Surface Water Aspects for the Koidu Kimberlite Expansion Project as part of the Hydrogeological Study

Report Prepared for

Koidu Holdings SA

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October 2010

Report Prepared by

SRK Consulting
Engineers and Scientists

Surface Water Aspects for the Koidu Mine Kimberlite Expansion Project as part of the Hydrogeological Study

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Executive Summary

The Koidu Project in Sierra Leone, managed by Koidu Holdings S.A. (“Koidu”), a company wholly owned by BSG Resources (“BSGR”), currently consists of two kimberlite pipes, No.1 Pipe and No.2 Pipe, four dykes zones and two blows on the dyke zones, with an established mining operation geared up to feed a nominal 50tph DMS plant. A feasibility study is underway to enlarge the plant. In order to enlarge the plant the following additional infrastructure is required:

- The K1 and K2 pit will be enlarged to mine the kimberlite;
- A new plant and tailings dam are envisaged to be constructed to the south of the existing plant;
- Pit offices will be constructed to the north of the K1 pit;
- Waste dumps will be enlarged to cater for the additional waste rock;
- Additional workshops, fuel storage, stores and changehouses will be built;
- An airstrip will be constructed

The stormwater control forms a part of the feasibility and this report outlines the stormwater controls required to minimise the water entering the pit, stormwater controls around the plant, workshop and tailings facilities. The approximate costs to implement the work is about U$7 million.

The major water issues that need to be addressed include:

- damage to the aquatic ecosystem due to substances contained in releases from the mine;
- increased risk of flooding due to changes in catchment hydrology.
- Groundwater is the main water supply to the surrounding towns and the water quality is currently of good quality compared with the WHO guidelines for drinking water. A deterioration in groundwater quality could have an impact on the towns water supplies.

In order to meet the Equator principal requirements for the EIA the following additional work is envisaged

- Monitoring the flows in the river (quantity and quality);
- Identifying methods to minimise discharge and maximise the use of water on site

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Surface Water Aspects for the Koidu Mine

1 Introduction

The Koidu Project in Sierra Leone, managed by Koidu Holdings S.A. ("Koidu"), a company wholly owned by BSG Resources ("BSGR"), currently consists of two kimberlite pipes, No.1 Pipe and No.2 Pipe, four dykes zones and two blows on the dyke zones, with an established mining operation geared up to feed a nominal 50tph DMS plant. A feasibility study is underway to enlarge the plant. In order to enlarge the plant the following additional infrastructure is required:

- The K1 and K2 pit will be enlarged to mine the kimberlite;
- A new plant and tailings dam are envisaged to be constructed to the south of the existing plant;
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- Waste dumps will be enlarged to cater for the additional waste rock;
- Additional workshops, fuel storage, stores and changehouses will be built;
- An airstrip will be constructed

SRK Consulting ("SRK") was requested to prepare a surface water study for the proposed mine, outlining the existing hydrology data and impacts of the mine of the surface water resources. A stormwater plan has been prepared with budget costs to construct the stormwater controls.

Furthermore the environmental impact assessment will not meet the equator principal environmental requirements and the report needed to identify the gaps in the study that will be need to be addressed in order for the EIA to meet the equator principals.

2 Objective

The following work was undertaken:

- Undertake a site visit to carry out an overall assessment of the existing surface water measures in place and understand what additional stormwater is envisaged;
- Describe the hydrology for the area;
- Confirmation and quantification of rainfall and surface water inflow into the pit.
- Describe the proposed surface water management measures for minimise water entering the open pit and methods to control runoff from the mine;
- Prepare a stormwater plan for the site;
- Prepare budget costs for the storm water controls;
- Identify gaps in the existing information to meet with IFC guidelines and equator principals;
- Prepare a draft impact assessment.

3 Activities

The following activities are envisaged:

- A site visit was undertaken to identify where the runoff is entering the pit and identifying what potential water control measures will be required to minimise the inflow into the pit and what water management will be required for the rest of the mine. During the site visit available rainfall data was collected;
- The rainfall was analysed to determine rainfall amounts for various recurrence intervals;
- The catchment areas for the various flows into the pit were estimated from the contour maps as well as the data collected on site;
- A water management plan was prepared indicating areas from where water will need to be diverted and to where the water can be diverted;
- The peak flows were determined using the Rational method and the SCS method;
- The capacity of the proposed channels was determined using the UPD hydraulic programme. This programme uses the Mannings hydraulic method to determine the amount of flow in a canal;
- The runoff volumes into the pit for various storm return periods were determined using the SCS method;
- Areas where flow into the pit can be diverted away from the pit were identified and the canals required to divert the flow were sized using the UPD, rational and SCS methods;

- Costs for the stormwater controls were prepared;
- Impact assessments were undertaken at a conceptual level at this stage.

4 Hydrology Description

4.1 Rainfall

The Koidu area is extremely wet with about 2600mm of rain falling during the year. Approximately 2400mm falls within an 8 month period from April to November with 5 of the months exceeding 300mm.

Table 4-1 : Rainfall measured on site (mm)

Month	Rainfall (mm)							Monthly Statistics (2006-2010)			
	2005	2006	2007	2008	2009	2010	DW EIA	Mean	1σ	CV	% of Total
January	--	0	0	0	0	0	9	0	0		0.0%
February	--	0	9	105	95	20	43	46	50	109.4%	1.7%
March	--	68	0	126	124	97	88	83	52	62.7%	3.2%
April	93	159	113	229	80	178	160	152	58	38.1%	5.8%
May	178	218	147	145	158	315	260	197	30	15.4%	7.5%
June	153	309	246	219	333	402	309	302	73	24.1%	11.5%
July	153	481	430	361	500	150	364	384	142	36.9%	14.6%
August	150	402	571	590	550		370	528	86	16.2%	20.1%
September	290	36	629	402	363		450	465	244	52.6%	17.6%
October	325	482	327	307	416		332	383	81	21.2%	14.5%
November	229	72	85	59	156		176	93	43	46.6%	3.5%
December	7	0	0	2	1		41	1	1	127.7%	0.0%
Total		2,655	2,556	2,545	2,776	1,161	2,600	2,632			100.0%

Note : the DW EIA record is a regional record for the area used in the previous EIA. The measured data in 2005 seems very low and is excluded from the statistics. The September 2006 value is also excluded from the statistics as it seems very low for that time of the year.

The evapotranspiration for the area is about 1400mm (*Source: UNDP/FAO- TR5, 1980)* and therefore there is significantly more rainfall then there is evaporation at the mine and spillages and discharges will occur from the mine.

4.2 Design Rainfall Data

A statistical analysis was done on rainfall data for the last 4 years, as well as 1 day data that were available for the Koidu site in Sierra Leone. The mean annual precipitation for the study areas was determined from the rainfall data as 2600 mm for the catchments. The adopted 1 day rainfall depths of the respective areas for the various return periods are given in Table 4-1:

Table 4-2: Adopted design rainfall

Duration	Return Period Rainfall (mm)						
	1:2	1:5	1:10	1:20	1:50	1:100	1:200
1 day	122	155	181	209	251	288	330

4.3 Catchment description

As outlined from the existing EIA the project area lies within the Meya stream sub-catchment which is a tributary of the Bafi river, covering an area of about 188 km^2. Many of the streams which flow directly or indirectly into the Meya stream have their source at Monkey Hill and run through the project area. The regional drainage is from South to North.

The bulk of the water supply in the area comes from rivers, streams, and swamps. The pH of the water in the major rivers in Sierra Leone ranges between 6.5 and 7 in the wet season and 6.2 and 6.5 in the dry season. The pH of water in the swamps ranges between 5.2 and 6.0. The pH for samples selected in the project area ranges between 6.4 and 7.6 with a mean value of 6.9.

The mine area has been divided into 5 areas and each of the areas is described in more detail below. Figure 4.1 indicates the catchment boundaries while Figure 4.2 indicates the proposed and existing layout of the mine. Included in the mitigation measures are initial thoughts on the clean and dirty water diversions that will be updated as more information is made available

Catchment A includes the catchment to the south of the mine area. The catchment is presently minimally impacted upon by mining and the river flows to the south. In the future expanded mine this catchment will include the tailings dam, plant, offices, changehouses, clinic and workshops and will form the hub of the mining.

Catchment B includes the existing K1 pit and the water drains to the North West of the mining area.

Catchment C in an area to the north west of the site and the river from catchment B flows into catchment C.

Catchment D is to the west of catchment A and presently is not impacted upon by the mine but is in a catchment that is a possible site for the tailings dam. The river in this catchment flows to the south of the mine.

Catchment E includes the present day plant area and main dam and the water exits the site to the east.

4.4 Catchment Characteristics

A catchment area is defined as the total area drained by a river or stream, measured from the mouth of that particular water body. Assuming an evenly distributed rainfall event, a bigger catchment area will collect, and based on its slope, feed its water body with more water than a small catchment. This is one, amongst other of the catchment characteristics such as, slope, vegetation cover, soil type, hydraulic length, etc that affect the volume of water running in a river given the type and duration of rain falling. The catchment sizes, their hydraulic lengths, and average slopes (measured from 10-85% of hydraulic length) are given in Table 4-2 below. Refer to Figure 4-1 for the delineated catchment areas.

Table 4-3: Catchment Characteristics

Catchment name	Incremental Area (km^2)	Longest watercourse (m)	10:85 slope (m/m)	Tc (hrs)	C-Factor
A	0.395	925	0.0076	0.37	0.401
B	0.638	1120	0.0339	0.24	0.401
C	0.034	350	0.0486	0.08	0.396
D	0.230	916	0.0677	0.16	0.396
E	0.573	1288	0.0023	0.74	0.421

Please note:

- These catchment characteristics were determined using 1m contour detail and aerial photographs in GIS.
- 10-85 slopes denote the slope of the catchment from a point 10% from the end point and 85% of the distance to the furthest point.
- Time of concentration denotes the length of time it takes for a raindrop to travel from the furthest point of the catchment to the outlet point.
- The runoff factor was adopted to describe the runoff response of the specific catchment to the design rainfall.

