Final

Hydrologic Analysis of 2014 – 2015 Field Data, Faro Mine Remediation Project

Prepared for

Government of Yukon and the Government of Canada as represented by Indigenous and Northern Affairs Canada

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# Introduction

## Purpose

The purpose of this appendix is to provide an overview of the surface water field activities and data evaluations completed in 2014 and 2015 in support of the remediation and closure planning of the Faro Mine Complex (FMC). This appendix references key deliverables which have previously been prepared by CH2M HILL Canada Limited (CH2M) in support of the Faro Mine Remediation Project (FMRP) co‐proponents (the Government of Canada, as represented by Indigenous and Northern Affairs Canada [INAC], and the Government of Yukon [YG]).

## Scope of Work

This appendix provides a summary of field investigations and data evaluations for each of the Reclamation Units (RUs) within the Faro Mine Area (FMA).

The FMA has been divided into the following RUs:

Perimeter (west, east, and south)

Faro Pit

Waste Rock Dump (WRD)

Mill Building Area and Emergency Tailings Area

Rose Creek Tailings Area

Cross Valley Dam and Intermediate Dam and Associated Ponds (Dams and CVD Pond)

Figure 1-1 outlines the boundaries of the RUs, key channels and diversions discussed in this appendix, and the surface water and seepage monitoring stations located within each of the RUs.

Emphasis has been placed on comparing the 2014 and 2015 field activities and data evaluations to the *Revised Gaps Assessment Faro Mine Remediation Project* report (CH2M, March 2014o) to identify where surface water data gaps have been closed and where they still exist. Table 1-1 outlines the data gaps and field work necessary to close the data gaps. A high-level summary of completed field work and data evaluations pertaining to these gaps is also included in this appendix.

# Perimeter Reclamation Units

## Field Investigation Activities

### West Perimeter RU

The North Wall Interceptor Ditch (NWID) and Upper Guardhouse Creek (UGC) are located within the West Perimeter RU. The NWID, constructed in 1980 and 1981, diverts flows west from UCG, diverging from the natural creek channel that flows south towards where the Intermediate Impoundment is currently located. The reach of the original UGC downstream of this diversion is now known as Lower Guardhouse Creek, which is discussed further in the Rose Creek Tailings Area RU section. Construction records indicate that the NWID was designed and constructed to convey a 1-in-50-year storm event (Golder, 1982). The NWID consists of alternating reaches of natural creek channel and constructed diversion ditch. UGC is a mostly undisturbed natural creek that originally drained an approximately 4.5-‑square-kilometre (km2) catchment area west of the Faro Creek drainage basin. The natural creek route trended south, converging with Rose Creek at a location that is now downstream of the Intermediate Tailings (CH2M, March 2015j).

Field investigations were performed in 2014 at the NWID and UCG. The purpose of the investigations was to gather information about the NWID and UCG to inform the evaluation of flow capacity and design of potential channel improvements. The investigation was also intended to evaluate the channel’s suitability to convey flows from Faro Creek in a western valley diversion routing configuration. A field investigation and sampling program was conducted in accordance with Field Sampling Plan (FSP) 102.3 (CH2M, June 2014f) to support the characterization of the existing channel, which included cross section surveys, an engineering geological field reconnaissance, and excavation of test pits (CH2M, March 2015j). The geological reconnaissance and test pits are discussed in Appendix F, Geotechnical Data Analysis, of this report.

#### Cross Section Surveys and Rapid Geomorphic Assessment

A two‐person team from Challenger Geomatics Ltd. (Challenger) completed three channel cross section surveys at UCG and five at the NWID on September 18 and 21, 2014, using a Leica Viva RTK GNSS differential global positioning system (GPS). Cross section survey methodology and results are detailed in the *Summary of 2014 Field Investigation – North Wall Interceptor Ditch and Upper Guardhouse Creek* technical memorandum (CH2M, March 2015j). These details include cross section survey data and corresponding photos.

