Environmental Protection Agency (Ireland)

Boliden Tara Mines Tailing Management Facility (TMF) Industrial Emission Licence Review

Assessment of Proposed Stage 6 TMF Extension Expert Report

Document No. L116-17-R2418

December 2017

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					Study Manager	Sign-off	Client
0	March 2017	Draft Report issued for comments	DB	CM	PLC		
1	April 2017	Draft Report issued for comments	DB	CM	PLC		
2	Dec 2017	Final Report	ES	PLC	PLC		

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1. INTRODUCTION

Amec Foster Wheeler Earth & Environmental UK Ltd, now Wood plc (Amec Foster Wheeler) was selected as first ranked tenderer for the provision of technical assistance and advice to the Environmental Protection Agency of Ireland (EPA) on mines, extractive waste and related works (OEE-12-WLTU003-Framework).

Under this framework contract Amec Foster Wheeler was appointed to undertake an assessment of Boliden Tara Mines Ltd. (Tara Mines) proposed Stage 6 Tailings Management Facility (TMF) extension as part of a review of the existing Industrial Emissions Licence (IEL) for the facility (Register No. P0516- 04).

The EPA has outlined the tasks expected from Amec Foster Wheeler as follow:

- Assess relevant documents related to the design, construction and operational stages of the proposed Stage 6 TMF extension
- Assess the proposed updated Closure Restoration and Aftercare Management Plan (CRAMP)
- Identify any issues of an engineering, operational, environmental or safety nature arising from reviewed documents that should be of concern to the EPA in the context of deciding whether to grant a revised licence that would authorise the lateral extension
- Determine and advise whether the design of the TMF extension, and the manner in which it is proposed to be operated, represent BAT for management of tailings
- Determine and advise whether the TMF design, and the proposed nature of operations, address the requirements of Regulations 6(2), 11(2) (a) to (e) and 13(1) (a) to (c) of the Waste Management (Management of Waste from the Extractive Industries) Regulations (SI No. 566 of 2009)
- Advise on what, if any, additional information should be sought from the applicant to address identified concerns prior to determination of the licence review application
- Advise on whether particular concerns can adequately be addressed by conditions in a revised licence.

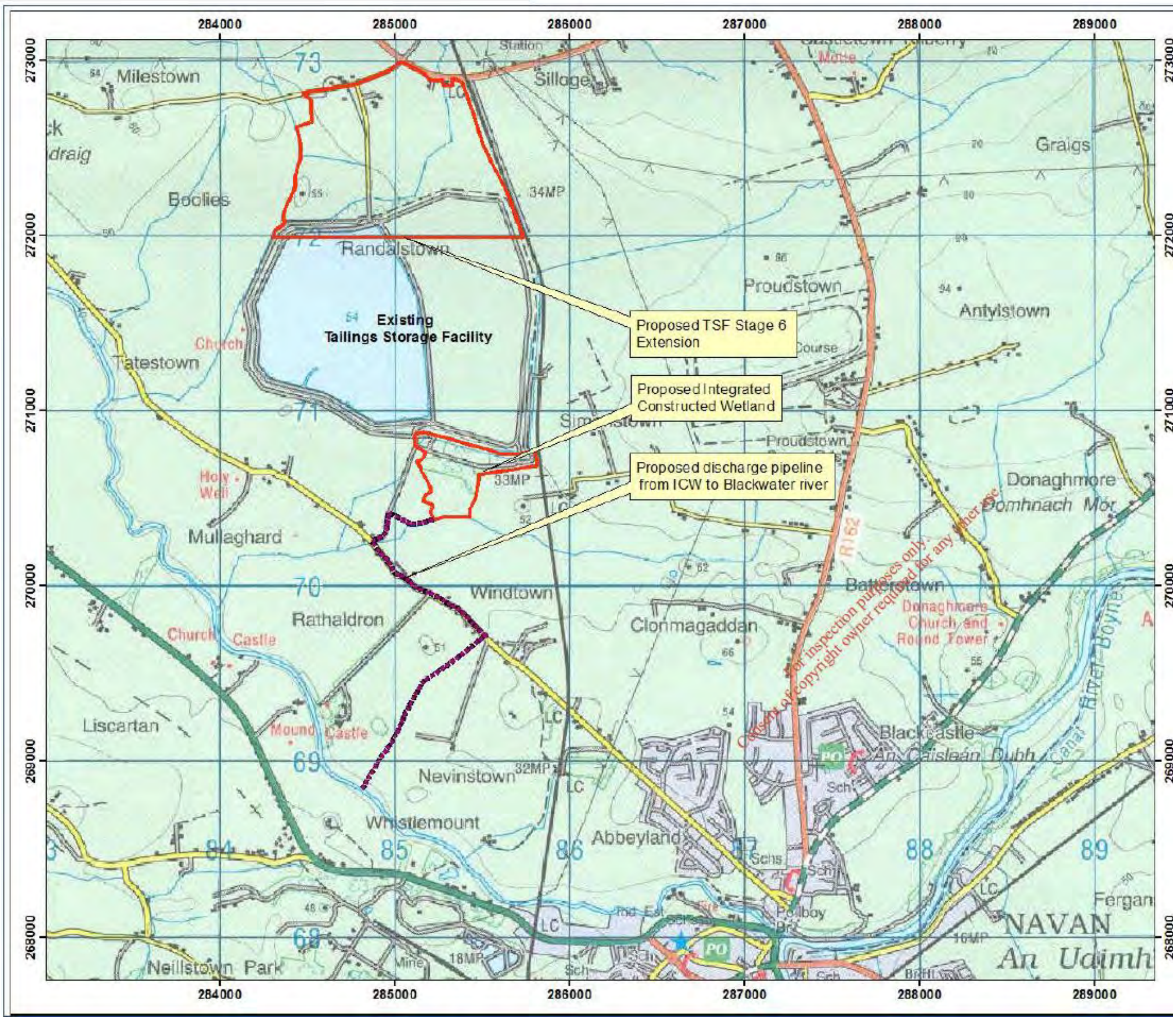
2. BACKGROUND

The TMF associated with the operating mine falls within the scope of European Directive 2006/21/EC as a Category A facility. The Regulations 2009 (S.I. No. 566 of 2009 on Management of Waste from the Extractive Industries implemented the European directive in Ireland. The legislation was subsequently amended by the European Union Regulations 2013 -Industrial Emissions (S.I. No. 138 of 2013).

Tara Mines currently holds an Industrial Emissions Licence IEL (Reg. No. P0516-03) for its lead zinc mine located in Navan, Meath County, Ireland. The licence sets out in detail the conditions under which Tara Mines must operate and manage this installation.

Tara Mines is now proposing an extension of the TMF (Stage 6) north of the existing facility to increase storage capacity. The proposed extension has triggered a review of the existing IEL. The licence review has been assigned Register No. P0516-04.

Figure 2.1
Proposed TMF Stage 6 Extension (Ref. 1)



An Environmental Impact Statement (EIS) (Ref. 1) and Natura Impact Statement (NIS) (Ref. 2) were submitted to the local authority (Meath Country Council) as part of the TMF development Planning Application.

The following definitions were used in the EIS document to describe the proposed development:

- *"Perimeter embankment refers only to the walls, constructed of clay fill, within which the tailings are deposited.*

- *Tailings Storage Facility [TSF] refers only to the total area of deposited tailings within the perimeter embankment.*
- *Tailings Management Facility [TMF] refers to the whole operational site, which, in addition to the tailings dam, includes the supporting infrastructure such as the interceptor channel, perimeter road, pump house, etc."*

The design for Stage 6 TMF and the proposed Integrated Constructed Wetland (ICW) were developed by Golder Associates and Vesi Environmental respectively (Ref. 1).

