is made to a possible span crossing over the creek. In addition, temporary span structures may be used at other creek crossings along the access road, as noted in Section 6.22 of the DAR. CZN is aware of a number of used Bailey bridges at various locations in the Mackenzie Valley. The GNWT Department of Transport has informed CZN that these bridges are available. CZN's plan is to acquire the bridges, assuming they are available at the time or acquire similar bridges if not, and to use them on the access road as temporary creek spans. The bridges would be moved into place seasonally, using the frozen creek banks as abutments. On seasonal road closure, the bridges would be moved off the crossings to a nearby location ready for the subsequent season.

In Section 6.21.2 of the DAR, road construction was discussed. Segments of the existing access road and proposed re-alignments occur on sloped ground and will require cut and fill techniques in order to construct a level road bed for safe operations. This construction will be carried out during the cold months of November–March.

The exact route of the alternate re-alignments will only be determined following ground truthing ahead of equipment during construction. Some segments within the alternate routes will require more extensive cut and fill for levelling of the road bed due to steeper slope gradients. On the Polje by-pass, more extensive cut and fill is expected to be required from the western end of the by-pass (Km 47-Km 49, refer to Figure 6-21 in the DAR). In addition, the steep gradient east of Polje Creek up to the existing access road would also need to undergo cut and fill (Km 52-Km 54).

The Silent Hills alternate route cut and fill road building will need to be completed on the gradient leading up to Wolverine Pass from approximately Km 92.5, just east of the Fishtrap Creek crossing, to Km 97 at Wolverine Pass (refer to Figure 6-22 in the DAR). It is difficult to estimate the exact amount of cut and fill required. This route generally follows the contour of the slope, but would require local areas of cut and fill where streams have incised the terrain or where localized steep gradients exist. A total cut and fill length of up to 4.5 km is expected. On the east side of the pass, the new alignment follows the foothills of the Silent Hills range, and a cut and fill length of 6 km is expected.

The Nahanni Front Range alternate route generally contours along the east facing gentle front slope of the Nahanni Range. While the overall slope appears to be quite manageable from a road building perspective, local areas would need to be cut and filled in order to allow safe trucking. It is estimated that a cumulative total of up to 5 km of road would need to be cut and filled.

A summary of approximate cut and fill requirements is as follows:

| | |
|---|---|
| Polje by-pass | 4 km |
| Silent Hills | 4.5 km |
| Wolverine-Grainger | 6 km |
| Nahanni Front Range | 5 km |
| Total | 19.5 km |

The occurrence of ice-rich soil or permafrost is very sporadic and unpredictable in the region and would require detailed ground truthing to accurately delineate. The following comments were included in the Golder Associates report in Appendix 16 of the DAR, Appendix II – Ground Stability Overview, page 9: "The access route traverses land that is expected to include discontinuous permafrost. at some locations along the route, the permanently frozen ground is likely to be ice rich. while no specific investigation for ice rich ground was carried out as part of this assessment, it is believed it will be found to exist along the proposed re-aligned section of access road between approximately Km 48 and Km 59 (particularly approximately 2 km to 3 km west of the proposed crossing of Bubbling Springs (Polje) Creek); within the 2 to 3 km width of the base of the Tetcela Valley (between Km 89 to Km 92); possibly along the proposed re-alignment on the western flank of the Silent Hills (between Km 92 and Km 99) and along the proposed re-alignment east of the front range between Km 125 and Km 155)."

In the same Golder report, in Table III-1 with respect to the Polje re-alignment and the Silent Hills re-alignment, Golder notes that "Investigation of the ground conditions, particularly with respect to the possible presence of ground ice, is recommended so that appropriate mitigation strategies can be developed during the design phase of this project." Regarding mitigation, Golder note that "The proposed roadway has not yet been designed in detail, however, it is recommended that every effort be made to avoid significant side hill cuts and side hill fills through detailed selection of the alignment. Consideration should be given to the use of snow and ice locally to create temporary road grade. Drainage management should be such to avoid blockage or concentration of drainage as it crosses the alignment. Seasonal ice formation due to groundwater discharge along this section of the alignment should be considered in design."

As recommended by Golder Associates, during road construction the existing organic layer will be retained to help insulate any permafrost that occurs. Regarding the possible presence of permafrost in cut and fill sections, Golder have advised that a number of mitigation steps can be taken. The approach would be to minimize cut and fill in such areas by using a frozen road bed and filling with snow. Difficulties can be minimized by carefully selecting a route that avoids local grades. The route can also be locally selected to make use of trees immediately south of the roadway which provide shade and help maintain frozen ground. Cut and fill is still possible depending on the slope and local soils. In difficult ground, more filling and less cutting may be appropriate, with the possible use of aggregate for better drainage and road bed stability. Care will need to be taken not to "overload" the bed which could promote minor failures. Site specific approaches will need to be selected for each segment of difficult terrain, and may vary along a particular stretch of road in response to conditions.

If permafrost were to exist over 30% of the alternate routes where cut and fill may be required, approximately 6 km of the cut and fill areas may be in ice-rich soil.

# 7.0 IMPACTS ON THE BIOPHYSICAL ENVIRONMENT

Impact predictions were provided in the DAR for the valued components (VC) of Mine Site Water Quality (Section 3.3.2 in the Terms of Reference (TOR)), Fish and Aquatic Habitat (Section 3.3.5) and Terrain (Section 3.3.7). These predictions are re-iterated below with the addition of significance determinations.

Significance determinations for impacts include consideration of direction/magnitude, geographic extent, duration, frequency of occurrence, confidence level and reversibility of effects.

The following criteria have been used for the significance determinations:

- **Magnitude** – The degree, extensiveness, or scale to which an activity may affect a VC. Impacts are assumed as being negative (adverse). Magnitude may be defined as low, moderate or high, depending on whether it exceeds a threshold of manageable change;
- **Geographic Extent** – The geographic location or area where the effect is predicted to occur. The geographic extent may be identified as local (confined to the Prairie Creek Mine site and/or access road), immediate area (downstream waterways or lands adjacent to the access road) or regional (i.e. the Dehcho) in scale;
- **Duration** – The length of time that an effect is expected to occur as a result of an activity. Short-term duration is defined as approximately 1-2 years, medium-term duration several years up to the projected mine life of 14 years, or long-term duration extending for decades and beyond;
- **Frequency** – The predicted rate of occurrence over which an effect is predicted to occur. Frequency is defined as low if it occurs once, medium if it occurs intermittently or periodically, or high if it occurs often or continuously;
- **Variance** – The level of possible variance attributed to the prediction; and,
- **Reversibility –** Whether the predicted effect(s) are reversible, or the capacity of the VC will be restored to pre-development conditions with mine closure and reclamation.

Qualitative assessment levels for the significance criteria are explained in Table 1.

**Table 1: Qualitative Assessment of Effects Criteria Associated with the Project**

| Criterion (of effect) | Low | Moderate | High |
|---|---|---|---|
| Magnitude (severity of adverse environmental effects) | Change is above baseline conditions but within thresholds and within likely range of natural variability | Change is substantially above baseline conditions but within thresholds and within likely range of natural variability | Change exceeds baseline conditions and causes changes beyond the range of natural variability |
| Geographic extent | Area of effect does not extend past the footprint of the project | Area of effect extends beyond the project footprint but not of regional or territorial consequence | Area of effect is likely to extend into the region or be of territorial consequence |
| Duration | Effect is only evident for 1-2 years | Effect is evident for several years up to mine life | Effect extends longer than the mine life |
| Frequency | Factors causing the effect occur infrequently (*i.e.,* <once per year) | Factors causing the effect occur at regular intervals but infrequently (*i.e.,* once per month) | Factors causing the effects occur regularly and frequently (*i.e.,* > once per month) |
| Variance | Main factors contributing to determination are not likely to vary significantly | Main factors contributing to determination are prone to some variation | Main factors contributing to determination are likely to vary significantly |
| Reversibility | Effect is readily reversible over a short period of time (*i.e.,* one season) | Effect is reversible after several years | Effect is not reversible even after mine closure and reclamation |

An explanation of the overall significance of environmental effects based on the criteria outlined in Table 1 is provided in Table 2.

**Table 2: Significance Criteria for Environmental Effects Assessment**

| | | |
|---|---|---|
| **Overall Significance** | Low | The effect is expected to be of low significance and further assessment and/or specific management are likely not required. |
| | Moderate | The effect is expected to be of moderate significance and specific management measures and monitoring are necessary. |
| | High | The effect is expected to be of high significance and further study or monitoring is necessary to supplement the baseline data, and for use in refining a management strategy and planning. |

### *7.1 Mine Site Water Quality*

Consideration of mine site water quality will be sub-divided into the operations phase and the post-closure phase since the discharges and potential impacts will be different.

***Operations***

In Section 8 of the DAR, it was explained that the two main discharges during operations will be excess water from the mine and process water from the mill. In Section 8.6.1, predictions of key metal concentrations in receiving waters as a result of the discharges were explained, with results given in Table 8-9. None of the predicted in-stream metals concentrations exceed site specific objectives in any month with average creek flows. This is because of the assimilative capacity of the creek flows, and the process water treatment strategy where the rate of treatment is matched to receiving water flows. It is assumed that discharge would be curtailed if monitoring indicates creek flows are less than average. The site specific objectives are based on the measured natural variability of background metal concentrations.

Effects on pH were also considered. Treated water will likely have a pH of approximately 9 when it leaves the Water Treatment Plant (WTP). However, it could periodically be as high as 9.3. The background pH in Prairie Creek is on average 8.3 (DAR Appendix 8, Table A8-9). For average flows in Prairie Creek, the greatest predicted pH increase occurs in March (the low flow month) and is 8.5. This compares with a Canada-wide (CCME) objective of 9.0. The WTP will include a clarifier to remove suspended solids (TSS). Therefore, sediment levels in discharges are expected to be low.

It was also explained in Section 8 of the DAR that ammonia concentrations in discharges will be controlled by not using ammonium nitrate-based explosives (ANFO) in wet areas where residues could be dissolved. This effectively means ANFO will not be used in mining stopes because these are expected to be wet.

Discussion of chloride, sulphate and the nutrient phosphate was not given in the DAR, but is provided here. There is no federal (CCME) guideline for chloride. The BC guideline for the protection of aquatic life is 1,500 mg/L. Monitoring of Prairie Creek water quality upstream by Environment Canada indicates an average chloride concentration of 0.34 mg/L. The chloride concentration in mill process water will be approximately 20 mg/L (DAR Table 6-7). The chloride concentration in mine water will be approximately 1-2 mg/L (DAR Appendix 1A, Tables 3-4 to 3-7). Note that the annual average ratio of site discharge volume based on mine flows of 100 L/sec to Prairie Creek flow is approximately 50:1, and 3.5:1 for the low flow month of March.

There is no CCME guideline for sulphate. The BC guideline for the protection of aquatic life is 1,000 mg/L. Monitoring of Prairie Creek water quality upstream by Environment Canada indicates an average sulphate concentration of 68 mg/L. The sulphate concentration in mill process water will be approximately 200 mg/L (DAR Table 6-7). The sulphate concentration in mine water will be up to 400 mg/L, but will likely be in the 200-300 mg/L range (DAR Appendix 1A, Tables 3-4 to 3-7).

There is no CCME guideline for phosphate. Rather, it is suggested that an appropriate phosphate concentration in a receiving water is a site-specific consideration. Monitoring of Prairie Creek water quality upstream by Environment Canada indicates a phosphate concentration range of 0.004-0.01 mg/L. The phosphate concentration in mill process water will be approximately 1 mg/L before treatment, and slightly less after (DAR Appendix 2, Table 16 Test 16C)). The phosphate concentration in mine water will be 0.01 mg/L before treatment, and approximately 0.2 mg/L after (DAR Appendix 2, Table 2 (Test 1D)). Camp sewage is expected to have low phosphate concentrations since phosphate-free detergents only will be used.

Based on the above data, an impact significance matrix has been developed in Table 3 for each water quality parameter discussed.