Field reconnaissance of UGC and the NWID was also performed in 2014 and 2015 to assess their flood conveyance capacity and the condition of the channels, and their confluences. The UGC is a natural channel which begins on the lower southeast flank of Mount Aho. The UGC is a variably steep (3 to 10 percent), first-order channel, draining approximately 231 hectares at the point where it becomes the NWID. The UGC flows at the toe of the Northwest Dump for approximately 100 metres (m), upslope of the NWID transition. Within this 100‑m reach, the UGC exhibits excess sedimentation and has a high width-to-depth ratio and relatively flat channel slope. The UGC generally flows from northeast to southwest until it becomes the NWID, which flows east to west. The NWID begins just north of the LGC. By contrast, the NWID is trapezoidal and much flatter in slope than the UGC. The NWID drains 300 hectares until its confluence with a natural drainage channel 200 m north of the Rose Creek Tailings Area (RCTA).

#### Surface Water Data Collection

The FMC has various surface water stations and seepage stations that allow for the development of flow estimates for each. Stations with only staff gauges installed are referred to as spot flow stations. Stations with a pressure transducer and level logger installed are referred to as continuous water level stations.

One surface water monitoring station, X5, is present in the West Perimeter RU, as listed in Table 2-1. Figure 1-1 depicts its location. Spot flow data was collected from X5 in 2014 and 2015.

### East Perimeter RU

The Faro Creek Diversion (FCD), West Valley Interceptor Ditch (WVID) and North Fork Rose Creek (NFRC) are located in the East Perimeter RU. The WVID travels northeast across the western slope of the Faro Creek valley where it joins Faro Creek. The FCD conveys flow along the eastern slope of the Faro Creek valley, north of the Faro Pit and subsequently southeast towards its confluence with the North Fork of Rose Creek.

Field investigations were performed at the FMC in 2014 at the existing FCD and WVID, and along a potential replacement diversion channel alignment proposed by Steffen Robertson and Kirsten Consulting Engineers and Scientists (SRK) (SRK, March 2010a). The purpose of the investigation was to gather information about the existing diversions that would help with the design of the relocated diversion channel and investigate conditions along the proposed replacement channel alignment. A field investigation and sampling program was conducted in accordance with FSPs 102.1 (CH2M, June 2014d) and 102.2 (CH2M, June 2014c) to support the characterization of the existing channel, which included cross section and bed and bank characterization surveys and an engineering geologic field reconnaissance (CH2M, March 2015i). The geological reconnaissance completed within the East Perimeter RU is discussed in Appendix F, Geotechnical Data Analysis.

#### Cross Section Surveys and Rapid Geomorphic Assessment

A two‐person team from Challenger completed 10 channel cross section surveys at the WVID and 10 at the existing FCD on September 20 and 22, 2014, using a Leica Viva RTK GNSS differential GPS. Cross section survey methodology and results are detailed in the *Summary of 2014 Field Investigation – Faro Creek Diversion East Valley and Faro Creek Diversion West Valley Interceptor Ditch* technical memorandum (CH2M, March 2015i). These details include cross section survey data and corresponding photos.

Channel cross section surveys were also completed in support of the NFRC Temporary Diversion design efforts. Details of these surveys can be found in Appendix B of the *Draft Preliminary Final Design Basis Report* (CH2M, March 2016b).

In addition to these cross sectional surveys, a rapid geomorphic assessment was completed for the WVID and the FCD in 2014 and 2015 to assess the condition of the channel. The WVID begins roughly 0.5 kilometre (km) due east of UGC at an elevation of 1370 m. The WVID is an along-contour ditch that intersects the natural Faro Creek Channel at an elevation of roughly 1313 m. From that confluence, the ditch system becomes the FCD, and continues as an along-contour ditch to an elevation of roughly 1280 m. From that elevation, the FCD drains to the NFRC. The WVID drains an area of 157 hectares and the FCD drains approximately 1461 hectares.

The WVID is an excavated ditch constructed adjacent to an access road. As noted in the *Summary of 2015 Field Investigation – West Side and East Side Diversions, technical memorandum* (CH2M, 2016h), the WVID exhibits multiple bedrock outcrops and is downslope of several small slope failures. These conditions limit the conveyance of the WVID. The sediment produced by mass wasting and bedrock weathering obstruct flow and flatten the channel slope.