The proposed Stage 6 TMF will consist of a lateral extension of the exiting ring-dyke facility over an area of 58 ha to a height of 22 m above ground level. The ICW system will be constructed for water treatment purpose at closure.

In November 2016 a notification of decision on the planning application permit was issued by Meath Country Council for the proposed TMF (Reg. NA 160408), the decision was subsequently appealed to the An Bord Pleanála (Reg. No PL 17.247707). In July 2017, following An Bord Pleanála, permission was granted subject to conditions for the tailings facility extension, but not for the proposed ICW.

3. INFORMATION REVIEWED

The following documents were reviewed:

i. Licence review application documentation (P0615-04)
ii. Project description and engineering design (EIS Attachment – B6 – 1, Section 3)
iii. Water Framework Directive Assessment (EIS Appendix – 8.1B)
iv. Various reports related to hydrogeology and soil contamination in the vicinity of the TMF (See Attachment I.5 and Appendix I of the Application Form for background regarding this matter)
v. EIS for TMF extension Stage 6 (EIS Attachment – B6 – 1)
vi. Current industrial emissions licence (Register No. P0516-03) and the Inspectors Report for that licence application
vii. Updated closure, restoration and aftercare management plan (Attachment K to the Application Form)
viii. Other documentation related to the industrial emissions licence that is deemed necessary to the assessment.

A list of the documents provided as part of the IEL Review application is presented in Attachment 1, which includes comments and requests for clarification to validate concerns with the documents provided.

In April 2017 following the initial review Amec Foster Wheeler provided comments on the TMF design together with reference to documents relevant to the Stage 6 TMF extension and request for further information.

Additional documents provided by Tara Mines in response to the EPA's request for further information are presented in Appendix 2.

4. TMF STAGE 6 EXTENSION PERMITTING

The proposed extension for the TMF will require planning permission and the revision of Tara Mines current IEL by the EPA.

In November 2016 a "Notification of Decision" (Reg. No NA/160408) was issued by the Planning Department of Meath County Council with regard to the planning application for the extension of the TMF at Tara Mines. The decision to grant permission was subject to 28 requests for further *"information/revised plans"* included in the Schedule of Conditions.

In April 2016 the notification of Meath County Council was appealed to An Bord Pleanála (Reg. No PL 17.247707). In July 2017, following An Bord Pleanála decision, a permission was granted subject to conditions for the tailings facility extension, but not for the ICW.

5. TMF STAGE 6 DESIGN REVIEW

5.1 GEOTECHNICAL SITE AND LABORATORY INVESTIGATIONS (GSI)

5.1.1 General

The proposed extension will cover an area within the existing TMF borrow areas. *"The footprint of the Stage 6 facility is confined to the existing northern and seven fields borrow areas. Virtually all the area is exposed indicating rock or glacial till over the site." (*Ref. 1)

It is understood that geotechnical borehole drilling and trial pitting was undertaken at the project site together with a geophysical survey to assess soil foundation conditions, identify any palaeokarstic features in the limestone bedrock and determine the 'excavatability' of the bedrock "(Ref.1).

"The palaeokarst investigation did not identify any large voids beneath the footprint of the Stage 6 TMF Facility that might pose a risk to the integrity of the Stage 6 TMF Facility" (See Attachment 2 - Tara Mines Response to Further Information Request 12/09/2017).

Wells were also installed to monitor groundwater levels around the existing TMF. However, the monitoring wells in the northern section of the existing TMF would be decommissioned and replaced with boreholes located around the perimeter of TMF Stage 6 extension.

5.1.2 Geotechnical Design Parameters

The geotechnical strength parameters adopted in the stability modelling are presented in the table below. As per EIS report (Ref. 1) *"Effective strength parameters are typically used to assess long-term stability (after closure), whereby the excess pore pressures developed in any fine grained soils have dissipated."*

Table 5.1
Geotechnical Parameters (Ref. 1)

Material Type	Unit Weight (kN/m^3)	Effective Strength	
		c'	ϕ'

		(kPa)	(deg)
Type A	19	0	32
Typed D1 and D2	21	0	37
Tailings	18	0	32
In-situ Glacial Till	20	5	32
Limestone Bedrock [1]	-		

Note 1. Assumed impenetrable for slope analysis

5.1.3 Amec Foster Wheeler Comments

The tabulated geotechnical parameters included in the design report should make reference to a separate comprehensive geotechnical interpretive report to include:

- Site investigation plan (boreholes, trial pits and geophysics)
- Geotechnical logs
- Soil and rock laboratory testing (foundation soil and construction materials)
- Tailings geotechnical characterisation
- Geological plan and sections

It is understood that Tara Mines is proposing to import "*demolition waste or materials made from construction and demolition waste*" for TMF construction (Appendix 2 Response to Further Information Request 08/11/2017. The geotechnical investigation should also address imported material to confirm suitability for construction

A variability assessment should be undertaken to assess any potential variation in the parameters for soil foundation, tailings and embankment construction material.

5.2 GEOCHEMICAL CHARACTERISATION

5.2.1 General

The EIS suggests that the *"physical and chemical characteristics of the deposited tailings will remain unchanged from those deposited previously"* (Ref. 1).

Based on laboratory testing on tailings samples collected in 2015 *"the tailings are expected to be non-acid generating"* (Ref. 2).

5.2.2 **Amec Foster Wheeler Comments**

The assessment of potential for acid generating drainage should also include construction materials. It is recommended that laboratory testing is also carried out during TMF operation to confirm that there are no significant changes in the tailings geochemistry.

5.3 TAILINGS DISPOSAL OPTIONS STUDY

5.3.1 General

The preliminary site options review for the TMF location considered three alternatives:

- *"A lateral extension of the existing facility to the north, south, east or west.*
- *A vertical extension of the existing facility.*
- *Construction of a completely new facility at an unspecified location."*

A qualitative appraisal of potential engineering and environmental impacts concluded that a lateral extension to the north of the existing facility is the most favourable option.

Following Amec Foster Wheeler review and EPA's request for further information, an evaluation of tailings disposal options was undertaken addressing various methods (See Attachment 2- Tara Mines Response to Further Information Request 08/11/2017). The assessment used Multiple Account Analysis methods through the development of accounts and sub-accounts of the impact of various proposed alternative.

The quantitative evaluation of the TMF options technical, environmental and socio-economic impacts concluded that conventional slurry tailings deposition is the most favourable option.

5.3.2 **Amec Foster Wheeler Comments**

Following pre-screening stage the filter cake disposal option was discarded due to *"a number of reasons but primarily;*

- *potential mechanical damage to the lining system from either trucks or conveyor system,*
- *insufficient storage capacity to manage storm events*
- *having the greatest negative environmental impacts."*

However there are advantages in using a filtered tailings (dry stacking) disposal system which were not considered in the pre-screening assessment including:

- Smaller footprint compared to other options
- Very low potential for groundwater contamination through seepage
- Reduced risk of catastrophic failure
- Reduce volume of construction material required (no need for tailings dam)

The assessment also suggests that unlike dry stacking for the other options considered (slurry, thickened and paste tailings) the *"TSF can act as water reservoir"*. Amec Foster Wheeler strongly advices that the TSF **should not be designed or used for water storage.**

5.4 TMF DESIGN CRITERIA

5.4.1 General

No specific TMF design criteria document has been provided for review.

5.4.2 Amec Foster Wheeler Comments

A design criteria document should be developed summarising the TMF design basis. The design criteria should include design input data from various sources (seismicity, geotechnical, geochemical, environmental, process etc.). Each criterion should be source referenced and notes included where assumptions have been made that may require further verification.

5.5 FLOOD RETENTION AND FREEBOARD

5.5.1 General

It is understood that the TMF will be constructed in two phases only consisting of a 14 m high starter embankment extension of the existing TMF embankment to the north (Phase I) followed by a downstream raise to 67.29 m AOD final elevation (Phase II) (Ref. 1).

