AREVA

Kiggavik Project
Final Environmental Impact Statement

Tier 3 Technical Appendix 2E:
Water Diversion and Collection Design

September 2014

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KIGGAVIK PROJECT

Conceptual Freshwater Diversions and Wasterock Collection Channels for Kiggavik and Sissons Sites Volume 2E

REPORT

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1.0 INTRODUCTION

AREVA Resources Canada Inc. (AREVA) is proposing to develop the Kiggavik Uranium Project (the Project) located approximately 80 kilometres (km) west of Baker Lake, Nunavut. Two mine development areas are planned for the project. These are the Kiggavik site and the Sissons site, with ore processing at the Kiggavik site. The Kiggavik site consists of three open pit mines, clean waste rock piles, ore storage, the mill and water treatment facilities, the main camp and other ancillary structures. The Kiggavik site occurs primarily in the Pointer Lake drainage area. The Sissons site consists of one open pit, an underground mine, waste rock and ore storage areas, a small camp and other ancillary buildings. The Sissons site is within the Shack Lake drainage. Both the Pointer Lake drainage and the Shack Lake drainage report to Judge Sissons Lake.

This report provides a conceptual design for water management on the Kiggavik and Sissons mine footprint areas. The focus is to separate clean runoff draining from upstream and clean runoff generated within the site boundaries from potential contaminant source within the mine footprint areas. The objective is to reduce water treatment requirements and to provide continuity of flow in existing drainage pathways where possible. Drainage around the site is facilitated with freshwater diversion channels which take advantage of local topography to route flow around the site through channels constructed using berms and excavations depending on the channel alignment topography. Detailed topography and contributing areas for the design of the fresh water diversion channel were obtained from the available LiDAR data. The watershed boundary and flow pathways were derived using the GIS application ARC-Hydro.

The freshwater diversion ditches and other conveyance structures are conservatively designed to manage the Probable Maximum Precipitation (PMP) which has been calculated at 183 mm in 24 hours (Technical Appendix 4A). This is about 2.5 times greater than the 1:100 year precipitation event, which is calculated to be 75 mm over a 24 hour period. The 24 hour PMP event produces substantially greater peak runoff than maximum expected flows during the snowmelt period, which may occur over several weeks. The PMP event would produce a volume of water similar to melting 1.5 to 2.0 m of snow in 24 hours. This conservative design basis for peak flows provides substantial excess conveyance capacity for heavy rains and large snowmelt runoff, and is predicted to contain the runoff generated from the PMP storm event.

An erosion and sediment control plan for managing disturbed areas has been prepared for the Project and is detailed in Technical Appendix 5O. The document and supporting material provides details on best management practices for the numerous construction activities that are required to develop the Project, including the freshwater diversions and collection ditches.

2.0 SCOPE OF WORK

The scope of this work involves preliminary designs and concept drawings for the Kiggavik and Sissons sites including:

- determine runoff volumes and flow pathways during the PMP event;
- design of diversion channel to intercept runoff from natural stream channel and overland flow pathways to convey flow around the core facilities area;

- align the diversion channel to discharge to the natural receiving watercourse down gradient of the core facilities areas; and
- design of collection channels to manage the PMP runoff from clean waste rock piles and pass the drainage through sedimentation pond prior to release in the receiving environment.

3.0 BACKGROUND

The Project is located in the Southern Arctic terrestrial ecozone, which is characterized by continuous permafrost. Summers are short (approximately four months) and cool and winters are long and cold. Low precipitation and extremely low winter temperatures characterize the regional climate. The topography is gently undulating, and is filled with hummocks and patterned ground resulting from permafrost. Vertical drainage is impeded by the permafrost layer, and wetlands, small ponds, and lakes are common over the landscape. Rock outcrops along a ridge trending northeast near the Kiggavik site provides strong local relief.

Climate and permafrost play an important role in the hydrological regime of this area. Peak stream discharges in the region are a result of spring melt, which can account for most of the total annual runoff. Throughout the summer and fall, the active layer of permafrost increases, thereby increasing the amount of storage available. Secondary peaks are common in the late summer or early fall periods, due to precipitation later in the season. Most streams freeze-off as winter progresses and there is very little flow from even larger streams that drain areas of hundred square kilometres.