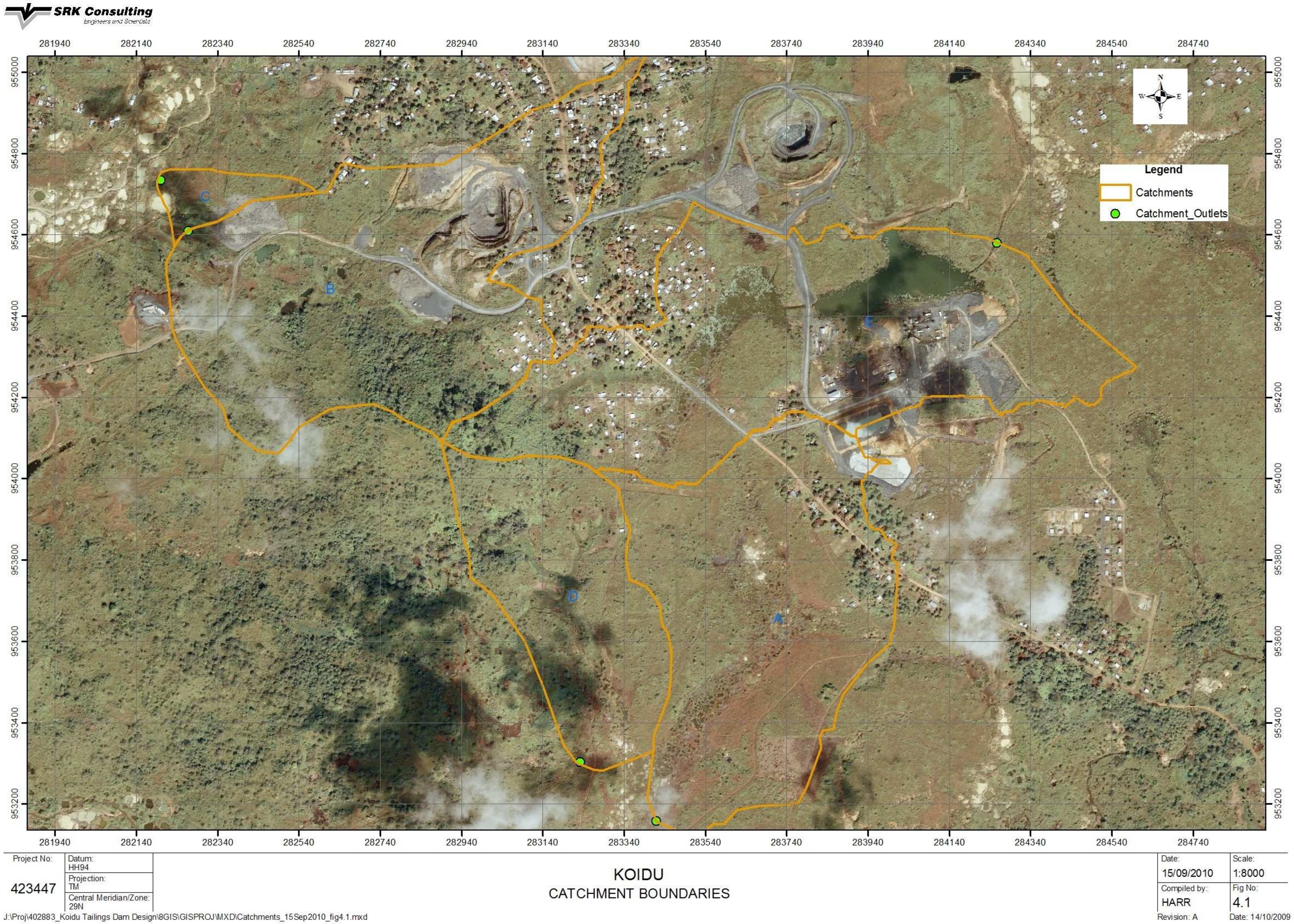

Figure 4.1: Catchment Boundaries for Water Course Outlets

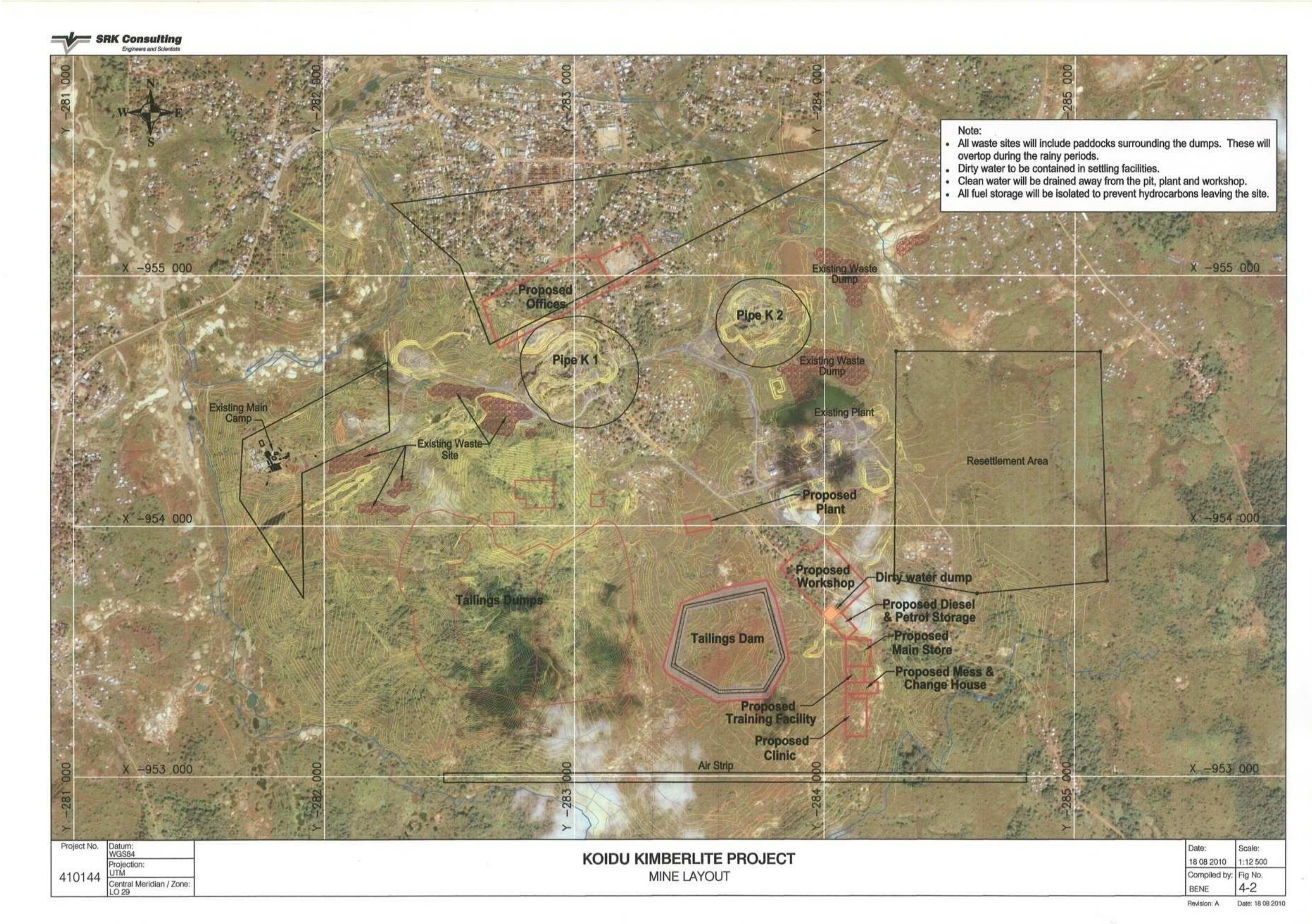

Figure 4.2 : Existing and proposed mine layout

4.5 Flood Hydrology

Flood hydrological methods used in this study include the Rational method and the SCS method. These models are suited for a catchment of these size ranges. The software - Universal Programs for Discharge (www.sinotechcc.co.za) incorporates the Rational method, and the software – VisualSCS incorporates the SCS method. These programs were therefore used to model the flood peaks. Sections below give more details into the methodologies applied.

4.5.1 The Rational Method

The Rational formula is defined as:

$$Q = \frac{CIA}{3,6}$$

where:

Q	=	peak flow (m^3/s)
C	=	run-off coefficient (dimensionless)
I	=	average rainfall intensity over catchment (mm/hour)
A	=	effective area of catchment (km^2)
3,6	=	conversion factor

The Rational formula has the following assumptions:

- The rainfall has a uniform area distribution across the total contributing catchment;
- The rainfall has a uniform time distribution for at least a duration equal to the time of concentration;
- The peak discharge occurs when the total catchment contributes to the flow occurring at the end of the critical storm duration, or time of concentration;
- The runoff coefficient , C remains constant for the storm duration, or time of concentration;
- The return period of the peak flow, T, is the same as that of the rainfall intensity.

It was assumed that the flows in the various catchments were in a defined water course. Time of concentration was hence calculated using the following formula:

$$T_C = \left(\frac{0,87L^2}{1\,000\,S_{av}} \right)^{0,385}$$

where:

T_C	=	time of concentration (hours)
L	=	hydraulic length of catchment, measured along flow path from the catchment boundary to the point where the flood needs to be determined (km)
S_{av}	=	average slope (m/m)

4.6 SCS method

The SCS method, described fully in Schmidt and Schulze (1987), is based on the United States Soil Conservation Service Hydrograph Generating Technique. It is particularly suited to small rural catchments and takes into account most of the factors that affect runoff, such as quantity, time distribution and duration of rainfall, land use, soil type and size and characteristics of the generating catchment. It is based on the principle that runoff is caused by the rainfall that exceeds the cumulative infiltration of the soil. Soil types are divided into four hydrological groups ranging from soils with low runoff potential (well-drained with high infiltration ability and permeability such as sand and gravel) to soils with high runoff potential (very low infiltration rates and permeability such as shallow soils with clay, peat or rock). The SCS method is restricted through the software to catchments less than 30km².

For the application of the SCS method to catchment A, the following was applied:

- SCS Curve Number (related to land use and soil type) equal to 75. This relates to a medium catchment runoff potential;
- SCS Storm distribution type 2 event storms. This distribution relates to areas with convection and coastal activity (thunderstorms) as the main cause of flood rainfall.

4.7 Adopted Flood Peak

Table 4-3 below gives a summary of the 1:50 and 1:100 year flood peaks calculated using the methods described above.

Table 4-4: Summary of flood peaks

Catchment name	Area (km²)	Return period years (m^3/s)						
		2	5	10	20	50	100	200
A	0.395	6.6	9.1	11.3	13.8	17.5	20.8	24.5
B	0.638	13.6	18.7	23.3	28.3	35.9	42.6	50.3
C	0.034	14.0	19.0	24.0	29.0	36.0	43.0	51.0
D	0.230	6.0	8.2	10.3	12.5	15.8	18.8	22.0
E	0.573	6.2	8.6	10.7	13.1	16.6	19.8	23.4

The adopted peak selected for all the catchments is based on the SCS T_C Method. This method produced the most conservative results and is a preferred method for catchments of these sizes.

4.8 Pit Storm water management

The pit storm water management plan involves the management of the stormflow that originates within the pit as well as the diversion of the clean water away/around the pits into other water courses.

4.8.1 Pit Inflows

The inflow into the Pit would originate from flow directly onto the cone surface, the benches within the pit as well as parts of the contributing catchment that would not be able to be diverted away from the pit.

The Runoff into the K1 pit has will be substantial during a storm event to about 38000 m^3 for a 1:50 year storm (see Table 4-5). An in-pit sump will be required to cater for the 1:5year 1hour storm (say 10 000m^3 which is still 50mx50mx4m deep) rather than the 50 year event. This will mean that during larger storms there may have water lying at the bottom of the pit for 8-10 days. Mining could continue on the higher benches but it will mean more water will seep into the underlying material.

Table 4-5 : Runoff into the K1 Pit

Return Period (1:x years)	Runoff into K 1 pit (24 Hour Storm)						
	2	5	10	20	50	100	200
Curve Number	84.18	84.18	84.18	84.18	84.18	84.18	84.18
24 hour Design Rainfall (mm)	124.30	159.50	190.30	224.40	276.10	323.40	378.40
Runoff depth (mm)	85.41	118.24	147.56	180.41	230.73	277.11	331.29
Runoff from external catchment	7,119	9,856	12,299	15,037	19,231	23,097	27,614
Runoff from haulroads	6,038	8,359	10,431	12,754	16,311	19,589	23,420
Direct Pit Area Volume	1,287	1,652	1,971	2,324	2,860	3,350	3,919
TOTAL INFLOW INTO PIT	14,444	19,866	24,701	30,115	38,402	46,036	54,953

Table 4-6 : Runoff into Pit K2

	Runoff into K 2 pit (24 Hour Storm)						
Return Period (1:x years)	**2**	**5**	**10**	**20**	**50**	**100**	**200**
Curve Number	84.18	84.18	84.18	84.18	84.18	84.18	84.18
24 hour Design Rainfall (mm)	124.30	159.50	190.30	224.40	276.10	323.40	378.40
Runoff depth (mm)	85.41	118.24	147.56	180.41	230.73	277.11	331.29
Runoff from external catchment	4,473	6,193	7,728	9,449	12,084	14,513	17,351
Runoff from haulroads	3,794	5,252	6,554	8,014	10,249	12,309	14,716
Direct Pit Area Volume	809	1,038	1,238	1,460	1,797	2,105	2,463
TOTAL INFLOW INTO PIT	9,076	12,483	15,521	18,923	24,130	28,926	34,529

4.8.2 Diversions around the pits

In order to minimise the storm water flowing into the pits, the runoff from upstream of the pit needs to be diverted away into neighbouring water courses. Figure 4-3 and Figure 4-4 indicate the conceptual designs of the diversions for the K1 and K2 pits which consist of diversion channels and bunding. The location of the waste rock dumps near the pits have been taken into consideration for the storm water design. Where possible the clean water was diverted either around or under the rock dump. The 1:50 year flood peak was used to size the diversion channels. These channels are typically concrete lined trapezoidal channels (1:1 side slope) or earth excavated channels (1:3 side slope) depending on the slope of the diversion.

Table 4-7 : Details of the diversion design for pits K1 and K2

Diversion	Catchment Area (km^2)	1:50 year Peak (m^3/s)	Design depth (m)	Bottom Width (m)	Flow depth (m)	Channel Slope	Velocity (m/s)
K1 North Pit Diversion (upper section – concrete lined)	0.244	8.75	1.0	1.0	0.77	1:30	6.50
K1 North Pit Diversion (lower section – earth excavation)	0.244	8.75	1.2	2.0	1.12	1:220	1.46
K1 South Pit Diversion	0.139	7.66	1.0	1.0	0.54m – to 0.76m	1:10 to 1:38	9.4 to 5.7
K2 Pit Diversion (upper section concrete lined)	0.047	1.75	0.5	0.5	0.413	1:25	4.64
K2 Pit Diversion (lower section earth excavation)	0.047	1.75	1.0	3	0.464	1:265	0.86

Where the flow cannot be diverted as in Pit K1, a series of storage sumps will be used to contain the storm runoff and then be pumped to the plant for reuse and if the water is clean enough the water will be discharged into a neighbouring water courses away from the pit. The storage sumps were designed to store the 50 year volume and be 3m deep. The runoff volumes were determined using the SCS storm flow depth equation and are indicated table below as well as in Figure 4.3.

Table 4-8 : Details of the diversion design for the Waste Rock Dumps

Diversion	Catchment Area (km^2)	1:50 year Peak (m^3/s)	Design depth (m)	Bottom Width (m)	Flow depth (m)	Channel Slope	Velocity (m/s)
K1 North Dump Diversion (upper section – lined)	0.473	15.8	1.0	2.0	0.58	1:15	8.63
K1 North Dump Diversion (lower section – unlined)	0.473	15.8	1.5	3.0	1.34	1:220	1.68
K1 East Dump Diversion (unlined)	0.084	5.42	1.0	5.0	0.621	1:190	1.271

Table 4-9 : Details of the storage sumps surrounding the pit

Sump	Area (m2)	1:50 Year runoff volume (m^3)
K1_1	17000	4100
K1_2	33900	7500

A series of pipes will be used to discharge storm water under the western portion of the waste rock dump (K1 Pit). This has been calculated to consist of 4 x 1.050m diameter pipes which require a head water of 3m to discharge a peak flow (1:50 year) of 13.9 m^3/s. At the junction of the K1 north diversion and the K1 south diversion a sump will be required to create this headwater. The dimensions of the sump are 3m deep, 5m x 3m. A series of culverts will be required to discharge the storm water under the eastern portion of the waste rock dump. Two 3.6m wide x 1.5m high culverts will be required to discharge a peak flow (1:50 year) of 15.4 m^3/s.