As part of the EIS, a preliminary appraisal was undertaken addressing flood risk within the Stage 6 TMF and environs. The review used information available from the preliminary flood maps developed by the Office of Public Works (OPW) in 2011 and from the national Preliminary Flood Risk Assessment (PFRA) Overview Report dated March 2012.

The scoping study concluded that *"on the basis of the PFRA screening maps it is therefore probable that a full FRA will be called for within the planning application for the proposed extension at the Tara Mines facility due to the presence on a possible flood plain."* (Ref. 4).

Section 3.9 of the EIS report (Ref. 1) suggests that *"During the operation of Phase 1 and Phase 2 the tailings level will be filled to a point leaving a 'free board' of 1 metre. The pond water level will be kept to 1.5m below the crest during operations."*

The report also suggests that the *"type of perimeter dam used for tailings storage, which has no external catchment area, is normally operated without spillways. There is always adequate control on the tailings water level which can be achieved by adjusting the discharges into the TMF and removal of tailings water by pumping from the TSF to the plant site.*

5.5.2 Amec Foster Wheeler Comments

Amec Foster Wheeler disagree with the presumption that "There is always adequate control on the tailings water level". Lack of control of the tailings water level has been a contributing factor to tailings dam failures and provision of an emergency spillway is considered good practice.

Alternatively, capacity to store the Probable Maximum Precipitation (PMP) of appropriate duration would be acceptable. The PMP is determined for very long return periods and although generally not defined is considered to be in the order of 100,000 years or greater.

Although the construction of the starter embankment (Phase I) and subsequent downstream raise should ensure that sufficient retention volume will be available, reference should be made to the criteria adopted to determine the minimum design freeboard. In the absence of an emergency spillway the adopted freeboard during operations need justification, including:

- Depth-storage capacity curve showing tailings rate of raise and embankment crest elevation
- Definition of the design storm events for various duration and return period and PMP.
- Assessment of TSF design storm events storage capacity

Amec Foster Wheeler agree that a detailed flood risk assessment to include potential impact of climate changes is required.

5.6 TMF DAM CROSS SECTIONS

5.6.1 General

A description for the proposed Stage 6 TMF dam is presented in Section 3 of the EIS report (Rev. 1). The dam upstream slope "*will be constructed with a slope of 2H:1V and will be keyed into the northern embankment wall of the existing facility…. The crest width of the dam walls for all phases is 6 m and the maximum wall height will be approximately 22 m. The upstream sector of the proposed dam will consist of a 6m wide unit of clayey glacial till (Type A1 and/or Type A2). The footprint of the dam wall will be constructed with a 1m minimum thickness of Type D2 rock which acts as a drainage blanket.*

To bring the dam wall up to an elevation of 44.29 m AOD will require approximately 2,500 m^3 of Type D2 material. On the lower parts of the downstream sector of the dam wall, a 6 m width of Type A2 glacial till will be placed. Between the upstream Type A1/A2 zone and the downstream Type A2 zone is a random fill zone which would include Type A2 and A3 as well as Type D2 material.

The northern embankment wall of the existing TSF, perimeter interceptor channel and finger drain channels will be stripped of topsoil and vegetation prior to receiving the protection material and lining system forming Stage 6.
A 100 mm layer of processed rock-fill Type C material would be placed over the Type A materials on the upstream side of the new Stage 6 dam walls and on the northern face of the existing embankment wall to provide protection for the lining system. The maximum particle size of the Type C would be 20 mm and the material would be well graded.

A 1,000 g/m^2 non-woven geotextile will be placed on top of the Type C material prior to placement of the lining system. The adjoining wall would be cleaned of vegetation, trimmed to receive the 100 mm layer of Type C followed by the 1,000 g/m^2 nonwoven geotextile. The Type C material on the dam walls would continue over the backfilled finger channels and backfilled perimeter interceptor channel.

5.6.2 **Amec Foster Wheeler Comments**

The proposed dam will be constructed "*from several materials which include cohesive glacial till, granular glacial material and processed rock fill".* It is proposed that TMF dam earthfill (type A1, A2 and A3) will be placed in 300 mm lifts, compacted to 95 % Standard Proctor to form 1V:2H slopes. However, subject to earthfill grading and moisture conditions it may prove difficult to achieve the required compaction. Also, the constructability of placing a 100 mm thick only protection layer is of concern. Provision of a permeable horizon would not be recommended as it can increase the potential for seepage.

For ease of construction and safety purposes during geosynthetics installation, Amec Foster Wheeler recommend that consideration is given to providing a 1V:3H slope for the TMF dam upstream slope.

5.7 CONSTRUCTION MATERIALS

5.7.1 General

From the EIS report (Rev. 1) the TMF embankment will consist of the following material types:

- *Type A1 and A2 Cohesive Glacial Till*
- *Type A3 Glacial Granular Material*
- *Type B Road Material*
- *Type C Protection Material*
- *Type D1 Backfilling Existing Borrow Area Drains*
- *Type D2 Dam Footprint Drainage Blanket Material*
- *Type E 75 mm Coarse Drainage Backfill for Perimeter Interceptor Channel and Concrete Chutes."*

For type C it is suggested that the material *"will be nominally compacted with a smooth roller on the basin floor. The protection material placed on the dam wall side slopes will also be nominally compacted with a smooth roller winched down from the crest or by an alternative method agreed by the Engineer."*

5.7.2 Amec Foster Wheeler Comments

Type A1, A2 and A3 as the description is identical for all materials. There are no specification for particle size grading other than the requirement for the maximum size. PSD curves should be provided for all the proposed materials.

The need for a transition/filter zone between the D2 drainage blanket and type A fill should be addressed.

As noted in Section 5.6, it is recommended that a 1V:3H slope is adopted for the TMF dam upstream slope to facilitate material compaction.

5.8 SLOPE STABILITY & SEEPAGE ANALYSES

5.8.1 Seepage Analyses

Section 3.5 “Seepage” of the EIS report discusses the “likelihood” of potential leakage through the liner based on design equations available from published technical literature. Estimates were *“based on a number of variables including infiltration rate based on the range of vertical permeability values of the tailings, the range of defects in the lining per hectare, the effective permeability of the composite lining and head acting on the lining.”* (See Tara Mines Response to Further Information Request 12/09/2017). Current design assumptions on materials permeability will need to be validated as part of the detailed design.

5.8.2 Slope stability Analyses

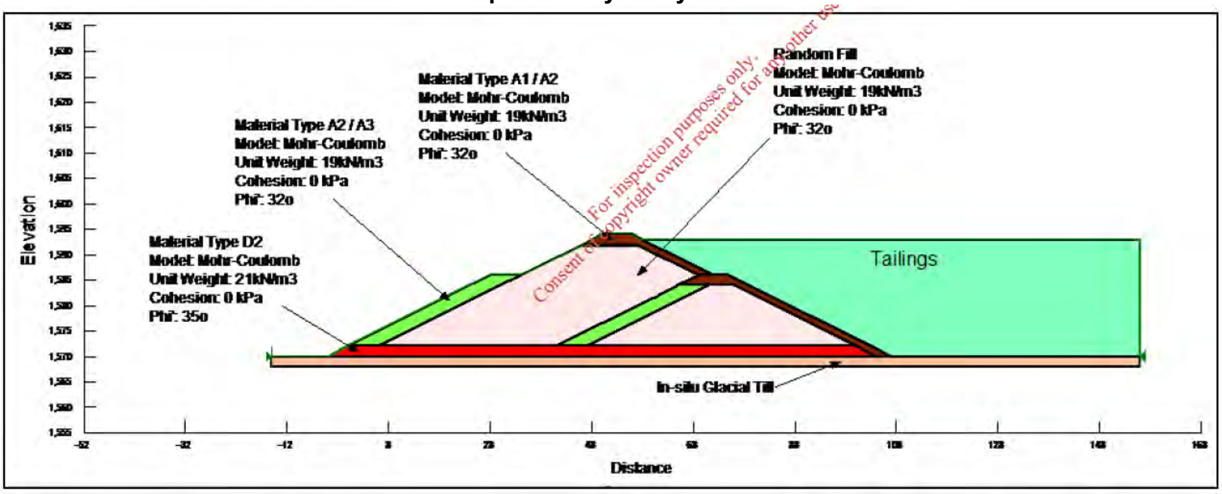
The slope stability of the Stage 6 TMF has been evaluated by means of limit equilibrium analyses. Minimum factors of safety have been computed with the commercial software. The models were analysed for both static and pseudo-static (seismic) loading.

