Foreword

Date: July 12, 2016

From: Ian Wilson, SRC Environmental Remediation Manager

Re: Technical Memorandum – Gunnar Other Site Aspects

The attached Technical Memorandum reflects interim supplemental information supporting the 2015 Gunnar Mine "Other Site Aspects" Preliminary Design Report. This memo was submitted to the Canadian Nuclear Safety Commission (CNSC), at their request on June 25th, 2016, as a preliminary update on the design changes associated with the waste rock piles grading plan and proposed cover thickness. Information contained in this Technical Memorandum has been discussed with local community and stakeholder members previously during meetings and workshops. Much of this information also reflects input or provides answers to previous local community and stakeholder members' inquires. The analysis and figures in this memo should be considered draft in nature. An update of this memo along with supporting engineering analysis will be shortly submitted to the CNSC, Saskatchewan Ministry of Environment and posted on SRC's website as part of the 2016 Gunnar Mine "Other Site Aspects" Final Remediation Design Report.

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Memo

To:	Skye Ketilson, Project Manager, Environment Division	**Client:**	Saskatchewan Research Council (SRC)
From:	Trevor Podaima, PEng and Jordan Graham, EIT	**Project No:**	1CS056.003
Reviewed By:	Mark Liskowich, PGeo	**Date:**	June 25, 2016
Subject:	Gunnar Project "Other Site Aspects" Detailed Remediation Plan Optimization of Waste Rock Grading and Gamma Cover		

1 Introduction

SRK Consulting (Canada) Inc. (SRK) was requested by the Saskatchewan Research Council (SRC) to provide a summary of the detailed remediation plan for the Gunnar Mine waste rock grading and gamma cover. The intent of this summary is to present the design changes associated with the waste rock grading subsequent to the preliminary remediation design and to provide justification that the 0.5 m thick gamma cover along the waste rock slopes will be stable for the long term (i.e. low susceptibility to erosion). In essence, this memorandum further addresses Comment #5 from the Canadian Nuclear Safety Commission (CNSC), which is discussed below.

The analysis and figures included herein are Draft and modifications will likely result during final preparation of the Detailed Plan for the "Other Site Aspects".

1.1 Context

The Preliminary Remediation Design Report for the Gunnar Mine "Other Site Aspects", was completed August 2015, which was subsequently reviewed by the Canadian Nuclear Safety Commission (CNSC). In general, the CNSC found that the Preliminary Remediation Design Report met the requirements of the environmental assessment (CNSC 2014) to reduce radiation exposure, minimize contaminant loadings to the environment, consolidate and stabilize the waste, and promote vegetative growth at the overall site. However, the review identified areas that require further supporting information and clarification prior to acceptance of the remediation plan and comments were sent to the Saskatchewan Research Council (SRC) on December 18, 2015. Responses were submitted to the CNSC, which are included following this memo as Attachment B. For reference, Comment #5 and the SRC/SRK Response is provided below.

CNSC Comment #5:

The landform design of Gunnar other site aspects remediation is to promote use of a landform consistent with current landscape, promote sustainable vegetation, ensure positive drainage, and *reduce erosion potential. The landform designed should not only be stable geotechnically, but should also maintain the long-term integrity of the remediated features such as the waste rock pile and the landfill. The side slopes of the landfill containment structures for non-contaminated demolition debris and for contaminated and hazardous materials, and the side slopes of waste rock piles are designed with a gradient of 1V:3H without sufficient justification for their long term integrity. The experience from mine reclamation in northern Saskatchewan such as the Cluff Lake waste rock pile reclamation and the Rabbit Lake waste rock pile reclamation implies that a gentler landform slope is needed in order to ensure the integrity of waste disposal structures (i.e., landform and waste rock piles). SRC is expected to justify the side slope gradient of the waste disposal structures to ensure their long-term integrity or otherwise to provide sufficient information to demonstrate the integrity of the designed structures is in the long term, should the proposed options be justified adequately by addressing other comments.*

SRK/SRC Response:

Both landfill and waste rock pile configurations, that include 3.0 Horizontal to 1.0 Vertical (H:V) slopes, were designed to be stable geotechnically and for the long term.

Waste Rock Piles

Preliminary engineering included access ramps to facilitate construction and to provide access should adaptive management measures for unforeseen events be required. Drainage channels were positioned along the 3.0H:1.0V slopes at a frequency where each channel will accommodate flow from a 1 ha area and the top surface of the waste rock piles and benches have a 1.0 % grade towards the drainage channels. The intent of this configuration was to reduce, surface flow velocities to below 1.0 m/s, the potential of surface erosion and to promote sustainable vegetation that will intern uphold the long-term integrity of the remediated waste rock piles.

The waste rock pile configurations include a series of 3.0H:1.0V slopes that are 6 m in height and are separated by benches that are 8 to 10 m in width. Such configuration results in an overall average slope angle of 4.0H:1.0V to 5.0H:1.0V. Therefore the benches could be excavated to form a gentler landform and the volumetrics will be the same. Landform design will be considered in the next phase of engineering, which will include a review of historical reclamation designs in Northern Saskatchewan, a trade-off study (benches vs. flatter uniform slope), and a FMEA to assess the consequences of erosion. This exercise will ultimately determine the final landform configuration for the waste rock piles.

Waste Disposal Structures

Both non-contaminated and contaminated landfill designs include surface/slope water management features that will promote sustainable vegetation, reduce the potential of erosion and thus facilitate the long-term integrity of the structure. Specifically, the crest of the non-contaminated landfill will be graded at 1.0% to form a swale-like feature towards the center of the crest, which will ultimately drain towards the Open Pit via an armored drainage channel situated along the 3.0H:1.0V slope.

The crest of the contaminated landfill is much smaller and will therefore be graded at 1.0% towards the exterior slope. Water bars comprised of riprap will be situated along the 3.0H:1.0V slope of the landfill to manage sheet flow and to reduce the potential of erosion from runoff. Runoff from surrounding watersheds will be diverted around both landfills and towards the Open Pit.

The proposed landfill slopes were also designed using guidelines from the Saskatchewan Environmental Code for Landfills (EMPA, 2010) where the recommended landfill slopes for Type I and Type II waste range from 3.0H:1.0V and 4.0H:1.0V.

Landform design will be included in the next phase of engineering as well as a FMEA and if required, the slopes may be flattened to support the final landform configuration.

Vegetation and Landform Design
One of the key components in reducing short term erosion potential is the establishment of sustainable vegetation species native to the Gunnar site. SRC's vegetation study will be utilized in the next phase of engineering to confirm the re-vegetation potential and to develop a re-vegetation plan.

2 Optimization of Preliminary Remediation Landform

A stepped approach was carried out in order to optimize the waste rock and landfill landform designs. The first step included an erosion analysis of the available cover materials to determine which borrow materials can be used as cover for various slope geometries and site conditions. Step 2 was a volumetric assessment to determine where to excavate waste rock to accommodate the tailings remediation design as well as minimizing material movement to achieve the final landform. The final step included a hydrotechnical assessment to determine the types of structures required to accommodate areas of the landform where concentrated flow may occur.

2.1 Step 1 – Erosion Analysis

The following sections are based on the results of the cover erosion analysis, which is attached following this memo as Appendix A.

2.1.1 Scope and Purpose of the Erosion Analysis

The effects of wind and water erosion on the cover were analyzed for short and long term performance. In the water erosion assessment, only sheet and rill erosion were considered. Sheet and rill erosion occur as a result of overland flows that are not concentrated into a particular flow path. The design of the waste rock pile landform will include channels where concentrated flow is expected to occur. These areas will be armoured with non-woven geotextile or coconut matting and rip rap, which will mitigate erosion along these concentrated flow areas.

Wind erosion was estimated using the Wind Erosion Model presented by Skidmore (1994) and the USDA (2002). Wind erosion should occur relatively uniformly over an erodible surface, which is reflected in the model.

All calculated erosion estimates are presented as “soil loss”. Soil loss is a mass or depth of eroded material that leaves the slope entirely. Material that is detached and deposited on the slope is not included in the estimates for soil loss.

2.1.2 Cover Criteria

The sum of gamma radiation and radon gas exposure measured 1 m above impacted area must be no greater than 2.64 μSv/hr (2.5 μSv/hr above background) as a spot reading and no higher than 1.14 μSv/hr (1.0 μSv/hr above background) as an average measured over 1 ha. The background gamma dose rate over 1 ha is 0.14 μSv/hr.

A remediation performance criterion for gamma radiation was established as part of the EIA (SRC, 2013). Several gamma radiation surveys have been completed at the Gunnar Mine Site that range from 1986 to 2009. The results of the most recent gamma survey completed in 2009 and 2011 indicate gamma dose rates ranged from 0.3 to 6.0 μSv/h with an average value of 1.2 μSv/h (SRC, 2013). OKC completed a gamma shield assessment as part of the detailed tailings remediation design, which revealed that a cover system 0.2 m thick will be sufficient to bring the average gamma radiation of the tailings below the target of 1.14 μSv/h and the maximum value below the 2.64 μSv/h. Unlike the tailings, which have a higher gamma signature, the waste rock piles do not require the same level of protection (i.e. cover thickness) as the average and maximum gamma signature of the waste rock piles are 70% and 50% lower than the tailings. Therefore the proposed minimum cover thickness of 0.5 m over the waste rock piles will provide more than adequate protection from gamma radiation and a contingency should there be loss due to erosion.

There is no requirement for infiltration reduction or oxygen reduction and the cover material must be able to support self-sustaining vegetation. For landfills, covers must adhere to landfill cover standards.

2.1.3 Soil Loss Criteria

The Revised Universal Soil Loss Equation for application in Canada (RUSLEFAC) was used to determine the effects of sheet and rill erosion on site. The RUSLEFAC is accompanied by soil loss classifications. Class 1 soil loss, also considered tolerable soil loss, is defined as the “maximum annual amount of soil which can be removed before the long term natural soil productivity of a hillslope is adversely affected.” The value of tolerable soil loss considered by RUSLEFAC is 6 T/ha/year. This value should be achieved on site, as one of the design objectives is to establish and then maintain a vegetated cover surface. Although this value was presented in the RUSLEFAC, which only takes water erosion into account, the target of 6 T/ha/year applies to the sum of soil loss due to both water and wind erosion. The 6 T/ha/year target was used to assess the short term stability of the cover system against erosion.

Annual soil loss quantities determined by the RUSLEFAC were multiplied by 100 years to determine the total soil loss over the project design life (i.e. long term stability against erosion). The target value of 6 T/ha/year would then equal 600 T/ha/100years. To visualize this loss, the mass of soil was converted to an average depth over the eroded surface using a dry soil density of 1.7 T/m^3. The corresponding depth was 3.5 cm over the course of the design life, which will not impact the objective of the cover system to reduce gamma signatures. The remediation of the other site aspects is expected to be effective in perpetuity; however, it is not credible to suggest this design criteria can be met in geological timeframes. Therefore a 100-year design life has been adopted similar to that of the Lorado Remedial Project (SRK, 2014).

2.1.4 Factors Affecting Soil Loss Due to Water Erosion

Slope Length

Slope lengths ranging from 10 m to 200 m were assessed, which were based on the existing topography of the waste rock piles. The results of the analysis indicated that soil loss increases as the slope length increases.

Slope Steepness and Shape

Soil losses for straight, complex and benched slopes were assessed. Complex slopes (i.e. concave) and benched slopes were assessed as they are both occasionally implemented as landform designs in the mining industry. In practice, complex slopes are intended to appear more natural by imitating the shapes of surrounding landforms, and also to cause a reduction in velocity as flow progresses down the slope. Benches are intended to reduce flow velocities and to create a flat area where soil deposition can occur.