After the confluence with the Faro Creek Channel, the diversion ditch, now termed the FCD, is a trapezoidal channel with a marked increase in conveyance capacity and is lined with angular riprap. This condition continues to the point where the FCD follows gravity drainage to NFRC.

#### Surface Water Monitoring Plan Implementation

In support of the Site Wide Surface Water Monitoring Field Sampling Plan SW-005 (CH2M, March 2014i) stilling wells and water level transducers were installed at three existing staff gauge locations (FCD‑2, FCD‑3, and FCD‑4) in the East Perimeter RU on October 8, 2014. CH2M’s technical memorandum, *Summary of 2014 Field Investigation – Site-wide Surface Water Monitoring* (CH2M, March 2015dd) outlines the installation details. Stilling wells were installed by fastening well screens to the staff gauges. Water level transducers were suspended within the inner stilling wells and winterized with an antifreeze mechanism. Instrumentation was also installed at two existing streambed piezometers in the East Perimeter RU, CH13-107-PZ011 and CH14-107-PZ028.

#### Surface Water Data Collection

Eighteen surface water monitoring stations are present in the East Perimeter RU, as listed in Table 2-1. Figure 1-1 depicts their locations.

Spot flow measurements were collected from eight stations in 2014 and ten stations in 2015. Continuous water level measurements were collected for five stations in 2014 and 2015.

### South Perimeter RU

The Rose Creek Diversion (RCD) is located within the South Perimeter RU, immediately south of the RCTA and is approximately 4 km long. It travels northwest starting from the North Fork Diversion, immediately east of the original impoundment at the RCTA, and travels along the southern border of the RCTA past the Cross Valley Dam (CVD), where it intersects with Rose Creek.

Field investigations were performed at the RCD in 2014 to gather information about the RCD channel morphology to inform the design of channel upgrades. The field investigation was conducted in accordance with FSP 203.1 (CH2M, June 2014h) and consisted of two cross section surveys and a bed and bank material characterization survey (CH2M, March 2015y). The geological reconnaissance completed at East Perimeter RU is discussed in Appendix F Geotechnical Data of this report.

#### Cross Section Survey

A two‐person team from Challenger completed two cross section surveys (cross sections RCD 43 and RCD 44) at the RCD on September 18, 2014, using a Leica Viva RTK GNSS differential GPS. Cross section RCD 43 was completed at the approximate mid‐point of the RCD. Cross section survey methodology and results are detailed in the *Summary of 2014 Field Investigation – Upgrade Rose Creek Diversion* (CH2M, March 2015y). These details include cross section survey data and corresponding photos.

#### Surface Water Monitoring Plan Implementation

In support of the Site Wide Surface Water Monitoring Field Sampling Plan SW-005 (CH2M, March 2014v), stilling wells and water level transducers were installed at two existing staff gauge locations, RCSG-4 and X10, in the West Perimeter RU on October 8, 2014. CH2M’s technical memorandum, *Summary of 2014 Field Investigation – Site-wide Surface Water Monitoring* (CH2M, March 2015dd) outlines the installation details. Stilling wells were installed by fastening well screens to the staff gauges. Water level transducers were suspended within the inner stilling wells and winterized with an antifreeze mechanism.

#### Surface Water Data Collection

Four surface water monitoring stations (X3A, RCSG-4, X10, and X14) are present within the South Perimeter RU. Figure 1-1 depicts their location. Spot flow data was collected at X3A, X10, and X14 in 2014 and 2015. No spot flow data was collected at RCSG-4 in either 2014 or 2015. Continuous water level data was collected for X14 in 2014 and 2015.