The results of the stability analyses were as below (Ref. 1):

- *“The factor of safety for the static and pseudo-static cases assuming the internal drainage system is operational are satisfactory.*
- *Where the drainage system is non-operational, the factor of safety for the static condition is satisfactory.*
- *In the statistically unlikely event of an earthquake, the factor of safety is 0.99 which under these conservative conditions, is acceptable.”*

“The model geometry is based on a typical cross-section of perimeter dam wall at full height (67.29 m AOD) including the bench at 59.29 m AOD…..The geotechnical strength parameters adopted in the stability modelling are presented in the table 3.10 and the geometric configuration presented in Figure 3.14.”

Figure 5.1
Slope Stability Analysis Model



The stability of the TMF wall for each option was considered under the following conditions:

- *Long-term downstream embankment stability, with tailings level 1 m below the crest. The HDPE liner was assumed to be intact and an assumed phreatic surface was drawn down through the embankment by the downstream drainage blanket and the rock used in downstream construction.*
- *Long-term downstream embankment stability, with tailings level 1 m below the crest. The HDPE liner was considered to undergo complete failure and the drainage system was no longer free draining and the phreatic surface exits the dam wall in the slope at one third of its height. This is a very extreme scenario which is unlikely to develop.*
- *Further analyses were undertaken using pseudo-static conditions corresponding to a 0.06 g acceleration for the liner intact."*

The analysis addressed both short term (following construction) and long term scenarios (TMF development and closure) under static and pseudo-static loading condition.
Following EPA's request for further information a "Dynamic response analysis" was undertaken to determine the embankment wall settlement as a result of Maximum Credible Earthquake the impact of seismic event.

Although the scenario associated with a factor of safety of 0.99 is stated to be "statistically unlikely" the result of pseudo-static analysis indicates that the selected scenario does not meet the stability criteria. However, dynamic analyses suggest "*that the level of deformation of the tailing dam during and after a MCE event would not impact the integrity of the dam wall and therefore considered satisfactory."*

5.8.3 Amec Foster Wheeler Comments

It is not clear why the model shows various elements/zone for random fill and type A materials as the parameters adopted and material description are identical.

There is no indication of the criteria adopted for the selection of the seismic design parameters (design earthquakes and associated ground acceleration) used for the analysis. Appropriate ground motion parameters and return period associated with the design seismic events should be adopted as per International Commission on Large Dams ICOLD. In accordance with the ICOLD guidelines (Ref. 5) the definitions of earthquakes for which the structure should be designed are:

- Maximum Credible Earthquake (MCE)
- Operating Basis Earthquake (OBE).

Although the project site may be located in a low seismic area, the potential for liquefaction should be addressed based on the anticipated maximum seismic peak ground acceleration, embankment fill and foundation soil conditions.

5.9 COMPOSITE LINER

5.9.1 General

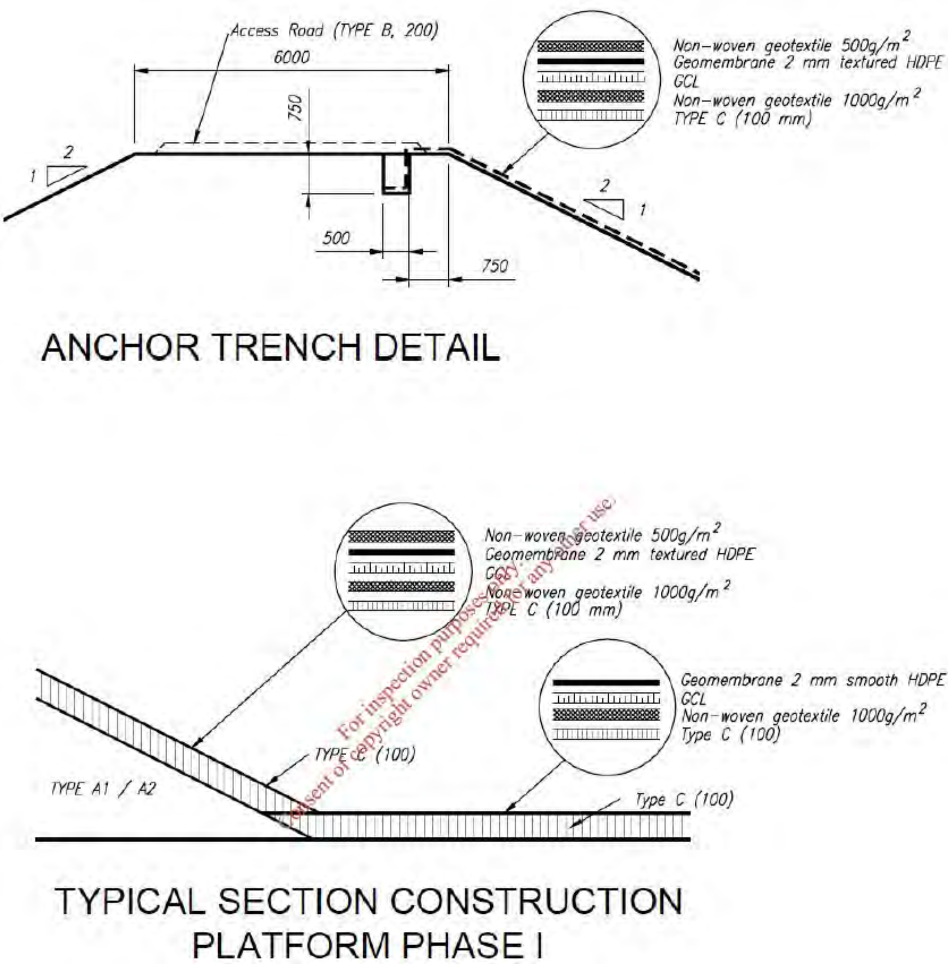
As per the EIS report *"The proposed stage 6 extension will incorporate a composite lining system which consists of high density polyethylene (HDPE) geomembrane over a geosynthetic clay liner (GCL). The composite lining will overlie a 1000 g/m^2 geomembrane which in turn overlies 100 mm of Type C protection material".*

The HDPE will be 2 mm thick, double textured and is placed directly over GCL on the 2H:1V upstream slopes of the dam wall. In the basin area the HDPE is 2 mm thick and smooth and is placed directly over the GCL.

Three types of geotextile material are required, a 1000 g/m^2 non-woven needled punched geotextile to protect the lining system from underneath, a carbon rich 500 g/m^2 non-woven needled punched geotextile to protect the lining system from above on the slope and a Terram 1000 or equivalent as a separation medium.

A permanent surcharge is required on the exposed geomembrane to prevent the HDPE from being lifted and damaged by wind action and minimise damage from pipe movements. It also acts as a ladder if someone accidently falls into the facility. The surcharge will consist of car tyres in filled with Type C material and placed on the carbon rich 500 g/m2 non-woven needle punched geotextile"

Figure 5.2
TMF Composite liner



It is understood that "*A leak detection survey using DC electric current will be undertaken after the installation of the lining system.*"

Section 3.6 suggests that *"The regional groundwater flow is from the north east to the south west and the minimal seepage passing through defects in the lining system will mix and be diluted with the ground water."*

5.9.2 Amec Foster Wheeler Comments

It appears that no leak detection and collection system will be installed. The term leak detection in Section 3 of the EIS report applied to geophysical (DC) survey is misleading. However, the use of a geophysical method following installation of the HDPE geomembrane and the adoption of a comprehensive QA/QC plan during installation should minimise the risk of leakage through the geomembrane.