**Table 3: Impact Significance Matrix - Mine Site Water Quality, Operations**

| | Magnitude | Geographic Extent | Duration | Frequency | Variance | Reversibility |
|---|---|---|---|---|---|---|
| Cadmium | Moderate | Moderate | Moderate | High | Moderate | Low |
| Copper | Moderate | Moderate | Moderate | High | Moderate | Low |
| Lead | Moderate | Moderate | Moderate | High | Moderate | Low |
| Selenium | Moderate | Moderate | Moderate | High | Moderate | Low |
| Zinc | Moderate | Moderate | Moderate | High | Moderate | Low |
| Ph | Moderate | Moderate | Moderate | High | Low | Low |
| TSS | Moderate | Moderate | Moderate | High | Moderate | Low |
| Chloride | Moderate | Moderate | Moderate | High | Low | Low |
| Sulphate | Moderate | Moderate | Moderate | High | Low | Low |
| Phosphate | Moderate | Moderate | Moderate | High | Low | Low |

Magnitude was assigned a moderate rating because, while parameter concentrations in receiving water are predicted to increase, the increases should be within or potentially just above the natural range of variability. Geographic extent was considered to be moderate because the water quality changes, albeit small, are likely to persist beyond the mine area downstream for several kilometres. Duration is moderate because it does not extend beyond the period of the mine's life. Frequency is high because the discharges will occur routinely year-round and throughout the mine's life. Variance is low to moderate because some parameters are not likely to have elevated concentrations, and for the other parameters, reliability of water treatment testing is considered to be high. Reversibility is low because receiving water quality would quickly revert to background values in the absence of mine operations and the discharges.

Overall, the significance of impacts from mine site water discharge during operations on receiving water quality is expected to be moderate.

***Post-Closure***

In Section 8 of the DAR, it was explained that the existing vein fault structure will continue to discharge groundwater to Harrison Creek after mine closure. This discharge will be a combination of groundwater that has flowed within the fault outside of the mine workings, and groundwater that has come into contact with the workings and the backfilled mine waste. In Section 8.6.2, predictions of key metal concentrations and sulphate in receiving waters as a result of the discharge were explained, with results given in Table 8-10.

Post-closure metal concentrations in Prairie Creek are predicted to be less than the site specific objectives for all months during normal monthly flows. However, when monthly flows are lower than normal from December to April, concentrations of cadmium, lead and zinc could exceed the objectives. Note that cadmium and lead are not conservative in the natural environment, and concentrations readily reduce due to various natural attenuation reactions. Also, the predicted 'low flow' concentrations are considered a 'worst case' because source term flows were not reduced, and these flows are likely to be less during unusually dry periods. Impacts associated with the post-closure elevated zinc concentrations likely occurred naturally before mine development.

Based on the above data, an impact significance matrix has been developed in Table 4 for each water quality parameter discussed.

**Table 4: Impact Significance Matrix - Mine Site Water Quality, Post-Closure**

| | Magnitude | Geographic Extent | Duration | Frequency | Variance | Reversibility |
|---|---|---|---|---|---|---|
| Cadmium | Low | Moderate | High | High | Moderate | High |
| Copper | Low | Moderate | High | High | Moderate | High |
| Lead | Low | Moderate | High | High | Moderate | High |
| Selenium | Low | Moderate | High | High | Moderate | High |
| Zinc | Low | Moderate | High | High | Moderate | High |
| Sulphate | Low | Moderate | High | High | Low | High |

Magnitude was classified as low because predicted concentrations are within the range of natural variability during normal stream flows, and in all likelihood, concentrations for most metals will be less than predicted due to attenuation. Zinc is not prone to attenuation, but post-closure concentrations are expected to be similar to pre-mine values. Duration, frequency and reversibility are all considered to be high because the discharge will occur year-round in perpetuity.

During abnormally low stream flows, magnitude would increase for cadmium and lead to the moderate to high range. However, duration and frequency would commensurately decrease to the low to moderate range because such flows are infrequent and of relatively short duration.

Variance was adjudged to be moderate. Source terms for water quality were estimated from geochemical studies, primarily laboratory-based data and are prone to variation. However, there is considered to be as much or more potential for concentrations to be lower than estimated as opposed to being higher. Estimates will be refined during operations as field data becomes available. Additional management measures can be considered in the unlikely event that estimates are higher than initially predicted.

Overall, the significance of impacts from mine site water discharge post-closure on receiving water quality is expected to be moderate.

## *7.2 Fish and Aquatic Habitat*

In Section 10.2 of the DAR, the potential for impacts to fish and aquatic habitat was discussed. The main issues were considered to be as follows:

- Downstream water quality during mine operations;
- Downstream water quality after mine closure;
- Sediment dispersal from the mine or as a result of access road operations;
- Habitat alteration associated with the road; and,
- Accidents and malfunctions from mine and access road operations.

An impact significance matrix has been developed in Table 5 for each of these issues.

**Table 5: Impact Significance Matrix – Fish and Aquatic Habitat**

| | Magnitude | Geographic Extent | Duration | Frequency | Variance | Reversibility |
|---|---|---|---|---|---|---|
| Water quality, operations | Moderate | Moderate | Moderate | High | Moderate | Low |
| Water quality, post-closure | Low | Moderate | High | High | Moderate | High |
| Sediment | Low | Low | Low | Moderate | Moderate | Low |
| Habitat alteration | Low | Moderate | Moderate | Low | Low | Low |
| Accidents and malfunctions | Low | Moderate | Moderate | Low | Moderate | Low |

The matrices for water quality, operations and post-closure follow those assigned for mine site water quality above. Toxicity data support the conclusion that predicted receiving water quality will not be detrimental to aquatic health if parameter concentrations are within the site specific objectives. Sediment dispersal was assigned a low-moderate rating because of the successful history of existing site operations in limiting sediment production, and the intention to avoid in-stream activities along the access road and to use temporary spans for many of the significant creek crossings. Habitat alteration was similarly assigned a low-moderate rating because mine and access road operations will entail very little if any aquatic habitat alterations. Accidents and malfunctions was assigned a low-moderate rating primarily based on annual access road operations. While any spills are unlikely to be of a significant magnitude, they could occur at any point along the road during any operating season. Risks at the mine site are considered to be lower because of the ability to respond quickly to malfunctions and to contain any spills within the bermed area.

Overall, the significance of impacts on fish and aquatic life is expected to be low to moderate.

### *7.3 Terrain*

In Section 10.4 of the DAR, the potential for impacts associated with terrain was discussed. The main issues were considered to be as follows:

- Waste rock pile;
- Terrain stability in the mine area;
- Terrain stability along the access road;
- Karst stability along the access road; and,
- Stability of structures considering seismicity and climate extremes.

An impact significance matrix has been developed in Table 6 for each of these issues.

**Table 6: Impact Significance Matrix – Terrain**

| | Magnitude | Geographic Extent | Duration | Frequency | Variance | Reversibility |
|---|---|---|---|---|---|---|
| Waste rock pile | Low | Low | High | Low | Low | High |
| Terrain stability, mine | Low | Low | Moderate | Low | Low | Moderate |
| Terrain stability, road | Moderate | Moderate | Moderate | Moderate | Low | Moderate |
| Karst stability | Low | Moderate | Moderate | Low | Low | Low |
| Stability of structures | Low | Low | Moderate | Low | Moderate | Low |

The risk of terrain impact associated with the waste rock pile is considered to be low. The pile will remain in perpetuity. The risk of terrain impact associated with the mine was similarly considered to be low. Some terrain issues were noted related to the access road, specifically the potential for small-scale soil slope failures, and complications associated with the presence of permafrost. CZN's engineering consultant recommended the avoidance of unstable terrain by using the proposed road re-alignments, and road construction practices to avoid instability (drainage, retaining the organic layer). No significant issues related to karst structures were noted. Geotechnical designs for mine site structures account for potential seismic events, and stability should not be significantly compromised should such events occur, or climate extremes such as intense rainfall.

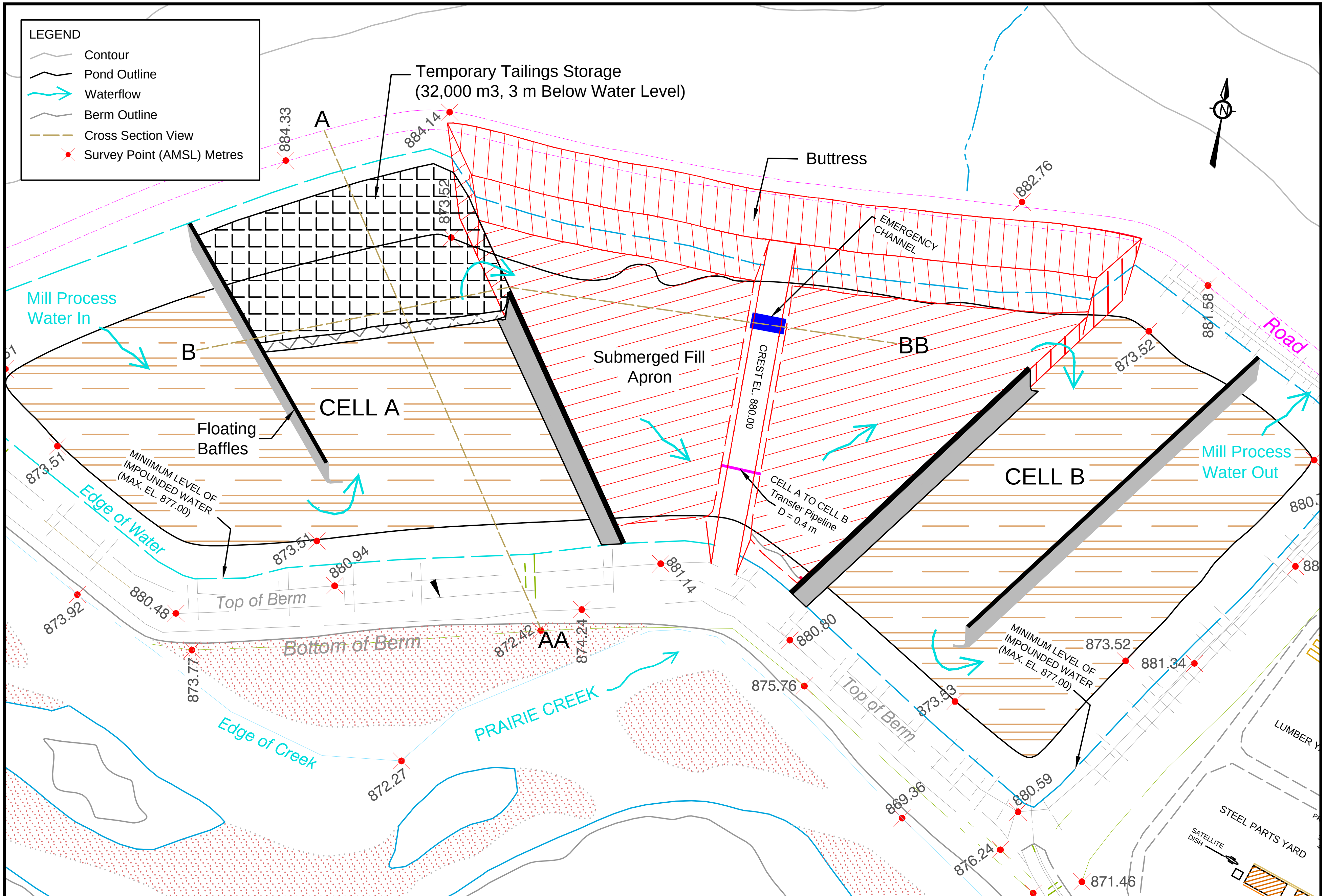
Overall, the significance of impacts associated with terrain is expected to be low to moderate.

## 8.0 FLOOD PROTECTION BERM REPORTS

CZN was requested to provide copies of the reports on the above noted subject that were referenced in Section 10.4.3 of the DAR. As noted in the DAR, these reports are available on the Review Board website for EA0809-002, specifically "RfR 23 0f 56 – Material Related to Maximum Probable Flood Calculations, 2005", posted on November 26, 2008. For ease of reference, the contents of the posting are reproduced in Appendix C.

## 9.0 CAPITAL AND ANNUAL OPERATING COSTS

CZN has not released pre-feasibility or feasibility level project development financial data for public consumption since such economics are preliminary in nature, vary with fluctuations in metal markets, and are in part time dependent on the outcome of the current EA. CZN has developed project economics for internal planning purposes. While the information remains confidential, CZN is able to provide the Review Board with a preliminary summary. The terms proposed by the Review Board in their April 23, 2010 DAR conformity/deficiency letter for the management of this information are acceptable to CZN. Accordingly, an estimate of capital costs associated with placing the Prairie Creek Mine into production broken down by major components, and an estimate of annual operating costs during the life of the mine, will be provided to the Review Board under separate cover.