4.8.3 Costing

A typical bill of quantities has been developed for the storm water diversions around the pit and is given in table below. The rates used are indicative but this needs to be confirmed

Table 4-10 : Summary of costs for the storm water plan for the pits

	Description	Amount (US Dollars - $)
	PIT K1 DIVERSION	
1	Site clearance including clear and grub & spoiling material as specified by the Engineer	4,000
2	Bulk Excavation in all material and use for berm or dispose as ordered by the Engineer	71,000
3	Extra over for intermediate excavation	9,000
5	Extra over for hard rock excavation	12,000
6	Place, compact and shape material from excavations or borrow pit areas	58,000
7	Overhaul of excess material to specified stockpiles	1,000
8	Concrete to concrete lined channels	201,000
9	Pipes under the waste rock dumps	1,000,000
10	4100m^3 dam	261,000
11	7500m^3 dam	382,000
	TOTAL FOR PIT K1	**1,999,000**
	PIT K2 DIVERSION	
1	Site clearance including clear and grub & spoiling material as specified by the Engineer	3,000
2	Bulk Excavation in all material and use for berm or dispose as ordered by the Engineer	8,000
3	Extra over for intermediate excavation	3,000
4	Extra over for hard rock excavation	2,000
5	Place, compact and shape material from excavations or borrow pit areas	64,000
6	Overhaul of excess material to specified stockpiles	2,000
7	Concrete to concrete lined channels	17,000
9	Pipes under the waste rock dumps	800,000
	TOTAL FOR K2	**899,000**

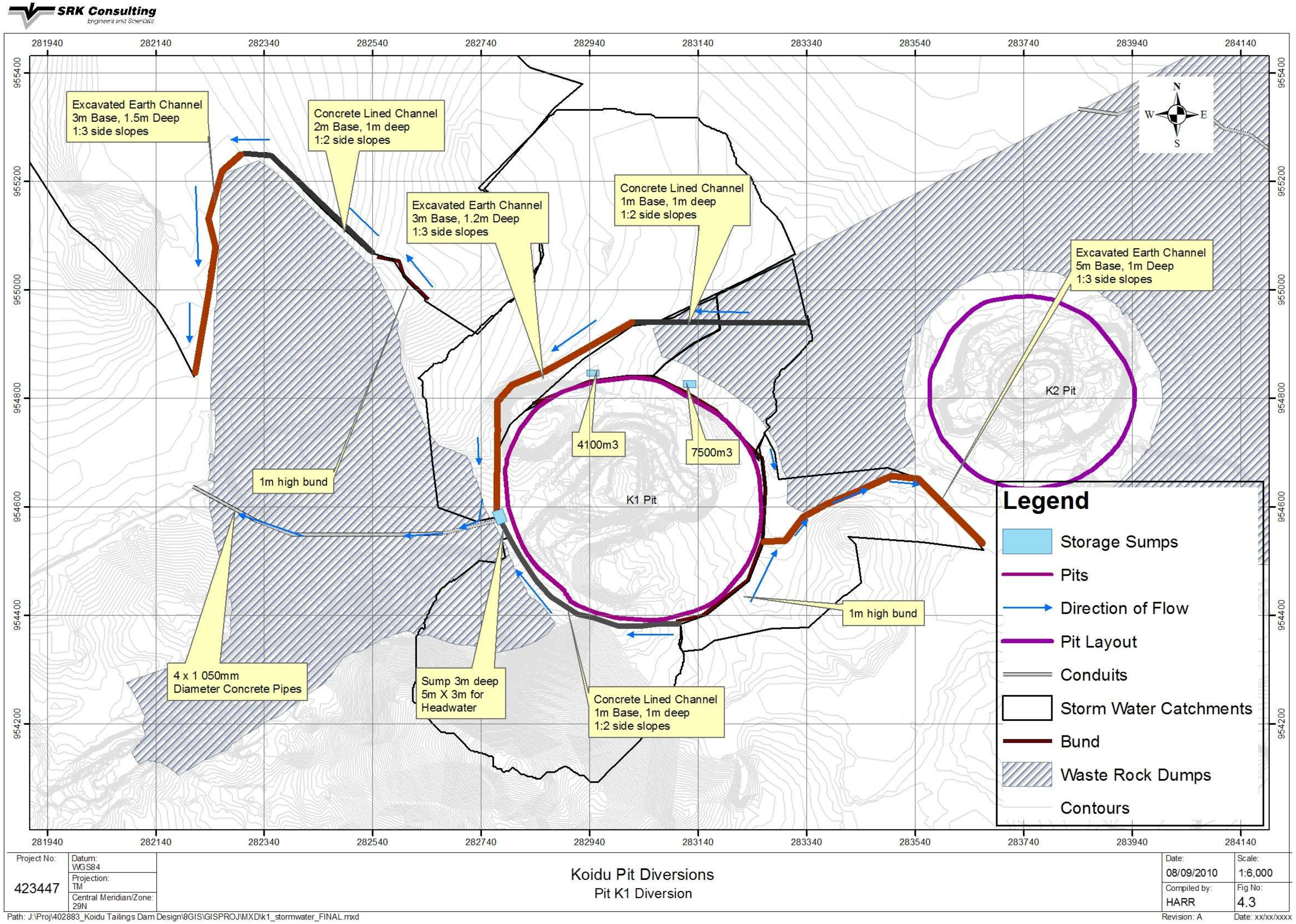

Figure 4.3 : Storm water diversion for Pit K1

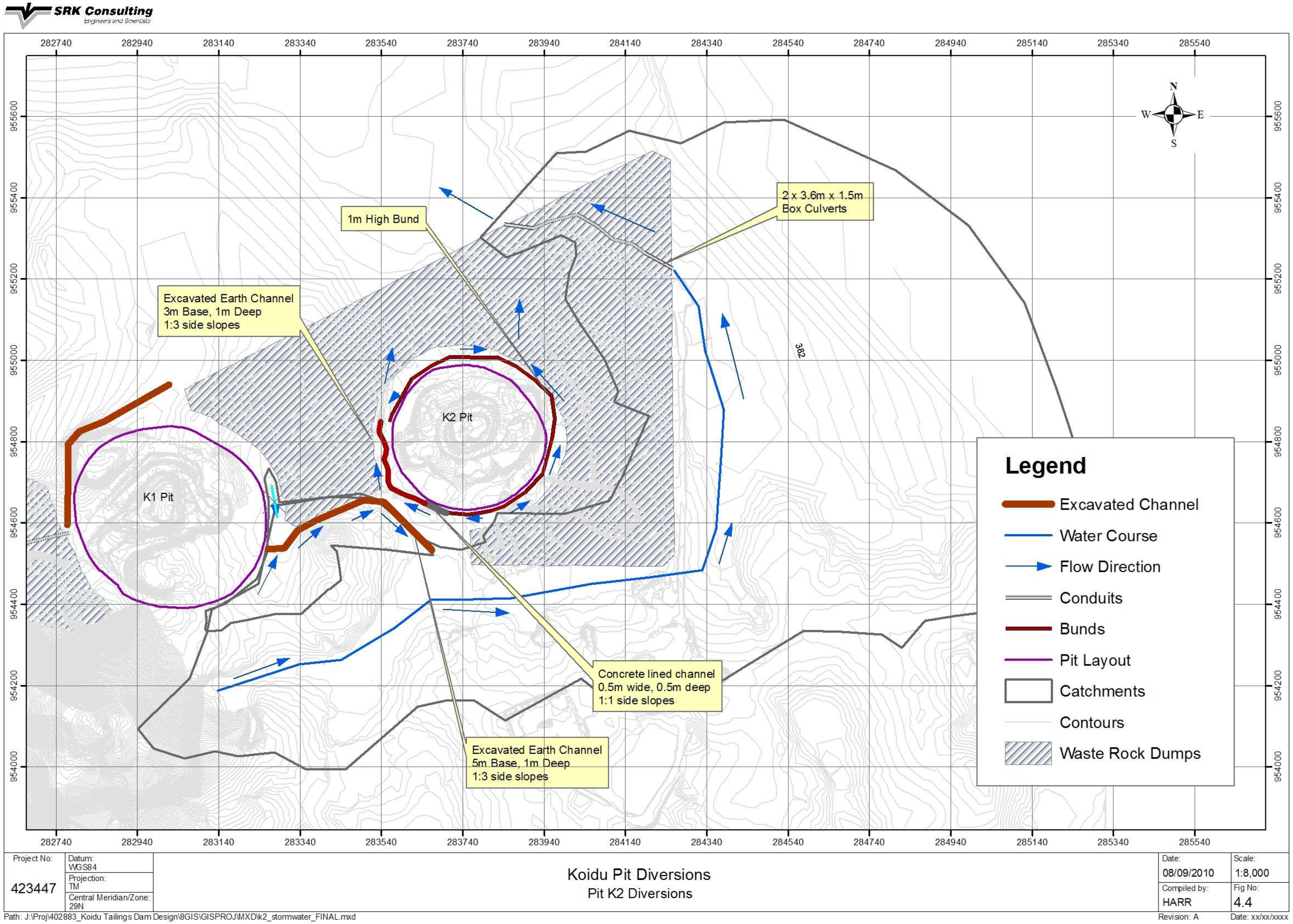

Figure 4.4 : Storm water diversion for Pit K2

4.9 Plant and Workshop Stormwater

The plant and workshop stormwater was designed such that all dirty water emanating from the plant and workshop area is channelled to a storage facility for containment and treatment. All clean water that flows towards the plant and workshop is to be diverted away into clean water courses to prevent contamination.

All dirty water channels are concrete lined trapezoidal channels with 1:1 side slopes. Due to the high rainfall of the area (mean annual precipitation - 2600mm/year), it is not feasible to capture the 1:50 year flood volume runoff from the "dirty" plant/workshop area. It is hence suggested that the very dirty hydrocarbon areas are bunded and roofed and that the runoff from the rest of the workshop area be collected via sump. These sumps will be designed on a first flush principal where a 20mm rainfall event would be captured and pumped back to the plant for treatment and processing. This first 20mm of rainfall should have most of the contaminants which will be treated within the plant. The rest of the runoff from the plant/workshop area should be fairly clean and allowed to discharge into the environment. This will only be done if good water management is undertaken.

1m high bunds are required on the eastern and western boundaries of the plant area to divert the clean water away from the plant and hence preventing contamination. These bunds are indicated in Figure 4-5 while a 1m bund is required on the North western boundary of the workshop area and is indicated in Figure 4-6.

Table 4-11 : Details of storm water management for the plant area

Pit Diversion	Catchment Area (km2)	1:50 year Peak (m3/s)	Design depth (m)	Bottom Width (m)	Flow depth (m)	Channel Slope	Velocity (m/s)
Western dirty water channel	0.02	0.16	0.5	0.5	0.181	1:220	1.02
Southern dirty water channel	0.01	0.76	0.5	0.5	0.291	1:65	2.42
South Eastern dirty water channel	0.02	1.50	0.5	0.5	0.320	0.04	4.14
Clean water channel (concrete lined)	0.04	2.79	0.5	0.5	0.467	1:37	4.17
Clean water channel (earth excavation lined)	0.04	2.79	1.0	1.0	0.869	1:225	1.17

Table 4-12 : Details of storm water management for the workshop area

Pit Diversion	Catchment Area (km2)	1:50 year Peak (m3/s)	Design depth (m)	Bottom Width (m)	Flow depth (m)	Channel Slope	Velocity (m/s)
Western dirty water channel	0.03	2.41	0.5	1.0	0.43	1:77	3.01

The dirty water dam's storage sumps for both the plant and workshop area were designed to store the runoff from a 20mm rainfall event volume and be 3m deep. The runoff volumes were determined using the SCS storm flow depth equation and are indicated in table below as well as in Figure 4-5 and Figure 4-6.

Table 4-13 : Details of the storage sumps for the plant area

Sump	Area (m2)	20mm rainfall event runoff volume (m3)
Plant Area	35 000	250
Workshop Area	52 000	350