From the liner typical sections it would appear that the access road will run above the anchor trench. This should be avoided to prevent any risk of damaging the liner during construction and operation. A road safety berm should also be adopted.

5.10 RUNOFF CONTROL

5.10.1 General

It is proposed that the "*interceptor channel close to the base of the dam captures vertical and horizontal seepage. Seepage water collected in the interceptor channel is then pumped back up to the TMF (tailings pond) from pumps with automated level controls, located at intervals around the interceptor channel. By returning seepage back to the TMF, a closed water cycle system operates which helps to protect the local water environment."* (Ref. 1)

As per TMF Closure Plan (Ref. 2) *"The Stage 6 unlined perimeter interceptor channel will discharge into the existing TMF east and west perimeter interceptor channels during operation. An unlined perimeter interceptor channel surrounds the Stage I, II and III embankment walls collecting seepage water via a blanket of finger drains and intercepts flow from under the dam. The internal drainage system for Stage 4 and Stage 5 is directed to the perimeter interceptor channel by means of manholes, pipework and chutes. The perimeter interceptor channel feeds two collection sumps from which all water is pumped back to the tailings pond."*

Section 3.6 of the EIS report suggests that a *"The regional groundwater flow is from the north east to the south west and the minimal seepage passing through defects in the lining system will mix and be diluted with the ground water…..perimeter interceptor channel will collect surface water runoff from the dam walls, perimeter road and borrow areas. This seepage will be insignificant when compared with the clean surface water runoff from the dam walls and surrounding land."*

From the EPA Inspectors report dated April 2012 it appears *that "there is evidence of contamination of groundwater with sulphate to the south west of the TMF, i.e. downstream of the TMF. This indicates that, historically, some seepage has escaped the interceptor channel and moved away from the TMF."*

5.10.2 **Amec Foster Wheeler Comments**

It is recommended that an alternative seepage detection and collection system reporting to a lined peripheral channel be considered to minimise potential for groundwater contamination.

5.11 TAILINGS DEPOSITION SYSTEM

5.11.1 General

"Stage 6 will be operated similar to the existing TSF by discharging the tailings from spigots from the dam crest. The spigots will be open sequentially and the tailings will be discharged uniformly over the TMF. The discharge spigots will be spaced at 50 metre centres and two tailings lines will be operated around the facility in opposite directions. Unlike the current Stage 5 operation, there will be a considerable depth between the crest and the basin floor initially."

A typical layout of the tailings pipeline, deposition points and decant location were provided for review.

5.11.2 Amec Foster Wheeler Comments

The embankment cross-section shows a 6 m crest width. This may not be sufficient to accommodate the tailings delivery pipelines and safety bunds.

The EIS report does not contain information on the tailings pipeline from plant to TMF. The Environmental Emergency & Preparedness Response Procedure in Appendix to the IEL review application suggest that *"The tailings pipeline is constructed from 630mm high-density polyethylene (HDPE) and is buried for all of its length."*

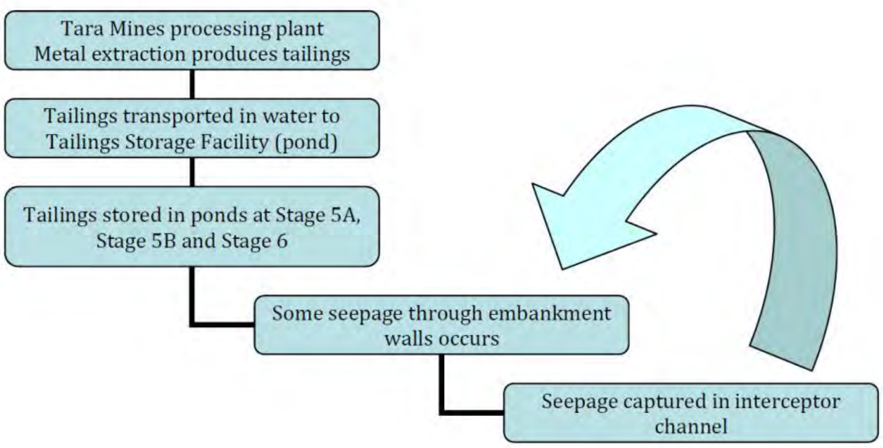
No information on the pipeline route, or proposed pipe cross-section and long section was presented in the design report. Amec Foster Wheeler note that burying tailings pipelines is not always best practice and consideration of containment in the event of leakage should be considered and discussed.

5.12 WATER MANAGEMENT

5.12.1 General

A conceptual water management model is discussed in Section 8.2.1 of the EIS report: "*The proposed design for water management would be similar to that proposed for Stage 5 closure which involves the use of a spillway system connected to the interceptor channel. This would divert water to a wetland area for water treatment prior to discharge into the local river system as described in the Scott Wilson EIS (Scott Wilson, 2009). The spillway would be located and designed in detail closer to the end of the life of the Stage 6 facility.*"

Figure 5.3
TMF Water management model



A schematic describing the Tara Mines Water System is included in the Attachment D to the IEL application. The document identifies "*three sources of water that are considered process water. These are as follows:*

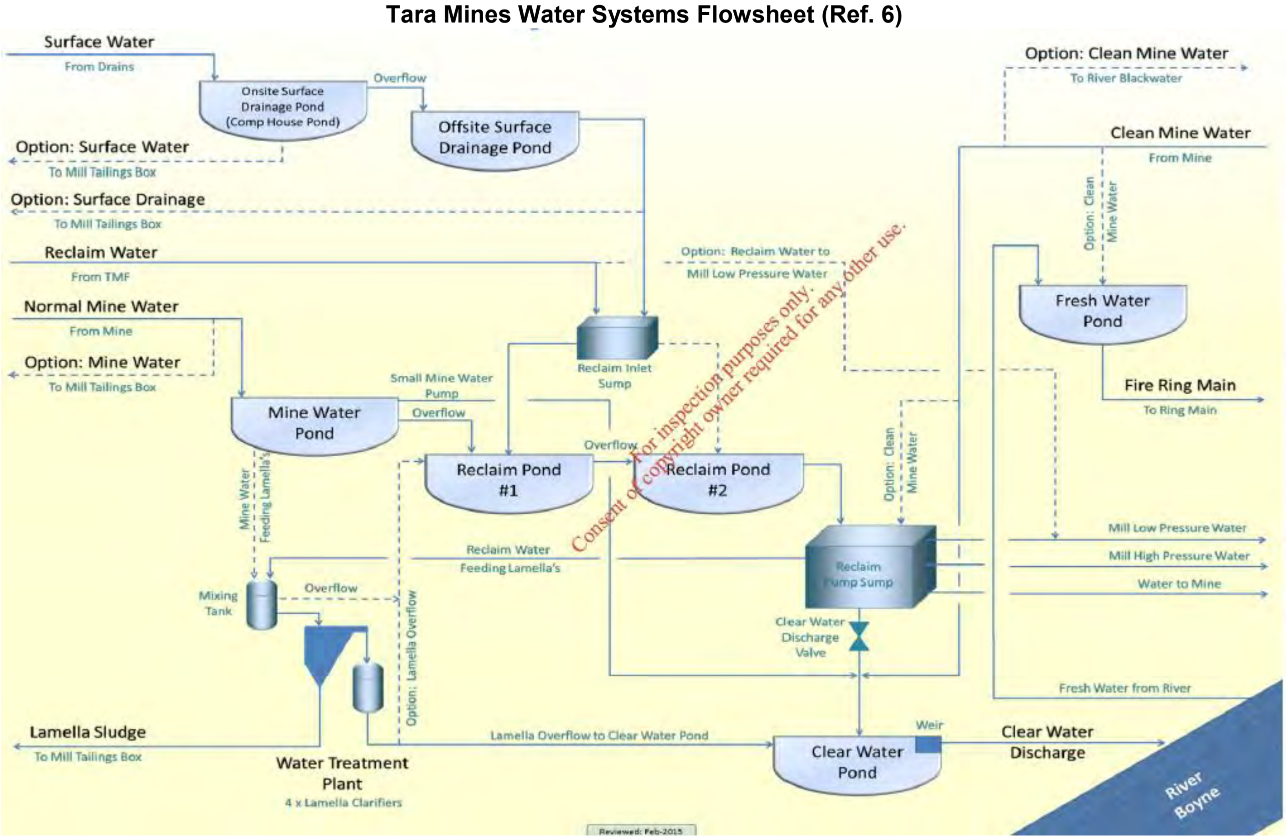
- Water ingress to the mine that is pumped out to maintain a suitable dry working environment
- Surface run-off
- Water from processing plant.