The results revealed that complex slopes and benched slopes yield less soil loss than an equivalent straight slope (i.e. straight slope of 4H:1V vs. a complex slope with an overall slope of 4H:1V), approximately 9% and 15% less, respectively. Although the analysis indicates these slopes may perform somewhat better, other issues may arise with complex and benched slopes. It has been shown that, while benches can reduce flow energy if the design storm is not exceeded, standing water on terraces and benches can increase erosion (Sawatsky and Beersing, 2014). Benches have led to many different types of erosion degradation such as subsidence, piping, rilling and differential settling, which are costly to repair and create liability concerns (Clark, 2008). For these reasons, benches are no longer being considered as part of the waste rock design as previously proposed in the Preliminary Remediation Design Report. Complex slopes tend to be difficult to construct and they require that a greater quantity of material to be displaced, which offsets the marginal reduction in soil loss.

Due to constructability and potential performance issues with complex and benched slopes, respectively, straight slopes were selected for the waste rock grading plan. The steepness of the straight slopes that were analyzed ranged from 2H:1V to 6H:1V. Slopes flatter than 6H:1V were deemed to be impractical due to the quantity of waste rock excavation that would be required. The results of the analysis showed that soil loss increases with increasing slope grade (Appendix A).

Soil Type

Four different soils were compared in the erosion analysis, which were based on the material types available in Borrow Areas 5 and 6W. These two borrow areas will be utilized for the remediation of both the tailings and other site aspects. The soil parameters used in the analysis were based on the borrow investigations completed by Golder Associates (EIS, 2013) and O'Kane Consultants (OKC, 2016) at the Gunnar Mine site.

The results of the analysis indicated that the material from Borrow Area 6W is the least erodible material (at least 55% less erodible than the next least erodible material). Furthermore, this material is not as susceptible to freeze thaw action and ice lensing. Based on the borrow investigation completed by O'Kane Consultants (OKC, 2016), it is understood that there is enough material in Borrow Area 6W to complete the cover systems for the other site aspects. Therefore the cover systems for the other site aspects will utilize the material from Borrow Area 6W.

Vegetation and Surface Cover

Two surface cover scenarios were considered in this analysis: undisturbed soil with no surface vegetation (assessed for short term stability), and undisturbed soil with 40% surface coverage of small, short-rooted vegetation (for long term stability). SRC indicated that establishing this degree of surface coverage is achievable based on the revegetation trials that have been undertaken at the Gunnar Site (Petelina, 2013a).

The results indicated that soil loss is significantly reduced as more vegetation is established. The reduction from no vegetation to 40% coverage with small, short-rooted vegetation is generally greater than 65%. Hence the importance of establishing vegetation as soon as possible.

Climate and Storm Events

Soil loss due to water erosion was assessed on an annual basis as a result of average precipitation, and on an event basis as a result of single storms. Erosion was assessed as a result of three storm events: a 1 in 100 year 24 hour event, a 1 in 200 year 24 hour event, and a 1 in 200 year 24 hour event that accounts for an increase in precipitation due to the potential effects of climate change. These events were chosen as the project design events based on the consequence classification for surface water management throughout the site.

The results of the analysis for 4H:1V slopes that are 100 m in length, indicated that each of the events exceed the soil loss target of 6 T/ha/year for non-vegetated slopes covered with material from Borrow Area 6W. However, if vegetated (small, short-rooted plants, 40% coverage), each of the events result in less soil loss than the target value.

Figure 1, reveals that each storm event can generate more than a years' worth of erosion. The soil loss target is for an entire year, and if added to the average annual soil loss, each of the storm events would contribute to a loss of greater than 6 T/ha/year in the year that the storm occurred. However, as stated in Section 2.1.3, tolerable soil loss is the maximum annual amount of soil which can be removed before the long term natural soil productivity of a hillslope is adversely affected. Therefore, if total soil loss marginally exceeds the target in a single year, it will not necessarily adversely affect the natural soil productivity of the hill slope. These results indicate that, prior to establishment of vegetation, microtopography should be utilized to reduce potential soil loss due to storm events.

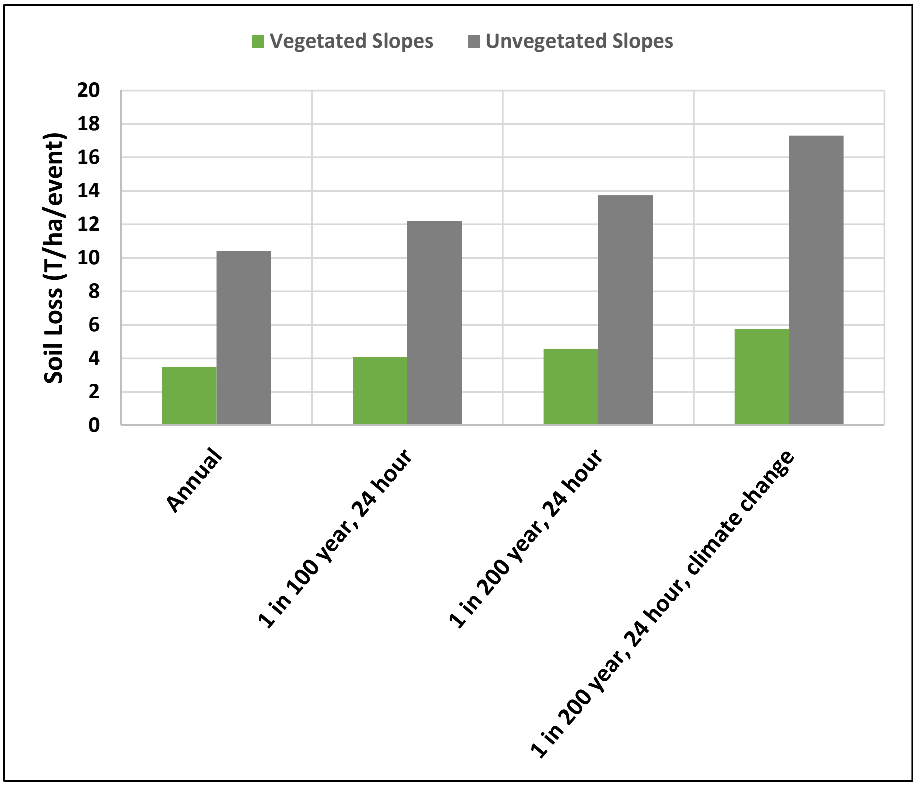

Figure 1: Soil Loss on an Annual Basis and for Storm Events (Vegetated and Non-vegetated)

Microtopography

Another limitation of the RUSLEFAC is that it does not account for erosion in concentrated flow paths where gullies may begin to form. The RUSLEFAC provides an estimate of the average amount of erosion that will occur over the entire erodible surface.

To mitigate the potential for flow to concentrate in certain areas causing channel or gulley erosion, microtopography features will be incorporated in the design. Features such as ridges, wattles, woody debris or mulch, and surface roughening can all contribute to breaking up surface flow paths. These features, when placed strategically, can also help to reduce sheet, rill and wind erosion. In certain applications, microtopography features have shown to reduce soil loss by 10% and up to 75% or greater. Microtopography features are not intended to have long term impacts: mulch eventually degrades, wattles lose their shape over time, and rough surfaces eventually become smooth. However, microtopography features should retain their effectiveness in reducing soil loss until self-sustaining vegetation is established.

2.1.5 Soil Loss Due to Wind Erosion

Soil loss due to wind erosion is driven by the following parameters: climate (specifically wind, precipitation and temperature), soil type, vegetative cover, microtopography and roughness, and the size of the erodible area. Generally, soil loss increases on a unit area basis with higher wind speeds, higher fines content of the soil, and larger erodible areas that do not contain a wind break. Soil loss generally decreases with an increase in surface roughness, an increase in microtopography features, and increased vegetative cover.

The impacts of wind erosion were only assessed for material from Borrow Area 6W. The results of the analysis indicated that one of the soil samples from Borrow Area 6W was significantly more susceptible to wind erosion than the other. However, the analysis also indicated that soil losses due to wind erosion from either material are insignificant once the areas are vegetated. In the shorter term (non-vegetated), substantial amounts of erosion could occur from the material that is more susceptible to wind erosion if no microtopography features are included in the design (similar quantities of soil loss to that of water erosion may occur). If microtopography features are included, soil loss caused by wind of either material is nearly eliminated on all areas of the site.

2.1.6 Erosion Analysis Summary

The waste rock cover system for the other site aspects was assessed for both short term and long term stability against erosion and the results of the assessment were used to optimize the preliminary grading design for the waste rock piles. The series of 3H:1V slopes and benches initially proposed have been modified to a straight slope with an overall grade of 5H:1V. The overall grade was selected based on the maximum slope length of the re-graded waste rock piles, approximately 80 m, which is located at the north east flank of the East Waste Rock Pile.

2.2 Step 2 – Volumetric Assessment

Based on the results of Step 1 (Erosion Analysis), the volumetric assessment initially considered a conservative approach by excavating all slopes of the east and south waste rock piles and the perimeter of the open pit to 5H:1V. Such excavation resulted in approximately 1.1 Mm^3 of waste rock, which is significantly more than the 851,000 m^3 that is required for the tailings remediation design. Therefore to reduce the amount of excavation, the erosion analysis was used to assess short and long term soil erosion for various slope lengths and angles. Based on the topography and height of the existing waste rock piles, it was determined that the assessment consider slope lengths and angles of 30 m at 3H:1V, 50 m at 4H:1V and 100 m at 5H:1V. The results of the assessment are provided in Table 1.

Table 1: Summary of Soil Loss for 30 m, 50 m and 100 m Long Slopes

Slope Configuration Length and Angle	Non-vegetated – Short Term Stability (T/ha/year)[1]	Vegetated – Long Term Stability	
		(T/ha/year)	(cm/100 years)
30 m (3H:1V)	7.9	2.6	1.6
50 m (4H:1V)	7.5	2.5	1.5
100 m (5H:1V)	7.8	2.6	1.6

As shown in Table 1, each of the three slope configurations will be stable under long term erosion conditions. For short term conditions where vegetation has not yet been established, the annual soil losses marginally exceed the target value of 6 T/ha/year. However, soil loss below 11 t/ha/year is still classified as a low soil loss (Class 2, RUSLEFAC). As stated in Section 2.1.4, microtopography will be incorporated in the design and is expected to reduce short term soil loss to below the target value. Once vegetation is established, soil losses on all of the proposed slopes will be substantially below the target value. Therefore the following criteria was used to further optimize the grading plan for the waste rock piles:

- Waste Rock Slopes > 50 m in length will be graded to 5H:1.0V
- Waste Rock Slopes ≤ 50 m in length will be graded to 4H:1V
- The Channel slopes through the East Waste Rock Pile will be ≤ 30 m in length and will be graded 3H:1V.

Several grading iterations were carried out to satisfy the 851,000 m^3 waste rock requirement for the tailings remediation design and to limit the amount of grading to achieve a landform that would conform to the above criteria. The proposed configuration of both waste rock piles and area surrounding the perimeter of the Open Pit is shown in Figures 1 and 2.

2.3 Step 3 – Hydrotechnical Design and Microtopography

There are three areas along the waste rock piles where concentrated flow will occur (Figure 2). To determine the type of hydrotechnical design required for these areas, SRK has reviewed recent hydrology data (2016) and has updated the hydrological design criteria (separate memorandum). In summary three rip rap drainage channels and two channels lined with coconut matting will be required to accommodate channelized flow (Figure 2). Details of the rip rap drainage channels are shown in Figure 3.