**CANADIAN ZINC CORPORATION**

| | |
|---|---|
| Date: | May 2010 |
| Drawn By: | C. Reeves |
| Scale: | As Shown |
| Drawing: | DAR_ Ad_Fig 1.dwg |

SCALE

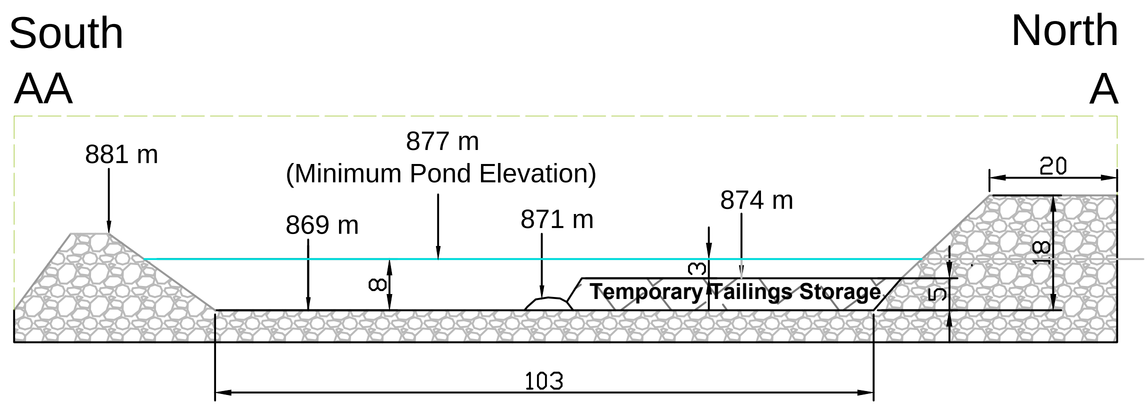
0 20 40 60 80 100

METRES

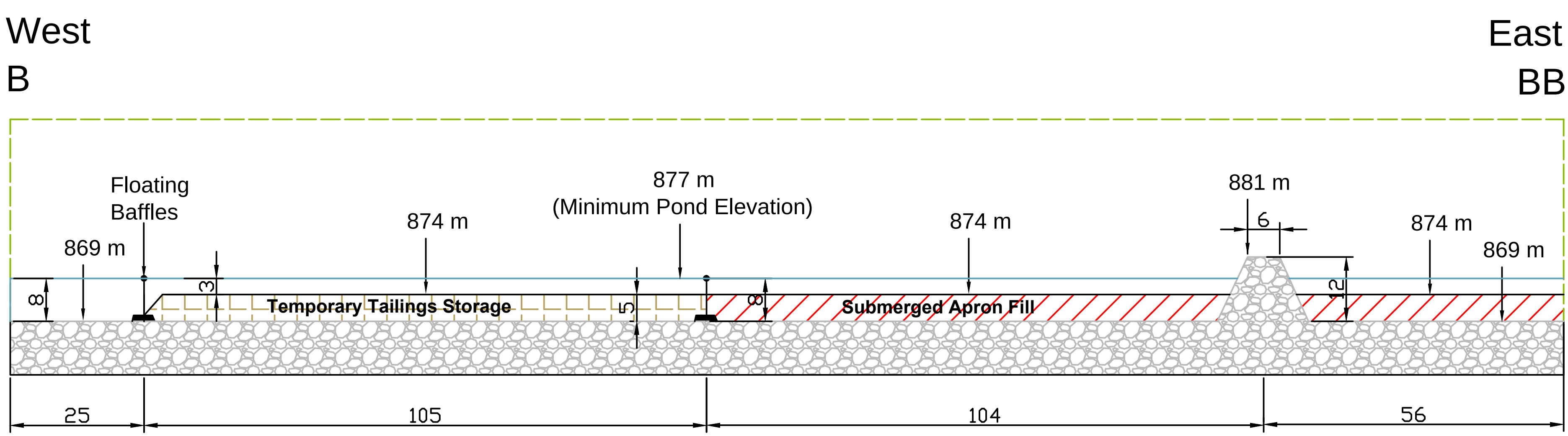
PRAIRIE CREEK MINE

# FIGURE 1:

## RECONFIGURED WATER STORAGE POND




# Cross Section View from Figure 1




CANADIAN ZINC CORPORATION

| | |
|---|---|
| Date: | May 2010 |
| Drawn By: | C. Reeves |
| Scale: | As Shown |
| Drawing: | DAR_ Ad_Fig 2.dwg |

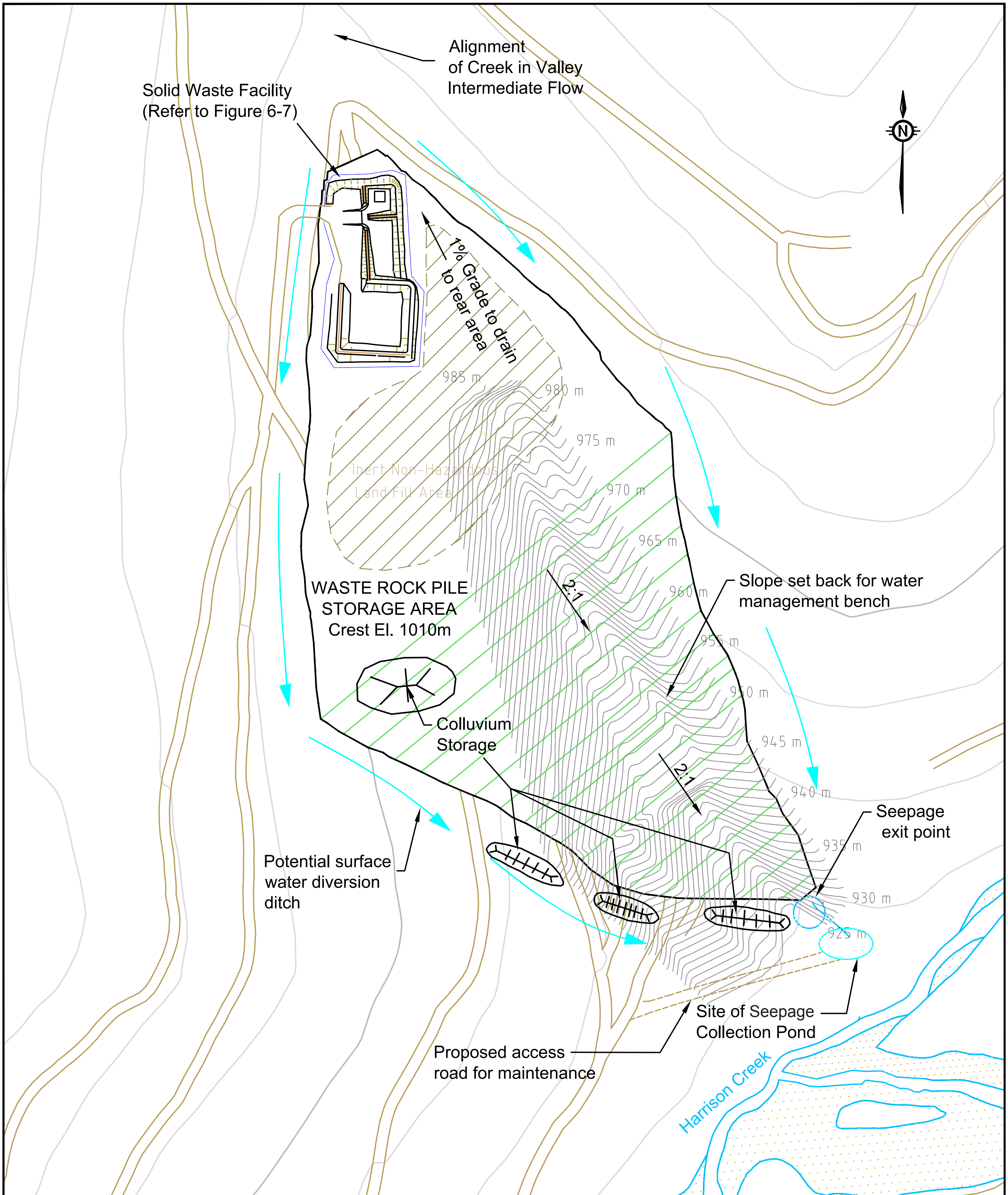
SCALE

0 20 40 60 80

METRES

PRAIRIE CREEK MINE

FIGURE 2:
RECONFIGURED WATER STORAGE POND
CROSS SECTION VIEW




Legend

- Waste Rock Boundary
- Surface Roads
- Contour (Surveyed 2009)
- Watercourse

Scale in Metres

0 20 40 60

CANADIAN ZINC CORPORATION

Scale: As Shown

Drawn By: C. Reeves

File Name: DAR_Ad_Fig 3.dwg

Date: October 2010

PRAIRIE CREEK MINE

Figure 3:
LOCATION AND DESIGN
OF WASTE ROCK PILE

# APPENDIX A

Mackenzie Valley
Review Board

Our file: EA0809-002

Vial email

April 23, 2010

Mr. David Harpley
VP –Environment and Permitting Affairs
Canadian Zinc Corporation
Suite 1710-650 West Georgia Street
PO Box 11644
Vancouver, BC
V6B 4N9

Dear Mr. Harpley:

**Re: Canadian Zinc Corporation, Prairie Creek Mine**
**Conformity Check of Developer's Assessment Report and Deficiency Statement**

## Introduction

The Review Board has completed a conformity check of the Prairie Creek Mine Developer's Assessment Report (DAR) and found it to not be in conformity with the June 26, 2009 Terms of Reference for this environmental assessment.

A conformity check determines whether the developer has responded to the items in the Terms of Reference (ToR) with enough information to address potential adverse impacts from the project on the environment. The Review Board met April 20-22, 2010, to perform a conformity check on the Prairie Creek Mine DAR. The following is a deficiency statement which lists the information requirements from the ToR that are not in conformity.

Selected portions of the ToR that remain outstanding have been provided in italics in this deficiency statement. Canadian Zinc Corporation is asked to answer the specific requirements described below so that the DAR can be considered in conformity with the Terms of Reference.

### 3.2.5 Development Description

**ToR Section 3.2.5 – temporary storage of tailings in water storage pond**

> **3)** *A table of all existing infrastructure components, whether and how they are proposed to be altered (e.g., larger or smaller buildings, new equipment, altered material flows) and for what purpose, and a description of which existing infrastructure will be removed entirely and how it will be replaced*
>
> **4):** *For each existing infrastructure component, a prediction of any changes from its current level of usage during full scale operations (e.g., increased frequency of aircraft flights), as well as comparison of maximum expected usage to the design capacity for the development component*
>
> **10)** *The backfill technology to be used, the paste backfill plant, transport of the paste backfill to the underground works, the planned bulkheads system, and when and how tailings stored on the surface will be transported to and used in the paste backfill system*

Request to developer

As described in Section 6.3.7 of the DAR, the former tailings pond will be converted into a water storage pond. This water storage pond is later identified briefly in Section 6.12.2 and in Appendix 12 as a temporary storage site for mill tailings. Temporary storage of tailings in the water storage pond instead of on surface adjacent to the pond as originally proposed in the Project Description is an important change in project design. No mention is made of temporary tailings storage in the water storage pond in Table 6-2 or Section 6.3.7 of the DAR. Please describe use of the water storage pond as a location for the temporary storage of tailings. Specifically, please provide details on:

- volume of tailings to be stored in the water storage pond;
- method of tailings transport to the pond and method of tailings placement in the pond;
- location of tailings storage in pond identified on a figure in plan view and cross section;
- duration of tailings storage in the pond;
- method of tailings removal from the pond with predicted ability to remove all temporarily stored tailings; and
- impacts of temporary placement of tailings in storage pond on pond water quality in ToR Section 3.3.2.

**ToR Section 3.2.5 – storage of overburden and organic material removed from waste rock pile site**

> **11)** *The location, contents and estimated amounts of mined materials, soil and overburden at all surface storage facilities, along with estimates of storage requirements and underground storage capacity limits*

Request to developer

The estimated amounts of overburden and organic material to be removed from the waste rock pile site and storage location are not included in the DAR. It is understood from the Preliminary Design of the Waste Rock Pile (Appendix 11) that some quantities of overburden material are suitable for construction of the containment berm for the seepage collection pond and that a storage site for some of the overburden material may therefore be temporary. Please describe the estimated volume of overburden and organic material to be removed from the waste rock pile site, the temporary or permanent storage locations for the materials and an estimated storage footprint. In addition, please show the storage locations on a map.

**ToR Section 3.2.5 – aggregate sources**

> **13)** *Location(s) and proposed activities of aggregate production and storage, with an estimate of the amount of aggregate that will be produced per year over the life of the mine, by location*

Request to developer

General locations of aggregates are described in Section 6.13 of the DAR, however, estimated amounts of aggregate that will be produced per year are not included. Please provide an estimated amount of aggregate that will be produced per year over the life of the mine, by location with a focus on realigned sections of the winter road.

**ToR Section 3.2.5 – access road improvements**

> **21)** *All existing or proposed access roads required for the Prairie Creek Mine, with particular emphasis on the winter road, including analysis of necessary one-time improvements, initial and annual construction techniques, proposed water crossing types by location, and amount of water and other materials required*

Request to developer

In Section 6.21.1 of the DAR (Access Road Alternatives, Polje Creek By-Pass km 48-59), reference is made to a possible span crossing over the creek. Please describe the type of span crossing proposed for Polje Creek. In addition, please describe the type of temporary span structures that may be used at creek crossings along the winter road as referenced in Section 6.22.1 of the DAR.