Water from these three sources is collected, pumped and treated prior to discharge to the River Boyne at Emission Point Reference SW1.

All water from the process plant is pumped to the TSF. This water is recycled back to the reclaim pond in the mine site after suspended solids have settled at the TSF. Minewater and surface run-off, representing a low risk effluent are treated in the onsite water treatment system….Water from the Reclaim Water Pond decants, via a controlled overflow, to a Clear Water Pond (Discharge pond).

The discharge from the Clear Water Pond to the River Boyne is via a weir structure, which measures and controls the discharge."

Figure 5.4
Tara Mines Water Systems Flowsheet (Ref. 6)



Section 5.4.1.2 of the EIS report (Ref. 1) suggests that the "*continued monitoring of the TMF since operation of the Stage 5 extension has shown that the interceptor channel is effectively capturing almost all seepage from the tailings storage facility through the embankment walls. As this water is then recycled back to the Stage 5 TMF, a closed water cycle system is operating.*"

Appendix B6.6 of the IEL application suggests that currently "*All water from the process plant is pumped to the tailings facility for treatment prior to return of treated water to the reclaim pond. Minewater and surface run-off, representing a low risk effluent are treated in the on site water treatment system.*"

5.12.2 **Amec Foster Wheeler Comments**

Collection systems for clean runoff and for seepage from the TMF should be separated. The seepage peripheral channel should be fully lined if used to collect and discharge seepage water into the water treatment system.

The statement that "*All water from the process plant is pumped to the tailings facility"* need clarification. The TSF **should not be designed or used for water storage.**

5.13 WATER BALANCE

5.13.1 General

No water balance provided for review

5.13.2 **Amec Foster Wheeler Comments**

A water balance is required for the proposed Stage 6 for the TMF with input parameters such as tailings throughput, tailings pulp density, rainfall, evaporation, runoff and other losses.

The water balance should be based on monthly time step over the life of mine and for a range of meteorological scenarios. The aim is to determine the TMF water management system requirements based on the amount of water returned to the process plant and the need for make-up water and water treatment.

The determination of the volumes associated to the water balance are of particular importance given consideration of the statement mentioned in 5.12.2 above

5.14 RETURN WATER SYSTEM

5.14.1 General

There are no specific details provided of the proposed return water system for Stage 6 TMF. EIS report (Ref. 1) suggests that *"Where the reclaim pumps are located, a continuous protection (liner protection) of in filled tyres will be required some 20 m wide. The optimum location of the reclaim pumps is firstly along the existing northern wall of Stage 5 in the south east sector where the future spillway can discharge into the eastern perimeter interceptor channel.*

The second option is along the existing northern wall but in the south west sector where the future spillway can discharge into the western perimeter interceptor channel.

The sand line also poses a potential challenge as this would be discharged from a 600 mm diameter pipe. Again the liner will be protected with a minimum 20 m wide continuous in filled tyre. This line will be located on the northern wall of Stage 5 where the composite lining and lining protection can be installed for both the phases from the beginning.

To prevent damage of the lining at the point of discharge and to provide surcharge for the base, the basin should be filled with a minimum of 1 m of water equating to approximately 430,000 m^3"

5.14.2 **Amec Foster Wheeler Comments**

A more detailed description of the proposed return water system should be provided. Figure 3.20 of the EIS report shows a concrete platform 2 m from the toe of the slope (adjacent) to the 500 g/m^2 geotextile. The design criteria and requirement for a concrete platform need clarification. Details of liner/concrete seal should be provided.

Alternative to the proposed 1 m water cover geomembrane protection should be considered (polyethylene mat covers or similar). Compatibility of providing a water cover with the objective of minimising water pressure on a liner to reduce potential seepage should be considered.

5.15 WATER TREATMENT SYSTEM

5.15.1 General

It is proposed that (Ref. 1) *"The operation phase of the proposed Stage 6 tailings pond, including treatment of excess tailings pond supernatant water and surface water run-off within the existing treatment scenario via a recirculation system. Finally, the decommissioning of Stage 6 will include the decommissioned Stage 5 site and surface water run-off from both areas will be treated via a constructed wetland system and subsequently discharged to the River Blackwater.*

The existing drainage system within the TSF will be modified to accommodate the extra storage capacity provided by Stage 6, but the previous system would still operate as designed for the Stage 5 raise.
As such the existing water reticulation system will continue to operate, i.e. water will be pumped back to the mine and subsequently discharged to the River Boyne, under the existing IE licence."

5.15.2 **Amec Foster Wheeler Comments**

It is proposed that the existing water treatment will be used for both Stage 5 and Stage 6 TMF until an Integrated Constructed Wetland system will be operating, following Stage 6 decommission. Most of the studies included in the IEL address the design and operation of the ICW. More information should be provided on the suitability of the existing water treatment to accommodate the increased volumes following Stage 6 start up and prior to Stage 5 decommissioning.

5.16 TAILINGS RUN-OUT ANALYSIS

5.16.1 General

Dam breach analysis was undertaken for the TMF (See Attachment 2- Tara Mines Response to Further Information Request 12/09/2017). The study included *"Five failure scenario locations have been considered during both operations and closure, totalling 10 failure scenarios and are as follows:*

- Stage 5A – East;
- Stage 5B – West;
- Stage 5B – South;
- Stage 6 – North-west; and
- Stage 6 – North-east."

The analyses suggest that *"In the event of a failure of the TMF, properties in proximity to Simonstown Stream, Yellow River and Stage 6 are particularly at risk of inundation. An early warning system will be implemented for those at risk, however residents will have very limited time in which to react.*

Given the high consequence (on local residents) of a dam break failure in the immediate vicinity of the TMF facility at Tara as demonstrated in this study, we would recommended that future consideration is given to undertaking a further assessment based on non-Newtonian tailings dam breach (i.e. tailings viscosity, rather than assuming water)".

5.16.2 Amec Foster Wheeler Comments

The dam breach analysis confirmed that the proposed TMF facility should be classified as high risk. Amec Foster Wheeler agree that further analysis should be carried out based on actual tailings characteristics to fully assess TMF zone of influence in the event of dam breach.

Mitigation measures must be adopted to prevent any risk for local residents and nearby properties associated with dam failure.

5.17 OPERATION, MAINTENANCE AND SURVEILLANCE

5.17.1 General

The existing TMF and Stage 6 extension fall within the scope of European Directive 2006/21/EC as a Category A facility. Emergency preparedness and response procedures have been developed in accordance with the current IEL schedule of conditions. The Internal Emergency Plan (IEP) and the Major Accident Prevention Policy (MAPP) address the implementation of monitoring and response protocols to minimise risk of accidental emissions of contaminants to the environment and prevent major accidents.