The main channel design to route Catchment 3 flow to Zeemel Bay is relatively consistent with the design proposed in the Preliminary Remediation Design Report, which in general, consists of a trapezoidal excavation that has a 6 m wide base and 3H:1V side slopes. Non-woven geotextile will be placed along the bottom of the excavated channel and keyed-in to an anchor trench. The non-woven geotextile will prevent migration of fine particles through the rip rap. Rip rap will then be placed against the non-woven geotextile. The upper portion of the channel side slopes above the rip rap will be protected with a coconut mat to stabilize the cover material until vegetation is established. The bench situated at the top of the rip rap armoring will act as a temporary sediment trap subsequent to construction until vegetation is established along the slopes. Details of the channel are shown in Figure 3. This channel configuration will safely convey the 1-in-1000 year design storm event.

As discussed in Section 2, microtopography features such as ridges, wattles, and surface roughening will be incorporated into the detailed plan for the waste rock piles. These features will significantly reduce erosion during the most sensitive stage of the remediation, which is immediately after construction and prior to establishment of a self-sustaining vegetation over the cover system. The layout of such microtopography is currently being designed, which will be included in the design drawings. Installation details will be provided in the technical specifications for the other site aspects.

2.4 Summary of Optimized Grading and Cover Design

In follow up to the response to CNSC Comment #5, the waste rock slope and cover design has been optimized as part of the detailed plan for the Gunnar Mine Other Site Aspects in the following manner:

- Waste Rock Slopes > 50 m in length will be graded to 5H:1V;
- Waste Rock Slopes ≤ 50 m in length will be graded to 4H:1V;
- The Channel slopes through the East Waste Rock Pile will be ≤ 30 m in length and will be graded 3H:1V, which is consistent with the configuration in the Preliminary Remediation Design Report;
- Gamma cover thickness will be 0.5 m thick, consistent with the Preliminary Remediation Design Report;
- Microtopography features such as ridges, wattles, surface roughening are currently being designed and the layout for such features will be included in the detailed plan for the other site aspects;

Sincerely,

SRK Consulting (Canada) Inc.

Jordan Graham, EIT
Staff Consultant

Trevor Podaima, PEng
Senior Consultant

Mark Liskowich, PGeo
Practice Leader

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

3 References

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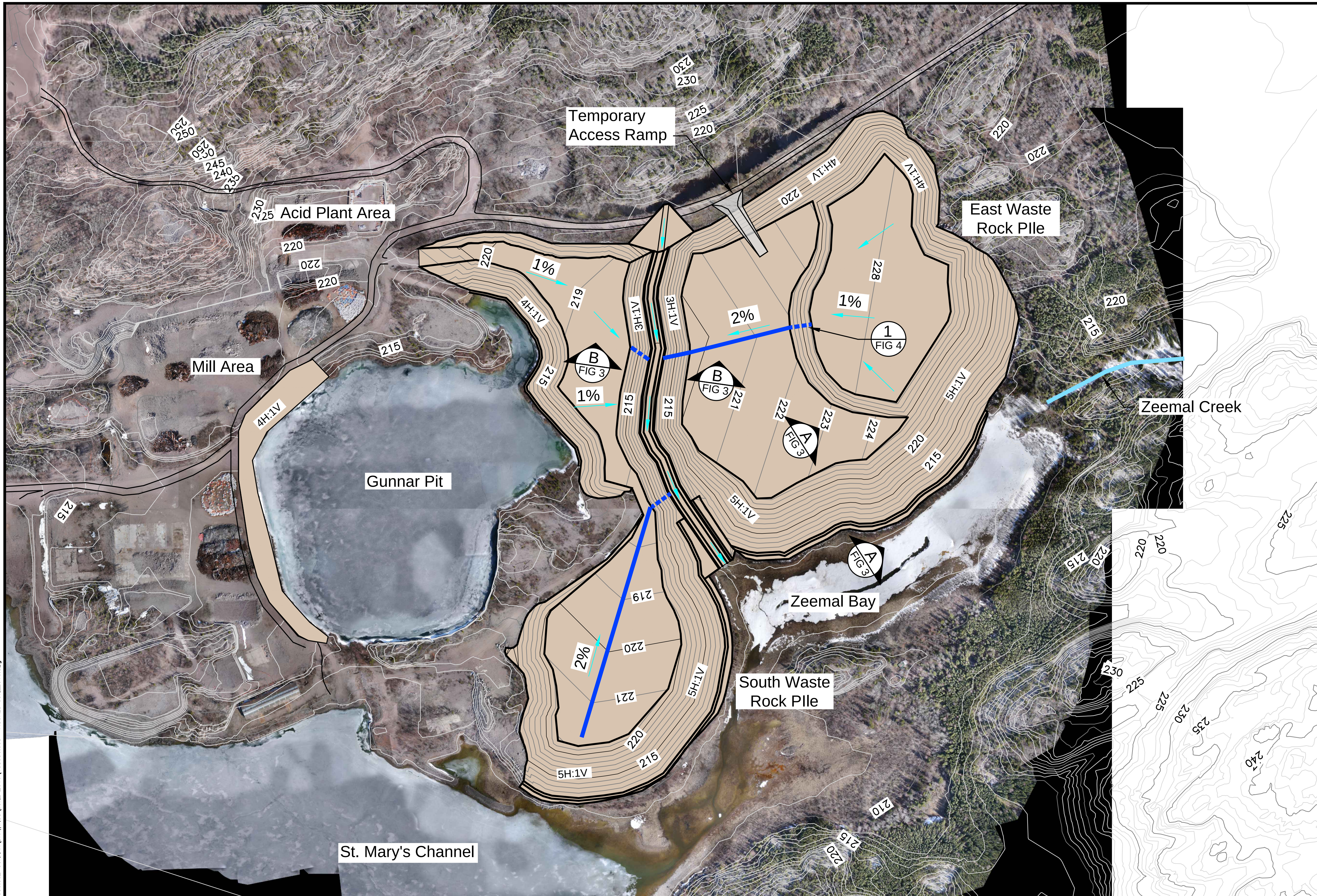
Figures



LEGEND

Re-graded Surface

Coconut Mat Drainage Channel

Rip Rap Drainage Channel

Flow Direction

ISSUED FOR REVIEW

0m 40 80 120 160

1 : 4000

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srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

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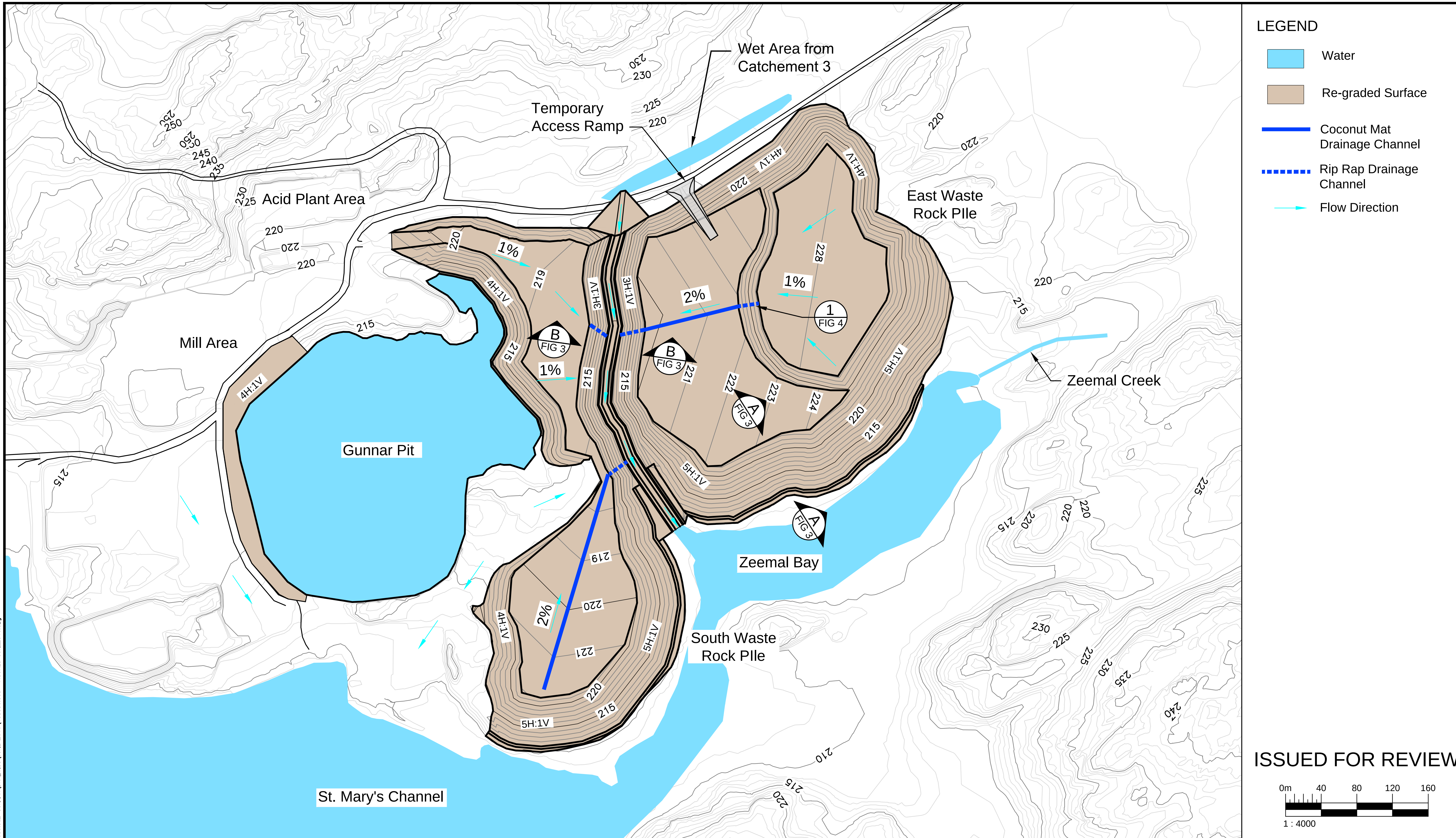
GUNNAR MINE "OTHER SITE ASPECTS"

DETAILED REMEDIATION PLAN

WASTE ROCK RE-GRADING PLAN

DATE:	APPROVED:	FIGURE:
JUNE 2016	TPP/MWL	1



DETAILED REMEDIATION PLAN

WASTE ROCK RE-GRADING PLAN

srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

GUNNAR MINE "OTHER SITE ASPECTS"