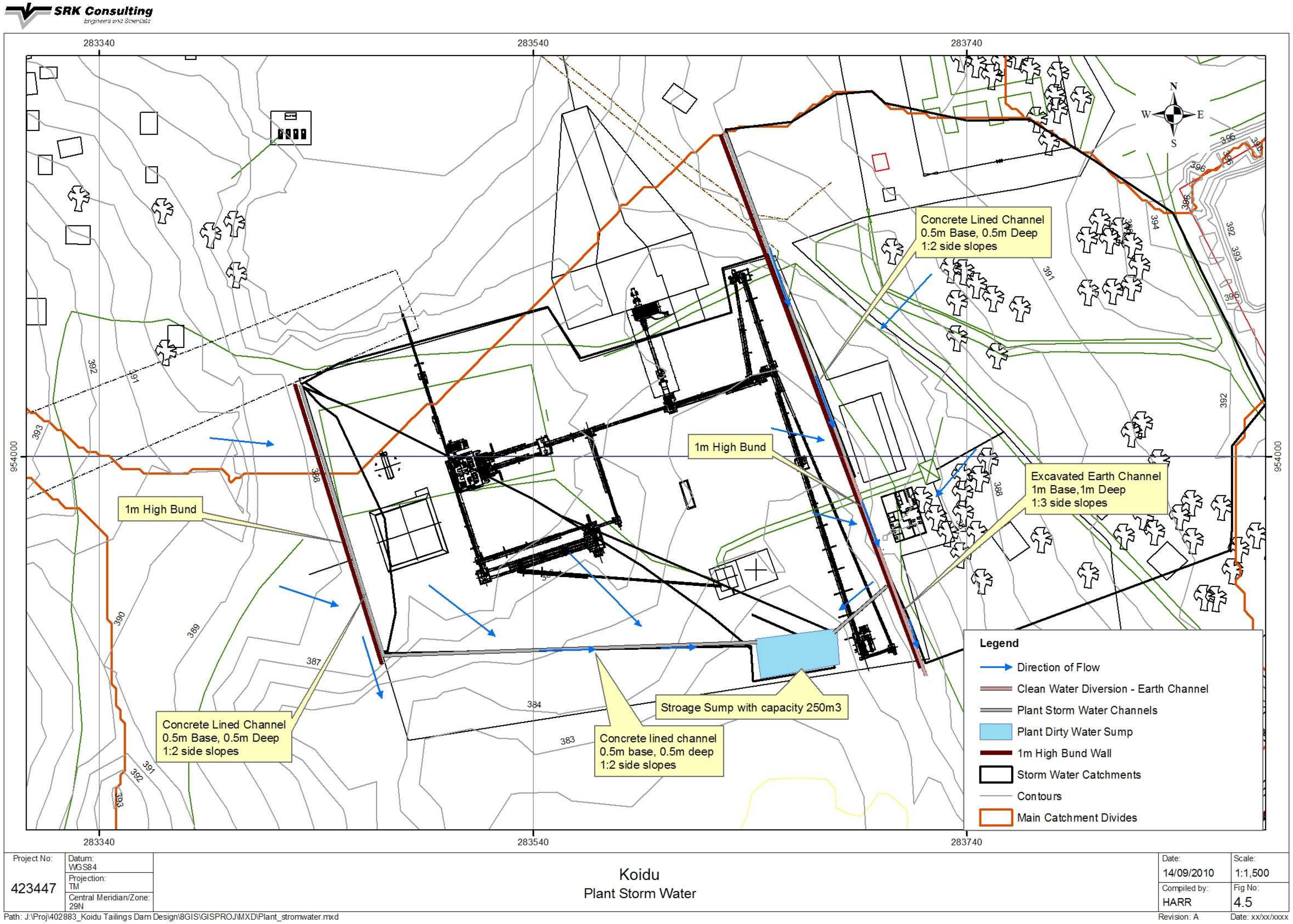

Figure 4.5: Plant storm water management plan

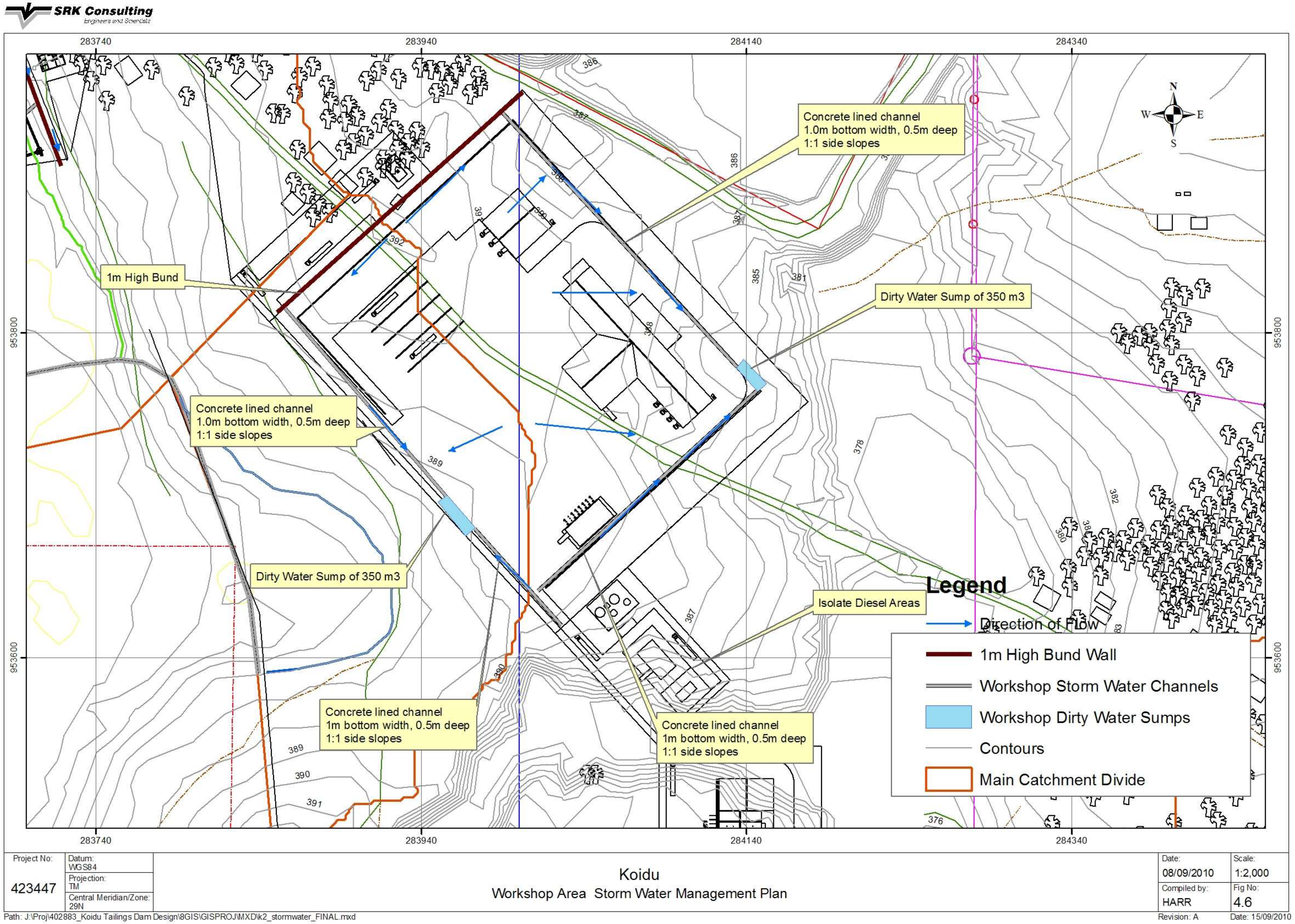

Figure 4.6: Workshop storm water management plan

4.9.1 Costing

A typical bill of quantities has been developed for the storm water diversions for the workshop and plant area and is given in table below. The amounts reflected below are in US dollars.

Table 4-14 : Summary of costs for the storm water plan for the plant

Item	Description	Amount (US Dollars)
A	**Berms, channel & conc rete Channel**	
1	Site clearance including clear and grub & spoiling material as specified by the Engineer	1,000
2	Bulk Excavation in all material and use for berm or dispose as ordered by the Engineer	16,000
3	Extra over for intermediate excavation	3,000
4	Extra over for hard rock excavation	3,000
5	Place, compact and shape material from excavations or borrow pit areas	23,000
6	Overhaul of imported material to specified stockpiles	1,000
7	Place 200mm top soil to berm side slopes as directed by the Engineer	17,000
8	Place approved hydroseed grass seed mix to top soiled areas as directed by the Engineer	17,000
	Total Berms, channel & concrete Channel	78,000
	250 m3 SUMP	
B	Excavations(Sump)	7,000
C	CONCRETE(sump)	127,000
Grandtotal		**293,000**

Table 4-15 : Summary of costs for the storm water plan for the workshop

Item	Description	Amount (US Dollars)
A	**BERMS, EARTH CHANNEL& CONCRETE CHANNEL**	
1	Site clearance including clear and grub & spoiling material as specified by the Engineer	1,000
2	Bulk Excavation in all material and use for berm or dispose as ordered by the Engineer	8,000
3	Extra over for intermediate excavation	2,000
4	Extra over for hard rock excavation	2,000
5	Place, compact and shape material from excavations or borrow pit areas	12,000
6	Overhaul of excess material to specified stockpiles	1,000
7	Place 200mm top soil to berm side slopes as directed by the Engineer	9,000
8	Place approved hydroseed grass seed mix to top soiled areas as directed by the Engineer	9,000
	Total Berms, channel & concrete Channel	40,000
	2 sumps each 350 m3	
B	Excavations(Sump)	18,000
C	CONCRETE(sump)	322,000
	Grandtotal	**424,000**

4.10 Tailings Stockpile and Slimes Dam Stormwater

In terms of the regulations and good mining practices, stormwater runoff must be separated into clean and dirty stormwater runoff. Dirty water runoff is stormwater that has been contaminated by the mining area and needs to be stored in sumps and used as far as possible in the mining processes. Clean water runoff that has not been contaminated by the mining area, needs to be diverted away from the mining area and back into natural water courses. The diversion berms have all been designed to a 1.0m height. This is to protect the seepage drain and to make the drains more visible, to ensure the drains are not mistakenly removed by mining equipment. The clean and dirty water diversion channels as well as the sumps are detailed below in Table 4-15 and Table 4-16. Figures 4-7 show the alignment and positioning of the channels and sumps respectively. Figures 4-8 to Figure 4-11 give the typical sections of the channels which form part of a more detailed design.

4.10.1 Tailings Stockpile Area

The Tailings Stockpile area has three phases of expansion which require both clean and dirty water facilities (Figure 4-7). The dirty water seepage drains have been designed to contain 2mm of seepage water over the area of the stockpile, while the clean water diversions have been sized for the 1:100 year return period. The three phases have been detailed below:

Phase 1

The stockpile has the smallest footprint during this Phase and will consist of several combination channels which will route dirty water to a sump and clean water to a watercourse. There are three dirty water sumps which will be fed by the dirty water channels (SU1, SU2 and SU3).

Sump SU3 as indicated in Figure 4-7 will however be a combination sump, with clean water being captured in a separate compartment which will need to be pumped to a natural watercourse. This is due to the topography and the stockpile position. Channel CH4 will consist of pipelines to drain clean and dirty water away from an isolated low point higher in the catchment which does not warrant a sump.

Phase 2

The pump and any re-usable equipment at sump SU3 must be removed at the beginning of this Phase. The new tailings deposition will cover all channels and sumps (SU3, CH4, CH5 and CH6) to the west of the stockpile from Phase 1

The western extent of Phase 2 stockpile, has been designed so that the majority of seepage will be forced to drain towards the three natural water courses and captured at sump SU4 while the remainder will drain towards SU2. This has been done as the expansion during Phase 3 will cover the three watercourses; therefore the area will be contaminated in the future Phase. The runoff and seepage from Phase 2 stockpile area will be cheaper to drain to one large sump (SU4) rather than building three smaller sumps and supplying pipelines and pumps which will need to be removed when Phase 3 begins, before they are buried.

Sump SU4 will also have two compartments for clean and dirty water. The clean compartment will drain stormwater from the northern and western parts of the Phase 3 stockpile areas, but more importantly will allow the clean water diversions along the northern boundary (CH16 and 17) to drain to a central exit point.

Phase 3

This Phase will require the least expenditure with channel CH21 and sump SU5 needing to be built.

4.10.2 Tailings Slimes Dam Area

The tailings slimes dam area will be in operation for all the Phases of the tailings stockpile area. Clean water diversion have been designed for the 1:100 year return period and placed around the perimeter of the tailings facility. Some stormwater will be directed to the northern half of the tailings dam toward a containment dam before being pumped away, while stormwater to the southern half of the tailings dam will be diverted back to natural watercourses.

A sump and pipeline system will need to be installed along the eastern side of the tailings dam. This is due to the topography in relation to the tailings dam. The catchment area is relatively small so it would be more economical for a pipeline than a pumping system.

Two concrete drifts must also be built to drain water over the haul roads which flank the containment dam. The drifts will protect the road surface from being eroded from stormwater directed by channels CH 25 and 27.

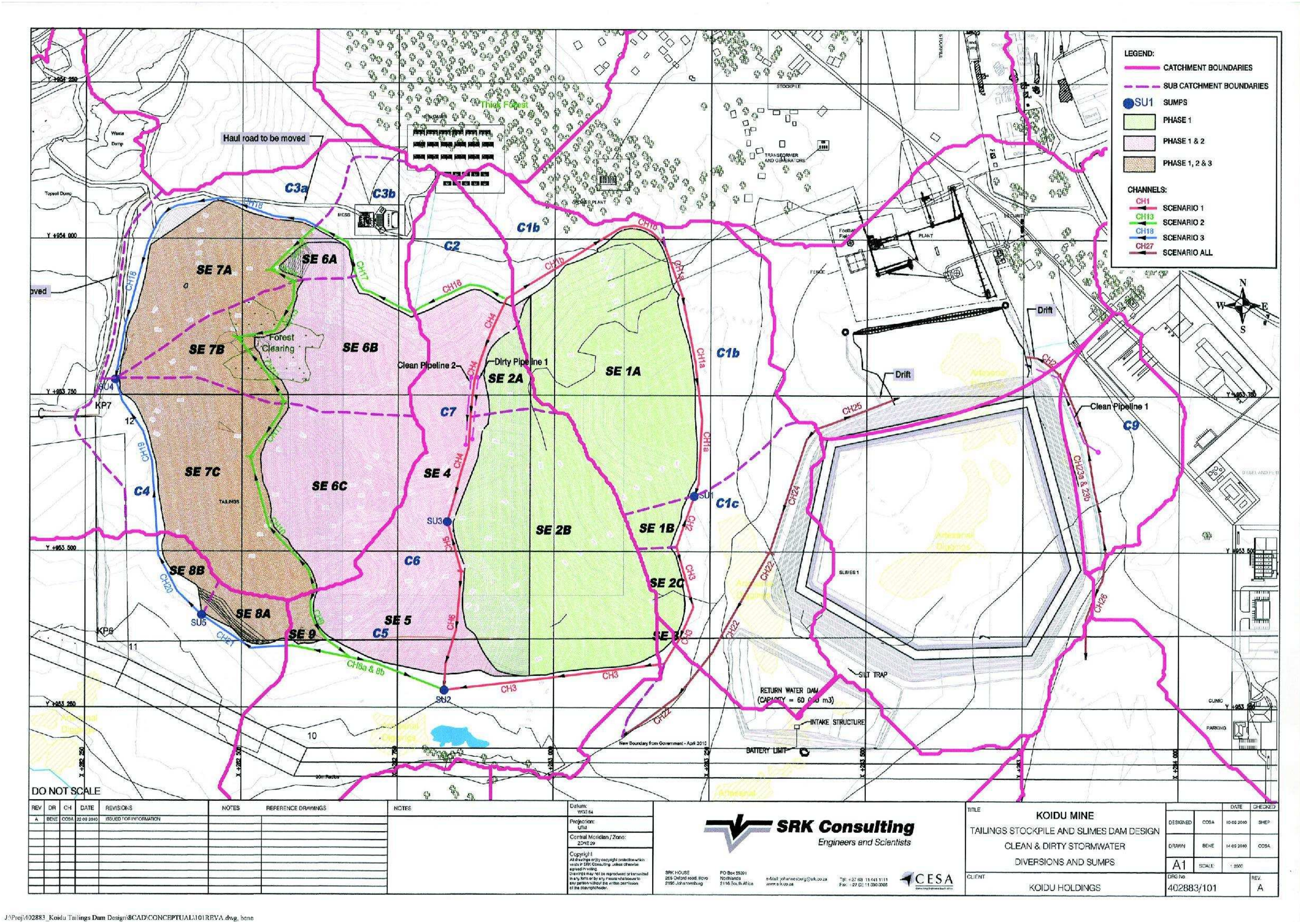

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Figure 4.7: Tailings and stockpile storm water management plan