The closest meteorological station with long climate records is at Baker Lake. According with this station, the mean annual precipitation is about 270 mm and about 156 mm falls as a rain. Adjusted precipitation data for Baker Lake is also available and are often used for hydrological investigations. These values are primarily adjusted for snow gauge undercatch. The adjusted annual precipitation is 344 mm, with 169 mm occurring as rain. The extreme daily rainfall recorded was 52.1 mm in July 30 of 1975 while the extreme daily snow fall (30.3 cm) was recorded in November 1 of 1977. Snow cover is expected for about eight months of the year and the average maximum snow depth at month-end (54 cm) occurs in March or April. The extreme snow depth recorded (119 cm) was in May 1 of 1978.

The mean annual temperature from a daily average is approximately -11.8°C. The month with the maximum mean daily is July (11.2°C) while January presents the minimum mean daily (-32.4°C). The extreme maximum temperature (33.6°C) was recorded in July 18 of 1989, while the extreme minimum (-50.6°C) was recorded in January 20 of 1975.

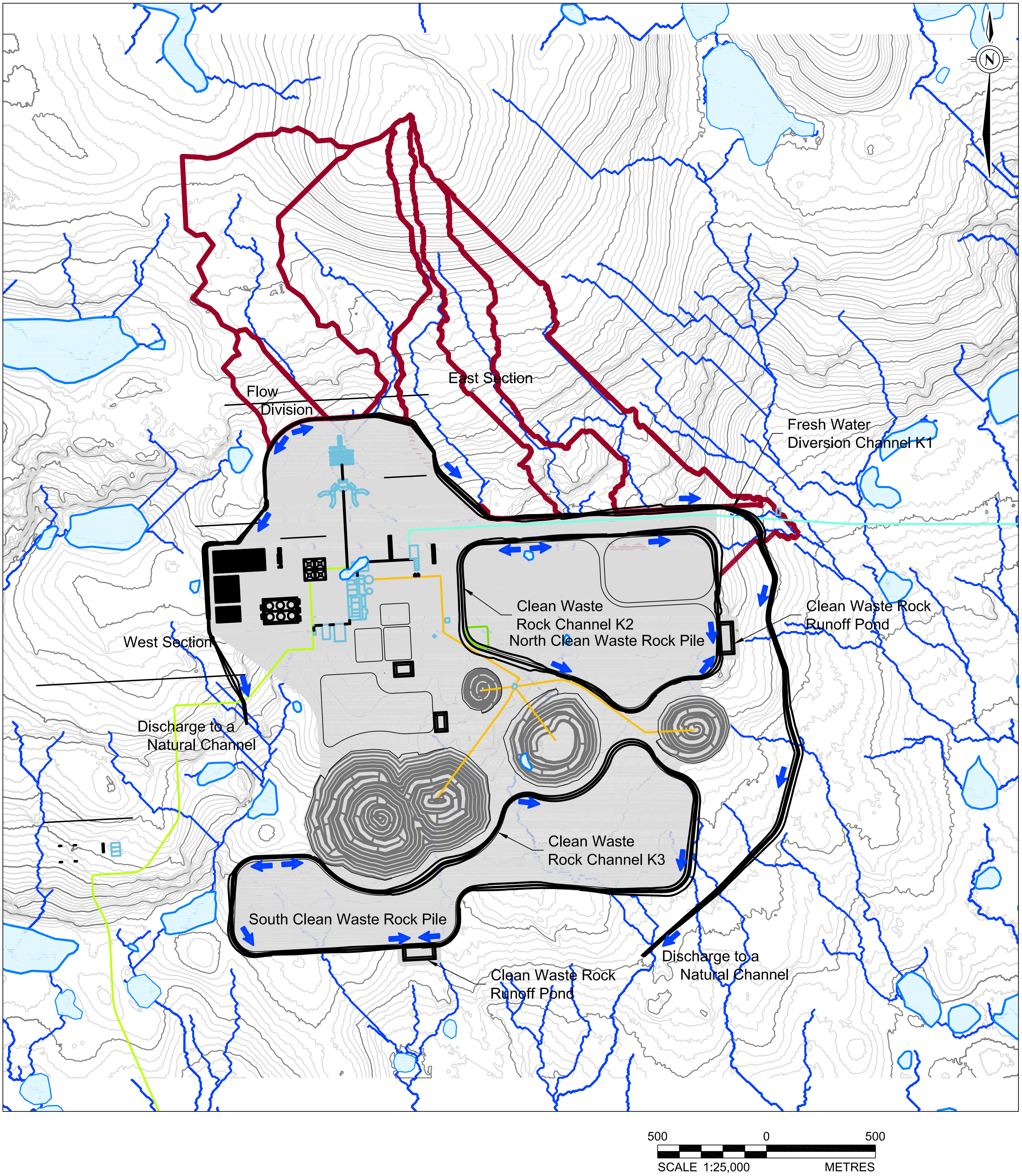
The average wind speed ranges from 16.9 km/h in June to 23.9 km/h in January, with the most frequent wind direction is from the north and northwest. A maximum hourly speed of 124 km/h was recorded in February 19 of 1959. Permafrost conditions are expected to be similar to those found at the Diavik Mine, where the seasonal active layer is expected to be between 1.5 to 2.0 m deep in till deposits, about 2 to 3 min well drained granular deposits, but in poorly drainage areas the active zone is expected to be less than 1 m depth (Nishi-Khon/SNC - Lavalin 1999).