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DATE: JUNE 2016

APPROVED: TPP/MWL

FIGURE: 2

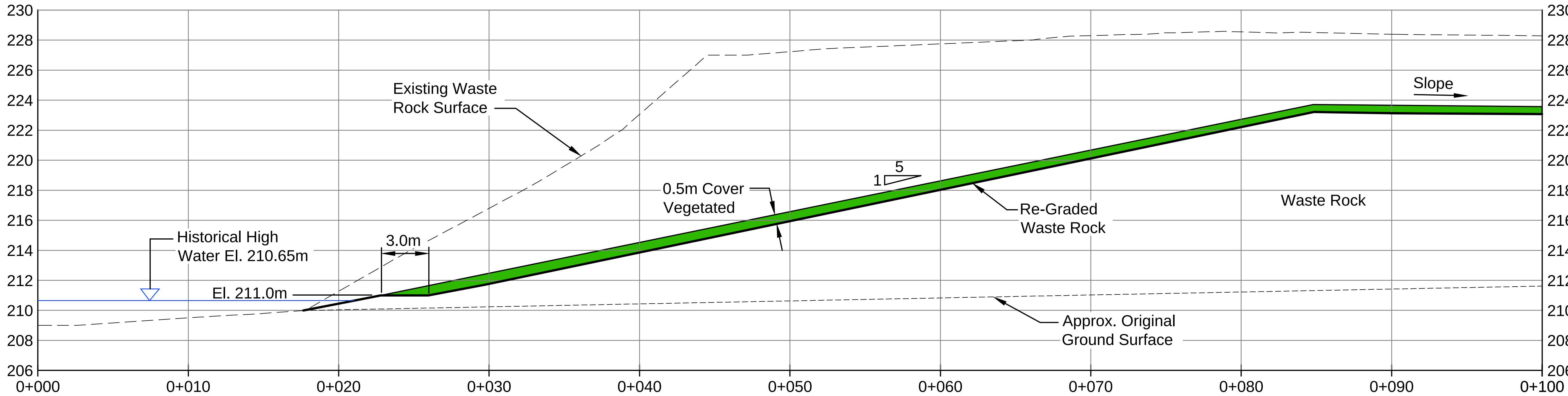

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FIG 1/2

SECTION EAST WRD

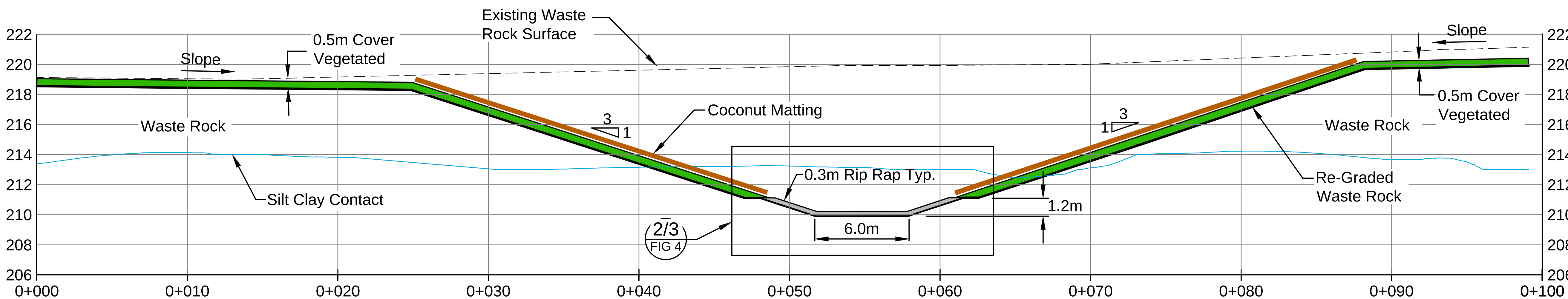

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FIG 1/2

SECTION THROUGH CHANNEL

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GUNNAR MINE "OTHER SITE ASPECTS"

DETAILED REMEDIATION PLAN

WASTE ROCK RE-GRADING SECTIONS

DATE:	APPROVED:	FIGURE:
JUNE 2016	TPP/MWL	3

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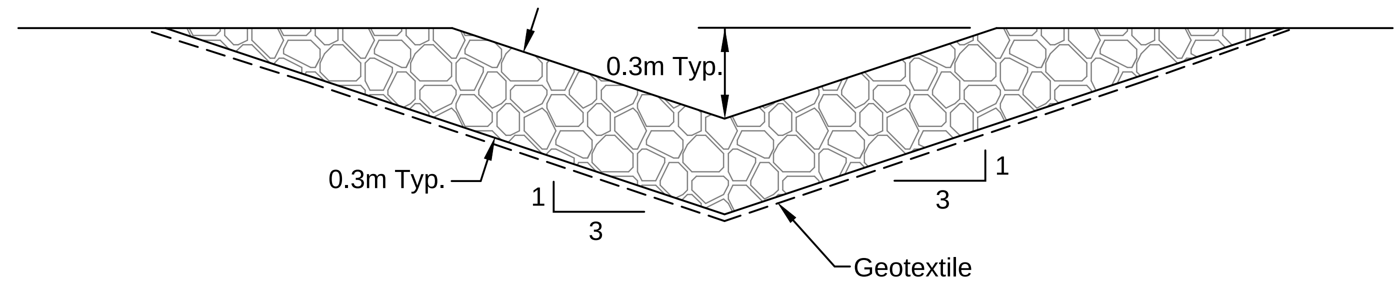

1 FIG 1/2

TYPICAL RIP RAP DRAINAGE CHANNEL SECTION

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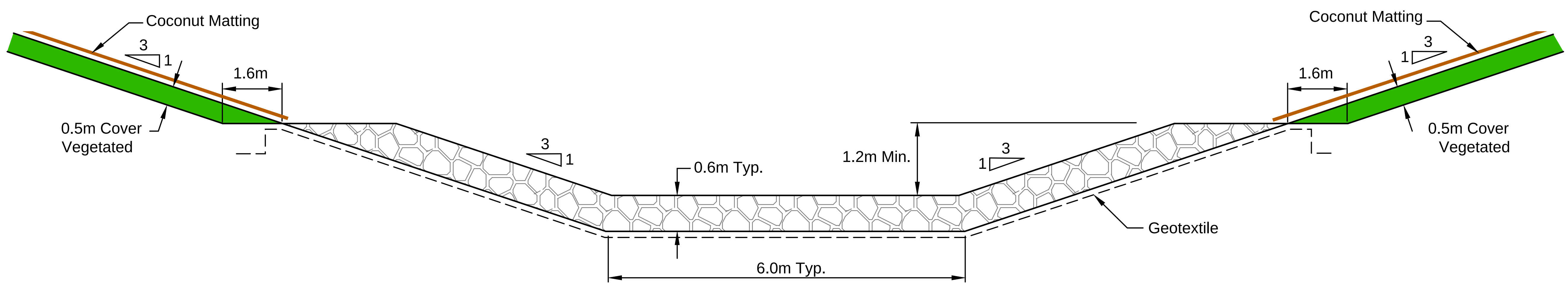

2 FIG 3

MAIN CHANNEL SECTION GREATER THAN 1%

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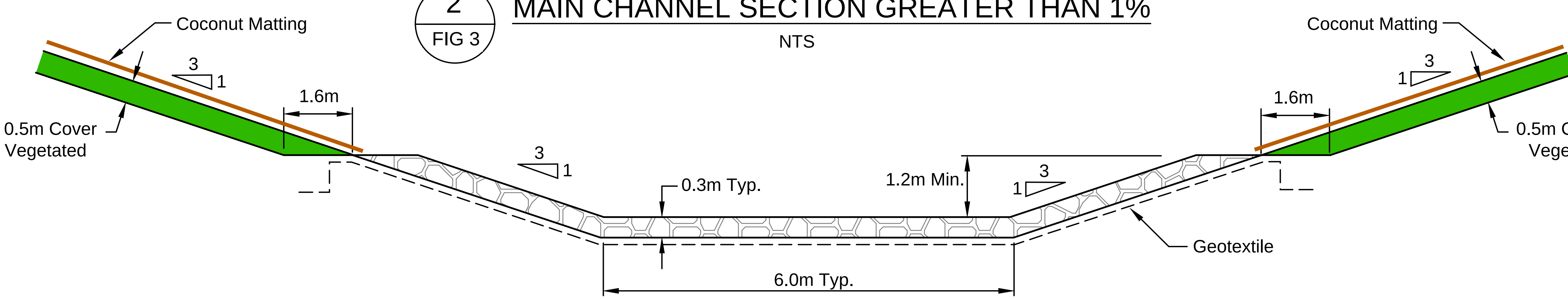

3 FIG 3

MAIN CHANNEL SECTION 1% AND FLATTER

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ISSUED FOR REVIEW

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GUNNAR MINE "OTHER SITE ASPECTS"

DETAILED REMEDIATION PLAN

TYPICAL DRAINAGE AND MAIN CHANNEL SECTIONS

DATE:	APPROVED:	FIGURE:
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Appendix A – DRAFT Gunnar Project “Other Site Aspects” Detailed Remediation Plan – Cover Erosion Analysis

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Memo

To:	Project File	**Client:**	SRC
From:	Jordan Graham, EIT and Erik Ketilson, PEng	**Project No:**	1CS056.003
Reviewed by:	Trevor Podaima, PEng and Maritz Rykaart, PEng	**Date:**	June 25, 2016
Subject:	DRAFT – Gunnar Project “Other Site Aspects” Detailed Remediation Plan Cover Erosion Analysis		

1 Introduction

SRK Consulting (Canada) Inc. (SRK) is currently undertaking the detailed design plan for the “Other Site Aspects” at the former Gunnar Mine, located near Uranium City, SK. SRK’s scope includes the reclamation and detailed design planning for the waste rock piles, and proposed hazardous and non-hazardous landfills.

Determining the potential impacts of water and wind erosion is an important aspect in closure planning particularly when considering the long-term performance of proposed landform designs, as erosion can significantly alter an engineered landscape. Several areas at the former Gunnar Mine (the Site) require landform design including the waste rock piles and landfills. SRK is considering methods of mitigating water and wind erosion during construction, during the post-construction monitoring period, and into long-term passive closure stages. The purpose of this memo is to present the potential soil losses due to sheet and rill water erosion, as well as wind erosion that could occur on the engineered slopes over short-term and long-term periods at the Site. The intent is then to determine what methods of erosion protection are sufficient to reduce erosion to acceptable levels and to characterize what (if any) sacrificial thickness should be added to the cover to account for erosion, without impacting the performance objectives for the cover of a particular area.

In the water erosion assessment, only sheet and rill erosion were considered. Sheet and rill erosion occur as a result of flows that are not concentrated into a particular flow path. Erosion that may occur within channel flow, and the necessary armouring will be discussed as part of the hydrotechnical design of the defined channels, as a separate memorandum.

All calculated erosion estimates are presented as “soil loss”. Soil loss is a mass or depth of eroded material that leaves the slope entirely. Therefore, the estimates within this memo are not representative of the total volume of material that is displaced by wind or water. Material that is detached and deposited on the slope is not included in the estimates for soil loss. The results presented are therefore conservative.

2 Soil Loss Estimation Methods

There are several methods available for estimating water erosion including the Universal Soil Loss Equation (USLE), the Revised Universal Soil Loss Equation (RUSLE) Versions 1 and 2, the Revised Universal Soil Loss Equation for Use in Canada (RUSLEFAC), the Water Erosion Prediction Project (WEPP), Community Surface Dynamics Modeling System's SIBERIA, and many others. Most of these programs take several factors into account to compute soil loss such as climate, topography, soil type, vegetation, and land management practices. The key difference between these methods is that some are based on empirical data while others are based on a mathematical approach using soil physics. The USLE and its variations are largely based on empirical data, while WEPP and SIBERIA are based on soil physics. RUSLE Version 2 is based on empirical data, but uses soil physics to fill in gaps in empirical data.

The USLE was developed in 1960 and then revised in 1978 (RUSLE) by the United States Department of Agriculture. The empirical relationships in the RUSLE were modified by the Provincial and Federal Governments in 2001 for use in Canada (RUSLEFAC). The RUSLEFAC uses metric units and input parameters that apply to Canadian conditions. RUSLE Version 2 is one of the most current soil loss estimation methods and is an update of the RUSLE. RUSLE Version 2 is available only as a computer program, whereas the earlier versions were available as summary documents from which one could learn to calculate soil loss manually. WEPP and SIBERIA are also only available as computer programs.

The soil loss analysis described within this Memo uses only the RUSLEFAC method. The RUSLEFAC has an advantage over other current methods in that it can be calculated manually and the effects of each of the input parameters can be thoroughly understood.

3 RUSLEFAC Scope and Limitations

The RUSLEFAC (Wall et al., 2002) is a tool for calculating sheet flow erosion and rill erosion, and as stated in Section 2, is based on empirical data. The experimental soil plots used to develop the equations were subjected to conditions that generally reflected average annual climatic conditions. Therefore, the intent of the RUSLEFAC is to produce a numerical representation of an average annual quantity of soil loss in the units of tonnes per hectare per year, which can be converted to depth per year given an understanding of the soil's in-situ density. The equation is a useful tool for long term predictions, and can also be used for short term losses; however, due to the nature of the experimental data that was collected to develop the equations, short term estimates are likely associated with a greater degree of error.