Section 6.21.2 of the DAR describes construction for the winter road and proposed re-alignments. In particular, this section refers to segments of the winter route that are on sloped ground and will require cut and fill techniques in order to construct a level road bed. Please identify the time of year proposed for construction of the realigned road sections. Please identify the specific locations and total length along the winter road where cut and fill construction techniques will be required. In addition, please identify locations and estimated length of the route where cut and fill techniques within ice-rich soil or permafrost will be required.

### 3.3 Impacts on the Biophysical Environment

**ToR Section 3.3.2 Mine site water quality – use of criteria for impact assessment described in Section 3.3.1 in determining opinion on significance of impacts**

> Section 3.3.1 *When describing impacts and assessing their significance, Canadian Zinc must characterize:*
>
> - *The nature or type of the impact;*
> - *The direction of the impact (i.e., beneficial vs. adverse);*
> - *The magnitude of the impact, and whether it exceeds a threshold of manageable change;*
> - *The geographic range the impact will occur within, as well as impact loads on any location of heightened sensitivity or high local impact intensity;*
> - *The timing of the impact (including duration, frequency and extent);*
> - *The likelihood of the impact occurring;*
> - *The reversibility of the impact; and*
> - *The confidence level in the prediction, and any factors influencing the level of uncertainty in the predicted outcome (this uncertainty analysis must consider the confidence of the developer in underlying assumptions, models, and data sources).*
>
> *These criteria shall be used by the developer as a basis for its opinions on the significance of impacts on the biophysical environment. The Review Board will make the ultimate determination of significance once considering all the evidence on the public record at the end of the environmental assessment.*

<u>Request to developer</u>

The potential impact of the Prairie Creek Mine on local and downstream water quality is the key line of inquiry in the Terms of Reference for the Prairie Creek Mine. Section 3.3.1 of the ToR requires that the developer follow specific impact assessment steps and significance determination factors for each valued component. In the DAR, these impact assessment steps and significance determination criteria for mine site water quality have not been followed.

Please present the missing information and follow the assessment steps and significance determination criteria for water quality as required under Section 3.3.1 of the ToR.

**ToR Section 3.3.5 Fish and Aquatic Habitat – use criteria for impact assessment described in Section 3.3.1 in determining opinion on significance of impacts**

Request to developer

Section 3.3.1 of the ToR requires that the developer follow specific impact assessment steps and significance determination factors for each valued component. In the DAR, these impact assessment steps and significance determination criteria for fish and aquatic life have not been followed. Please follow the impact assessment criteria as described in Section 3.3.1 and provide a significance determination for impacts to fish and aquatic habitat.

**ToR Section 3.3.7 Terrain –use criteria for impact assessment described in Section 3.3.1 in determining opinion on significance of impacts**

Request to developer

Section 3.3.1 of the ToR requires that the developer follow specific impact assessment steps and significance determination factors for each valued component. In the DAR, these impact assessment steps and significance determination criteria for terrain have not been followed. Please follow the impact assessment criteria as described in Section 3.3.1 and provide a significance determination for impacts to terrain.

Note: An acceptable example of impact predictions and significance determination using the criteria in Section 3.3.1 of the ToR can be found in the Vegetation and Wildlife Assessment Report (Appendix 17) of the DAR. For the purposes of consistency, this example could be used for impact predictions and significance determinations in the DAR for the valued components of Mine Site Water Quality – Section 3.3.2, Fish and Aquatic Habitat – Section 3.3.5 and Terrain – 3.3.7.

**ToR Section 3.1.5 – DAR to be submitted as a stand alone document**

> *The Developer's Assessment Report will be submitted as a stand alone document. Relevant data and analysis from the Project Description Reports and other previous studies should be incorporated where applicable into the Developer's Assessment Report and combined with any supplementary material and analyses required herein.*

<u>Request to developer</u>

In Section 10.4.3 of the DAR reference is made to Flood Protection Berm reports related to the ability of the dyke to withstand flooding events. Please include these reports as part of the DAR submission as required in Section 3.1.5 of the ToR.

**3.4 Impacts on the Human Environment**

**ToR Section 3.4.2 – capital and annual operating costs**

> *1. Qualitative and quantitative estimates of all beneficial and adverse economic impacts from the Prairie Creek Mine, including at minimum:*
>
> *a. Capital costs associated with placing the Prairie Creek Mine in operation, broken down by major components (estimates should be in 2009 dollars Cdn. and may be in a +/- 20% range);*
>
> *b. Annual operating costs during the life of the Prairie Creek Mine (estimates should be in 2009 dollars Cdn. and may be in a +/- 20% range)*

<u>Request to developer</u>

Please provide an estimate of capital costs associated with placing the Prairie Creek Mine in production broken down by major components and an estimate of annual operating costs during the life of the mine. The Review Board is aware that this ToR requirement may be considered confidential by the developer. Confidential information will therefore be addressed in the same manner as the terms put in place for confidential portions of Traditional Knowledge Assessment Addendum Report, August 2009, submitted to the Review Board by the Nahanni Butte Dene Band for this environmental assessment. These terms are as follows:

- Capital and annual operating cost information will be held under confidential cover at the Review Board office throughout the environmental assessment;
- The Review Board will notify parties that the information provided is under confidential cover;
- Parties may make a request to the Review Board to view the confidential information provided there are legitimate reasons to view it, e.g. a reasonable claim that a party may be affected;

- Should viewing of the confidential portions be granted by the Review Board, no reproductions in any form will be permitted and the viewing will take place at the Review Board's office only;
- Confidential information will be available to the Review Board during Board proceedings and decision making; and
- Confidential information will be returned to Canadian Zinc Corporation at the end of the environmental assessment.

The developer may submit this portion of its response to the deficiency statement under separate cover in order to facilitate confidentiality. If capital and annual operating cost information for the Prairie Creek Mine cannot be provided to the Review Board under the terms described above, please provide an explanation of why Canadian Zinc Corporation cannot comply with this section of the ToR.

**Conclusion**

The response to this deficiency statement should be submitted to the Review Board as an addendum to the DAR. Once the Review Board has determined that the DAR is in conformity with the ToR, the environmental assessment of the Prairie Creek Mine will proceed to the next phase and an updated Work Plan will be issued.

If you have any questions or are unclear on what is expected in your response to this deficiency statement, please contact me by email or phone.

Sincerely,

Chuck Hubert
Environmental Assessment Officer
Mackenzie Valley Review Board
Phone (867) 766-7052
Fax (867) 766-7074
chubert@reviewboard.ca

# APPENDIX B

# MEMORANDUM

**TO** Mr. David Harpley, Canadian Zinc Corporation **DATE** May 20, 2010

**CC** John Hull

**FROM** David Caughill **PROJECT No.** 09-1376-1009

**ADDENDUM TO PRELIMINARY DESIGN REPORT – WATER STORAGE POND**

**APPROXIMATE VOLUME OF WATER HOLDING POND**

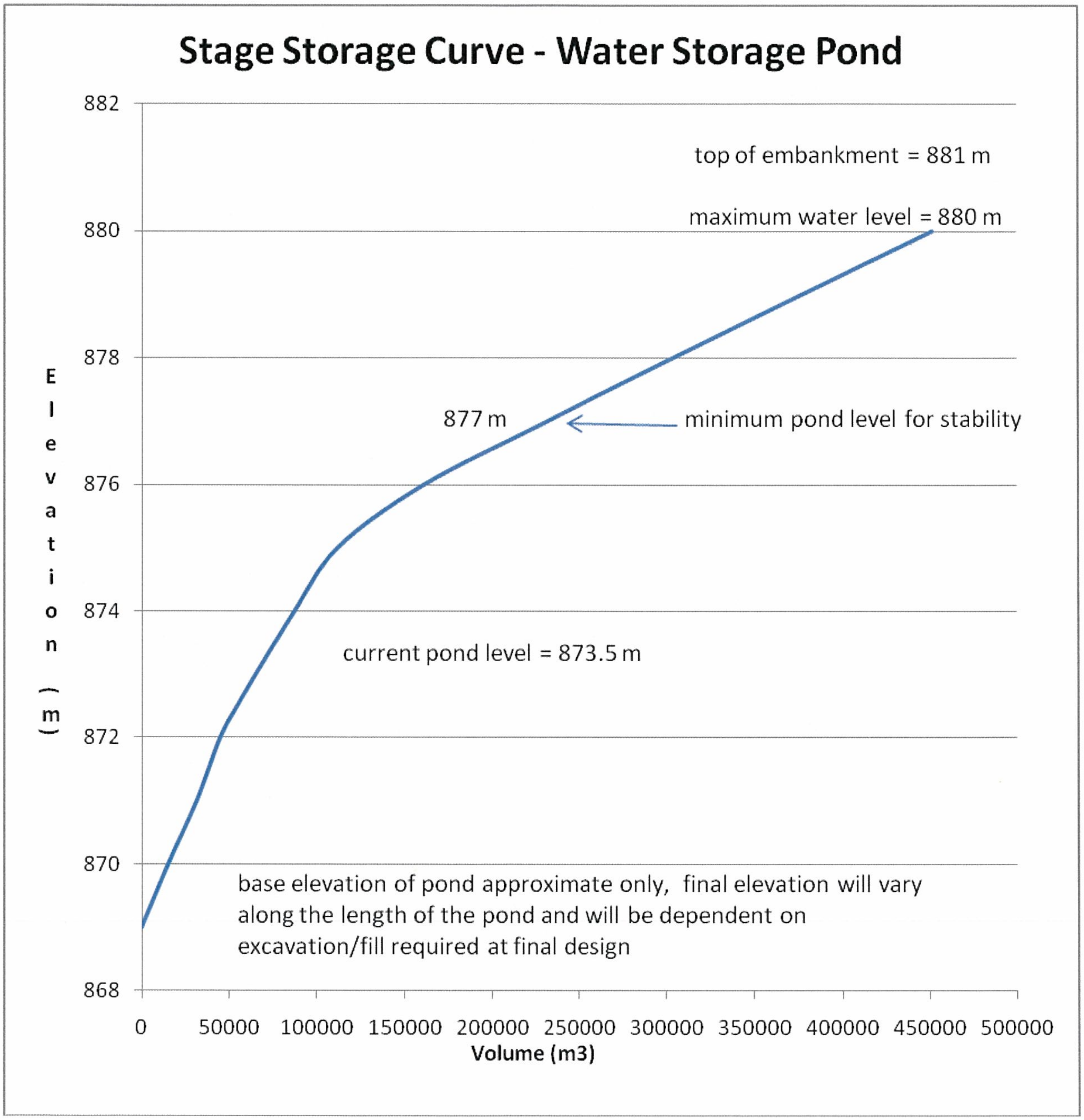
---

This memorandum is an addendum to the Preliminary Design Report for the Water Storage Pond at the Prairie Creek Mine, NWT, prepared by Golder Associates Ltd., dated March 2010. This memorandum provides a calculation and stage storage curve for the pond, with the planned interior berm and stabilising buttress.

The volume of the pond was calculated in AutoCAD Civil 3D©, using the currently available topographic contours and survey of the pond. The total volumes presented are preliminary as the current depth of water and thus the base elevations of the pond are estimates at this time. However, correlation of previous pond design drawings and recent survey data indicates that the pond base elevation is approximately 869 m. An average base elevation of 869 m was used for this calculation. The volume of the pond above the elevation of the current water level (873.5 m) is considered accurate, based on recent survey and the planned pond reconstruction.

The stage storage curve is presented in the figure below. Indicated on the figure are the current water elevation, minimum water level to promote stability of the north slope, maximum water level and the top of the embankment elevation. A freeboard of 1 m has been used based on the size of the pond and taking into account maximum precipitation events and the estimated wave action.

For further information regarding the water storage pond, please refer to the Water Storage Pond report as noted above.


Stage Storage Curve - Water Storage Pond
882
880
878
876
874
872
870
868
Elevation (m)
top of embankment = 881 m
maximum water level = 880 m
877 m
minimum pond level for stability
current pond level = 873.5 m
base elevation of pond approximate only, final elevation will vary
along the length of the pond and will be dependent on
excavation/fill required at final design
0 50000 100000 150000 200000 250000 300000 350000 400000 450000 500000
Volume (m3)

# APPENDIX C

Mackenzie Valley Land and Water Board
7th Floor - 4910 50th Avenue • P.O. Box 2130
YELLOWKNIFE, NT X1A 2P6
Phone (867) 669-0506 • FAX (867) 873-6610

March 24, 2005

File: MV2001L2-0003

Mr. David Harpley
Environmental Coordinator
Canadian Zinc Corporation
Suite 1202-700 West Pender Street
VANCOUVER, BC V6C 1G8

Fax: (604) 594-3855

Dear Mr. Harpley:

**Board Approval – Probable Maximum Flood Calculations**

The Mackenzie Valley Land and Water Board (the Board) has reviewed the aforementioned calculations required under Part D, Item 1 of Water Licence MV2001L2-0003. The Board hereby approves the Probable Maximum Flood Calculations as presented in the Probable Maximum Flood Profile Report dated March 19, 2004.