## Field Investigation Data Evaluation

### West Perimeter RU

With respect to the rapid geomorphic assessment, the hydraulic attributes and conveyance capacity of the UGC and NWID were evaluated by constructing a one-dimensional Hydrologic Engineering Centre’s River Analysis System (HEC-RAS) hydraulic model from 400 m above the Northwest Dump to the confluence with the natural drainage 200 m north of the RCTA (Figure 2-1). This entire ditch system is characterized by three natural reaches and two constructed, trapezoidal reaches. The natural channels are broad swales with a minor inset active channel. Within the hydraulic model, the UGC is approximately 1700 m in length, or from River Station (RS) 3894 – 2291. The NWID begins at RS 2291 and continues to RS 9. Within the NWID reach, there are two constructed, trapezoidal reaches separated by two intervening natural reaches (RS 1181 to approximately RS 702 and RS 209 to RS 9).

The model geometry consists of cross-sections created from a Lidar-derived 1‑m grid cell digital elevation model (Figure 2-1). The cross sections are on approximate 15‑m centers. Flood magnitudes for the 1-in-20-year flood and probable maximum flood (PMF) were estimated in Hydrologic Engineering Center's-Hydrologic Modeling System (HEC-HMS) and used as HEC-RAS model flows. The UGC catchment has estimated 1-in-20-year and PMF floods of 1.2 and 8 cubic metres per second (m3/sec), respectively. The NWID catchment has estimated 1-in-20-year and PMF floods of 2.2 and 19 m3/sec, respectively.

Results show that the longitudinal profile of the UGC and NWID (Figure 2-2) is concave-upwards to the transition to the NWID. There are some knickpoints (steep regions along the creek profile) within the upper portion of the UGC profile segment, likely because of bedrock outcrop and encroachment by the Northwest Dump (RS 3465 – 3323). From RS 2291 to RS 1181, the NWID is a constructed trapezoidal channel and its profile is nearly flat. This reach is characterized by a high width-to-depth ratio and periodic mid-channel bars, indicating lack of stream power to transport sediment. The profile of the downstream natural reach is generally straight, with a significant convexity at the downstream end (RS 821 to RS 702). At this convexity, the channel flows through a bedrock notch, forming an effective waterfall. This resistant feature causes the profile to flatten for roughly 100 m immediately upstream of the waterfall lip. The remainder of the profile, to RS 209, is again uniform and flat, characteristic of the constructed trapezoidal reaches. This constructed reach drains into a natural swale, and this final 200 m of the profile is concave-upwards, typical of a natural channel.

Figure 2-3 shows erosive energy, expressed as shear stress, at the 1-in-20-year and PMF floods. Shear values are lowest in the constructed trapezoidal channel segments. Highest shear stress values are observed in the downstream-most 200 m, where the channel drops steeply to another natural channel. High shear stress values are also characteristic of a first-order, headwater channel like the UGC. Given the low channel slopes of the constructed trapezoidal reaches, these reaches exhibit the lowest shear stress values as well.

The conveyance of the NWID was evaluated using an at-a-station hydraulic analysis of four of the NWID cross-sections (NWID 1 to 4, as defined in the Rapid Geomorphic Assessment 2015 Field Data Report [CH2M, 2016h]). These four cross-sections are all within the first constructed trapezoidal reach between RS 2291 and 1181. This analysis produced the discharge of the NWID as a function of depth (or stage) in the channel. These parameters are shown in the rating curves (Figures 2-4 through 2-7). All four cross sections easily convey the PMF flood of 19 m3/sec. However, the bed and bank material of the channel is largely placed gravel to small cobble. The resulting shear stress values at high floods may erode the channel bed and banks causing channel failure.

The capacity at bank overtopping stage ranges from 113 to 170 m3/sec for the four cross sections. However, the HEC-RAS hydraulic model of the NWID shows extensive overtopping of the NWID at the PMF at RS 1334 to RS 1181 (Figure 2-8). This overtopping may result from backwater effects at the transition to the natural channel at RS 1181.

The UGC and NWID ditch system is moderately complex owing to the juxtaposed natural and constructed channel reaches. Distinct changes in channel geometry and slope create vulnerable areas in the ditch system. Additionally, connection to the UGC enhances sedimentation potential to the NWID.