The RUSLEFAC has the following limitations:

- It does not accurately estimate soil loss from a single rainfall event. However, the erosivity of a single storm can be estimated using the method described in the RUSLE;
- It does not account for erosional losses once gullies or streams form;
- Although there is some account for erosional losses due to snow melt, the equation does not account for this loss with great accuracy; and

- Freeze/thaw can cause ice lenses in soil that will affect the rate of soil loss: the RUSLEFAC does not take this into account.

Ice lenses typically form in finer grained material with sufficient capillary action. The borrow material that will be proposed in this analysis is relatively coarse material and is not considered susceptible to ice lensing.

4 Design Criteria

Based on the RUSLEFAC, acceptable rates of erosion for the site have been preliminarily estimated at approximately 6 Tonnes per hectare per year. Table 4-1 presents the soil erosion classes included in the RUSLEFAC.

Table 4-1: Soil Erosion Classes

Soil Erosion Class	Potential Soil Loss (T/ha/year)
1. Very Low (i.e. tolerable)	< 6
2. Low	6-11
3. Moderate	11-22
4. High	22-33
5. Severe	> 33

The RUSLEFAC considers Class 1 soils to have:

> "Slight to no erosion potential. Minimal erosion problems should occur if good soil conservation management methods are used... A tolerable soil loss (<6 T/ha/year) is the maximum annual amount of soil which can be removed before the long term natural soil productivity of a hillslope is adversely affected." (Wall et al., 2002).

Although 6 Tonnes per hectare per year is considered an acceptable rate of erosion, landform designs at the Gunnar Site should yield the least amount of erosion possible. Establishing long term vegetation on the engineered landforms should be one of the primary objectives of the design. Recommendations for short-term (i.e. during construction) management practices will be provided as part of the detailed remediation plan to limit erosion and provide a suitable substrate for the vegetation to establish.

5 RUSLEFAC Equation

The RUSLEFAC equation is calculated manually by first determining several inputs. The RUSLEFAC equation is:

$$A = RKLSCP$$

Where,

A is the potential long term average annual soil loss in tonnes per hectare. *A* can be converted to depth per year if the density of the soil is known.

R is the rainfall factor, which is expressed in energy multiplied by depth over area times duration (MJmm/hah), is calculated using the equation:

$$R = EI$$

Where *E* is the volume of rainfall and runoff (mm/ha) and *I* is the prolonged peak rate of detachment that occurs with runoff (MJ/h).

- R value contours (isoerodent maps) have been developed by the Government of Canada and are included in the RUSLEFAC document (Wall et al., 2002). To determine the R value in a particular area, interpolation between contours is often required.
- R can be calculated for a single storm event using the R equation if the storm distribution is known or can be estimated.

K is the soil erodibility factor, which is expressed in terms of are multiplied by duration over energy times depth (hah/MJmm).

- *K* is dependent on the sand content, fine sand content, silt content, organic matter content, soil structure, and permeability of the soil.
- *K* is determined by applying the appropriate parameters to the soil erodibility nomograph included in the RUSLEFAC.

L is the length of slope factor (dimensionless)

S is the slope steepness factor (dimensionless)

- *L and S* are typically presented as a single value.
- The *LS* factor represents a ratio of soil loss in comparison to a “standard plot”, which is an experimental plot that has a steepness of 9% and a slope length of 22.13 m. Charts based on experimental data are included in the RUSLEFAC document (Wall et al., 2002), which is used to determine the *LS* factor.

- The *LS* factors presented in the RUSLEFAC are representative of straight slopes, but can be manipulated to represent complex slopes (i.e. convex, concave, slopes with benches).

C: the cover factor (dimensionless)

- *C* is *dependent* on the vegetative cover and the land use.
- This factor is based on tables available in the RUSLEFAC document (Wall et al., 2002).

P: the support practice factor (dimensionless)

- The support practice factor accounts for the effects of practices that may reduce the volume or rate of runoff water by altering the flow pattern, surface grade, or direction of surface runoff.

6 RUSLEFAC Inputs

To determine the impact and sensitivity of the input variables on soil loss, a range of values were used for each variable. The ranges of input values are discussed in the following subsections. The results of the analyses using the discussed ranges of input values are included in Section 0.

6.1 Erosivity/Rainfall Factor (R)

Annual erosivity represents the precipitation energy that causes soil loss over the course of an average year. The annual erositivity value should be used to determine the cumulative soil loss over a long period of time.

Storm event erosivity should be used to determine short term soil loss. As discussed in Section 3, the degree of accuracy of soil loss predictions for single storm events is relatively low.

6.1.1 Annual Erosivity

Annual R values are not shown on the Canadian Isoerodent Maps in Northern Saskatchewan near the Site. The farthest north that the maps extend is near Island Falls, Saskatchewan: the R value in this area is 400 MJmm/hah. Values in northern BC, Ontario and Quebec that have similar latitude and climate (and in the case of Ontario and Quebec, are also in the Canadian Shield) to that of the site are also shown on the isoerodent maps. Values in these areas are also similar to 400 MJmm/hah. Therefore, an annual R value of 400 MJmm/hah was used for the Site.

6.1.2 Storm Event Erosivity

Erosivity was calculated for single storm events using the method described in Wischmeier and Smith, 1978. The storm events were determined using intensity-duration-frequency curves for Stoney Rapids (Environment Canada, 2014). Single storm distributions are not available from Environment Canada and were estimated using a second quartile Huff distribution (Huff, 1990). The storm events erosivity values are presented in Table 6-1.

Table 6-1: Storm Event Erosivity Values

Storm Event	Total Precipitation (mm)*	Erosivity (MJmm/hah)
1 in 100 year, 24 hour	85	469
1 in 200 year, 24 hour	95	528
1 in 200 year, 24 hour (adjusted for estimated effects of climate change)	118	665

*Total precipitation for the 1 in 200 year climate change event was obtained from the Site Hydrology Review and Update Memorandum (SRK, 2016).

6.2 Soil Erodibility Factor (K)

SRK understands that Borrow Area 6W will be available for use on the landfills, waste rock piles, and other areas included in the “other site aspects” that require cover (Figure 1). Two test pits were excavated and sampled in Borrow Area 6W (Golder, 2013). The material in this area primarily consists of sand and gravel, with little silt or clay. This material was evaluated using the soil erodibility nomograph (Wall et al., 2002); the resulting K value was 0.09 (the two samples yielded very similar results).

Three representative soils from the August, 2015 field sample program (O’Kane, 2015) were also evaluated separately using the soil erodibility nomograph: a coarse textured soil, a medium-coarse textured soil, and a medium-fine textured soil, all from Borrow Area 5. SRK understands that it is unlikely that this material will be used for the “other site aspects”; however, the soils were assessed to determine how borrow from a different area would compare to that of Borrow Area 6W. The K values were 0.027, 0.038 and 0.099, respectively.

6.3 Length and Slope Steepness Factors (L&S)

Several different straight and complex slopes were assessed. Straight slopes of 6H:1V, 5H:1V, 4H:1V, 3H:1V, and 2H:1V were each assessed for lengths of 10 m up to 200 m. A variety of complex slopes were assessed that each had an average slope of 4H:1V and a length of 100 m. The complex slopes were assessed for the same length and slope to show the comparative difference between each type of slope. The complex slopes included four concave slopes (consisting of two to four straight segments), a straight slope with one 10 meter bench, and a straight slope with two 10 meter benches (the straight portions consisted of 4H:1V slopes, therefore the overall slope was substantially flatter than 4H:1V). The types of slopes that were assessed are illustrated in Figure 2. The drawing indicates the horizontal to vertical slopes, but it is not drawn to scale.

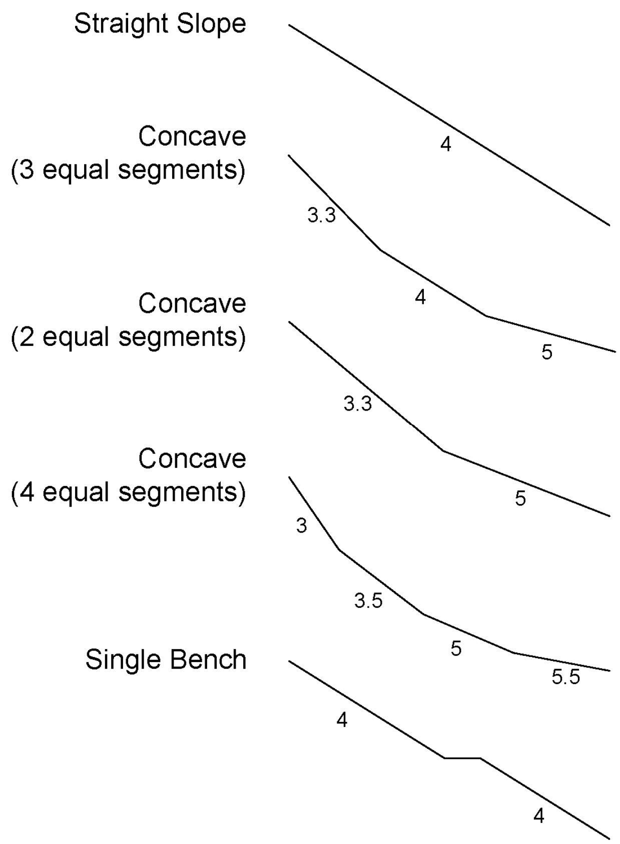

Figure 2: Types of Slopes Assessed

6.4 Cover Factor (C)

The *C* factor was determined using Table C-5 in the RUSLEFAC. Values decrease with lesser cover (yielding lesser soil loss). The value for bare, undisturbed soil with no vegetative canopy (canopy is considered having plants/weeds/shrubs of 0.5 m height or greater) or surface cover is 0.45. The value for 40% small, short-rooted plant coverage with no canopy is 0.15, and the value for 40% small, short-rooted plant coverage with a taller plant canopy is 0.13. Increasing small, short-rooted plant coverage to 80% with canopy decreases the cover factor to 0.04.

6.5 Support Practice Factor (P)

The design will not include long term protective measures of any kind; therefore, the P factor will not impact the soil loss equation and was made equal to one. The support practice factor is proportional to soil loss (i.e. a support practice factor of zero will yield zero soil loss).

7 Results and Discussion

The figures within this section show soil loss in units of Tonnes per hectare per year (T/ha/year) and in millimeters per year (mm/year). The depth per year values were determined using an average dry density of 1.7 T/m³. The depth represents the average depth of soil loss over the entire erodible surface area. The guideline values of 6 T/ha/year corresponds to a depth of 0.35 mm/year. The guideline values are not shown on Figures 5, 6, and 7, as these figures are intended to show the relative difference of how certain parameters affect erosion, and were not necessarily intended to show the design slopes that will be selected at the site.

7.1 Straight Slopes

Figure 3 illustrates the expected straight slope soil loss if no vegetative cover is established. For slope lengths shorter than 50 m, slopes as steep as 5H:1V will meet the guideline of 6 T/ha/year. If 4H:1V slopes are used for 50 m slope length, the expected soil loss will approach 10 T/ha/year.