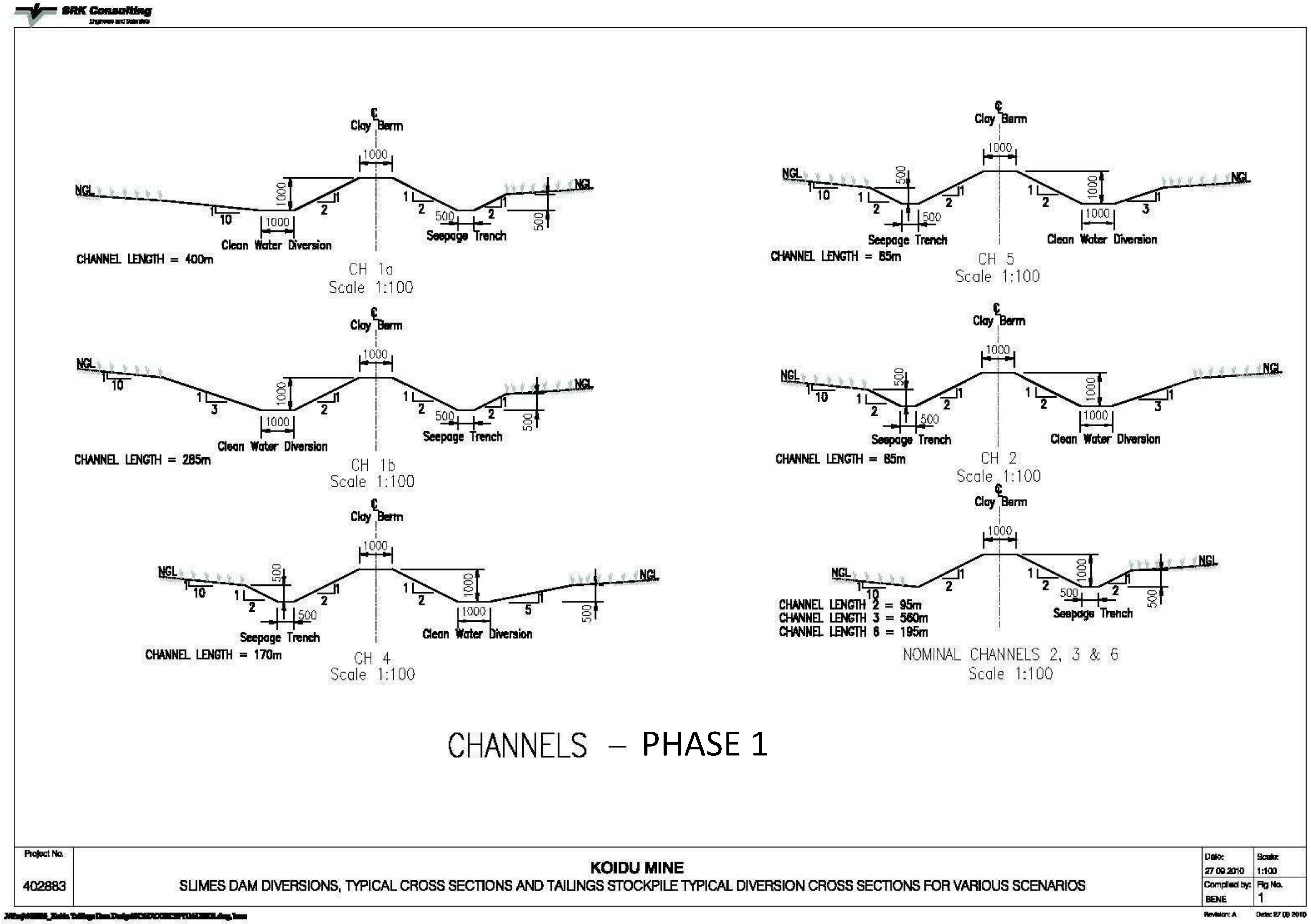


Figure 4.8: Tailings and stockpile storm water management plan

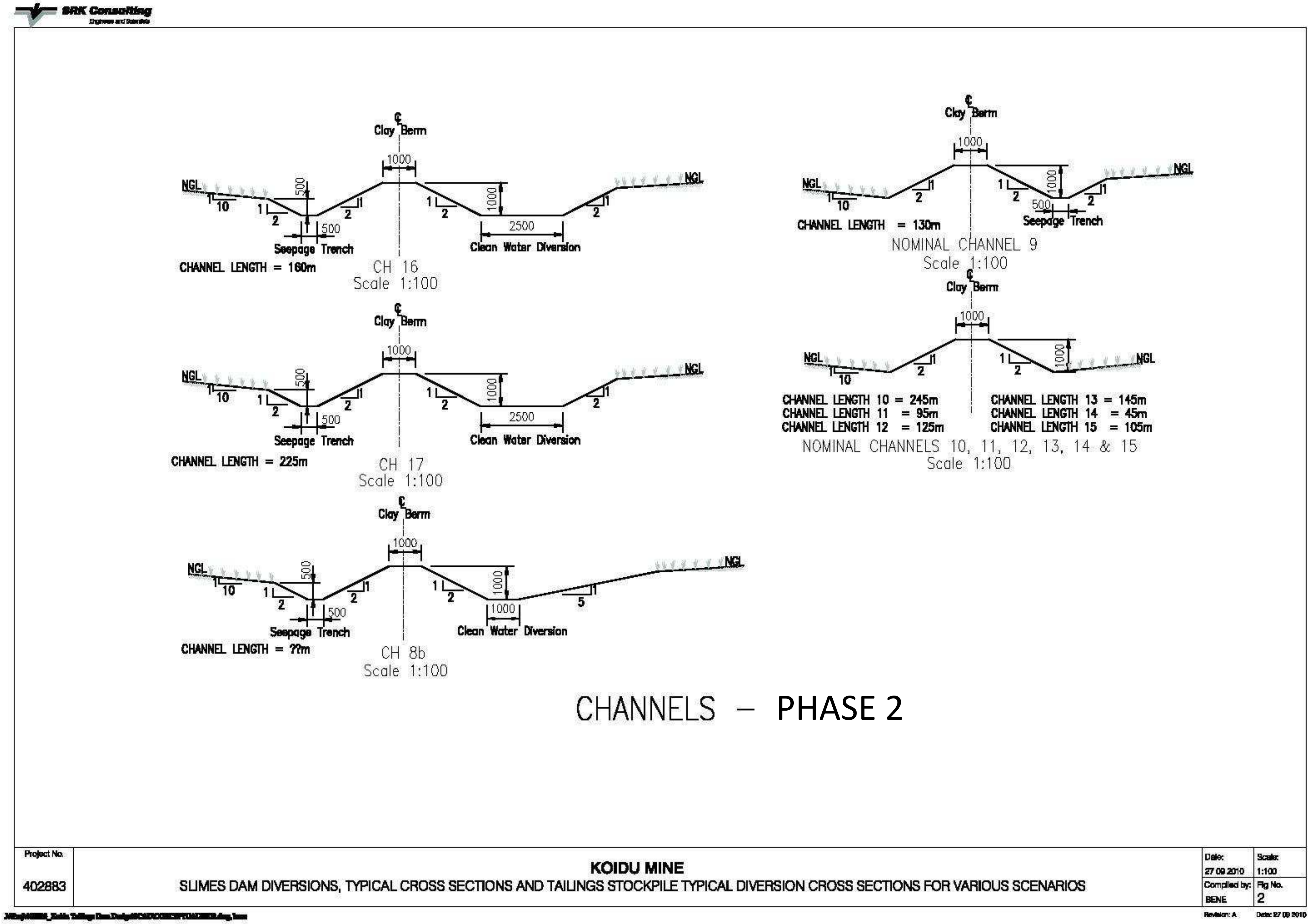


Figure 4.9: Tailings and stockpile storm water management plan

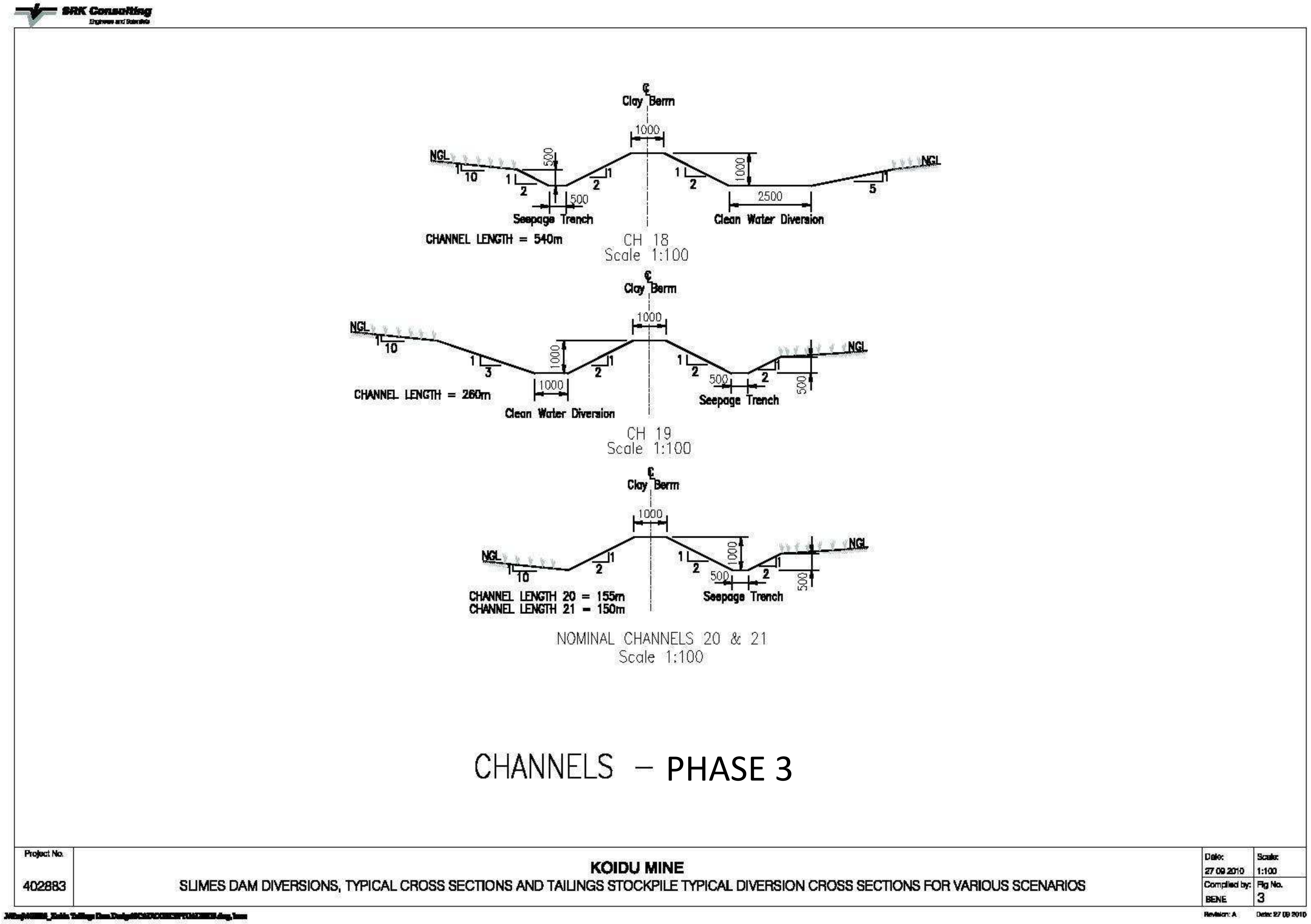


Figure 4.10: Tailings and stockpile storm water management plan

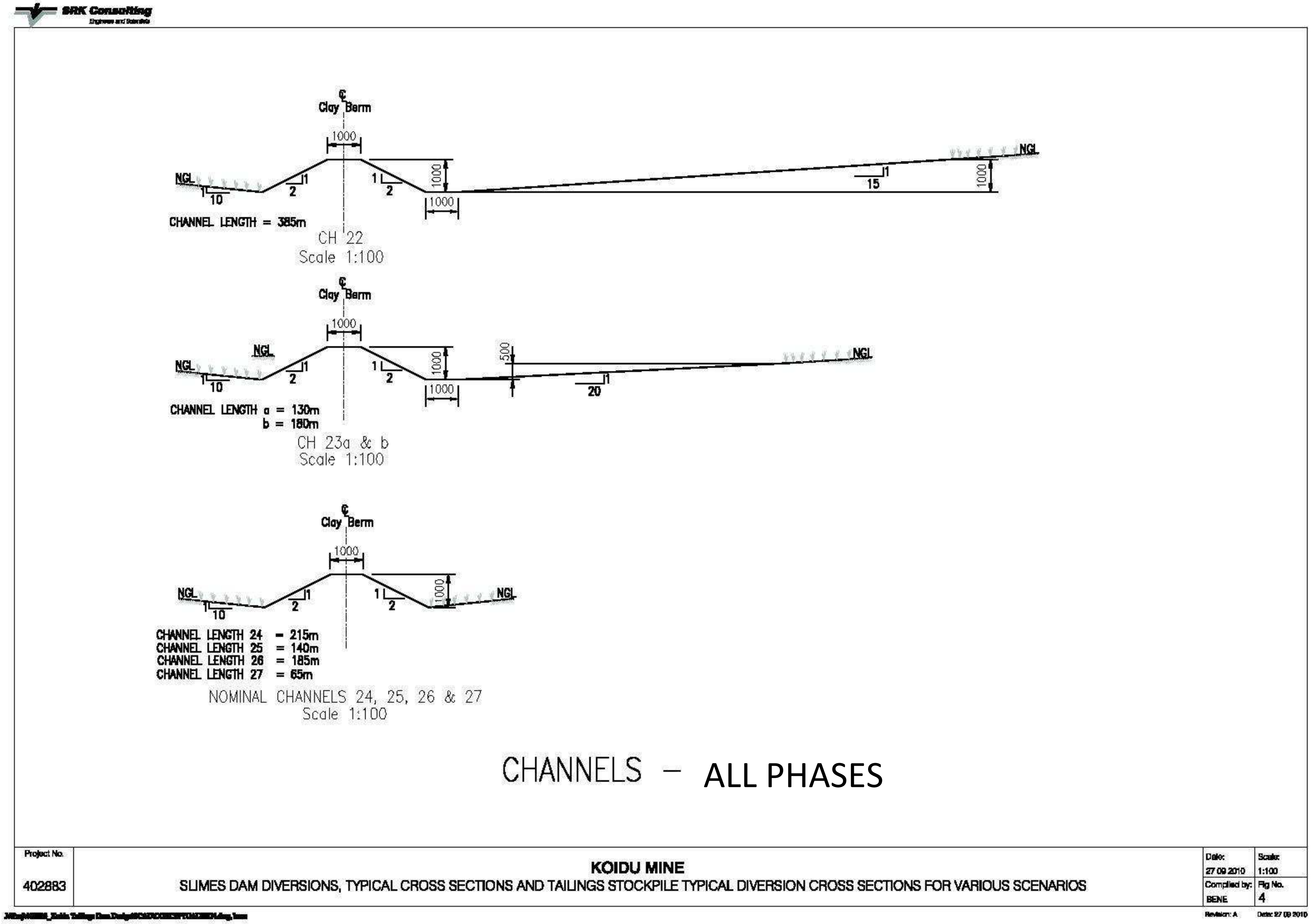


Figure 4.11: Tailings and stockpile storm water management plan

Table 4-16 : Details of sumps for the stockpile and slimes dams

Name	Volume (m3)	Depth (m)	Length (m)	Width (m)
				Phase 1
SU1	200	2.0	10.0	10.0
SU2	422.5	2.5	13.0	13.0
SU3-Clean	768.0	3.0	16.0	16.0
SU3-Dirty	2.7	1.4	1.4	1.4
				Phase 2
SU4-Clean	4332.0	3.0	38.0	38.0
SU4-Dirty	3570.0	3.0	35.0	34.0
				Phase 3
SU5	37.5	1.5	5	5

Table 4-17 : Details of channels for the stockpile and slimes dams

Name	Channel Length (m)	Bottom Width (m)	Berm Depth(m)	Left Side Slope (1/x)	Right Side Slope (1/x)	Seepage Drain (y/n)	Channel Lining
							Phase 1
CH1a	400	1.0	1.0	10	2	y	Grass
CH1b	285	1.0	1.0	3	2	y	Grass
CH4	170	1.0	1.0	5	2	y	Grass
CH5	85	1.0	1.0	3	2	y	Grass
CH6	195	-	1.0	-	-	n	Grass
CH2	95	-	1.0	-	-	n	Grass
CH3	560	-	1.0	-	-	n	Grass
							Phase 2
CH16	160	2.5	1.0	2	2	y	Grass
CH17	225	2.5	1.0	2	2	y	Grass
CH8b		1.0	1.0	2	7.5	y	Grass
CH9	130	-	1.0	-	-	n	Grass
CH10	245	-	1.0	-	-	n	Grass
CH11	95	-	1.0	-	-	n	Grass
CH12	125	-	1.0	-	-	n	Grass
CH13	145	-	1.0	-	-	n	Grass
CH14	45	-	1.0	-	-	n	Grass
CH15	105	-	1.0	-	-	n	Grass
							Phase 3
CH18	540	2.5	1.0	2	5	y	Grass
CH19	260	1.0	1.0	3	2	y	Grass
CH20	155	-	1.0	-	-	n	Grass
CH21	150	-	1.0	-	-	n	Grass
							Phase All
CH22	385	1.0	1.0	-	15	n	Grass
CH23a	215	-	1.0	-	-	n	Grass
CH23b	140	-	1.0	-	-	n	Grass
CH24	185	-	1.0	-	-	n	Grass
CH25	65	-	1.0	-	-	n	Grass
CH26	185	-	1.0	-	-	n	Grass
CH27	65	-	1.0	-	-	n	Grass

4.10.3 Costing

A typical bill of quantities has been developed for the storm water diversions for the workshop and plant area and is given in table below. The amounts reflected below are in US dollars.