4.0 KIGGAVIK SITE

The runoff management strategy within the site consists of the construction of drainage channels around the north and south clean waste rock piles to collect runoff water for passive treatment in exterior sediment ponds to reduce potential sediment loads prior to releasing flow to the natural receiving drainages. Runoff generated from outside the core facilities area, but draining toward the site will be collected in a diversion channel and redirected around the site to be discharged to the same natural pre-development drainage system. Figure 1 illustrates the main water management features at the Kiggavik site including the freshwater diversion and clean waste rock collection channels, topographic surfaces, drainage boundaries and runoff pathways.

Strong topographic gradients direct drainage from north toward the Kiggavik site from upland areas, while areas to the west and east side will drain primarily away from the site (Figure 1). Therefore, a diversion channel is required along the north side to collect all the runoff from the northern drainage areas and the channel will be aligned around the east and west sides of the site to reach the natural streams which will carry the runoff to Pointer Lake.

For the clean waste rock piles, channels to collect runoff will be located along the pile perimeter. These channels will collect runoff and direct discharge to the sedimentation ponds, which will drain to natural drainage pathways.



Legend
- Topographic Contour (1m Interval)
- Drainage Pathway
- Watershed Boundary
- Proposed Diversion Channel

Note:
Contours derived from LIDAR Survey, 2010

Reference:
Site Layout provided by AREVA, December 2010
NTS Mapsheet 66A05
NAD83 UTM Zone 14

PROJECT
AREVA
KIGGAVIK PROJECT

TITLE
KIGGAVIK SITE - DRAINAGE AREAS, STREAM FLOW PATHS, AND DIVERSION CHANNEL ALIGNMENTS

Golder Associates
Saskatoon, Saskatchewan

PROJECT	09-1362-0610		FILE No.			
DESIGN			SCALE	AS SHOWN	REV.	0
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CHECK	BT	08/12/11				
REVIEW	BT	08/12/11				

G:\2009\1362\09-1362-0610 AREVA Kiggavik Baseline and EIA\KI08_Environment\D_Hydrology\CAD\ Drawing file: KI08D145 - Site Layout with Drainage Lines.dwg Dec 08, 2011 - 10:52am

Fisheries investigations indicate that no fish species are know to occur in the diverted channel sections at the Kiggavik Site. Forage species have documented in the small lakes downstream of the K1 West Section and no fish have been documented in the K1-East Section with the exception of forage fish occurring at the mouth of the channel in Pointer Lake, located approximately 2 km downstream of the K1 East Section Channel.