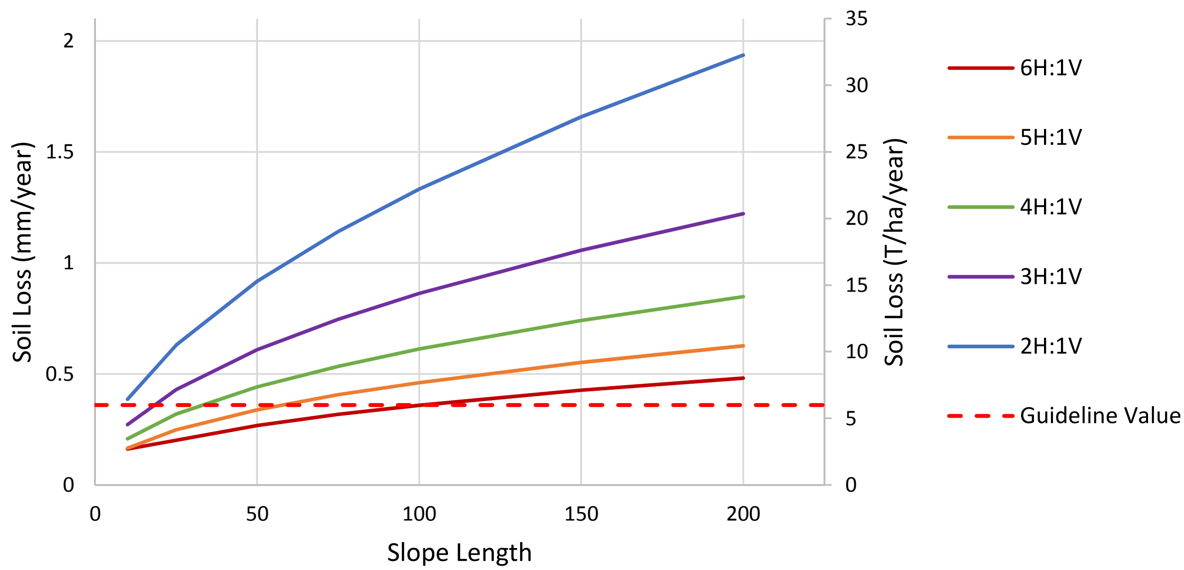

Figure 3: Straight slopes using Borrow Area 6W Material with no vegetative cover

7.2 Effects of Vegetation

Figure 4 illustrates the expected straight slope soil loss with 40% small, short-rooted plant coverage and no vegetative canopy. For slope lengths shorter than 100 m, slopes as steep as 3H:1V will meet the guideline value. Comparing Figure 3 and Figure 4 shows that established vegetation significantly reduces soil loss due to water erosion.

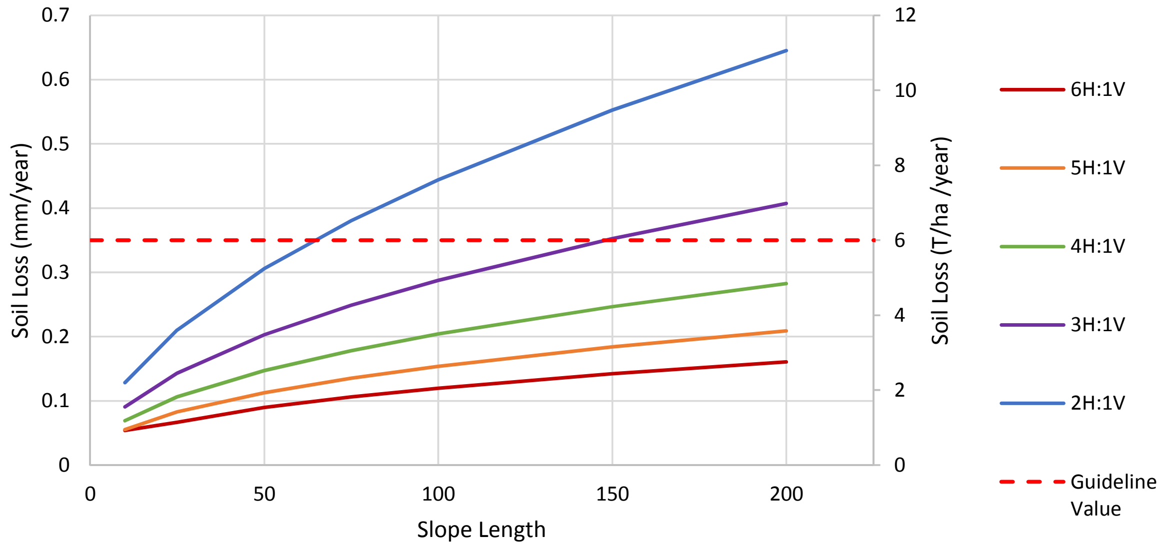

Figure 4: Straight slopes using Borrow Area 6W Material with 40% small, short-rooted plant coverage and no vegetative canopy

7.3 Effects of Complex Slopes

The soil losses for 100 m long complex slopes at 4H:1V are shown in Figure 5. The figure indicates that each of the complex slopes yields less soil loss than an equivalent straight slope. A slope with two 10 meter benches sloped outwards at a 1% grade yielded the least soil loss in this analysis; soil loss was reduced by 15% from that of a straight slope. Complex slopes were somewhat effective at reducing soil loss in this analysis: soil loss was approximately 9% less on concave slopes than on straight slopes. Although only 100 m, 4H:1V slopes are presented, SRK has determined via the RUSLEFAC, the reduction in soil loss on complex slopes is similar for other slopes and slope lengths in the same order of magnitude (i.e. 5H:1V slopes, 50 to 125 m slope lengths). The soil loss reductions are expected to be less similar to those presented if the slope length or steepness is increased substantially. The values in Figure 5 are representative of a surface consisting of material from Borrow Area 6W with no vegetative cover.

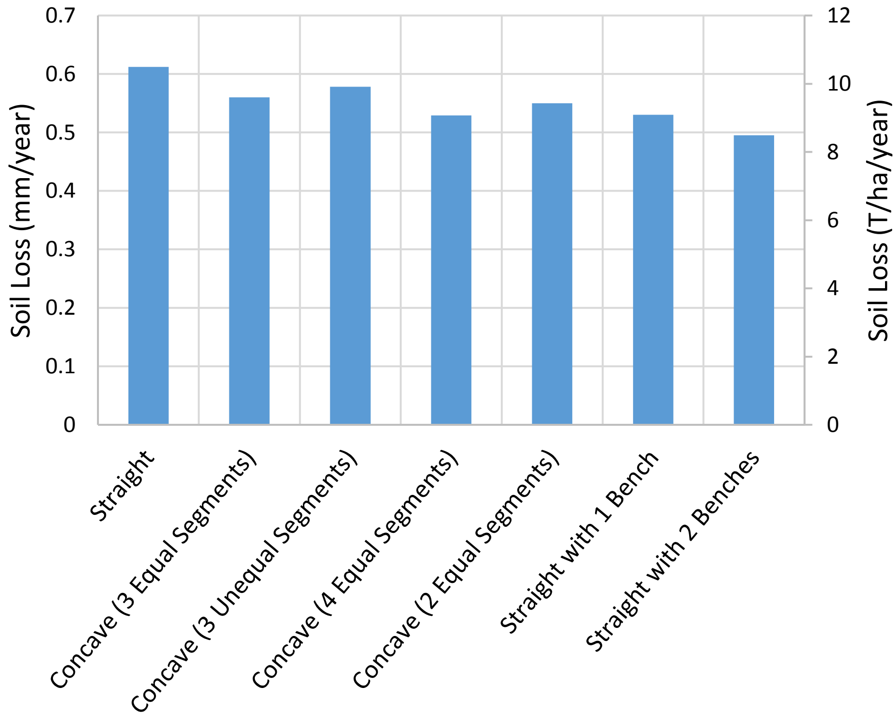

Figure 5: Complex Slope Comparison (100 m long at 4H:1V and no vegetative cover)

7.4 Effects of Soil Type

The effects of soil type are presented in Figure 6. Each of the soil loss estimates are based on 100 m long 4H:1V straight slopes, and no vegetative cover. The figure indicates that the material from Borrow Area 6W will erode less than the other materials that were assessed. The coarse and medium-coarse material could potentially be used with different slopes, slope lengths, and vegetative cover. The medium-fine material is highly erodible and should not be used for the “other site aspects”.

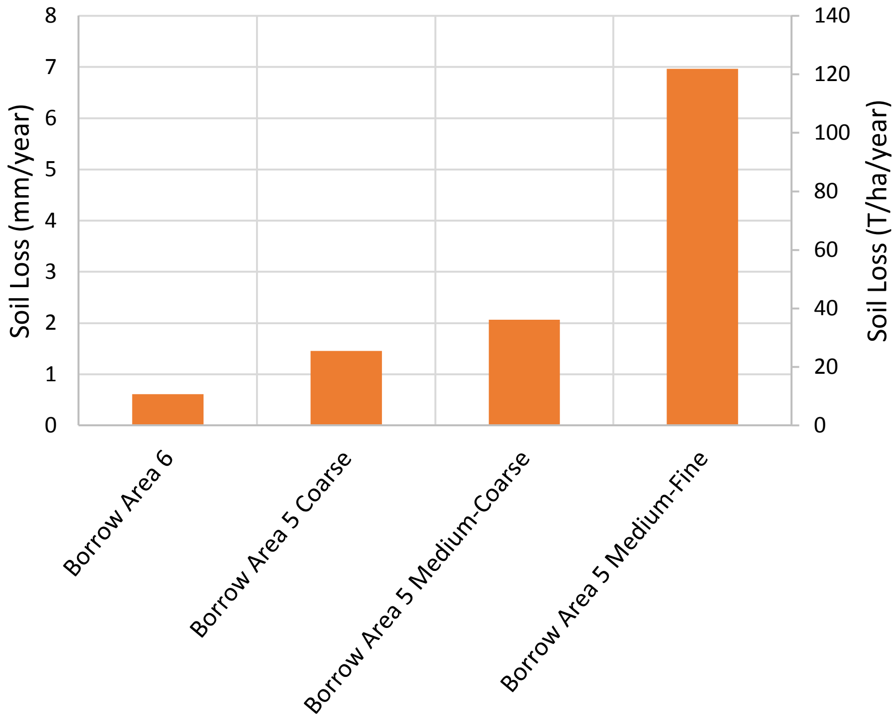

Figure 6: Soil Type Comparison (based on 100 m long 4H:1V straight slopes)

7.5 Effects of a Storm Event

The effects of erosivity resulting from major storm events are presented in Figure 7. Each of the soil loss estimates are based on 100 m long 4H:1V straight slopes, with material from Borrow Area 6W and no vegetative cover. Annual soil loss is included in blue as a relative reference. The figure shows that major storms have a greater impact than the average erosion that is expected to occur over the course of an entire year. However, based on this analysis, only the 1 in 200 year, 24 hour, storm that accounts for climate change caused greater than an average depth of one millimeter of soil loss.