Table 4-18 : Summary of costs Tailings Stockpile – Phase 1

Summary

Item	Description	Amount
1	Site clearance including clear and grub & spoiling material as specified by the Engineer	4,000
2	Bulk Excavation in all material and use for berm or dispose as ordered by the Engineer	43,000
3	Extra over for intermediate excavation	6,000
4	Extra over for hard rock excavation	8,000
5	Place, compact and shape material from excavations or borrow pit areas	67,000
6	Overhaul of imported material to specified stockpiles	3,000
7	Place 200mm top soil to berm side slopes as directed by the Engineer	142,000
8	Place approved hydroseed grass seed mix to top soiled areas as directed by the Engineer	142,000
9	SU1 - 200m3 Sump	47,000
10	SU1 - 422.5m3 Sump	78,000
11	SU1 - 768m3 Sump	119,000
12	SU1 - 2.7m3 Sump	4,000
	Grand Total	**663,000**

Table 4-19 : Summary of costs for Tailings Stockpile – Phase 2

Summary

Item	Description	Amount
1	Site clearance including clear and grub & spoiling material as specified by the Engineer	2,000
2	Bulk Excavation in all material and use for berm or dispose as ordered by the Engineer	25,000
3	Extra over for intermediate excavation	4,000
4	Extra over for hard rock excavation	5,000
5	Place, compact and shape material from excavations or borrow pit areas	53,000
6	Overhaul of imported material to specified stockpiles	3,000
7	Place 200mm top soil to berm side slopes as directed by the engineer	85,000
8	Place approved hydroseed grass seed mix to top soiled areas as directed by the Engineer	85,000
9	SU4 - 4332 m3 sump	478,000
10	SU4 - 3570m3 sump	405,000
	Grand Total	**1,145,000**

Table 4-20 : Summary of costs for Tailings Stockpile – Phase 3

Summary

Item	Description	Amount
1	Site clearance including clear and grub & spoiling material as specified by the Engineer	3,000
2	Bulk Excavation in all material and use for berm or dispose as ordered by the Engineer	34,000
3	Extra over for intermediate excavation	5,000
4	Extra over for hard rock excavation	7,000
5	Place, compact and shape material from excavations or borrow pit areas	32,000
6	Overhaul of imported material to specified stockpiles	2,000
7	Place 200mm top soil to berm side slopes as directed by the Engineer	103,000
8	Place approved hydroseed grass seed mix to top soiled areas as directed by the Engineer	103,000
9	SU5 37.5m3 Sump	16,000
	Grand Total	**305,000**

Table 4-21 : Summary of costs for stormwater related to the tailings slimes dam

Summary

Item	Description	Amount
1	Site clearance including clear and grub & spoiling material as specified by the Engineer	3,000
2	Bulk Excavation in all material and use for berm or dispose as ordered by the Engineer	29,000
3	Extra over for intermediate excavation	4,000
4	Extra over for hard rock excavation	6,000
5	Place, compact and shape material from excavations or borrow pit areas	39,000
6	Overhaul of imported material to specified stockpiles	3,000
7	Place 200mm top soil to berm side slopes as directed by the Engineer	443,000
8	Place approved hydroseed grass seed mix to top soiled areas as directed by the Engineer	443,000
	Grand Total	**970,000**

Table 4-22 : Total cost of storm water plan

Summary

Item	Description	Amount
1	Total Pit K1 and K2 Storm Water Diversion	2,898,000
2	Storm water for the plant	293,000
3	Storm water for the workshop	424,000
4	Storm water for Tailings Stockpile - Phase 1	663,000
5	Storm water for Tailings Stockpile - Phase 2	1,145,000
6	Storm water for Tailings Stockpile - Phase 3	305,000
7	Storm water for Tailings Slimes Dam	970,000
	Grand Total	**6,698,000**

5 Water quality

Figure 5.1 shows the locations of four surface water and five groundwater sampling points which are tabled below in Table 5-1. The hydrochemical analysis was undertaken by M&L Laboratories in Johannesburg and included major ions, pH, EC, TDS and an ICP scan for dissolved metals following filtering of the sample on site. The samples were also analysed for stable isotopes deuterium and ^{18}O by the University of Kwazulu Natal in South Africa.

Table 5-1: Water sample locations

Sample ID	Rest water level (mbgl)	Description	X coord	Y coord	Z coord
SW1		Near proposed new tailing dam	953299.227	283360.703	378.633
SW2		Discharge from dam below plant	954467.7	284120.21	382.549
SW3		Discharge from dam slurry dams	954553.43	284240.128	382.95
SW4		Stream downgradient of pit	955141.481	283862.204	374.75
BH1	59.85	Borehole at main accommodation	954252.652	281810.302	386.821
BH2	5.94	Borehole at office complex	954221.822	283763.263	390.721
BH3	8.52	Borehole at resettlement	954597.873	284513.472	388.31
WBH2	34.85	Piezometer at K1 Pit	954563.462	282867.562	375.38
WBH5	44.42	Piezometer at K1 Pit	954748.97	283086.94	383.2

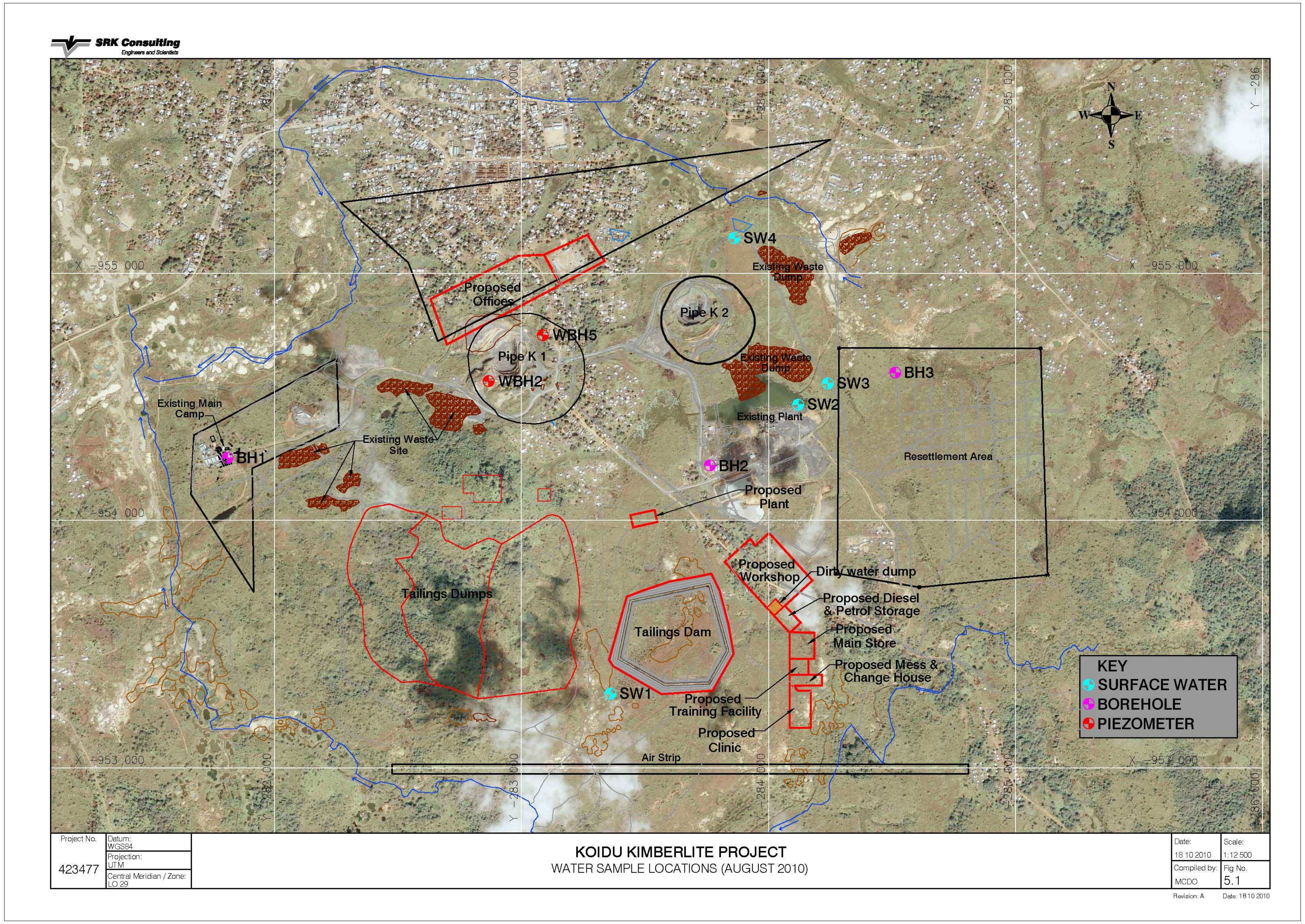


Figure 5.1 Locality map showing the water quality sampling points

5.1 Hydrochemical analyses

The 2003 EIA undertaken by Digby Wells concluded that within Saquee Town, 90% of the target group indicated groundwater as source for domestic water supply. Sokogbeh and Swarray Town respondents indicated 100% of the residents utilise groundwater for domestic supply. It can therefore be stated that groundwater is the major domestic water supply within the study area. Alternative sources are from streams or ponds within the area.

Table 5-2 shows the hydrochemical analyses for the water samples compared with the World Health Organisation (WHO) Drinking Water Guideline values (2006) as the groundwater and surface water is used as a potable water supply. The following comments are noted:

Camp water supply (BH 1): The water quality is reflective of recent recharge with a calcium/bicarbonate signature, and no evidence of chemical contamination that might affect its use as drinking water (although it should always be disinfected for drinking). The water is moderately saline (as indicated by the Total Dissolved Solids – TDS) and moderately hard (as indicated by the calcium concentration) . All constituents analyzed including dissolved metals and metalloids comply fully with the WHO Drinking Water Quality Guidelines (2008).

BH 2, Near Plant: Low TDS and hardness, without indication of chemical contamination, and fully compliant with the WHO Guidelines (2008).

BH3, Background groundwater quality: Water quality is reflective of recent recharge (calcium / bicarbonate signature), with moderately high TDS and acceptably low hardness, and fully compliant with WHO Guidelines (2008).

SW 1, Background Surface Water Quality: Low TDS dominated by calcium and bicarbonate with other constituents at trace levels. The cation-anion imbalance at -8% is slightly high but explained by the trace levels of many of the cation and anions, analyzed at concentrations close to their analytical detection limits. Dissolved metals and metalloids are generally close to detection limits, apart from iron probably derived from suspended soil particles in a slightly acid water.

SW 2 and SW 3, Water discharged from dam below the Plant (SW 2) and from slurry Dams (SW 3): These waters are essentially similar in composition with pH values slightly in the alkaline range and moderately high TDS values showing evidence of slightly elevated sulfate and nitrate values indicative of contact with mining wastes. The cation-anion imbalance for SW 2 is higher than desirable (orange shading) indicating minor under-recoveries of calcium and magnesium during analysis, although these are not considered significant. Despite these minor alterations to the background water quality, these analyses remain fully compliant with the WHO Drinking Water Quality Guidelines (2008).

SW 4, Surface water down-gradient of the Pit: Neutral water moderately low in TDS and hardness with no evidence of chemical contamination. Metals and metalloids remain in compliance with WHO Guidelines except for iron soluble iron and manganese which are widespread in these geological formations and probably leached from the suspended soil particles in the watercourse. At these levels the iron and manganese have nuisance value but no adverse health connotations. It is likely that the Fe and Mn in solution interfered slightly with the cation and anion analysis resulting in the rather high cation-anion imbalance, which is not considered significant.

WBH 5 and WBH 2, Piezometer holes adjacent to the Pit: This water complies with the WHO Guidelines except for elevated iron and manganese in WBH 5 and (of more concern) elevated dissolved lead at levels non-compliant with the WHO Guidelines (2008). The soluble lead indicates the presence of lead in the mineralogy around the Pit, and this should be noted in follow-up sampling of groundwater in the area.