### East Perimeter RU

With respect to the rapid geomorphic assessment, the hydraulic attributes and conveyance capacity of all channel segments was evaluated by constructing a one-dimensional HEC-RAS hydraulic model from the WVID inception to just above NFRC. The model geometry consists of cross sections created from a Lidar-derived 1‑m grid cell digital elevation model (Figure 2-9). The cross sections are on approximate 25‑m centers. Flood magnitudes for the 1-in-20-year flood and PMF were estimated in HEC-HMS and used as HEC-RAS model flows. The modeled 1-in-20-year flood for the WVID is 0.9 m3/sec, and then is increased to 5.2 m3/sec at the Faro Creek confluence. The modeled PMF flood magnitude for the WVID is 6 m3/sec and is then increased to 58 m3/sec at the Faro Creek confluence. Results show that the combined longitudinal profile of the WVID and FCD (Figure 2-10) is concave-upwards, with localized convexities or knickpoints, up to approximately RS 1200. From RS 1200 to the end of the modeled reach, the profile is convex. The transition to a convex profile begins roughly where the FCD is at its point of closest approach to the Faro Pit, and may indicate the presence of resistant bedrock underlying the channel. The knickpoints in the profile are near (downstream) areas where bedrock outcrops or slope failures were mapped, and near mapped in-channel depositional areas.

Erosive energy, expressed as shear stress, at the 1-in-20-year and PMF floods is shown in Figure 2-11. Shear values are lowest in the FCD segment between the Faro Creek confluence and the point where the FCD begins gravity drainage to NFRC. Shear values fluctuate within the WVID as knickpoints are encountered, which locally oversteepen the profile and increase shear stress.

The conveyance of the trapezoidal channel was evaluated using an at-a-station hydraulic analysis of a single surveyed cross section (FCD 3). This analysis produced the discharge of the FCD as a function of depth (or stage) in the channel. These parameters are shown in the rating curve (Figure 2-12) for the FCD 3 cross section. For an estimated reach slope of 0.5 percent, the FCD 3 cross section conveys the 1‑in-20-year and PMF floods at stages of roughly 0.4 and 1.0 m. The FCD 3 cross section conveys roughly 500 m3/sec before overtopping its banks. The extent of flood inundation on the WVID during the PMF is shown in Figure 2-13. Reaches where the WVID is overtopped by the PMF are circled. The FCD generally conveys the PMF within banks, but there are limited reaches that are overtopped. For the 1-in-20-year flood, the WVID is also overtopped at the same approximate locations (Figure 2-14). The FCD conveys the 1-in-20-year flood without overtopping. Because extent of inundation is influenced by the modeled hydraulic roughness, these results are approximate. However, these results do confirm field observations of limited conveyance in the WVID.

The FCD generally has the capacity to convey floods up to the PMF. However, an incipient motion analysis would be required to determine if the FCD can transport flood flows without failure because of erosion and transport of the ditch riprap lining. The transport capacity of the WVID is limited in multiple reaches because of interaction with the hillslope, both slope failures and bedrock outcrops. These features generate sediment by erosion and weathering, and are routed to the WVID. Improvement to the WVID are required and should take into account interactions with the hillslope.

Details of the NFRC surface water data evaluation can be found in Appendix B of the *Draft Preliminary Final Design Basis Report* (CH2M, March 2016b).

### South Perimeter RU

No data evaluation was completed in 2014 or 2015 for surface water within the South Perimeter RU.

# Faro Pit RU

## Field Investigation Activities

Faro Pit is located within the Faro Pit RU and is approximately 1,675 m long and 975 m wide, encompassing 1.06 km2. The Faro Pit is at 975 m above mean sea level, an elevation 335 m lower than the highest point of the western pit wall (CH2M, March 2015oo). In 2010, SRK proposed the installation of the Faro Pit Safety Berm – a linear earthen structure with an alignment that follows the perimeter of the Faro Pit at a proposed offset of 5 m from the edge of the pit. The purpose of the safety berm is to restrict access to the Faro Pit (CH2M, March 2015oo).