The related geotechnical engineer's report evaluating the current flood protection work at the Prairie Creek Mine site that is also required under Part D, Item 1 will be deliberated on by the Board at a later date.

If you have any questions, contact Sarah Baines, Regulatory Officer, at (867) 766-7457 or email sbaines@mvlwb.com.

Sincerely,

Todd Burlingame
Chair

Copied to: Alan Taylor, Canadian Zinc Corporation (Fax: 604-688-2043)
Distribution List



Copy of 00000001.max

Mackenzie Valley Land and Water Board
7th Floor - 4910 50th Avenue
P.O. Box 2130
YELLOWKNIFE NT X1A 2P6
Phone (867) 669-0506
FAX (867) 873-6610

# STAFF REPORT

| | |
|---|---|
| **Company:** Canadian Zinc Corporation (CZN) | |
| **Location:** Prairie Creek Mine Site | **Application:** MV2001L2-0003 |
| **Date Prepared:** March 16, 2005 | **Meeting Date:** March 23, 2005 |
| **Subject:** Probable Maximum Flood Profile Report (PMFP Report) | |

## 1. Purpose/Report Summary

The Probable Maximum Flood Profile Report (PMFP Report) and related Probable Maximum Flood Profile Report Follow-up (PMFP Report Follow-up) submitted by Canadian Zinc Corporation (CZN) were presented to the Board on November 15, 2004, and March 9, 2005. A decision on the PMFP Report and PMFP Report Follow-up was deferred until further discussions with legal counsel and with Water Resources Division, DIAND, took place.

The purpose of this staff report is to present the results of those discussions to the Board along with the PMFP Report and PMFP Report Follow-up for review and approval.

Probable maximum flood levels are calculated to determine the most severe flood that a specific region will experience. Factors that affect the probable maximum flood level include the climatological, hydrological, and physiographic characteristics of a region.

Predicted flood levels in the PMFP Report will be used to determine if the flood protection work (dykes and tailings dams) at the Prairie Creek Mine site will withstand flood events of various magnitudes.

## 2. Background

In 1980, Ker Priestman and Associates, a consulting firm from British Columbia, used empirical methods to determine the maximum possible flood that the Prairie Creek Mine site area could experience (Ker Priestman Report). The Ker Priestman Report was submitted to the MVEIRB during the 2001-2003 Environmental Assessment for the pilot plant and underground decline development at the Prairie Creek Mine. In the Report of Environmental Assessment, the Minister recommended that CZN provide updated probable maximum flood calculations.

In response to this Ministerial recommendation, the Board incorporated a condition, part D, item 1, in Water License MV2001L2-0003 (Type B) that required CZN to submit updated probable maximum flood calculations for the Prairie Creek Mine site area. Part D, item 1 reads as follows:

> Section 1
> *The Licensee shall submit to the Board for approval within six (6) months of the issuance of this license updated probable maximum flood calculations for flood elevations using at least the data available from 1975 to 1990, including data from the weather station at Virginia Falls hydrometric gauge.*
>
> Section 2
> *In addition to these calculations, a description of the adequacy of the current flood protection work shall be submitted with recommendations from a qualified Geotechnical Engineer for any improvements or modifications to be implemented upon approval by the Board.*

Canadian Zinc Corporation has addressed the two sections of this condition in two different documents because determining the adequacy of the flood protection work at the site is entirely dependent on the results of the probable maximum flood calculations. The document dealing with section 2 of the Condition will be finalized once the Board approves the PMFP Report.

The purpose of flood calculations is to determine for particular watercourses the flood magnitude of various return periods such as the 100 year, 500 year, 1,000 year, or probable maximum flood. The probable maximum flood is the most severe flood for a particular location. Engineers use flood calculations when designing dams, dykes and other containment structures to ensure that the elevation and strength structures can withstand specific floods.

Canadian Zinc Corporation contracted Hay and Company Consultants Inc. (HAYCO) to calculate the probable maximum flood for the Prairie Creek Mine site and to determine the most appropriate flood magnitude against which the flood protection at the site will be evaluate.

## Chronology

**March 19, 2004**: Probable Maximum Flood Profile Report (PMFP Report) received. This report was produced by HAYCO (HAYCO) on behalf of CZN.

**March 22, 2004:** PMFP Report distributed for review. Comments were due May 7, 2004.

**June 8, 2004:** Request for further information sent to CZN by Board staff. The deadline for the company's response was August 13, 2004.

**July 22, 2004:** Company response received. The document is titled Probable Maximum Flood Profile Report Follow-up (PMFP Report Follow-up) and was written by HAYCO.

**August 4, 2004:** The PMFP Report Follow-up distributed for review. Comments were due August 31, 2004.

**August 20, 2004:** Parks Canada indicates that they have a copy of the Ker Priestman Report. Board staff requested a copy of the report for the Public Registry.

**Sept. 27, 2004:** Board staff distributed a letter to CZN and to the reviewers that the review process would be stopped until the Ker Priestman Report was received.

**Oct. 15, 2004:** The Ker Priestman Report was received. It is a very large document with a number of maps and drawings so it took a long time to copy and have it delivered to the MVLWB office.

**Oct. 15-Nov. 7, 2004:** Board staff reviewed the Ker Priestman Report and researched how to calculate probable maximum floods and how the calculations are used.

**November 15, 2005:** The PMFP Report and the PMFP Report Follow-up were presented to the Board. The Board deferred their decision on the reports until Board staff held further discussions with legal counsel regarding the similarities and differences between the issues raised in the staff report and the circumstances that led to judicial review over the use of the tailings pond.

**March 9, 2005:** The results of the discussions between Board staff and legal counsel were presented to the Board along with the PMFP Report and the PMFP Report Follow-up. The Board deferred their decision until the Executive Director could follow up on a comment made by Water Resources Division, DIAND. Water Resources Division stated that CZN would be out of compliance with their WL if they did not produce true probable maximum flood calculations despite the company's arguments explaining that the true probable maximum flood cannot be calculated.

## 3. Discussion

The reviewers are mainly concerned that the PMFP Report does not satisfy the requirements of Part D, Item 1 because the PMFP Report does not represent a true calculation of the probable maximum flood. The reviewers questioned why Ker Priestman could calculate the Probable Maximum Flood in 1980 but HAYCO could not do the same at the present time. HAYCO responded to these concerns in a report titled, PMFP Report Follow-up.

In the PMFP Report Follow-up, HAYCO states that the estimates provided in the Ker Priestman report are actually not true probable maximum flood calculations. This conclusion was reached by HAYCO because Ker Priestman only used

18 years of data in his calculations, which is suitable for the derivation of the 40-50 year flood but not the probable maximum flood. Further support for this conclusion is provided by a statement in the Ker Priestman report itself: "It must be remembered that the estimation of flood flows by statistical methods, from data with a period of record, is uncertain at best" (page 66).

In the HAYCO PMFP Report, the 10,000 year flood is used to approximate the probable maximum flood for two reasons:

a) It is standard practice. Research conducted by Board staff indicated that a number of countries such as the United Kingdom, Australia and the United States construct major dams to withstand the 10,000 year flood.

b) The data to calculate the true probable maximum flood for the area is not available; the magnitude of large flood events cannot be predicted very accurately with only the short data record that is available. For example, a data record of 50 years will predict the magnitude of a 100 year flood with a 25% error margin. This error margin will increase substantially as the magnitude of larger flood events than the 100 year flood is predicted.

## 4. Comments

### Legal Counsel Analysis

*The Board did include the Minister's approved recommendations from the Environmental Assessment into the License. The issue in this staff report relates to a difference in opinion over how completely the licensee complied with the License requirement. This seems to be a technical issue, not a legal issue.*

*These circumstances are quite different from those that led to judicial review over the use of the tailings pond. In the judicial review case, the Board varied from the recommendation approved by the Minister to impose a more stringent condition. In this case, the Board included exactly what the Minister approved but made the report subject to Board approval. The question of whether the CZN engineering analysis satisfies the Board's condition in the License is a matter of fact, not law. Legal counsel suggests that the Board go ahead and exercise its judgement based on the analysis submitted by staff.*

### Executive Director's Discussion with Water Resources Division

*Will be delivered to the Board members at a later date but prior to March 23, 2005.*

## 5. Review Comments

- The DCFN, Parks Canada, and CPAWS are concerned that the HAYCO PMFP Report does not satisfy the requirements of part D, item 1.
- The DCFN and CPAWS recommend that the Board apply the Precautionary Principle and require that CZN evaluate the flood protection work on site using the most conservative standards.
- Environment Canada finds the approach taken in the PMFP Report reasonable and does not have any concerns with the conclusions. Roger Pilling, a Hydrometric Supervisor with Environment Canada, was asked by

Board staff to comment on the issue outside of the standard reviewer comment process. His comments are as follows:

> *"...it would be difficult to complete an estimated flow on Prairie Creek using South Nahanni River at Virginia Falls data due to the different flow regimes of the two basins. The South Nahanni is a much larger basin that has a rather large glacier melt component through the open water season, especially during the warmer months of June to August. The peak flows on the South Nahanni River are often (but not always) heavily influenced by glacial melt. On the other hand, Prairie Creek is significantly affected by summer rainfall events, with no glaciers feeding the basin. Prairie Creek is a much flashier basin with rapid changes over a short period of time, which is common in smaller basin scenarios."*

- Please see the comment summary table for further details on the issues raised in the Discussion section of this staff report.

## 6. Security

Not applicable.

## 7. Conclusion

The data that is available does not permit the calculation of the true probable maximum flood but only an estimation of the magnitude of the 10,000 year flood. The data is not appropriate for calculating the true probable maximum flood because the data record is too short and because the data from Virginia Falls is not applicable to the Prairie Creek Valley (see Environment Canada's comments).

Dr. Adrian Chantler is a professional engineer who signed the report stating that the 10,000 year flood is an event comparable to the probable maximum flood. By signing this report, he has accepted professional and legal liability for the contents of that report and the validity of that statement.

## 8. Recommendation

I recommend that the PMFP Report and PMFP Report Follow-up be approved and that the requirements of section 1 (as defined in the Background section of the staff report) of License condition part D, item 1 be considered fulfilled.

## 9. Attachments

- Comment Summary Table for the Prairie Creek Probable Maximum Flood Profile Report
- Comment Summary Table for the Prairie Creek Probable Maximum Flood Profile Report Follow-up
- Prairie Creek Probable Maximum Flood Profile Report
- Prairie Creek Probable Maximum Flood Profile Report Follow-up

- Excerpt from the 1980 Ker Priestman Report that deals with maximum possible flood levels at the Prairie Creek Mine site