4.1 Fresh Water Diversion Channel (K1) and Contribution Areas

Drainage areas reporting to the northern boundary of the Kiggavik site is provided in Figure 1. Runoff from the uplands to the north drains down slope toward the northern border of the site through numerous small flow pathways, and stream channels. The freshwater diversion channel, referred to as K1, will be located along the west, north and east boundary of the Kiggavik site footprint to collect water from all the natural pathways draining downslope. The highest elevation of the diversion channel invert is at the northwest corner of the site boundary. From this point, the flow in the diversion channel will be directed either east or south. The section flowing south passes around the west side of the core facilities area and is aligned with a natural channel approximately 1,500 m downstream of the high point in the channel. Once in the natural channel, flow passes southward through a series of small interconnected waterbodies which border the western side of the site. Flow continues southward through well established natural channels, ultimately discharging to Pointer Lake, approximately 2 km downstream.

The channel section flowing initially eastward turns south along the eastern margin of the site. The channel passes around the east side of the south clean waste rock pile and discharges to a natural channel that also drains to Pointer Lake and is the receiving channel that carries most of the flow passing through the footprint area under natural conditions.

The channel alignment and stationing is provided in Appendix I, Figure 001. The total length of the fresh water diversion channel is approximately 6,200 m. This channel stationing begins at the west side where the west segment discharges to the natural drainage system (station 0+000) and extends around the site to the southern outlet (station 6+184). The channel flow direction divide is located at station 1+471 and thus the direction of the flow would be from Station 1+471 to Station 0+000 on the west side (West Section in Figure 1), and from station 1+471 to station 6+184 at the north and east sides (East Section in Figure 1).

This portion of the diversion channel will be constructed around the north and east boundary of the Kiggavik site as shown in Figure K1. Runoff contribution to the north ditch section is from a series of drainage pathways that flow from an uplands area and are intercepted by the diversion channel. Most of the runoff reporting to the east boundary is collected from drainages north of the site footprint. Once the diversion channel turns southward addition flow is intercepted from small drainages occurring between the east site footprint boundary and the diversion channel.

For design purposes, small drainage areas are delineated and channel sub-sections are defined for the cumulative increase in discharge along the channel length. The first section starts at station 1+470 and collects runoff from the westernmost of the north drainage areas. Diversion channel inflow increases as the channel passes eastward and additional drainage pathways are intercepted. The discharge for the new sections will be the combination of the local runoff plus the discharge contributed from sections upstream. The same rational is used for the southward flowing end of the diversion channel where three small drainages are intercepted. A summary of the local contributing areas for each of the sub-sections (K1-1E to K1-12E) is provided in Table 1.

This table also includes the proposed slope for the channel bottom in each section. The total channel length of the East Section is approximately 4,920 m.

Table 1: East Segment Channel Sections and Contributing Drainage Areas

Channel Sub-section	From Station	To Station	Length (m)	Proposed Channel Bottom Slope (m/m)	Local Contributing Area (km²)
K1-1E	1+470	1+796	326	0.007	0.10
K1-2E	1+796	1+994	198	0.007	0.57
K1-3E	1+994	2+253	259	0.007	0.48
K1-4E	2+253	2+680	427	0.022	-
K1-5E	2+680	3+130	450	0.022	0.38
K1-6E	3+130	3+393	263	0.022	0.36
K1-7E	3+393	3+495	102	0.030	-
K1-8E	3+495	3+908	413	0.030	0.47
K1-19E	3+908	4+130	222	0.006	-
K1-10E	4+130	4+800	670	0.006	0.08
K1-11E	4+800	5+280	480	0.006	0.09
K1-12E	5+280	6+390	1110	0.006	0.16

Flow direction: from K1-1E to K1-12E; Channel Sub-section K1-11E receives the discharge from the north waste rock pile sediment pond.

4.1.1 West Section (K1)

This portion of the diversion channel will be constructed around the west boundary of the Kiggavik site as shown in Figure 1. As illustrated in the figure, comparatively small drainage areas report to the channel along this segment and the channel is sub-parallel to the natural drainage direction, so less runoff is intercepted.