5.17.2 **Amec Foster Wheeler Comments**

It assumed that the current IEL licence schedule of conditions detailing control and monitoring requirements for the existing TMF will also be applied to the proposed Stage 6 extension.

Monitoring methods and frequency are also included in the current Extractive Waste Management Plan (EWMP) (Ref. 7).

The EWMP refers to existing TMF Operation, Maintenance and Surveillance Manual. These documents will need to be updated to include Stage 6 and the TMF zone of influence as identified by the dam break study.

5.18 ACCESS ROADS

5.18.1 General

It is understood that approximately 1.1 Mm^3 of soil and rock material will be required to complete the proposed TMF dam extension. Local and regional roads will be used to access the TMF site.

The EIS (Ref. 1) suggests that "*traffic generated by the TMF is expected to operate on national roads which are designed to accommodate such traffic without producing any additional adverse environmental effects*."

An assessment was undertaken of the impact of the traffic generated by the TMF construction. The study considered two routes: i) from the TMF to Navan and ii) from the TMF to Slane. The study provided recommendation for appropriate signage and for the development of a Construction Stage Traffic Management Plan.

5.18.2 **Amec Foster Wheeler Comments**

The potential impact on local and regional roads raised concerns from local residents on road safety, dust and construction vehicles emissions along the TMF proposed routes.

Reference to Tara Mines full responsibility for the costs due to potential damages to regional and national road has been included in the Schedule of Condition of Meath County notification on the planning application. However, it is recommended that the contractor provides road safety and mitigation measures as a priority to prevent accidents on public roads due to TMF construction vehicles traffic.

5.19 CLOSURE

5.19.1 General

The rehabilitation and closure plan for the TMF undertaken in 1996 was based mainly on the vegetation of the tailings and pond. Based on the current Closure Remediation and Aftercare Management Plan (CRAMP, Ref. 8) an alternative arrangement has been selected consisting of "*a 350mm thick layer of soil placed on top of the tailings and drained using a combination of rock fill access roads, perforated pipe and geosynthetic drains.*"

The covering of the tailings with an inert cap will prevent erosion of the tailings from surface runoff. The profiling of the cap and tailings will allow surface water to be confined to the decant structures adjacent to the south west corner of Stage 5A and the south east corner of Stage 5B. Run-off will be controlled by a permanent decant spillway system which will be installed once deposition of tailings has ceased."

A permanent decant spillway system will be installed once deposition of tailings into the Stage 6 TMF ceases. The decant will control surface runoff from precipitation after closure and drainage of the cap. There will be no permanent open water against the dam wall other than temporary ponding during major storm events. A simple open spillway will be the final decant structure in the south-east corner of Stage 6. The spillway will exit to a concrete cascade chute on the downstream slope of the dam wall and into a stilling basin. From the stilling basin, flow will discharge to the eastern perimeter channel and channel southwards to a Passive Treatment System (PTS) located to the south of the existing TMF. The spillway will be designed to accommodate normal discharge requirements and those resulting from the most extreme 1 in 10,000 year storm events.

The suggested PTS will comprise of an Integrated Constructed Wetland (ICW) which will *"provide final attenuation and treatment prior to discharge."*

Following *"closure of the TMF and the decommissioning of the existing water treatment plant, any runoff from the capped TMF and mine influenced water (MIW) collected in the perimeter channel will be channelled through the wetland treatment system*"

A meso-scale ICW trial facility has been operated on sites since 2015 providing initial data on the performance of this system (Ref. 9). The ICW design report suggests that the "*Initial monitoring of the meso-scale ICW has shown that ICWs can manage and treat heavy metals and sulphate concentrations".*

EIS report (Ref. 1) suggest that *"A spillway is required post-closure to control water levels and discharges. The spillway will be constructed prior to closure of the new cell."*

The spillway will be located in the south east corner of the Stage 6 dam wall where the reclaim pumps are located. In the event of premature closure the wall would be cut down to accommodate a lower tailings level. The water will be discharged into the eastern perimeter interceptor channel. However, the final location will be dependent on the location of the return water pumps which will ensure the lowest tailings level and the location of the sand ramp where the shortest route from the mill is also the south east corner of Stage 6. If this was chosen for the sand line, then the return pumps and spillway would be located in the south west corner of the Stage 6 dam wall.

5.19.2 **Amec Foster Wheeler Comments**

The combination of soil cover and spillway for TMF is typical of ring-dyke type facilities and should be suitable for the proposed TSF. However, considerations should be given in the design of the cover system in preventing water infiltration into the tailings.

Cost implications for the proposed closure plan were not addressed by Amec Foster Wheeler.

Condition 2 of Meath County Council notification NA/160408 requires that *"The Passive Treatment System to the south of the existing Tailings Storage facility shall not permitted. The Passive Treatment System shall be subject of a separate planning approval.*" Amec Foster Wheeler suggest that it would be preferable that the development of the tailings storage facility Stage 6 includes the development and testing of a suitable water treatment system.

Although initial results from ICW trials suggest that the system can "*manage and treat heavy metals and sulphate concentrations",* further study and field works are required to confirm suitability of this system.

A composite liner system (compacted low permeability soil and geomembrane) is recommended for the ICW ponds.

The flood risk assessment undertaken as part of the EIS study suggests that *"overall, the flood risk to and from the proposed ICW development is low'*. However, this is subject to "upsize" of the existing culvert structures. Further detail of culvert upsizing is required as part of the design.

It is recommended that the perimeter channel used to discharge water from the TSF will be lined.

Precipitation associated with PMP events should be considered for closure spillway design.

5.20 CONCLUSIONS AND RECOMMENDATION

Amec Foster Wheeler have reviewed documentation related to the proposed Stage 6 TMF extension. Conclusions and Recommendations are made in each section above and should be referred to in the first instance. The following list is a short summary of some of the issues noted:

- The TMF report for the proposed Stage 6 TMF extension (Ref. 10) does not state the level of report (pre-feasibility, feasibility etc.) and does not include a discussion on further work required before implementation and further studies required to support environmental assessment and regulatory requirements
- The TSF interceptor channel should be lined to prevent any potential seepage into the ground
- Limited information was provided on water management and adopted design criteria for freeboard and storm events. The lack of an emergency spillway a concern
- No Water Balance Model was provided
- The TSF should not be designed or used for water storage
- The assessment of potential for acid generating drainage should also include construction materials. It is recommended that laboratory testing is also carried out during TMF operation to confirm that there are no significant changes in the tailings geochemistry
- It is understood that Tara Mines is proposing to import "demolition waste or materials made from construction and demolition waste" for TMF construction (Appendix 2 Response to Further Information Request 08/11/2017. The geotechnical investigation should also address imported material to confirm suitability for construction

- A sensitivity analysis should be undertaken to assess any potential variation in the parameters for soil foundation, tailings and embankment construction material.
- The assessment of potential for acid generating drainage should also include construction materials. It is recommended that laboratory testing is also carried out during TMF operation to confirm that there are no significant changes in the tailings geochemistry.
- In the absence of an emergency spillway the adopted freeboard during operations need justification, including i) definition of the design storm events for various duration and return period and PMP and ii) assessment of TSF design storm events storage capacity
- Although the project site may be located in a low seismic area, the potential for liquefaction should be addressed based on the anticipated maximum seismic peak ground acceleration, embankment fill and foundation soil conditions.
- It is recommended that an alternative seepage detection and collection system reporting to a lined peripheral channel will be considered to minimise potential for contamination.
- Collection systems for clean runoff and for seepage from the TMF should be separated. The seepage peripheral channel should be fully lined if used to collect and discharge seepage water into the water treatment system.
- The dam breach analysis confirmed that the proposed TMF facility should be classified as high risk. Amec Foster Wheeler agree that further analysis should be carried out based on actual tailings characteristics to fully assess TMF zone of influence in the event of dam breach.
- Mitigation measures must be adopted to prevent any risk for local residents and nearby properties associated with dam failure.
- The current existing Internal Emergency Plan (IEP), the Major Accident Prevention Policy (MAPP) and TMF Operation, Maintenance and Surveillance Manual will need to be updated to include Stage 6 extension and the TMF zone of influence as identified by the dam break study.
- The combination of soil cover and spillway at closure for TMF is typical of ring-dyke type facilities and should be suitable for the proposed TSF. However, considerations should be given in the design of the cover system in preventing water infiltration into the tailings.
- A composite liner system (compacted low permeability soil and geomembrane) is recommended for the ICW ponds.
- It is recommended that the perimeter channel used to discharge water from the TSF will be lined.
- Precipitation associated with PMP events should be considered for closure spillway design.