**Respectfully submitted,**

for

**Sarah Baines**
**Regulatory Officer**

# Comment Summary Table
## Canadian Zinc Corporation -Probable Maximum Flood Profile Report

| Reviewing Agency, Date Comments Received | Comments | Mitigation Measure |
|---|---|---|
| Deh Gah Got'ie Dene Council, April 23, 2004 | 1. During the April 15, 2004 Council meeting it was agreed by to support the First Nations of Nahanni Butte and Ft. Simpson. This support is for any concerns they may have in relation to the report and their endeavour to have them addressed. | 1. Presented to the Board. |
| Environmental Protection Branch, Environment Canada, May 4, 2004 | 1. The Regional Hydrologist reviewed the PMFP Report and finds that the approach is reasonable.<br>2. EC has no concerns with the conclusions reached. | 1. Presented to the Board.<br>2. Presented to the Board. |
| Deh Cho First Nations (DCFN), May 7, 2004 | 1. DCFN requires clarification on several statements within the report produced by HAYCO & Company Consultants Inc.:<br>• "very rough analysis...using limited data that are available"<br>• "strictly speaking this is not a Probable Maximum Flood analysis, as such an analysis requires a lot of detailed data and some weeks of work"<br>• "it has not been possible to review the earlier calculations of the PMF and the corresponding flood profile, as these have not been made available"<br>2. It is inconsequential that a true Probable Maximum Flood analysis may take some weeks of work given that CZN has had 6 months to produce the report.<br>3. It is unclear why the consulting firm (HAYCO) had a lack of data from which to draw more significant conclusions. DCFN requests clarification on why the consulting firm is noting a lack of available data with which to produce a more accurate Probable Maximum Flood analysis. | 1. In the PMFP Report Follow-up, HAYCO clarifies each of these points. Please see the Discussion section of the staff report for further detail.<br>2. True PMF calculations cannot be done as not all of the required data is available.<br>3. It is not that the data was not provided to HAYCO but rather that all the data needed does not exist. See the Discussion section of the staff report for further details. |
| Parks Canada, May 7, 2004 | 1. The report does not fulfill the requirements of Part D, Item 1 of Water License MV2001L2-0003. | 1. Presented to the Board. |

| | | |
|---|---|---|
| | 2. Considering that the mine is within a floodplain, the submission of a "rough analysis…using the limited data that are available" is inadequate. Parks Canada has expressed its concerns about the water quality of the South Nahanni River and possible contamination from several aspects of the Prairie Creek Mine, including the tailings pond, the fuel storage facilities and the chemical storage area. Inadequate or poor information on probable maximum flood levels will not enable the Board to provide recommendations on the required improvements or modifications needed at the site to ensure adequate flood protection.<br>3. This analysis does not include recent data; the Rainfall Atlas used to calculate Probable Maximum Precipitation dates back to 1985, and therefore, the analysis does not factor in the possible changes to precipitation as a result of global climate change. | 2. HAYCO clarifies why true probable maximum flood calculations were not carried out in the PMFP Report Follow-up. See the discussion section of the staff report for further details.<br>3. Data from the Virginia Falls hydrometric gauge as well as three other gauges were used in conjunction with the Rainfall Atlas. |

# Comment Summary Table
## Canadian Zinc Corporation -Probable Maximum Flood Profile Report Follow-up

| Reviewing Agency, Date Comments Received | Comments | Mitigation Measure |
|---|---|---|
| Deh Cho First Nations (DCFN), September 10, 2004 | 1. Given the location of the Prairie Creek Mine site within an active floodplain and an area of seismic activity, DCFN must stress that the highest possible standards should apply to ensure that the flood protection structures are structurally sound along their entire length, and designed to deal with a worst case scenario. Given the continued level of uncertainty regarding the flood history of the site, DCFN can only conclude that the Board must adopt the Precautionary Principle with regards to all earthworks, structures, floodworks and associated infrastructure at the Prairie Creek Mine.<br>2. The DCFN recommend that in the absence of additional data, that a precautionary approach to risk management would be more appropriate in these circumstances, and that CZN be required to undertake measures to ensure that the dyke and riprap can withstand the more conservative calculations provided in the HAYCO report. | 1. Presented to the Board. See the Discussion section of the staff report for further details.<br>2. Presented to the Board. See the Discussion section of the staff report for further details. |
| CPAWS-NWT, September 10, 2004 | 1. Given that HAYCO did not submit a PMF and is of the opinion that a PMF can not be completed, CPAWS-NWT recommends that the Board consult and work with the MVEIRB on this issue to obtain a clear indication of why it was included in the Report of Environmental Assessment and how to evaluate the applicability of the reports submitted. | 1. Presented to the Board. |
| Water Resources Division, October 21, 2004 | 1. Despite the arguments and reasoning presented in the report, the Company is in non-compliance with the terms of their WL if a PMF Flood calculation is not submitted.<br>2. If the 200 year flood calculations are adopted as the standard, more conservative freeboard limits than 0.5 m should be required. | 1. Presented to the Board.<br>2. Presented to the Board. |

CANADIAN ZINC
CORPORATION

July 22, 2004

Via fax/mail: 867-873-6610

Mackenzie Valley Land
& Water Board
File ______________
JUL 22 2004
MV2001C0023
Application # MV2001L2-0003
Copied To SB/PLH/BW/Reg.

Sarah Baines
Regulatory Officer
Mackenzie Valley Land & Water Board
7th Floor, 4910-50th Avenue,
Yellowknife, NT
X1A 2P6

Dear Sarah:

**Re: MV2001C0023, MV2001L2-0003, Prairie Creek Probable Maximum Flood Profile Report Follow-up**

Please find enclosed 2 duplicate reports from Hay & Company Consultants Inc. dated July 6, 2004, regarding Prairie Creek Mine Flood Calculations on behalf of Canadian Zinc Corporation. This report represents a requested follow-up with reference to your letter of June 8, 2004 for your review and consideration.

A follow-up report regarding your additional requests on the A & R Plan Requirements referencing your letters of June 8 and June 30, 2004, will be forthcoming shortly.

Yours truly,

Alan B. Taylor
VP Exploration

Suite 1202-700 West Pender Street
Vancouver, BC V6C 1G8
Tel: (604) 688-2001 Fax: (604) 688-2043
E-mail:alan@canadianzinc.com, Website: www.canadianzinc.com

HAYCO

HAY & COMPANY
CONSULTANTS INC.
One West 7th Avenue, Vancouver, B.C., Canada V5Y 1L4
Tel: (604) 875-6391 Fax: (604) 875-6383
E-mail: hayco@hayco.com Web Site: http://www.hayco.com/

2004 July 6

FILE: EBA.012

Canadian Zinc Corporation
Suite 1202 – 700 West Pender Street
Vancouver, BC V6C 1G8

Attention: Mr. Alan B. Taylor, P.Geo.

Dear Alan:

Re: Flood Calculations

Thank you for the opportunity to discuss the flood calculations at the Prairie Creek Mine on June 17. This letter provides some background to the flood calculations and addresses the comments we have received from the water licence application reviewers regarding our letter of March 10, 2004.

**BACKGROUND**

Previous work done on the site by Ker Priestman (1980) refers to a "Maximum Possible Flood" in Prairie Creek, which was used to estimate flood levels and the corresponding required dyke elevations. For the extracts of this report provided, it appears that this flood was derived from an analysis of hydrometric data for "Prairie Creek at Cadillac Mine", for which there were six years of record available at the time, and "South Nahanni River above Virginia Falls", for which there were 18 years available. It is not clear what KPA meant by a "Maximum Possible Flood" or how it was derived. Eighteen years is a relatively short period of record to use for derivation of anything beyond about a 40- or 50-year flood, which would be a much smaller event. Clearly some extrapolation was involved, which is the only practicable approach in such situations, but it must always be accompanied by a word of caution regarding the accuracy. It should be understood that Ker Priestman did not estimate a Probable Maximum Flood (PMF). UMA (the company which acquired Ker Priestman) have confirmed that the calculations done by KPA in 1980 are no longer available.

There is now more flow data available at the hydrometric stations mentioned above than there was in 1980, and this was utilized in Hayco's recent analysis.

## PROBABLE MAXIMUM FLOOD

The definition of Probable Maximum Flood (PMF) adopted by the US Committee of the International Commission on Large Dams is as follows:

> *The Probable Maximum Flood identifies estimates of hypothetical flood characteristics (peak discharge, volume and hydrograph shape) that are considered to be the most severe "reasonably possible" at a particular location, based on relatively comprehensive hydrometeorological analysis of critical runoff-producing precipitation (snowmelt if pertinent) and hydrologic factors favourable for maximum flood runoff.*

For watercourses such as Prairie Creek, for which the annual maximum flood is snowmelt-dominated, PMF estimation would involve developing a maximized snowpack and a critical temperature sequence. These are then modelled in combination with a rare, but not extreme, rainfall even, such as a 100-year storm. All additional factors, such as soil moisture and base flow in the creek would be set at conservatively higher than normal values. Other combinations of events are usually investigated, such as the Probable Maximum Precipitation (PMP) occurring on a 100-year snowpack and a "pre-storm" plus the PMP on the 100-year snowpack. The PMP is either determined by meteorologists from a consideration of dew points, maximum precipitable moisture and other factors, or from statistical relationships with precipitation of known return periods. The Hershfield method is an example of the latter technique. It is unlikely that the necessary data exist to calculate a PMF.

## FLOOD PROTECTION STANDARDS

The Probable Maximum Flood is typically used in the design of spillways for major dams, in the Very High consequence category (Canadian Dam Association, 1995). This is defined as a situation that would cause a large increase in loss of life (over what would have occurred without the structure) or excessive increase in social, economic and/or environmental losses. BC Hydro is an organization that carries out PMF studies for its major dams. Typically these studies require a vast amount of data on rainstorms, temperatures, snowpack and water equivalent, dew points etc., which is not available in many areas of the country. A PMF study takes several months to complete and costs in the order of $100,000. The accuracy of the result is probably ±30%.

The PMF is not considered applicable to the issue of flood control in Prairie Creek. For river flood control works, the design criterion in British Columbia is the 200-year flood plus a freeboard allowance of up to 0.6 m. In Alberta the standard is the 100-year flood. The Probable Maximum Flood is only used for dams associated with a high hazard (National Research Council Canada, 1989).

## FLOOD ESTIMATES BY HAY & COMPANY

We were initially asked to provide an estimate of a Probable Maximum Flood for the purposes of assessing the adequacy of the existing Prairie Creek dyke. In our response, we were careful to say that what we could produce was not a true Probable Maximum Flood, as defined above, but was an extreme flood with a return period in the order of 10,000 years. This is considered to be an event of comparable magnitude to a PMF. As outlined in our letter of March 10, 2004, two approaches were adopted: one using a regional analysis of hydrometric data; and, the other using an estimate of Probable Maximum Precipitation and a catchment runoff model. The two approaches yielded similar flows of about 500 $m^3/s$. The resulting flood water surface profile was below the crest of the dyke at all but one of the cross sections (Chainage 126+00 ft), where the crest elevation is about 0.3 m too low. However, we consider this design standard to be extremely conservative by Canadian standards and it would be more appropriate to consider assessing the dyke adequacy for a lower design flood.

The hydrometric records for the four regional stations referred to in our letter of March 10, 2004 were analyzed to determine the 200-year flood flow in Prairie Creek using the relationship between the 200-year flood flow and drainage area (see Figure 1). The 200-year flood in Prairie Creek at the minesite is estimated to be 250 $m^3/s$.

The HEC-RAS program was then applied to establish the water levels in Prairie Creek during a 200-year flood. The results are presented in Table 1 below. Freeboard is the vertical height between the flood elevation and dyke crest elevation.

Table 1: 200-Year Water Surface Profile

| Chainage (ft) | 200-Year Water Level (ft) | 200-Year Water Level (m) | Dyke Crest Elevation (m) | Freeboard (m) |
|---|---|---|---|---|
| 102+20 | 2851.4 | 869.1 | 870.5 | 1.4 |
| 114+00 | 2845.1 | 867.2 | 868.1 | 0.9 |
| 120+00 | 2840.1 | 865.7 | 868.1 | 2.4 |
| 126+00 | 2836.9 | 864.7 | 865.6 | 0.9 |
| 131+00 | 2832.3 | 863.3 | 864.7 | 1.4 |
| 153+60 | 2814.2 | 857.8 | 858.3 | 0.5 |

It can be seen from Table 1 that there is at least 0.5 m freeboard at all points along the dyke.
In addition to the above, if very large flood were to occur at present, equipment and manpower is available to undertake sand-bagging and/or fill placement on the lower sections of the dyke, should this be necessary.

## WATER LICENCE APPLICATION REVIEW COMMENTS

In response to the specific comments we make the following observations:

- Mackenzie Valley Land and Water Board, June 8, 2004
  *"CZN is required to submit the following "Probable maximum flood calculations for flood elevations using at least the data from 1975 to 1990, including data from the weather station (sic) at the Virginia Falls hydrometric gauge."*
  Data from this gauge was used, along with data from three other stations.

- Deh Cho First Nations, undated
  *"very rough analysis... using limited data that are available"; "strictly speaking this is not a PMF analysis" etc. (Hay & Company). "CZN has had 6 months to complete this report"; "DCFN requests clarification on why the consulting firm is noting a lack of available data with which to produce a more accurate PMF analysis."*
  The comments in the foregoing pages of this letter address these issues. The data required to do a true PMF study for Prairie Creek, probably do not exist. This, and the appropriateness of the PMF are the main issues, rather than the time required.

- Parks Canada, May 6, 2004
  *"This is not a Probable Maximum Flood analysis etc"; "very rough analysis... using the limited data that are available" (Hay & Company)*
  These comments have been explained in the earlier part of this letter.
  *This analysis does not include recent data; the Rainfall Frequency Atlas used to calculate the PMP dates back to 1985 and therefore does not factor in the possible changes to precipitation as a result of global climate change.*
  The comment regarding the Rainfall Atlas is correct, but it remains a useful and convenient indicator of precipitation quantities of various durations and return periods. It is likely that updated data would lead to a result well within the accuracy of the current estimate.