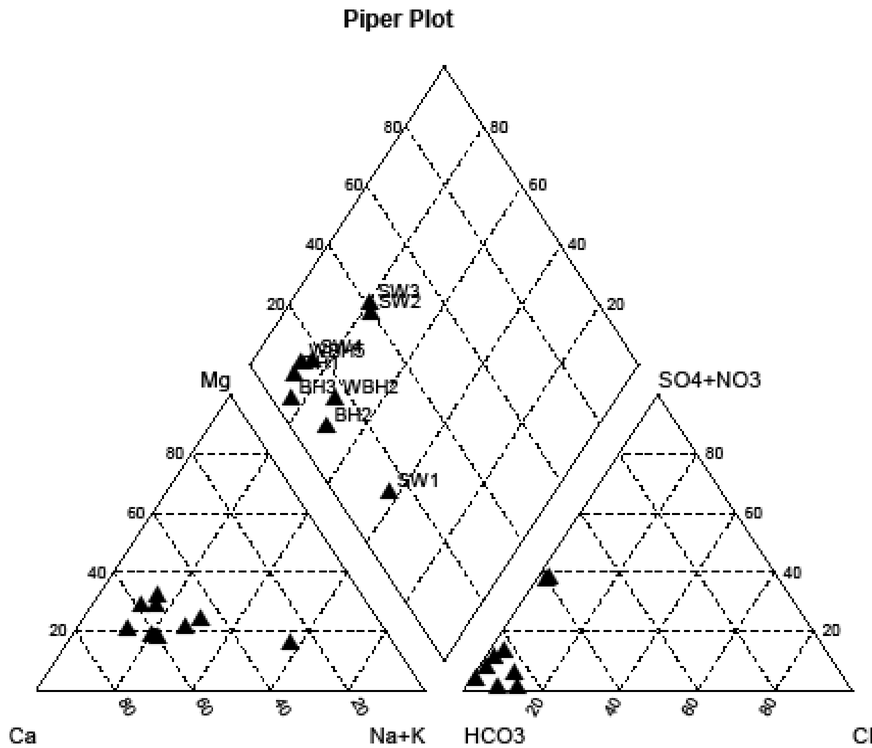
The Piper plot in Figure 5-2 shows that SW2 and SW3 apart from the rest of the water samples due to the increasing sulfates and nitrates.

Excess water that may be required to be pumped from dewatering boreholes could be disposed of directly to the rivers, although the iron and manganese are marginally elevated. In terms of the IFC Environmental, Health and Safety Guidelines (2007), total iron in effluent should not exceed 2 mg/l. The surface water sample taken from the stream below the pits has a high iron concentration of >13mg/l which means that decant from the pit should not be disposed of directly to the stream. If there is a need to discharge to the stream, the water should be allowed to settle and the clear supernatant water discharged.

Table 5-2 Hydrochemical analyses for Koidu Water Samples (mg/l where applicable)

SAMPLE ID	WHO Guidelines (3rd Ed 2008)	BH 1	BH 2	BH 3	SW 1	SW 2	SW 3	SW 4	WBH 5	WBH2
		Camp	Plant	B/ground	B/ground	Discharge	Discharge	Pit	Pit	Pit
pH Value @ 19°C	6.5-9.5	7.8	6.8	7.5	6.8	8.1	8.0	7.3	6.8	7.0
Conductivity mS/m @ 25°C		42.8	13.2	28.2	4.26	38.5	37.7	15.4	22.8	37.5
Total Dissolved Solids	1200	298	110	218	52	264	254	112	164	262
Calcium, Ca		58	11.9	34	2.1	39	44	14.4	21	45
Magnesium, Mg	ns	11.3	3.9	11	0.8	7.4	8.4	5.4	5.5	13.5
Sodium, Na	200	11	6.7	9.3	4	11.6	11.7	2.8	10.6	8.7
Potassium, K		3.3	3.8	3.5	2	8.3	8.3	3.1	3.9	3.7
Total Alkalinity as $CaCO_3$		210	60	143	20	115	114	69	97	177
P Alk as $CaCO_3$		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bicarbonate, HCO_3		256	73	174	24	140	139	84	118	216
Carbonate, CO_3		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Chloride, Cl	250	2.7	3.7	1	2.1	3.1	3.2	2.1	7.8	2.7
Sulfate, SO_4	500	18.1	0.8	5.8	0.3	47	54	10.7	5.6	23
Nitrate, NO_3	50	<0.1	<0.1	0.1	<0.1	36	30	<0.1	2.7	<0.1
Nitrate as N		<0.1	<0.1	<0.1	<0.1	8.1	6.8	<0.1	0.6	<0.1
Fluoride, F	1.5	0.5	<0.1	0.3	<0.1	0.2	0.2	<0.1	0.2	0.2
Sum of Cations meq/ℓ		4.386	1.303	3.095	0.396	3.272	3.608	1.364	2.061	3.829
Sum of Anions meq/ℓ		4.675	1.32	3.023	SW	3.955	3.987	1.661	2.329	4.102
% Imbalance		-3.186	-0.633	1.174	-8.053	-9.455	-4.99	-9.816	-6.096	-3.444

DISSOLVED METALS and METALLOIDS										
SAMPLE ID		BH1	BH2	BH3	SW1	SW2	SW3	SW4	WBH5	HBW2
Arsenic, As	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium, Se	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium, Ti		0.001	<0.001	0.001	0.026	0.005	0.001	0.004	0.002	0.025
Aluminium, Al	ns	0.047	0.022	0.032	1.5	0.079	0.066	0.11	0.044	0.075
Nickel, Ni	0.07	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Manganese, Mn	0.4	0.17	0.018	0.019	<0.001	0.048	0.047	**2.1**	**3.1**	0.085
Iron, Fe	0.3	<0.001	<0.001	0.28	**1.3**	0.016	0.004	**13.4**	**0.36**	<0.001
Vanadium, V	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Zinc, Zn	3	0.008	<0.005	0.82	<0.005	<0.005	<0.005	<0.005	0.23	0.022
Antimony, Sb	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead, Pb	0.01	0.001	0.002	0.001	0.002	0.004	<0.001	<0.001	**0.011**	**0.19**
Cobalt, Co	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper, Cu	2	0.014	0.004	0.009	0.005	0.006	0.007	<0.002	0.018	0.011
Total Chromium, Cr	0.05	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Silicon, Si		19.5	11	30	4	8.8	9.9	2.9	17	13.5
Tin, Sn		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zirconium, Zr		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth, Bi		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.009	<0.005	<0.005
Thallium, Tl		<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Beryllium, Be		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium, Cd	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium, Sr		0.45	0.18	0.23	0.037	1.3	1.4	0.26	0.19	0.43
Boron, B	0.5	0.03	0.012	0.01	<0.006	0.01	0.011	<0.006	<0.006	<0.006
Phosphorus, P		0.06	<0.04	0.08	<0.04	0.11	<0.04	<0.04	0.05	<0.04
Uranium, U		<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Molybdenum, Mo	0.07	0.024	0.007	0.006	0.005	0.012	0.01	0.001	0.002	0.011
Barium, Ba	0.7	0.44	0.2	0.18	0.054	0.26	0.26	0.22	0.63	0.3
Silver, Ag	0.1	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Thorium, Th		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury, Hg	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001



DESCRIPTION: Piper plot for Koidu Water Samples		
SRK Consulting	PROJECT: Koidu	PROJECT NO: 332563
	CLIENT:	DATE: 28 September 2010

Figure 5.2 Piper plot showing the major ion composition

5.2 Stable isotopes

To understand the recharge processes of the aquifers, the hydrochemistry has been evaluated using isotope analyses. The stable isotopes, deuterium (D or ^2H) and ^{18}O indicate the origin of water and the site specific hydrologic processes. Different concentration levels along defined trend lines are indicative of the water origin. Temperature is the fundamental control on the stable isotopic composition of water. With increasing temperature, precipitation becomes enriched in the heavier isotopes ^2H (D) and ^{18}O in a linear relationship. As a result of fractionation of oxygen and hydrogen, waters develop unique isotopic compositions that can be indicative of their source or the processes that formed them. The concentration of the stable isotopes ^2H (D) and ^{18}O depends on factors such as the conditions of condensation during precipitation and evaporation, as depicted in Figure 5-3. On a global basis, the interdependence of δD and $\delta\,^{18}O$ for precipitation worldwide can be described by the slope of the Meteoric Water Line (MWL) or Global Meteoric Water Line (GMWL) from the equation:

$\delta D = (8\delta\,^{18}O + 10)$

If concentration values for a sample fall on the GMWL, the water originated from rainwater. During evaporation, the light molecules are more volatile and consequently the remaining water body becomes enriched in δD and $\delta\,^{18}O$. Water that has been subjected to evaporation will evolve along a lesser slope depending on the relative humidity. Water subjected to condensation plots above the meteoric water line along a condensation line.

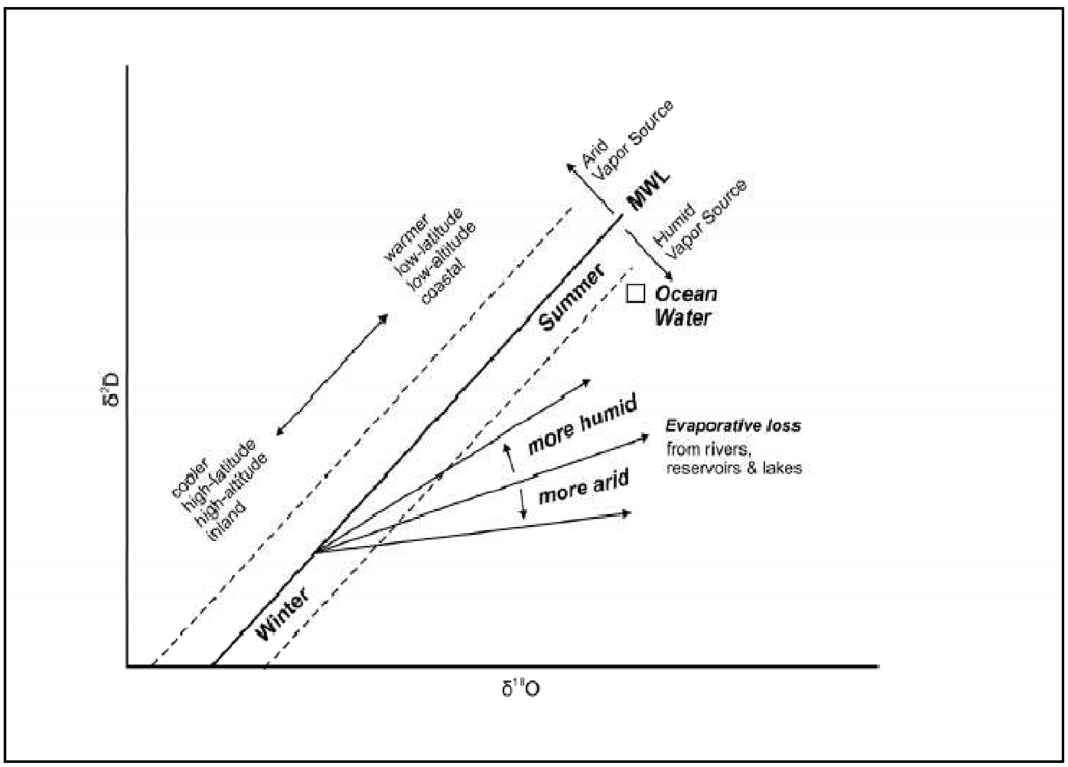


Figure 5.3 Hydrologic processes and the impact on oxygen and hydrogen isotopes

The stable isotope results are shown in Table 5-3 and Figure 5-4 shows the plot of deuterium versus ^{18}O in relation to the GMWL for the Koidu water samples.

Table 5-3 Stable isotope analyses for Koidu water samples

Sample Name	□^{2}H Reportable Value (permil)	□^{2}H Standard Deviation (permil)	□^{18}O Reportable Value (permil)	□^{18}O Standard Deviation (permil)
SW1	-12.20	0.96	-2.79	0.19
SW2	-5.61	1.64	-1.69	0.06
SW3	-5.12	0.25	-1.30	0.07
SW4	-8.28	1.29	-2.42	0.29
BH1	-17.96	1.88	-4.37	0.14
BH2	-22.21	1.60	-3.95	0.19
BH3	-14.79	2.03	-3.76	0.25
HBW2	-15.46	1.30	-4.66	0.19
WBH5	-15.68	1.08	-3.80	0.21

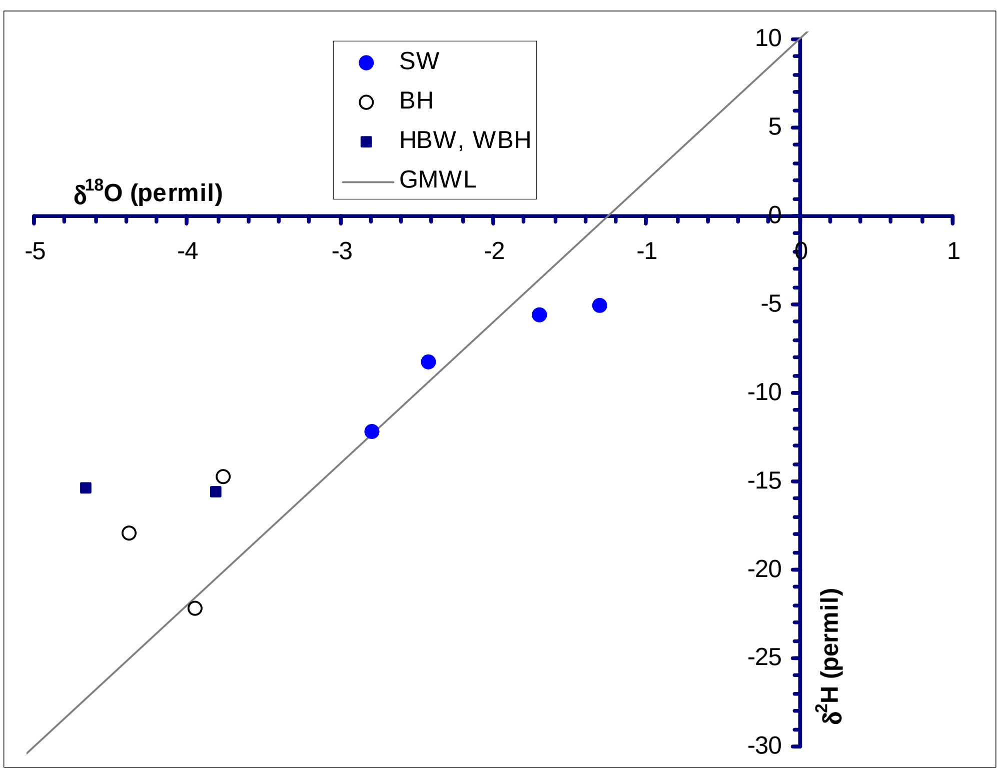


Figure 5.4 Plot of deuterium versus ^{18}O for Koidu samples

SW2 and SW 3 plot along an evaporitic line (dotted brown) typical of evaporation from an open body of water such as the slurry dams. BH2 is the borehole at the office complex with a shallow water table of 5mbgl, indicating active recharge from rainwater as it plots along the global meteoric water line. The rest of the samples from the boreholes plot above the GMWL indicating condensative processes during the recharge to the aquifer.