In 2014, field reconnaissance was conducted which included walking the proposed alignment to identify potential locations that may require test pit exploration for evaluation of foundation conditions. The work was conducted in accordance with FSP 101.2 (CH2M, May 2014g) by a geotechnical engineer/geological engineer. In particular, observations of groundwater seeps or surface water along the proposed alignment were noted. Details of the field reconnaissance are available in the *Summary of 2014 Field Investigation – Faro Pit Safety Berm* technical memorandum (CH2M, March 2015oo). Of relevance to surface water, the northern pit edge has several springs and a boggy area near the pit edge of the segment. The extent of the soft soils is not expected to be problematic for berm construction if pervious riprap and waste rock materials or large boulders, which do not obstruct water flow, are placed as barriers.

One surface water monitoring station (X22b) and one seepage station (A30) are present in the Faro Pit RU, as listed in Table 2-1. Figure 1-1 depicts their location. Spot flow data was collected from X22b during 2014 and2015; no seepage data was collected for A30 during 2014 or 2015.

## Field Investigation Data Evaluation

From the field reconnaissance, it was determined that no additional test pits are recommended to support the existing alignment (CH2M, March 2015oo). However, revisions to the alignment may warrant additional investigations, including surface water observations.

# Waste Rock Dump RU

## Field Investigation Activities

No surface water field activities were completed in 2014 or 2015 for the WRD RU.

One surface water monitoring station (FCO) and one seepage station (SP5-6) are present in the WRD RU, as listed in Table 2-1. Figure 1-1 depicts their location. No surface water data was collected from FCO during 2014 or 2015; seepage spot flow data was collected for SP5-6 during 2014 and 2015.

## Field Investigation Data Evaluation

No data evaluation was completed in 2014 or 2015 for surface water within the WRD RU.

# Rose Creek Tailings Area RU

## Field Investigation Activities

Two surface water monitoring stations (GDHSECK and X4) are present in the Rose Creek Tailings Area (RCTA) RU, as listed in Table 2-1. Figure 1-1 depicts their location. Spot flow data was collected from both stations during 2014 and 2015.

## Field Investigation Data Evaluation

No data evaluation was completed in 2014 or 2015 for surface water within the RCTA RU.

# Mill Building Area and Emergency Tailings Area RU

## Field Investigation Activities

The ETA and Lower Guardhouse Creek (LGC) are located within the Mill Building Area and ETA RU. The ETA is located between the Faro Mill and the Rose Creek Tailings Facility, and overlaps with a section of the old Faro Creek Channel. The ETA is one of the contaminant sources to groundwater and surface water in the Faro Mine Area and as such, a field investigation program was completed to determine the optimal location and capacity of the ETA surface water collection structure (CH2M, March 2015n). Limited surface flow data at FCS-4 and X-23 was identified as a data gap for the design of the ETA surface water collection structure. In 2014, field reconnaissance that included a hydrologic investigation conducted at X23 and FCS-4 (seepage and surface water monitoring stations located upstream and downstream of the ETA, respectively) was undertaken to close the aforementioned data gap. CH2M installed stream stage recorders at FCS-4 and X-23 in October 2014 by instrumenting the existing 90‑degree V-notch weirs at these locations with stilling wells and water level transducers. Details of the field reconnaissance are available in the *Summary of 2014 Field Investigation –* *Design of a Surface Water Collection Structure for the Emergency Tailings Area* technical memorandum (CH2M, March 2015n). Photographs taken at FCS-4 and X-23 during the hydrologic investigation in 2014, including the seep sampling and stream stage recorder installation, are included in the photo log presented in Attachment 4 of the 2015 technical memorandum.

Two additional surface water monitoring stations (ETA Combined and X7) are present within the Mill Building Area and ETA RU. Table 2-1 outlines the data available in 2014 and 2015 for these two stations. Figure 1-1 depicts their location. Seepage spot flow data was collected for X23 in 2014. Surface water spot flow data was collected for ETA Combined, X7 and FCS-4 in 2014 and 2015.

Lower Guardhouse Creek (LGC) is an approximately 1.7- km-long, partly disturbed natural creek channel. It originally constituted the lower reach of Guardhouse Creek, a creek that drained an approximately 4.5‑km2 catchment area west of the Faro Creek drainage. The natural creek route trended south, converging with Rose Creek at a location that is now beneath the Intermediate Tailings.