## RECOMMENDATIONS

Our recommendation is to suggest to the Water Board that, in terms of the design criterion for flood protection at the minesite, consideration be given to bringing it into line with common practice in North America and elsewhere. A 200-year flood would be an appropriate level of protection, meaning that there is a 0.5% chance of failure in any year. This flood flow (and hence water level) has been calculated with a reasonable degree of accuracy using the hydrometric data and creek cross sections available. The resulting water surface profile shows that the there would be at least 0.5 m of freeboard along the dyke in a 200-year event.

As you are aware, we are working with Don Hayley, P.Eng., the Project Geotechnical Engineer to evaluate the adequacy of the riprap, which is a further condition of the water licence.

Yours very truly,

HAY & COMPANY CONSULTANTS INC.

A.G.Chantler

Dr. Adrian Chantler, P.Eng.
*President*
AGC/jk

cc: Mr. Rick Hoos, EBA Vancouver
Mr. Don Hayley, EBA, Kelowna

## REFERENCES

Ker Priestman & Associates, October 1980
Environmental Evaluation for Cadillac Explorations Limited Prairie Creek Project, NWT

Candian Dam Safety Asssociation, January 1995
Dam Safety Guidelines

National Research Council Canada, 1989
Hydrology of Floods in Canada – A Guide to Planning and Design

HAY & COMPANY
CONSULTANTS INC.

One West 7th Avenue, Vancouver, BC, Canada, V5Y 1L4
Tel: (604) 875-6391 Fax: (604) 875-8363
E-mail: hayco@hayco.com Website: www.hayco.com

2004 March 10

FILE: EBA-012

EBA Engineering Consultants Inc.
500-110 Melville Street
Vancouver, BC V6E 4A6

Attn: Mr. Rick Hoos

Dear Rick

Re: Prairie Creek Mine Probable Maximum Flood Profile

Hayco has carried out a very rough analysis of the flood flows in Prairie Creek, using the limited data that are available. Strictly speaking this is not a Probable Maximum Flood analysis, as such an analysis requires a lot of detailed data and some weeks of work.

Hayco adopted two approaches:

- A frequency analysis of the regional hydrometric data available; and
- An estimate of the probable maximum precipitation and a simple catchment model

Note that it has not been possible to review the earlier calculations of the PMF and the corresponding flood profile, as these have not been made available.

## 1. Regional Frequency Analysis

There are flow data available for the following hydrometric stations:

Table 1: Hydrometric Stations

| No. | Station Name | Years | Drainage Area (sq km) |
|---|---|---|---|
| 10EC002 | Prairie Creek at Cadillac Mine | 14 | 495 |
| 10EA003 | Flat River near the Mouth | 33 | 8560 |
| 10EB001 | S. Nahanni R above Victoria Falls | 34 | 14600 |
| 10EC001 | S. Nahanni R above Clausen Ck | 24 | 31100 |

The annual maximum instantaneous flows were analyzed using Environment Canada's Consolidated Frequency Analysis program. A generalized extreme value distribution was fitted to each set of data and the results were extrapolated to 10,000 years to be indicative of the order of magnitude of a Probable Maximum Flood. It must be stressed that there is limited accuracy associated with this approach. One cannot reliably estimate the flood of a return period longer than about twice the record length. However, this does provide an order of magnitude estimate. The results for all four hydrometric stations are given in Figure 1. Combining the results and applying the regression equation gives an estimate of the 10,000-year maximum instantaneous flow for Prairie Creek at the minesite of about **473 $m^3$/s.**

Note that this event uses actual hydrometric data, so could be a snowmelt or rainfall event.

## 2. Probable Maximum Precipitation and Catchment Model

Hershfield's method (NRC, 1989) was used to establish the Probable Maximum Precipitation using data published in the Rainfall Frequency Atlas (Hogg and Carr, 1985). This method is also very approximate due to the paucity of data and relatively short record periods, particularly when the atlas was published, however data from the (then) Cadillac Mine should be incorporated. A mean annual 24-hour maximum rainfall of 30 mm was determined from the Rainfall Atlas, along with a standard deviation of 12.5 mm. Hershfield's frequency factor $K_{24}$ is a function of the mean annual 24-hour maximum rainfall, $P_{24}$ and was determined to be 17.77 from the equation:

$$K_{24} = 19\ (10)^{-0.000965 * P_{24}}$$

Substituting this value of $K_{24}$ into the standard prediction equation gives:

$$PMP_{24} = P_{24} + K_{24} * 12.5 = 252 \text{ mm}$$

This is a point rainfall value and can be reduced to a mean value over the whole catchment using curves developed by Pugsley (1981). The probable maximum average catchment rainfall over the 495 square km of drainage area is estimated to be 227 mm in 24 hours.

This rainfall was then used in a simple catchment model (HEC-HMS) to estimate the peak flow that would result from such a storm. The lag time for the catchment was estimated at 25 hours and a curve number (CN) of 65 was assumed. The resulting peak discharge was **549 $m^3/s$**, which is comparable to the value determined by frequency analysis, given the approximate nature of both approaches.

## 3. Flood Profile Computation

A flood profile in Prairie Creek in the vicinity of the mine was computed using a discharge of 549 $m^3/s$ (the larger of the two values determined above) and creek cross sections given in a Figure 18 by Ker Priestman & Associates, probably dating from the 1980s. The results of this analysis are presented in the table below, with the corresponding water surface profile elevations given by Ker Priestman in their Figure 18, for comparison.

Table 2: Probable Maximum Water Surface Profiles

| Chainage (ft) | KPA Water Level (ft) | Updated Water Level (ft) | KPA Water Level (m) | Updated Water Level (m) |
|---|---|---|---|---|
| 102+20 | 2858 | 2854 | 871.1 | 869.9 |
| 114+00 | 2850 | 2848 | 868.7 | 868.1 |
| 120+00 | 2848 | 2843 | 868.1 | 866.5 |
| 126+00 | 2843 | 2841 | 866.5 | 865.9 |
| 131+00 | 2841 | 2836 | 865.9 | 864.4 |
| 153+60 | 2818 | 2816 | 858.9 | 858.3 |

It can be seen that the elevations calculated in this study are consistently lower than those calculated by KPA by between 0.6 and 1.6 m.

We hope this brief study meets your requirements. Please call if you have any questions.

Yours very truly,

HAY & COMPANY CONSULTANTS INC.

A.G. Chantler

Dr. Adrian Chantler, P.Eng.
*President*
*lagc*

REFERENCES

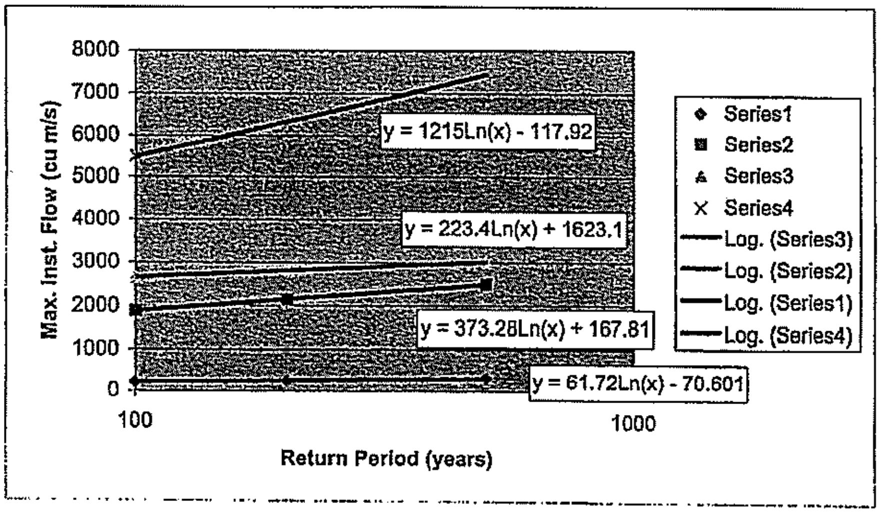
Hogg W.D., and D.A. Carr, 1985
Rainfall Frequency Atlas for Canada, Canadian Climate Program, Environment Canada

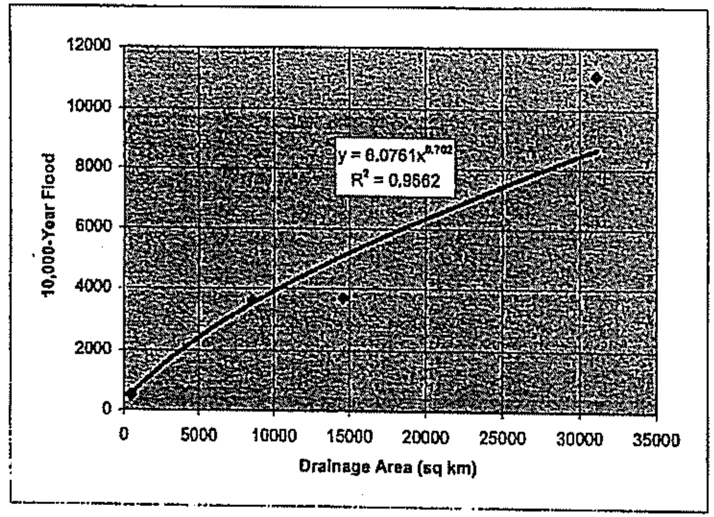
National Research Council Canada, 1989
Hydrology of Floods in Canada: A Guide to Planning and Design

Pugsley, W.I., 1981
Flood Hydrology Guide for Canada, CLI3-81, Environment Canada

Prairie Creek Flood Analysis

| Station No. | Station Name | Years | Drainage km$^2$ | $Q_{100}$ m$^3$/s | $Q_{200}$ m$^3$/s | $Q_{500}$ m$^3$/s | $Q_{10000}$ |
|---|---|---|---|---|---|---|---|
| | | | | 100 | 200 | 500 | |
| 10EC002 | Prairie Creek at Cadillac Mine | 14 | 495 | 215 | 254 | 314 | 498 |
| 10EA003 | Flat River near the Mouth | 33 | 8560 | 1890 | 2140 | 2490 | 3606 |
| 10EB001 | S. Nahanni R above Victoria Falls | 34 | 14600 | 2650 | 2810 | 3010 | 3681 |
| 10EC001 | S. Nahanni R above Clausen Ck | 24 | 31100 | 5500 | 6280 | 7450 | 11073 |




Based on the correlation of 10,000-year flood and drainage area, the 10,000 year flood at the minesite would be 473 m$^3$/s

FIGURE 1

### 5.1.4 Evaporation

There were no changes in the available data for mean monthly and annual evaporation. Therefore the evaporation rates given in the P.E.E., which were taken from Climatic Mapping, are also reproduced in Table 4.

### 5.1.5 Snow Cover

Snow cover data is available for Watson Lake, Norman Wells and Fort Nelson from 1962 to date, and for Tungsten for the two winters ending in 1977 and 1978. The average accumulations at the three longer te ... regate average is 25 inches. ... gsten, the mean snow cover the ... 40 inches annually.

Excerpt from the Ker Priestman Report, 1980.

The ... h at the minesite over the ... nches, which does not compare w ... tations. Consequently, ... ood estimates of snow cove ... ions from these other locations

### 5.1.6 Streamflows and Probable Maximum Flood calculations.

The ... n programme at the minesite ... rainfalls. The Atmospher ... provide a rate of rainfall ... necessary to establish a Cl ... te which will complement the two stream crest gauges installed at the site in July, 1980.

## 5.2 Hydrology

### 5.2.1 General

Runoff shows a marked peak in June, decreasing through the fall and winter to a low in February and March. Groundwater storage would be low in winter due to frozen ground, hence extremely low winter flows occur. For Prairie Creek, the ratio of the June: March average flows is 73:1. The index hydrograph, Figure 15, for flows on Prairie Creek illustrates this seasonal fluctuation.

Periods of ice cover are indicated. Smaller creeks will have a more extreme variation and larger creeks, less extreme. Annual peak flows on the larger drainage basins such as Prairie Creek are usually due to spring snowmelt, but may also be due to widespread rain, whereas the smaller creeks will produce flash floods as a result of localized thundershower activity.

### 5.2.2 Records

Published runoff data is available from the Water Survey of Canada. Additional data is being collected by the Water Resources Division of the Department of Indian & Northern Affairs, but no reference index is available at this time.

The relevant stream gauging stations are listed in Table 5 with their locations shown on Figure 13.

Data from Station 10EC002 (Prairie Creek at Cadillac Mine), and Station 10EC001 (South Nahanni River near Hot Springs) is considered to be the most pertinent to this study.

Because of a shortage of data having a reasonable period of record for small basins (i.e. less than 50 sq. miles), runoff characteristics for small catchments are not known.