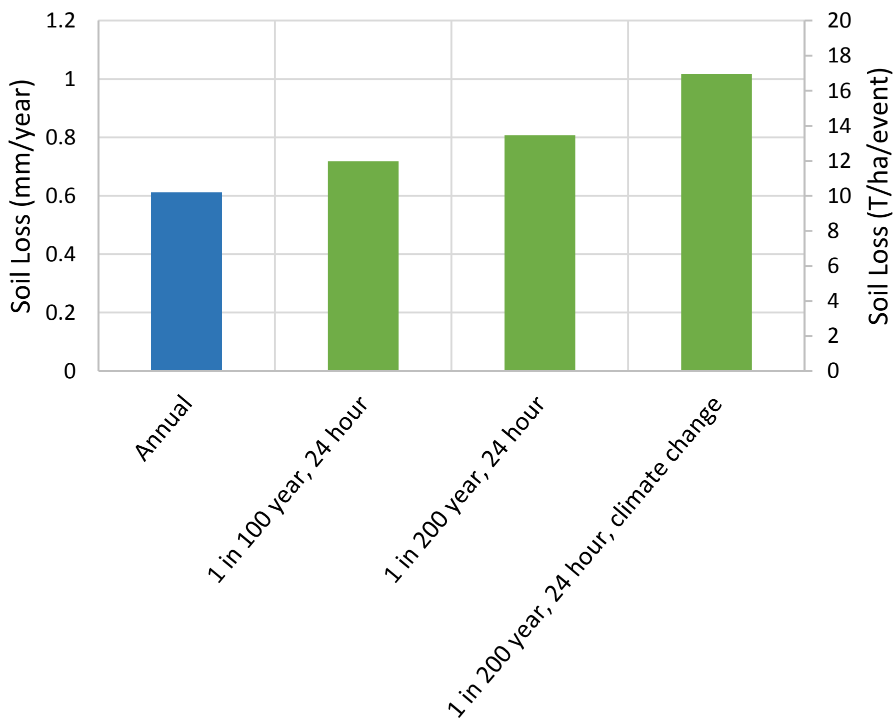

Figure 7: Storm Impacts Comparison (no vegetation)

8 Wind Erosion

Wind erosion was estimated using the Wind Erosion Model presented by Skidmore (1994) and the USDA (2002). Wind erosion is a function of the soil's erodibility, inflection points on the slope, ridges that may be present on the slope (tilled ridges), surface roughness, the local climate, the size of the exposed surface, and the vegetative cover. Wind speed, temperature and precipitation values from the 1961-1990 Climate Normals for Uranium City were used as inputs to the model.

8.1 Effects of Vegetation

The effects of vegetation on erosion are significant. In this analysis using the material from Borrow Area 6W, the addition of the same vegetation coverage in that of the water erosion analysis (40% small, short-rooted plant coverage, no canopy) reduces soil loss due to wind erosion to an insignificant quantity relative to loss due to water erosion. Therefore, the wind erosion estimates presented in the following sections are for bare soil with no vegetation.

8.2 Effects of Soil Type and Surface Area

As stated in Section 8.1, soil from Borrow Area 6W (Golder, 2013) was used in the wind erosion analysis. Two areas within Borrow Area 6W were test pitted and analyzed for grain size: one test has shown to be more susceptible to wind erosion than the other. Wind erodibility was assessed for both samples.

The size of the exposed area is somewhat proportional to soil loss. Table 8-1 presents high and low soil loss estimates (based on soil type) for different sized areas.

The slope inflection points, tilled ridges, and surface roughness were all held constant in the computations that produced the values in Table 8-1, and were set to standard values (i.e. a flat surface with no ridges and minimal roughness) that would not significantly influence the model.

Table 8-1: Soil Loss Due to Wind Erosion (no ridges or roughness)

Area		More wind erosion susceptible material		Less wind erosion susceptible material	
Site Area	**Approximate Size**	**Soil Loss (T/ha/year)**	**Soil Loss (mm/year)**	**Soil Loss (T/ha/year)**	**Soil Loss (mm/year)**
Mill Area Landfill	70m x 70m	5.5	0.32	0.0	0.00
Acid Plant Area Landfill	150m x 50m	6.4	0.38	0.1	0.01
South Waste Rock Pile	300m x 250m	14.9	0.88	1.8	0.11
East Waste Rock Pile	400m x 300m	15.1	0.89	1.8	0.11

As shown in Table 8-1, soil losses from wind erosion increase with increasing size of the exposed area and with the erodibility of the material.

8.3 Effects of Surficial Ridges and Roughness

Ridges and surficial roughness can substantially reduce wind erosion. The values in Table 8-2 were computed by adding ridges that were 15 cm high, spaced 2 m apart, and perpendicular to the predominant wind direction; a moderate increase in surface roughness was also made. An increase in surface roughness can be achieved if the material is not compacted with a flat roller. All other parameters that were used in Table 8-1 were held constant.

Table 8-2: Soil Loss Due to Wind Erosion (ridges and roughness accounted for)

Area		More wind erosion susceptible material		Less wind erosion susceptible material	
Site Area	**Approximate Size**	**Soil Loss (T/ha/year)**	**Soil Loss (mm/year)**	**Soil Loss (T/ha/year)**	**Soil Loss (mm/year)**
Mill Area Landfill	70m x 70m	0.3	0.02	0.0	0.0
Acid Plant Area Landfill	150m x 50m	0.5	0.03	0	0.0
South Waste Rock Pile	300m x 250m	3.0	0.18	0.1	0.0
East Waste Rock Pile	400m x 300m	3.6	0.21	0.2	0.0

In all cases assessed at the site, the addition of ridges and surface roughness reduce soil loss due to wind erosion by greater than 75%.

9 Design Life Soil Loss

Soil loss over the course of the design life was calculated to determine whether the average depth of soil loss would reduce the initial cover thickness to below the cover thickness required for gamma radiation reduction. Annual soil loss due to water erosion was multiplied by 100 years to determine design life soil loss, which is presented for several straight slope scenarios in Table 9-1. Material from Borrow Area 6W was used to calculate the design life soil loss. The total loss varies from 8 mm to 86 mm depending on the slope grade, the slope length, and the vegetative cover.

Table 9-1: Calculated Water Erosion Design Life Soil Loss

Slope Condition		Design Life Soil Loss (mm) per Slope Length			
		25 m	**50 m**	**75 m**	**100 m**
Non-Vegetated	**3H:1V**	43	61	75	86
	4H:1V	32	44	53	61
	5H:1V	25	34	41	46
Vegetated (40% Short-Rooted Plant Coverage, No Canopy)	**3H:1V**	14	20	25	29
	4H:1V	11	15	18	20
	5H:1V	8	11	14	15

Design life soil loss was also calculated for the wind erosion scenarios presented in Section 0. Design life soil loss due to wind erosion with no ridges and little surface roughness is shown in Table 9-2, while design life soil loss in the scenario that includes ridges and moderate surface roughness is included shown in Table 9-3.

Table 9-2: Calculated Wind Erosion Design Life Soil Loss (no vegetation, no ridges, flat surface)

Area		Design Life Soil Loss (mm)	
Site Area	**Approximate Size**	**Borrow Area 6W (More wind erosion susceptible material)**	**Borrow Area 6W (Less wind erosion susceptible material)**
Mill Area Landfill	70m x 70m	32	0
Acid Plant Area Landfill	150m x 50m	38	1
South Waste Rock Pile	300m x 250m	88	11
East Waste Rock Pile	400m x 300m	89	11

Table 9-3: Calculated Wind Erosion Design Life Soil Loss (vegetation, ridges, moderate roughness)

Area		Design Life Soil Loss (mm)	
Site Area	**Approximate Size**	**Borrow Area 6W (More wind erosion susceptible material)**	**Borrow Area 6W (Less wind erosion susceptible material)**
Mill Area Landfill	70m x 70m	2	0
Acid Plant Area Landfill	150m x 50m	3	0
South Waste Rock Pile	300m x 250m	18	1
East Waste Rock Pile	400m x 300m	21	2

Appropriate values from Table 9-1 and Table 9-2 or Table 9-3 can be summed to determine the total soil loss for a particular area and slope condition.

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Figures

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srk consulting

SRC SASKATCHEWAN RESEARCH COUNCIL

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GUNNAR MINE "OTHER SITE ASPECTS"

DETAILED REMEDIATION PLAN

BORROW AREA LOCATIONS FOR EROSION ANALYSIS

Date:	Approved:	Figure:
June 2016	JG	1

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Appendix B – Responses to CNSC Comments

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Project No: 1CS056.002

Project Manager, Gunnar Site
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Attention: Christopher Reid

Dear Mr. Reid:

Responses to the CNSC Review Comments of SRC's Gunnar Site Remediation Project – Gunnar Mine "Other Site Aspects"

Comment 1:
The MAA in Table 5-5 needs further information to improve the clarity and transparency needed to properly support the approach for remediation (e.g. excavating waste rock down to the original channel bed). For example, Table 5-5 contains a blank space in the cell where the advantages of backfilling the pit could be listed. Furthermore, there is no mention of several disadvantages of backfilling the pit such as the risk of worker safety related to potential collapse of backfilled waste rock in underground workings in the pit bottom and the requirement of perpetual treatment of contaminated water from the pit. SRC is expected to provide a clear and transparent discussion of the advantages and disadvantages of backfilling both waste rock piles into the pit versus excavating a channel and covering the remaining waste rock piles.

SRK Response:
In the following SRK responses, the Gunnar Mine "Other Site Aspects" Preliminary Design Report will be referred to as the "Draft Report" (SRK 2015) and the Gunnar Site Remediation Project Environmental Impact Statement as "EIS" (EIS 2013).

Section 5.0 as well as Tables 5-1, 5-2, 5-3 and 5-5 in the Draft Report will be revised so that advantages and disadvantages for each of the proposed remedial options are clear and transparent. For example, SRK will elaborate on the advantages and disadvantages of backfilling the Open Pit (Section 5.3), which will include:

Advantages of Backfilling Open Pit

- Potential to completely reduce the source load from waste rock deposits and impacted sub-soil as all of this material will be excavated and stored in the pit.
- Consolidation of non-contaminated and contaminated demolition debris, waste rock and impacted sub-soil below waste rock piles.

Disadvantages of Backfilling Open Pit

Human Health / Ecological / Active Remediation Risks

- Degree of Adaptive Management is poor as it will be extremely difficult to remove material from the Open Pit (not practical). Creating the potential for perpetual treatment.
- Disturbance from material placement in the Open Pit will cause mixing that may re-suspend contaminants.
- In regards to contaminated demolition debris, the majority of hydrocarbons on site have a density of <0.8 g/ml and may float. Creating the potential for hydrocarbons to remain on the surface of the pit water resulting in additional water treatment needs or mobilization of hydrocarbons to Lake Athabasca.
- If the Open Pit is completely filled and covered, there is risk of settlement/deformation into the underground workings. Significant borrow material volumes may be required, which will increase the borrow area footprints. If placement occurs within a water filled Open Pit, quality control during filling will be difficult and the absence of compaction may lead to significant deformation and subsidence.
- The volume of fill required to backfill the Open Pit is approximately 3.5 Mm^3 (SRC 2013, Appendix H). The combined volume of the East and South Waste Rock Piles is approximately 2.2 Mm^3, which will be reduced as the tailings cover requires approximately 820,000 m^3 of waste rock. If other waste rock areas at the site are not utilized as backfill, additional borrow will be required increasing the overall borrow source footprint.
- Placement of material in the pit during remediation has greater health and safety risks compared to other remedial options. Safety risks associated with placement include:
  - Potential collapse of underground workings at the bottom of the Open Pit (SRC 2013, Appendix F).
  - If the Open Pit is not dewatered, a more complex disposal method may be required for safe placement and to reduce disturbance to the Open Pit sidewalls (barge, conveyors or rock chutes).
  - Physical stability of the Open Pit walls may be compromised if dewatered prior to placement of debris, waste rock and/or soil (SRC 2013, Appendix F).

Construction / Feasibility / Efficiency

- Highest cost compared to other remedial options. Large volumes of material to be hauled to the Open Pit and water treatment is a significant cost.
- Perpetual water treatment may be required if the Open Pit is not completely filled and covered.
- The footprint of the excavated waste rock piles will require a cover.
- If the Open Pit is backfilled in a non-flooded state, the pit walls will require stabilization and access into the Open Pit may need to be established based on placement method.
- Geotechnical instrumentation will need to be established to monitor the Open Pit during remediation. This may include monitoring wells, piezometers and slope inclinometers.

Comment 2:
Site specific remedial objectives (SSROs) presented in Table 3-2 are higher than the current water quality conditions in Zeemel Bay and St. Mary's Channel. In the past, Environment Canada (EC-6) questioned the acceptability of the Surface Water Remedial Objectives in the Gunnar EIS and the local communities have expressed concerns about elevated SSROs. SRC needs to demonstrate that SSROs will be re-evaluated to reflect improvements in water quality that are expected to occur over time and to demonstrate that the remediation project is in line with the practices of pollution prevention and keeping releases as low as reasonably achievable (ALARA).