Field investigation activities were conducted on June 30, 2014, and consisted of geologic reconnaissance along LGC in support of FSP 102.4 (CH2M, June 2014g). The creek was surveyed along its approximate 1.7‑km length; the investigation was focused on the upstream portion of the creek. In addition to the geologic reconnaissance, additional observations and photos from these areas were collected during other investigation activities completed between May 2014 and September 2015. These were focused on surface water flows and groundwater seepage, namely channel shapes, bed and bank materials, approximate flow depths, and relative velocities were noted for surface water channels. Details of the reconnaissance are available in the *Summary of 2014 Field Investigation –* *Lower Guardhouse Creek Interception* technical memorandum (CH2M, March 2015k). Locations where groundwater seepage was observed were also noted were observed and photographed and are included in Attachment 1, Table 1, and Figure 1 of the 2015 technical memorandum.

### Cross Section Surveys and Rapid Geomorphic Assessment

Field reconnaissance of LGC was performed in 2014 and 2015 to assess the condition of the channel and its capacity for flood conveyance. The LGC begins just south of where the UGC ends and the NWID begins (immediately north of the CH2M office trailers) and drains an area of 205 hectares. At its inception, the LGC is a constructed, trapezoidal ditch for roughly 230 m. This segment is incised 2 to 3 m below the surrounding ground surface. It then transitions to a broad (75- to 85-m-wide) natural valley to the Mine Access Road, crossing over a channel length of roughly 700 m. Within this segment, the channel is braided with multiple threads in a wide floodplain. Below the Mine Access Road, the LGC follows a swale (for approximately 450 m) to its confluence with the RCTA. This swale is broad and the channel is weakly defined.

### Surface Water Monitoring Plan Implementation

The *Revised Gaps Assessment Faro Mine Remediation Project* report (CH2M, March 2014o) outlined the need to have a surface water monitoring station installed along Lower Guardhouse Creek and continuous water level data collected. A station was not installed in 2014 or 2015.

## Field Investigation Data Evaluation

The hydraulic attributes and conveyance capacity of all channel segments was evaluated by constructing a one-dimensional HEC-RAS hydraulic model from the LGC inception to just north of the RCTA. The model geometry consists of cross sections created from a Lidar-derived 1‑m grid cell digital elevation model (Figure 6-1). The cross sections are on approximate 15‑m centers. Flood magnitudes for the 1-in-20-year (1.1 m3/sec) and PMF (7 m3/sec) were estimated in HEC-HMS and used as HEC-RAS model flows. Results show that the longitudinal profile of the LGC (Figure 6-2) is straight to convex up to the last 160 m or so of the profile. The downstream 160 m has an average slope of 13 percent, but the remaining upstream profile has an average slope of 5 percent. Erosive energy, expressed as shear stress, at the 1-in-20-year and PMF floods is shown in Figure 6-3. Shear values are lowest in the segment characterized by a wide floodplain and indistinct channel (approximately RS 950 to RS 600). Shear values are highest in the steepest portion of the profile (last 160 m before the RCTA). Upstream of this reach, spikes in shear stress are observed where flow is confined, decreasing flow area and increasing flow velocity. In general, shear stress is greatest where channel slope is highest.

The conveyance of the trapezoidal channel was evaluated using an at-a-station hydraulic analysis of a single cross section (RS 1230). This analysis produced the discharge of the LGC as a function of depth (or stage) in the channel. These parameters are shown in the rating curve (Figure 6-4) for RS 1230. For an estimated reach slope of 1.3 percent, the RS 1230 cross section conveys the 1-in-20-year and PMF floods at stages of roughly 0.3 and 0.7 m. The LGC conveys roughly 100 m3/sec before overtopping its banks.

As a flood conveyance channel, the LGC has the capacity to convey floods up to the PMF. However, the bed and bank material of the channel is largely native, in situ material, or placed gravel to small cobble. The resulting shear stress values at high floods may erode the channel bed and banks causing channel failure.

No data evaluation was completed in 2014 or 2015 for surface water within the Mill Building Area and ETA RU.