### 5.2.3 Mean Flows

Based on the Prairie Creek and South Nahanni River gauges, the long term water yield for the Study Area is 1.1 cfs per square mile. Mean annual flow in the South Nahanni River is 14900 cfs with a minimum monthly average of 2000 cfs and a maximum monthly average of 50500 cfs. The catchment area above this gauge is 12900 sq. miles.

Mean annual flow in Prairie Creek is 204 cfs,with a minimum monthly average of 10 cfs and a maximum monthly average of 696 cfs, respectively. The catchment area above the Prairie Creek gauge is 191 sq. miles.

The mean annual yield ratio is defined as equivalent volume of annual runoff divided by volume of total annual precipitation. For the Study Area it is equal to 0.7. (Yield ratio is not the same as runoff coefficient (C) which relates rates of runoff and precipitation).

### 5.2.4 Peak Flows

*Streamflow and Rational Method Analysis*

Information presented in this section is based on streamflow records, discussions with J. N. Jasper (Hydrologist for Water Resources Division, Dept. of Indian & Northern Affairs, Yellowknife), and use of empirical calculations such as the Rational Method. The estimation of peak flows for small basins is very uncertain due to the unavailablity of reliable data.

A Gumbel (extremal probability paper) plot was prepared from the recorded peak flows in Prairie Creek and the South Nahanni River (Fig. 16). These curves, extrapolated to a 100-year return period, provided estimates of peak flows as follows:

$Q_5 = 0.8\ Q_{10}$ where $Q_5$ = flood flow with 5 year return period

$Q_{25} = 1.3\ Q_{10}$

$Q_{50} = 1.5\ Q_{10}$ where $Q_{10}$ = flood flow with 10 year return period

$Q_{100} = 1.7\ Q_{10}$

The unit peak flows (cfs/mi$^2$) for the two recording stations were plotted for the 10year return period (Fig. 17). Instantaneous flows for typical small basins of 1 and 10 square mile catchment areas, calculated by the Rational Method, were also plotted on this graph.

The Rational Method gives estimates of peak flows by a formula relating rainfall intensity, runoff coefficient and drainage area. Rainfall intensity was determined from the Fort Nelson IDF curves for a 10-year return period, assuming a 50-minute time of concentration for the 1 mi$^2$ basin and 90-minute time of concentration for the 10 mi$^2$ basin:

1 mi$^2$ basin - rainfall intensity 30 mm/hr. (1.2 in./hr.)
10 mi$^2$ basin - rainfall intensity 20 mm/hr. (0.8 in./hr.)

These times of concentration and corresponding rainfall intensities were based on estimates of overland and creek flow velocities at times of peak flow for typical basins in the Study Area.

Runoff coefficient (C) values of 0.3 to 0.5 were considered to be representative of ground conditions during peak rainfalls in the summer. The Suggested Design Curve (Fig. 17) has been drawn through C=0.3 because a C-value greater than this would likely only result from an infrequent combination of events (i.e. less frequently than once in 10 years).

Comparisons were also made with work done previously by others, including the Department of Indian & Northern Affairs (1979) for the Tungsten, N.W.T. area. Generally the Design Curve for the Cadillac Study Area (Fig. 17) gives higher flood values than those for the Tungsten area.

*Streamflow Data Extensions*

An isolated analysis of the short period of record on Prairie Creek is not sufficient to make confident predictions of the magnitude of major events. Therefore, an extension of the record was attempted by correlation with longer term records at both stations on the South Nahanni River. Because there was a poor correlation between the recorded peaks on Prairie Creek and those on South Nahanni River no further attempt was made to extend Prairie Creek flow data.

*Application of Liard Highway Hydrology Regression Formula*

In a report by M. M. Dillon Ltd., the hydrology studies of four other consultants were reviewed and a new hydrological design method was developed for creek and river crossings along the Liard Highway.

The hydrological design method developed in the report uses a regression formula and this was applied to the Prairie Creek and Harrison Creek basins. The 10 and 100 year return period flows obtained for Prairie Creek were 10,500 cfs and 15,800 cfs, respectively; for Harrison Creek they were 780 cfs and 1,180 cfs, respectively. These values compare fairly well with flows obtained from the Design Curve on Figure 17.

The regression formula is very sensitive to the precipitation and mean daily temperature and variations of 2 inches in the mean annual precipitation or of $2^{\circ}$ F in the mean daily temperature entered in the formula result in peak flow differing by 25% to 50%. However, the Dillon formula gives good confirmation of the streamflow and rational method analysis performed initially.

*Kinematic Wave Flood Analysis*

The Water Resources Division of the Department of Indian and Northern Affairs in Whitehorse has developed a computer model based on the kinematic wave theory of flood runoff routing and on data collected by Water Resources and Water Survey of Canada on smaller streams in the Yukon Territory.

Use of this model by government personnel gave the 10 and 100 year return period flows for Prairie Creek as 2970 cfs and 5010 cfs, respectively; for Harrison Creek flows were 128 cfs and 213 cfs, respectively. These results are not at all in agreement with other stronger and better corroborated evidence. It is felt that they are either in error or that the computer model has been poorly calibrated in the MacKenzie Mountain area. Therefore, the kinematic wave flood analysis has been disregarded.

*Summary and Recommended Design Method*

After reviewing many of the approaches available for hydrologic design in the area, it is believed the peak flows should be derived from the Design Curve shown on Figure 17. Design flows for Prairie and Harrison Creeks are therefore as follows:

| | 10 Year Flow (cfs) | 100 Year Flow (cfs) |
|---|---|---|
| Prairie Creek | 11,000 | 18,000 |
| Harrison Creek | 510 | 870 |

It must be remembered that the estimation of flood flows by statistical methods, from data with a short period of record, is uncertain at best. Usually flood estimates are not reliable to any great extent beyond the period of record. For example, if there are 15 years of record (as for the South Nahanni River), the 10 year flood can be estimated with confidence and the 15 and 30 year floods with somewhat lesser confidence. Confidence in estimates of the 100 year return period flood is poor. It would be safe to say that the 100 year flood on Prairie Creek at the minesite would fall in the range of 10,000 cfs to 22,000 cfs. Similar ranges would apply to the other small drainage areas.

### 5.2.5 Maximum Possible Flood (MPF)

cp = cn 0.028

From Chow (1964) and Fawkes, the maximum possible flood is the largest flood for which there is any reasonable expectancy in this climatic era. It is used in design where failure could lead to great damage and loss of life. The MPF is rigorously determined through detailed study of storm patterns and/or snowmelt patterns, transposition of the storms to a position that will give maximum runoff and calculation of the flood by unit hydrograph or computerized routing methods. It is assumed that the MPF will not result from a catastrophe such as the failure of an ice dam or similar failure of an earth obstruction.

In this study empirical methods have been utilized to calculate the MPF.

The first of 2 methods which were investigated is an extension of a calculation developed by D. M. Herschfield (1977) for probable maximum precipitation. The basic equation is:

$$\text{MPF} = (\text{mean of recorded annual peaks}) + k(\text{standard deviation of the recorded peaks})$$

A value for k in the Study Area would be between 15 and 20 (Fawkes, pers.com.). This gives an instantaneous MPF of about 38,000 cfs on Prairie Creek. The period of record is extremely short for this type of analysis.

The second method utilizes the results of studies of MPF carried out on the Columbia and Peace Rivers and utilized by SIGMA Resource Consultants Ltd. (1974) in The Development of Power in the Yukon. For the purposes of this work the MPF can be taken as 2.5 times the 25 year return period flood. The calculation gives 34,000 cfs.

The two results are reasonably consistent. However, in order to be conservative, the instantaneous MPF for Prairie Creek is taken as 38,000 cfs.

### 5.2.6 Flood Elevations and River Dyking

*General*

MPF and 100-year flood elevations on Prairie Creek and Harrison Creek in the vicinity of the mine have been estimated on the basis of the creek profile and cross sections which were surveyed in August, 1980.

Manning's equation has been used to develop the flood profiles and an estimation of Manning's "n" is from a lengthy discussion in Chow 1959. The value selected is 0.04. At the Prairie Creek gauge site, Water Survey of Canada estimated flows on the basis of the Slope-area Method which involves an estimation of "n". They selected a value of 0.032 for the improved reach immediately upstream from the gauge. However, there is no evidence to support an "n" value as low as 0.032 for design purposes. Manning's formula calculations are based on the assumption of uniform flow since the channel cross-section does not change abruptly. The flow is normally subcritical, hence the calculated flood profiles have been inspected for possible backwater effects and adjusted accordingly.

The design flood velocities are in the range of 7 to 13 feet per second for the 100-year return period flood and 9 to 16 feet per second for the MPF depending on the particular slope and cross section. These velocities are sufficiently high that some form of bank and dyke protection (i.e. riprap) will be necessary to prevent erosion and possible river breakthrough. As there appears to be few fines in the bank and dyke material, downstream siltation, as a

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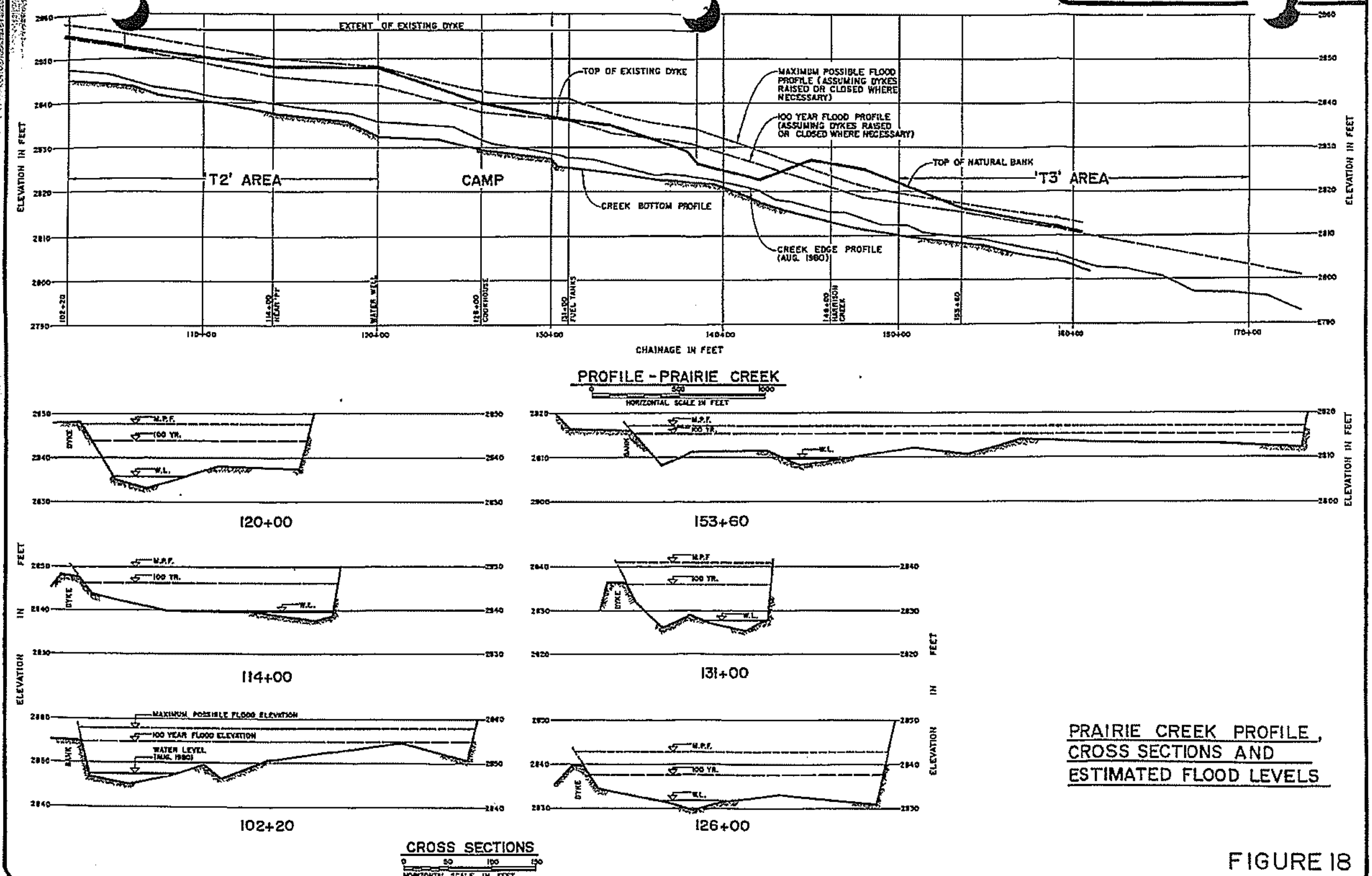


PRAIRIE CREEK PROFILE, CROSS SECTIONS AND ESTIMATED FLOOD LEVELS

FIGURE 18

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