Water vapour produced during evapotranspiration during the day in rainforests condenses during the night (as the temperature drops) producing fog that is enriched in deuterium compared with the local rainfall (Liu et al 2006). The Koidu groundwater samples clustered in the purple circle could indicate that fog drip due to condensation on the leaves is an important process in recharging the deeper aquifers of this site. The change in land use from primary forest to other uses may alter the water balance on the local and regional scale resulting in less recharge to the deeper aquifers in the longer term.

As groundwater is the main water supply to towns in the area, the deforestation will result in more runoff and decreased groundwater resources available to the local communities.

Stable isotope analysis of several rain events throughout the year and fog drip collected from the forested area would be required to confirm this possible recharge model and estimate the recharge rate to the deeper aquifer.

6 Gaps to meet Equator Principal Document

The following gaps in the water aspects of the EIA to meet the equator 2 principals EIA requirements from a surface water perspective envisaged:

- A long term water quality and quantity database is missing for both Surface and groundwater;
- Detailed Water Balances for the site;
- Understanding the qualities of potential discharge from the mine and identify the issues resulting from the discharges;
- Identification of additional mitigation measures to minimise the impacts;
- Geochemical analysis of the waste

The following activities are envisaged to meet the Equator Principal EIA requirements:

- Select appropriate water monitoring stations reflecting background (unaffected) sites in the relevant watercourses, as well as those potentially affected by future mining activities;
- Establish flow gauging equipment at about 5 selected monitoring stations, and train at least 2 site staff to manage them and maintain a linked database, using internationally accepted protocols and standards throughout. Depending on the potential for theft a portable ruler may have to be used but allowance has been made for automatic pressure transducers;
- Develop a comprehensive surface water quality protocol providing a rationalised description of the monitoring points, instructions for monitoring, sample preservation and despatch to laboratory. The protocol will also propose the specific range of analysis appropriate for each

monitoring station, and the frequency at which samples should be taken (suggested monthly for a period of 12 months), and the maximum detection limits appropriate for determining compliance with relevant water quality guidelines or standards;

- Provide on-site training in flow measurement and water quality sampling for two or more members of site personnel and supervise the collection of the first set of flow readings and water samples. These will be forwarded to the selected analytical laboratory, with results copied to SRK in Johannesburg;
- Estimate the 1:50 and 1:100 year floodlines for the rivers close to potential mine infrastructure;
- Identify the users of surface water within the area of influence of the proposed mine, and determine the applicable water quality and flow constraints that will ensure that downstream users are not adversely affected by the mining activities;
- Prepare water balance for the entire mine – mining and processing. The water balance will treat each of the elements as a single entity (e.g. the processing plant will be a single block)
- Scrutinise laboratory analysis reports to validate the analyses, and develop an Excel-based database for storage of the data in a format amenable to statistical manipulation and charting.
- Statistically analyse water quality chemistry to characterise the baseline water quality of affected surface water bodies;
- Undertake a detailed stormwater assessment for the plant area and the dirty water mining areas;
- Undertake a more detailed impact assessment for the area

7 Preliminary Surface water impact assessment

The Possible impacts on water resources that can arise from mining activities relate to both the volume and quality of water entering or leaving water resources and include the following:

- reduced availability to downstream/down-gradient water users due to changes in water quantity or flow regime;
- reduced availability of water to downstream water users due to changes in water quality;
- reduced availability of water to surrounding water users due to physical obstruction from mine infrastructure (open pits, residue deposits etc);
- damage to the aquatic ecosystem due to substances contained in releases from the mine;
- scouring effect on stream banks and bed due to releases from the mine (clean water diversions, storm water drains, road culverts etc);
- increased erosion from areas of exposed soils;
- increased risk of flooding due to changes in catchment hydrology.

7.1 Methodology

The first stage of impact assessment is the identification of environmental activities, aspects and impacts. This is supported by the identification of receptors and resources, which allows for an understanding of the impact pathway and an assessment of the sensitivity to change. The definitions used in the impact assessment are given below.

- An activity is a distinct process or task undertaken by an organisation for which a responsibility can be assigned. Activities also include facilities or pieces of infrastructure that are possessed by an organisation.
- An environmental aspect is an 'element of an organisations activities, products and services which can interact with the environment'1. The interaction of an aspect with the environment may result in an impact.

Environmental impacts are the consequences of these aspects on environmental resources or receptors of particular value or sensitivity, for example, disturbance due to noise and health effects due to poorer air quality. Receptors can comprise, but are not limited to, people or human-made systems, such as local residents, communities and social infrastructure, as well as components of the biophysical environment such as aquifers, flora and palaeontology. In the case where the impact is on human health or well being, this should be stated. Similarly, where the receptor is not anthropogenic, then it should, where possible, be stipulated what the receptor is.

Receptors comprise, but are not limited to people or man-made structures.

Resources include components of the biophysical environment.

Frequency of activity refers to how often the proposed activity will take place.

Frequency of impact refers to the frequency with which a stressor (aspect) will impact on the receptor.

Severity refers to the degree of change to the receptor status in terms of the reversibility of the impact; sensitivity of receptor to stressor; duration of impact (increasing or decreasing with time); controversy potential and precedent setting; threat to environmental and health standards.

Spatial scope refers to the geographical scale of the impact.

Duration refers to the length of time over which the stressor will cause a change in the resource or receptor.

The significance of the impact is then assessed by rating each variable numerically according to defined criteria as outlined in **Table 7-1**. The severity, spatial scope and duration of the impact together comprise the **consequence** of the impact: when summed can obtain a maximum value of 15. The frequency of the activity and the frequency of the impact together comprise the **likelihood** of the impact occurring and can obtain a maximum value of 10.The values for likelihood and consequence of the impact are then read off a significance rating matrix, as shown in Table 8.2 and Table 8.3.

[1] The definition has been aligned with that used in the ISO 14001 Standard.

Table 7-1: Criteria for assessing significance of impacts

SEVERITY OF IMPACT	RATING
Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful	5

SPATIAL SCOPE OF IMPACT	RATING
Activity specific	1
Mine specific (within the mine boundary)	2
Local area (within 5 km of the mine boundary)	3
Regional (Greater area)	4
National	5

DURATION OF IMPACT	RATING
One day to one month	1
One month to one year	2
One year to ten years	3
Life of operation	4
Post closure / permanent	5

CONSEQUENCE

FREQUENCY OF ACTIVITY / DURATION OF	RATING
Annually or less / low	1
6 monthly / temporary	2
Monthly / infrequent	3
Weekly / life of operation / regularly / likely	4
Daily / permanent / high	5

FREQUENCY OF IMPACT	RATING
Almost never / almost impossible	1
Very seldom / highly unlikely	2
Infrequent / unlikely / seldom	3
Often / regularly / likely / possible	4
Daily / highly likely / definitely	5

LIKELIHOOD

Table 7-2: Significance Rating Matrix

LIKELIHOOD (Frequency of activity)	CONSEQUENCE (Severity + Spatial Scope + Duration)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105
	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150

Table 7-3: Positive/negative mitigation ratings

Colour Code	Significance Rating	Value	Negative Impact Management Recommendation	Positive Impact Management Recommendation
	Very high	126-150	Improve current management	Maintain current management
	High	101-125	Improve current management	Maintain current management
	Medium-high	76-100	Improve current management	Maintain current management
	Low-medium	51-75	Maintain current management	Improve current management
	Low	26-50	Maintain current management	Improve current management
	Very low	1-25	Maintain current management	Improve current management

- The assessment of significance should be undertaken twice. Initial significance should be based only natural and existing mitigation measures (including built-in engineering designs). The subsequent assessment should take into account the recommended management measures required to mitigate the impacts. Measures such as demolishing of infrastructure, and reinstatement and rehabilitation of land, are considered post-mitigation.

- The model outcome of the impacts is then assessed in terms of impact certainty and consideration of available information. The Precautionary Principle is applied in instances of uncertainty or lack of information by increasing assigned ratings or adjusting final model outcomes. In certain instances where a variable or outcome requires rational adjustment due to model limitations the model outcomes are adjusted. Arguments and descriptions for such adjustments, as well as arguments for each specific impact assessment are presented in the text and encapsulated in the assessment summary table linked to each impact discussion.

- The overall objective of this assessment is to provide recommendations on how to prevent or minimise impacts arising from the mining. The specific actions needed to meet this objective at each infrastructure unit are set out in the following recommendation section.

- The potential impacts listed have been assessed according to the criteria above for each stage of the development:

  construction;

  operation;

  decommissioning and closure.

  An impact assessment for the surface water factors will summarise impacts significance, with no mitigation and post mitigation (i.e. when an action is taken to minimise the surface water impacts on the mine). The methodology followed is as per project requirement.

7.2 Impact of pollution water resources due to upstream clean water mixing with dirty water

The impact of no cleanwater diversion structures within the proposed mine will result in:

- Pits being flooded during storm events of a high magnitude;
- Erosion of the downstream rivers;
- The upstream clean water system not being separated from the dirty water system, resulting in downstream pollution of the stream running through the mine area.
- Flooding of the plant area by the upstream cleanwater system
- Flooding of the plant from water backing up against the TSF.

Significance before mitigation / enhancements

The table represented below is designed to rate the impact of no surface water mitigation measures on the proposed mines activities and on the plant area. The rating obtained is based on the frequency of the surface water impacts, in this case where there are no mitigation measures then all runoff will enter the open cast area. A rating of 80 is obtained and is characterized as a medium-high impact.

Likelihood		Consequence			
Frequency of activity	*Freq of impact*	*Benefit/Severity of impact*	*Spatial/Population scope*	*Duration*	*Rating*
4 Weekly / life of operation / regularly / likely	4 Often / regularly / likely / possible	4 Great / harmful	3 Local area (within 5 km of the mine boundary)	4 Life of operation	Medium-high
Score	8	11			88

Mitigation measures: Clean and dirty water stormwater controls

All clean and dirty water systems are designed to cater for the 1:50 year storm event. Although the 1:50 year storm event will not be a regular occurrence, rainfall events during the year and especially during the wet season will be more regular and therefore the impacts will be more frequent. The following measures are to be taken in order to mitigate the effects of the pollution of clean water:

- A cleanwater diversion structure upstream of the plant, tailings dam, open pits and waste rock dumps will be constructed.
- A detailed Plant Stormwater Management Plan is provided. This plan details the construction of stormwater canals within the plant area, and bunding around the Hydrocarbon storage facility.

Significance after mitigation / enhancement

After the proposed mitigation measure described above is put into place, the surface water impacts on the mining area and plant will be reduced. The now reduced surface water impact will reduce the overall impact rating to 18, which is characterised as being very low.

Likelihood		Consequence			
Frequency of activity	*Freq of impact*	*Benefit/Severity of impact*	*Spatial/Population scope*	*Duration*	*Rating*
1 Annually or less / low	1 Almost never / almost impossible	3 Significant / slightly harmful	2 Mine specific (within the mine boundary)	4 Life of operation	Very Low
Score	2	9			18

7.3 Impact of excess water discharged to environment

The mine will have excess water that cannot be used in the process This water together with surface water will be discharged to the environment if it cannot be used. The impact of excess dirty water being discharged into the environment is:

- Pollution of nearby surface water courses
- Dirty water percolating into the groundwater store and polluting the available groundwater

Significance before mitigation / enhancement

The following table gives a rating of the impacts of excess water being discharged into the clean water environment. A higher spatial population scope was given when rating the above impact due to the implications of surface water and groundwater resources being polluted downstream. This indicates that the pollution of groundwater and surface water on site will have an impact outside of the mine boundary. A pre mitigation impact rating of 88 was obtained for the following impact.

Likelihood		Consequence			
Frequency of activity	*Freq of impact*	*Benefit/Severity of impact*	*Spatial/Population scope*	*Duration*	*Rating*
4 Weekly / life of operation / regularly / likely	4 Often / regularly / likely / possible	4 Great / harmful	3 Local area (within 5 km of the mine boundary)	4 Life of operation	Medium-high
Score	8	11			88

Mitigation measures: Dirtier water be used in the process and cleaner water discharged

The following measures are envisaged:

- Identify what water will be available on the mine;
- Understand the impacts of discharge from the various areas;
- Identify what water can be used in what process
- Develop a water management plan to identify what waters can be discharged from the mine, what waters will need to be cleaned and what waters can be used in the process;

Significance after mitigation / enhancement

After the mitigation measures described above is put into place the impact rating is reduced from 88 to 80.

Likelihood		Consequence			
Frequency of activity	*Freq of impact*	*Benefit/Severity of impact*	*Spatial/Population scope*	*Duration*	*Rating*
4 Weekly / life of operation / regularly / likely	4 Often / regularly / likely / possible	3 Significant / slightly harmful	3 Local area (within 5 km of the mine boundary)	4 Life of operation	Medium High
Score	8	10			80

7.4 Impact of scouring of water course

The upstream watercourse will be affected by erosion at the outlets of the clean water diversion catchments. Presently the wetland acts as a sponge and once the sponge is removed then higher peak discharge rates at the clean water diversion structures will result in scouring of the water course at the outlet points. This is primarily due to high velocities of surface water captured in the clean water diversion structures. The extensive scouring will result in higher sediment loads being transported and deposited downstream of the river.

Likelihood		Consequence			
Frequency of activity	*Freq of impact*	*Benefit/Severity of impact*	*Spatial/Population scope*	*Duration*	*Rating*
3 Monthly / infrequent	4 Often / regularly / likely / possible	3 Significant / slightly harmful	2 Mine specific (within the mine boundary)	4 Life of operation	Low-medium
Score	7	9			63

Mitigation measures: Scouring of the surface at the outlet of clean and dirty water diversion structures

The following mitigation measures are required:

- Energy dissipators at canal outlet points
- Grassed water ways and earth channels as recommended clean water diversion structures

Significance after mitigation / enhancement

After mitigation measures described above is put into place the impact ration is reduced from 63, which is characterised as low to medium to a rating of 28 which is characterised as very low.

Likelihood		Consequence			
Frequency of activity	*Freq of impact*	*Benefit/Severity of impact*	*Spatial/Population scope*	*Duration*	*Rating*
3 Monthly / infrequent	1 Almost never / almost impossible	1 Insignificant / non-harmful	2 Mine specific (within the mine boundary)	4 Life of operation	Low
Score	4	7			28

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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