# Cross Valley Dam and Intermediate Dam and Associated Ponds RU

The Rose Creek tailings impoundment stores more than 55 million tonnes of tailings within an unlined containment area approximately 4 km long and 1 km wide. A series of three dams hold the tailings in place: the Primary Dam, Secondary Dam, and the Intermediate Dam (ID) (CH2M, March 2014m).

One surface water monitoring station (X5P) and four seepage monitoring stations (Weir 3, X11, X12, and X13) are present in the Dams and CVD Pond RU, as listed in Table 2-1. Figure 1-1 depicts the location of the four stations within the RU. Surface water data was collected from X5P during 2014 and 2015; seepage data was collected from all seepage stations in 2014 only.

## Field Investigation Activities

No surface water field activities were completed in 2014 or 2015 for the Dams and CVD Pond RU.

## Field Investigation Data Evaluation

The ID spillway does not have the capacity to safely pass a moderate or major flood event without potentially overtopping the dam, in the event of a breach of the RCD dike and flooding of the Intermediate Impoundment. The existing ID spillway has a capacity equal to approximately 32 m3/sec. The 1-in-500-year annual exceedance probability (AEP) return period runoff at the ID equals approximately 115 m3/sec; the PMF event has a runoff at the ID of approximately 674 m3/sec. The CVD spillway has a capacity of approximately 300 m3/sec (CH2M, July 2015a).

CH2M submitted conceptual and advanced designs to YG for the Down Valley Interim Hydraulic Upgrades. These designs increased the hydraulic capacity of the ID spillway by (1) raising the effective height of the ID crest, (2) increasing the cross sectional area of the spillway, and (3) removing existing pipelines and equipment from the spillway. The increase in cross sectional area would be achieved by increasing the width of the spillway and by lowering the bottom of spillway. Lowering the bottom of the ID spillway would reduce the storage capacity behind the ID. Operationally, this is an unaccepted reduction in storage.

As an alternative to reducing the storage capacity behind the ID spillway, CH2M prepared a revised ID spillway design that incorporated an ogee weir for the 1-in-500-year AEP spillway, replacing a broad crested weir. The revised concept provides an increase in the spillway capacity and maintains the existing storage capacity.

At the same time as the revised ID spillway design, and in conjunction with development of site-wide remediation concepts, CH2M developed design concepts for passing a PMF flood event at the ID spillway. The new design concepts provided significant improvements to previous designs developed and by incorporating a 60-m-long ogee weir into the spillway design. This change would reduce the required ID raise, estimated to be a minimum of 4.6 m (without the loss of storage capacity), to about 2 m. The change would reduce the requirements for dewatering and removing sludge from the CVD Pond to complete the dam raise.

In 2015, a trade-off study was completed to provide information for use in decision making regarding the schedule and sequence of constructing the 1-in-500-year annual AEP capacity spillway or the PMF capacity spillway at ID and CVD (CH2M, July 2015a). Details of this study are outlined in the draft *Task Authorization 016 Rose Creek Tailings Area Intermediate Dam Spillway and Cross Valley Dam Spillway Trade-off Study* report (CH2M, July 2015a). The following three options were evaluated:

* Option 1: Upgrade the existing ID spillway to increase its capacity to the 1-in-500-year AEP flood event, followed by constructing the permanent ID spillway with capacity for the PMF event to 13 years later.
* Option 2: Construct the permanent ID spillway with capacity for the PMF event as soon as can be reasonably achieved and without the temporary spillway improvements.
* Option 3: Construct the permanent ID spillway with capacity for the PMF event 8 to 13 years from 2016.

Suboptions were developed for Options 1 and 3. These options are further detailed in the report.

An event tree risk model was developed using three inputs for the trade-off analysis: (1) estimated construction and O&M costs for each option, (2) timelines for design, construction, and operation of each option, and (3) estimated ID failure probabilities. It was determined that Option 2, which involves the construction of the PMF spillway as soon as practical, minimizes the ID failure risk (expressed as an encounter probability). In addition, Option 2 is estimated to have the lowest net present value, because the escalation rates are greater than the discount rates.

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Tables

Figures