For designing purposes the west segment is divided in two main sections (Table 2). The highest channel invert elevation in the west section is located at station 1+470, and the channel flow direction is south to station 0+000, where the diversion channel discharges to a natural channel. The design flow for section K1-1W is the runoff reported from the local drainage area along the length of the section, while for section K1-2W includes local runoff draining directly to the channel plus the discharge from section 1W. The overall length of the west channel is 1,470 m.

Table 2: West Segment Channel Sections and Contributing Drainage Areas

Channel Sub-section	From Station	To Station	Length (m)	Proposed Channel Bottom Slope (m/m)	Local Contributing Area (km²)
K1-1W	1+470	0+550	920	0.012	0.05
K1-2W	0+550	0+000	550	0.039	0.01

Flow direction: from K1-1W to K1-2W.

4.2 Clean Waste Rock Channels

Drainage channels will be constructed around the clean waste rock piles with gradients generally following natural topography with the highest channel invert consistent with the area of highest topographic elevation around the pile perimeter. The channels will be constructed to flow in two directions from the channel flow divide location and terminating in a sedimentation pond at the lowest topographic location. The channel flow divide for both, the north and south waste rock piles, is at the northwest corners (Figure 1). The sedimentation ponds are at the south and at the east for the south and north piles, respectively. It is assumed that the piles will develop with a side slope 4H:1V but not higher than 50 m; therefore the runoff reporting to the ditches will increase with distance from the channel divide to the sedimentation ponds. The north clean waste rock pile channel has an approximately length of 3,500 m, while the length of the south clean waste rock pile channel is 5,600 m (Appendix I, Figure 001).

Sub-sections with changes in channel cross-section area due to gradual increase in discharge are defined. Due to the symmetry of the waste rock piles, runoff is expected to reach the channels at a uniform rate but contributes to flow at the outlet at varying times. For design purposes, the channels are divided in sub-section lengths of approximately 200 m to 300 m, to accumulate the gradual increase of discharge along the ditch from its headwater to its outlet at the sedimentation pond.

4.2.1 North Pile Clean Waste Rock Pile (K2)

The north pile clean waste rock runoff collection channel is referred to as K2. The stationing for the channel begins near the sedimentation pond (station 0+000) and ends near the sedimentation pond (station 3+3444) in counter clockwise direction. The channel flow divide is near station 1+600 (Appendix I, Figure 001). The channel is divided in 16 sub-sections as show in Table 3 and the direction of flow will be from sub-section K2-7 to sub-section K2-1 and from sub-section K2-8 to sub-section K2-16. The total drainage area is the clean waste pile surface area. For modeling purposes the runoff contributing area to each channel sub-section is equal to the sub-section length and upslope to the midpoint along the long axis of the top of the pile. The design flow for successive downstream sub-sections consists of runoff from the sub-section, plus the discharge from upstream sub-sections. Runoff from the north clean waste pile is discharged into the sedimentation pond located at the east side of the pile. Outflow from the sedimentation pond will be directed into a channel that drains to the freshwater diversion channel (Appendix I, Figure 001).

Table 3: Channel Sections K2 and Contributing Drainage Areas for the North Clean Waste Pile

Channel Sub-section	From Station	To Station	Length (m)	Proposed Channel Bottom Slope (m/m)	Contributing Area (km^2)
K2-1	0+000	0+250	250	0.020	0.054
K2-2	0+250	0+500	250	0.020	0.054
K2-3	0+500	0+750	250	0.020	0.054
K2-4	0+750	0+900	150	0.020	0.032
K2-5	0+900	1+150	250	0.007	0.054
K2-6	1+150	1+400	250	0.007	0.054
K2-7	1+400	1+610	210	0.007	0.045
K2-8	1+610	1+750	140	0.011	0.030
K2-9	1+750	1+950	200	0.011	0.043
K2-10	1+950	2+100	150	0.011	0.032
K2-11	2+100	2+350	250	0.044	0.054
K2-12	2+350	2+615	265	0.002	0.057
K2-13	2+615	2+800	185	0.002	0.040