The absence of an objective for Ra-226 in particular needs to be addressed as the relative hazards of uranium and Ra-226 (and other radioactive daughters) are fundamentally different (chemical toxicity versus radiotoxicity). Stakeholder concerns about radioactivity in the aquatic environment, and the ability of Ra-226 to act as an indicator of the presence of other "hard-to-measure" radionuclides (Addendum to this memo) are other factors to be taken into consideration in developing more comprehensive SSROs.

SRC is expected to re-evaluate the SSROs to reflect the existing water quality in Zeemel Bay, long-term water quality improvements expected at the site, and what is sustainable at this remote site. Furthermore, a SSRO value for Ra-226 should be developed.

SRK Response:
The overall objective of the Gunnar Mine Remediation Project (Project) is to reduce the risks that the site poses to human health, safety of the public, and integrity of the environment. This objective includes the "practices of pollution prevention and keeping releases as low as reasonably achievable (ALARA)". As documented in the Project's approved EIS (SRC 2013), in order to assist with the development of remedial options for the site, site specific remedial objectives (SSROs) have been developed for the discharge of site waters to the receiving environment.

Implementation of the remedial options described in the Draft Report will result with reductions of concentrations of contaminants of potential concern (COPC) to levels well below the SSROs, with the overall objective of meeting Canadian Environmental Quality Guidelines (CEQG) and/or Saskatchewan Surface Water Quality Objectives (SSWQO) in St. Mary's Channel and Zeemel Bay.

The rationale and objectives for the development of the SSROs are provided in detail in the Project's approved EIS (SRC 2013, Appendix J). The development of these SSROs was largely based on the results of the Human Health and Ecological Risk Assessment and did consider the chemical and radiotoxicity of uranium and radium-226. Ultimately the decision, as stated in Appendix J of the EIS, was made to not develop a SSRO for radionuclides in surface waters. Rather it was recommended and ultimately approved through the assessment process completed for the Project, that risks to human populations be controlled through enforcement of fish consumption advisories and continued monitoring of the expected declines in fish tissue radionuclide concentrations post remediation (SRC 2013, Appendix J). Although the SSROs will be considered during the post remediation monitoring program, the intent of the remediation program, and its level of success, will be to compare the monitoring results against Canadian and Saskatchewan water quality guidelines.

Comment 3:

The proposed plan measures remediation success in Zeemel Bay based on general surface water quality objectives. This is an insufficient means to track the success of remediation and to confirm a major reduction in loadings to the receiving environment. The choice of the excavated channel through the waste rock pile is based on model predictions of water quality in Zeemel Bay. It is recommended that water quality objectives or indicators be developed to monitor loadings to the environment at or near the source of contamination and to monitor water quality in upper Zeemel Bay. SRC is expected to also describe what kind of contingency measures are in place should concentrations in future years deviate from predicted values.

SRK Response:

Zeemel Bay has been identified as the immediate receiving environment for the Catchment 3 drainage (area directly east of Gunnar Main Tailings that drains towards the East Waste Rock Pile). As such, the potential impact to the surface water being conveyed by the waste rock channel into Zeemel Bay will be monitored extensively, with at least one of the monitoring stations being located in Zeemel Bay as proposed in the SRK Draft Report. A detailed Monitoring Management Plan will be developed as part of the next phase of engineering of the Gunnar Mine "Other Site Aspects". This Management Plan will, among other things, outline a series of monitoring stations and analytes focused on monitoring the results of the remediation activities such as the excavated channel and ultimately the reduced loadings of COPC in Zeemel Bay.

A Failure Modes and Effects Analysis (FMEA) is scheduled as part of the next phase of engineering for all aspects of remediation design associated with the "Other Site Aspects". This exercise will identify all potential areas where the remediation designs could fail and the associated results of these potential failures. Subsequently, any adjustments and/or contingencies required to the engineering design will be developed and incorporated into the "next phase" design report.

Comment 4:

In the EIS, the proposed and assessed design storm for the surface water drainage systems was a 1,000-year storm, but SRC uses a 200-year design storm in the current report without explanation. This is a significant reduction of flood protection capacity from the EIS. SRC should provide justification for reducing the design storm from 1,000 years in the EIS to 200 years in the current report. Selection of design storm duration needs to take into consideration the drainage basin size. SRC proposes to use a 24-hour design storm without justification. For such smaller drainage basins, the maximum peak flow will most likely be generated by a design storm with a shorter duration. As such the 24-hour duration storm may not be conservative. SRC is expected to conduct a design storm duration analysis to select a design storm duration that would generate the maximum peak flow rate.

SRK Response:
It is standard engineering practice to use a 200-year return period for surface water drainage systems that have a low consequence classification. The proposed channels and ditches in the Draft Report were considered to have a “low consequence classification” as damage and loss related to a failure were deemed to be minimal.

The primary channel through the waste rock includes an over-designed (6 m) base width to facilitate construction, and the channel side slopes extend approximately 6 to 8 m into the covered waste rock piles. An extreme design storm event, such as a 1,000-year return period, would not result in overtopping of the channel. Further, the height of riprap within the channel was set to the high water level mark in Lake Athabasca, which is above the design depth for the 200-year event, and will prevent erosion of the cover material on the side slopes under larger return periods. Notwithstanding this, an additional measure of protection has been incorporated into the design in the form of a coconut fiber erosion control mat that will be placed along the channel side slopes above the riprap armoring.

The peak flow estimate was based on a regional analysis of peak flows sourced from nearby gauging stations. The peak flow data is not based on a 24-hour duration, but includes all storm durations. A unit flow of 1 $m^3/s/km^2$ was used in the water drainage system designs, and is a conservative estimate (Figure 8, Draft Report). This rate is notably higher (approximately twice as high) than unit flows experienced at the regional gauges. The 24-hour duration rainfall was only used for the pit inflow estimate, since the 24-hour rainfall will produce the highest runoff volume. A shorter duration event may produce a higher peak flow rate, but will result in a smaller volume of water over the course of the event.

As stated in the Draft Report, a FMEA will be completed in the next phase of engineering to confirm the consequence classification and to address all aspects associated with the water drainage system designs such as storm event return period, storm duration, channel/ditch configurations, and extent of armoring.

Comment 5:
The landform design of Gunnar other site aspects remediation is to promote use of a landform consistent with current landscape, promote sustainable vegetation, ensure positive drainage, and reduce erosion potential. The landform designed should not only be stable geotechnically, but should also maintain the long-term integrity of the remediated features such as the waste rock pile and the landfill. The side slopes of the landfill containment structures for non-contaminated demolition debris and for contaminated and hazardous materials, and the side slopes of waste rock piles are designed with a gradient of 1V:3H without sufficient justification for their long term integrity. The experience from mine reclamation in northern Saskatchewan such as the Cluff Lake waste rock pile reclamation and the Rabbit Lake waste rock pile reclamation implies that a gentler landform slope is needed in order to ensure the integrity of waste disposal structures (i.e., landform and waste rock piles). SRC is expected to justify the side slope gradient of the waste disposal structures to ensure their long-term integrity or otherwise to provide sufficient information to demonstrate the integrity of the designed structures is in the long term, should the proposed options be justified adequately by addressing other comments.

SRK Response:
Both landfill and waste rock pile configurations, that include 3.0 Horizontal to 1.0 Vertical (H:V) slopes, were designed to be stable geotechnically and for the long term.

<u>Waste Rock Piles</u>
Preliminary engineering included access ramps to facilitate construction and to provide access should adaptive management measures for unforeseen events be required. Drainage channels were positioned

along the 3.0H:1.0V slopes at a frequency where each channel will accommodate flow from a 1 ha area and the top surface of the waste rock piles and benches have a 1.0 % grade towards the drainage channels. The intent of this configuration was to reduce, surface flow velocities to below 1.0 m/s, the potential of surface erosion and to promote sustainable vegetation that will intern uphold the long-term integrity of the remediated waste rock piles.

The waste rock pile configurations include a series of 3.0H:1.0V slopes that are 6 m in height and are separated by benches that are 8 to 10 m in width. Such configuration results in an overall average slope angle of 4H:1.0V to 5.0H:1.0V. Therefore the benches could be excavated to form a gentler landform and the volumetrics will be the same. Landform design will be considered in the next phase of engineering, which will include a review of historical reclamation designs in Northern Saskatchewan, a trade-off study (benches vs. flatter uniform slope), and a FMEA to assess the consequences of erosion. This exercise will ultimately determine the final landform configuration for the waste rock piles.

Waste Disposal Structures

Both non-contaminated and contaminated landfill designs include surface/slope water management features that will promote sustainable vegetation, reduce the potential of erosion and thus facilitate the long-term integrity of the structure. Specifically, the crest of the non-contaminated landfill will be graded at 1.0% to form a swale-like feature towards the center of the crest, which will ultimately drain towards the Open Pit via an armored drainage channel situated along the 3.0H:1.0V slope.

The crest of the contaminated landfill is much smaller and will therefore be graded at 1.0% towards the exterior slope. Water bars comprised of riprap will be situated along the 3.0H:1.0V slope of the landfill to manage sheet flow and to reduce the potential of erosion from runoff. Runoff from surrounding watersheds will be diverted around both landfills and towards the Open Pit.

The proposed landfill slopes were also designed using guidelines from the Saskatchewan Environmental Code for Landfills (EMPA, 2010) where the recommended landfill slopes for Type I and Type II waste range from 3.0H:1.0V and 4.0H:1.0V.

Landform design will be included in the next phase of engineering as well as a FMEA and if required, the slopes may be flattened to support the final landform configuration.

Vegetation and Landform Design

One of the key components in reducing short term erosion potential is the establishment of sustainable vegetation species native to the Gunnar site. SRC's vegetation study will be utilized in the next phase of engineering to confirm the re-vegetation potential and to develop a re-vegetation plan.

Comment 6:

One of the remediation objectives is to minimize contaminant loadings to St. Mary's Channel and Zeemel Bay. In order to achieve this objective, the cover system should be designed to limit the net infiltration and ensure its long term integrity. The current cover design of 0.5 m medium to coarse borrow materials seems not well justified to support achieving this objective. Based on the site investigation, a significant amount of fine-grained borrow material are available and should be used to enhance the cover design. SRC is expected to justify the current design of cover thickness. The fine-grained borrow materials should be considered to enhance the cover design and its performance.

SRK Response:

Medium to coarse grained borrow was proposed over fine grained borrow for the cover systems associated with the waste rock piles and peripheral areas, as these materials will be less susceptible to frost heaving and erosion. Further, this provided a conservative uranium load reduction estimate for Zeemel Bay (56% reduction) that was confirmed in the HHERA to have no adverse effects on humans and Aquatic Environment (SRK 2015).

A fine-grained borrow material can be used; however, flatter slopes and/or erosion control measures such as erosion control blankets and turf reinforcement mats may be required. A trade-off study utilizing the available information from the borrow investigation (O'Kane Detailed Design Report) will be completed in the next phase of engineering to assess erosion susceptibility and the reduction in net percolation through a till cover with different thicknesses and gradation. This assumes that the available borrow information will include the geotechnical properties of each borrow source and the true available volumes above and below the water table.

Sincerely,

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REFERENCES:

Saskatchewan Research Council (SRC, 2013). Gunnar Site Remediation Project Environmental Impact Statement. Revised Volumes 1 to 3, November 2013.

SRK Consulting (Canada) Inc. (SRK, 2015). Gunnar Mine “Other Site Aspects” Preliminary Remediation Design. Prepared for Saskatchewan Research Council. August 2015.

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