Table 3: Channel Sections K2 and Contributing Drainage Areas for the North Clean Waste Pile (continued)

Channel Sub-section	From Station	To Station	Length (m)	Proposed Channel Bottom Slope (m/m)	Contributing Area (km²)
K2-14	2+800	3+000	200	0.002	0.043
K2-15	3+000	3+250	250	0.002	0.054
K2-16	3+250	3+444	194	0.002	0.042

Flow direction: from K2-7 to K2-1 and from K2-8 to K2-16

4.2.2 South Clean Waste Rock Pile (K3)

The south clean waste rock channel is referred to as K3. Stationing for the south clean waste rock pile begins near the sedimentation pond at 0+00 and ends at 5+593. The flow divide is at station 4+300 with stationing in a counter clockwise direction. The channel is divided in 22 sub-sections as show in Table 4. The direction of flow is from sub-section K3-17 to sub-section K3-1, and from sub-section K3-18 to sub-section K3-22. The total drainage area associated with the pile surface is divided into sections proportional to the length of the sub-section to the midpoint on the long axis of the top of the pile. The design flow for sub-sections downstream consists of runoff reporting to the sub-section area, plus the discharge from sub-sections upstream. Runoff from the south clean waste pile is discharges to a sedimentation pond located on the south side of the pile. Outflow from the sedimentation pond will drain to a natural flow pathway leading to Pointer Lake (Appendix I, Figure 001).

Table 4: Channel Section K3 and Contributing Drainage Areas for the South Clean Waste Pile

Channel Sub-section	From Station	To Station	Length (m)	Proposed Channel Bottom Slope (m/m)	Contributing Area (km²)
K3-1	0+00	0+250	250	0.004	0.038
K3-2	0+250	0+500	250	0.004	0.038
K3-3	0+500	0+750	250	0.004	0.038
K3-4	0+750	1+050	300	0.004	0.045
K3-5	1+050	1+250	200	0.003	0.030
K3-6	1+250	1+500	250	0.003	0.038
K3-7	1+500	1+800	300	0.003	0.045
K3-8	1+800	2+100	300	0.003	0.045
K3-9	2+100	2+250	150	0.001	0.023
K3-10	2+250	2+500	250	0.001	0.038
K3-11	2+500	2+750	250	0.001	0.038
K3-12	2+750	3+000	250	0.001	0.038
K3-13	3+000	3+250	250	0.001	0.038
K3-14	3+250	3+500	250	0.001	0.038
K3-15	3+500	3+750	250	0.007	0.038
K3-16	3+750	4+000	250	0.007	0.038
K3-17	4+000	4+300	300	0.007	0.045
K3-18	4+300	4+600	300	0.030	0.045
K3-19	4+600	4+750	150	0.006	0.023

Table 4: Channel Section K3 and Contributing Drainage Areas for the South Clean Waste Pile (continued)

Channel Sub-section	From Station	To Station	Length (m)	Proposed Channel Bottom Slope (m/m)	Contributing Area (km^2)
K3-20	4+750	5+000	250	0.006	0.038
K3-21	5+000	5+300	300	0.006	0.045
K3-22	5+300	5+593	293	0.006	0.044

Flow direction: from K3-17 to K3-1 and from K3-18 to K3-22

5.0 SISSONS SITE

The Sissons site is located approximately 20 km southwest of the Kiggavik site. The main water management features include a runoff collection channel around a clean waste rock pile area and two fresh water diversion channels that intercepts flow from natural channels draining from the north. Based on LiDAR topography and an assessment using the GIS application ARC-Hydro, drainage toward the mine footprint area typically from the north and east. Areas south and west drain away from the site (Figure 2).

The freshwater diversion channel has three main sections, one flowing eastward around the core facilities area and reporting to End Grid Lake, the second flowing initially south and then west to discharge to the third section that flows southward through a series of small ponds, and discharges to a natural stream channel which reports to Shack Lake. The clean waste rock pile area is located at the west side of the site and will have a runoff collection channel (S4) around the perimeter that drains to a sedimentation pond on the south side. Outflow from the sedimentation pond will flow to Andrew Lake.