6. PROPOSED AMENDMENTS TO THE CURRENT IEL CONDITIONS

The current IEL conditions focus on requirements for pollution prevention and control for the mine, including the TMF. The proposed TMF extension does not substantially change those requirements, which remain valid. However, there are some specific references, such as those to the Stage 5 EIS in Section 6.18 and 6.19, that should be reviewed and updated.
The current license in Section 3.6.1 states:

> *"The licensee shall submit proposals for any Specified Engineering Works, as defined in Schedule D: Specified Engineering Works, of this licence, to the Agency for its agreement at least two months in advance of the intended date of commencement of any such works. No such works shall be carried out without the prior agreement by the Agency."*
>
> Where Schedule D includes "An extension or raise of the Tailings Management Facility."

Although the proposed design needs further work and definition, it is Amec Foster Wheeler's opinion that, Section 3.6.1 covers the submission and approval process for the Stage 6 extension of the TMF and that the particular concerns should be addressed as part of that approval process.

7. REFERENCES

1. Boliden Tara Mines Ltd (April 2016) Environmental Impact Statement TMF Extension 6, ICW and associated works
2. Tobin Consulting Engineers (April 2016) Boliden Tara Mines: Stage 6 Tailings Facility and associated developments Natura Impact Statement
3. Environment Canada (2011) Guidelines for the assessment of alternatives for mine waste disposal
4. AECOM (January 2016) Flood risk assessment report
5. ICOLD (2016) Selecting seismic parameters for large dams - Guidelines (revision of Bulletin 72)
6. Boliden Tara Mines Ltd (2016) IEL PO516-03 Review Application Attachment D Infrastructure and Operation
7. Boliden Tara Mines Ltd (2013) Extractive Waste Management Plan
8. Boliden Tara Mines Ltd (December 2016) Closure Remediation and Aftercare Management Plan (CRAMP)
9. Vesi Environmental (2016) Integrated Constructed Wetland for Tailings Management Runoff
10. Golder Associate (March 2016) Boliden Tara Mines Design for the Stage 6 Tailings Management Facility

Attachment 1
Documents Review Register

IEL Application Documents Review

PROJECT DOC. NO.:	
PROJECT NAME:	**Assessment of proposed extension to Tailings Management Facility at Boliden Tara Mines**
CLIENT:	**EPA Environmental Protection Agency**
DATE.:	**30-Dec-17**
PROJECT NO.:	**7879130116**

Item No.[1]	Document Title	Section	Report/Document Excerpt	AmecFW Comment/ Question/ Request	EPA Response/Further Information Received	AmecFW Final Comment/Request
1	Attachment A.1- Non Technical Summary	6.0	The facility is not an establishment to which the EC (COMAH) Regulations apply (now Seveso III Directive (2012/18/EU) - S.I. 209/2015 under Irish Regulations)	This will need clarification as from Appendix B.10 it would appear that this cannot be ruled out		
2		7.0	When the valuable minerals have been recovered in the flotation process, the remaining material is known as tailings. Slimes and fine particles are removed using cyclones and are pumped to the tailings pond, which is located 2.5 kilometres from the mine site. The suspended solids settle out and clean water is recycled to the mine site for re-use in various processes.	The term "clean water" should not refer to tailings pond water is incorrect		
3		8.0	This IE License review application is being requested to take account of the proposed Stage 6 extension to the TSF and extend the site boundary at the TSF and to extend the IEL boundary to cover possible extensions to future mining areas.	Amec Foster Wheeler addresses Stage 6 TMF only.		
4		9.0	An annual independent review of hydrogeological, hydrological and water quality monitoring at the Tailings Management facility is undertaken. Data collected during 2015 is presented in the AECOM report Review of 2015 Hydro-Environmental Monitoring Data in Appendix 1-1. The report reviews 2015 data and compares with historic monitoring data between 1996 - 2015 to identify changes and trends in hydrogeological and water quality conditions	Copy of 2016 TMF monitoring report was not provided. The review was based on AECOM report		
5	Attachment B - General	Section B.10	The facility is not an establishment to which the EC (COMAH) Regulations apply (now Seveso III Directive (2012/18/EU) - S.I. 209/2015 under Irish Regulations). The thresholds outlined in this legislation for hazardous materials are not being exceeded. Refer to report in Attachment B.10.	Need clarification. From Appendix B.10 would appear that this cannot be ruled out		
6	Appendix B.2 Location Maps					
7	Appendix B.6.1 - Boliden Tara Mines Ltd (April 2016) EIS - TSF Extension, Stage 6, ICW and associated works	1.3	E.I.A. Regulations	Reference should also be made to 2013 European Union Regulations on Industrial Emissions (S.I. No. 138 of 2013).		
8		2.6.1	the existing tailings facility acts not only as a location for the deposition of tailings but also as a reservoir for storage of water.	**The TSF should not be used for water storage.**		
9		2.6.2	Suitable options should provide for a suitable capacity for temporary water storage	The report suggests that the proposed TSF can potentially be used as "temporary" water retention facility. This is not best practice as water management should rather aim at minimising volume of water stored within the TSF		
10		2.6.2	The relative advantages and disadvantages of each option from an engineering and operational perspective are summarised in Table 2.1	Although the project refers to the extension of an existing facility a more detailed analysis should be undertaken related to the technical impacts of various options. It is recommended that Multiple Account Analysis will be undertaken as described in the Environment and Climate Change Canada (ECCC) "Guidelines or the Assessment of Alternatives for Mine Waste Disposal"	Document provided on "Evaluation of alternative tailings disposal methods using Multiple Account Analysis"	
11		2.6.2	A theoretical analysis was undertaken of the potential environmental impacts associated with the alternative options.	Same considerations as above apply to the environmental impacts	See Item 10 above	
12		2.6.2	Landownership was not considered as part of the "theoretical" review of options, although it is acknowledged as a major practical consideration for some of the options.	Any socio-economic impacts should be considered as part of the TSF options evaluation	See Item 10 above	
13		3.1.2	The upstream slope of phase 1 will be constructed with a slope of 2H:1V	For ease of liner installation and subgrade preparation purposes a 3H:1V slope should be considered		
14		3.1.2	Construction methodology	Design drawings needed for review	Feasibility Study drawings provided in response to request for information	
15		3.2	Construction Materials	Type A1, A2 and A3 as the description is identical for all materials. There are no specification for particle size grading other than the requirement for the maximum size. PSD curves should be provided for all the proposed materials. The need for a transition/filter zone between the D2 drainage blanket and type A fill should be addressed		
16		3.3	Generally, prior to the preparation of the foundations, a resistivity and microgravity survey would be undertaken to delineate the presence of any palaeokarstic features in the limestone bedrock	A comprehensive GSI of the site should be undertaken prior to construction as part of the TSF design to fully address foundation conditions		
17		3.4.4	A leak detection survey using DC electric current will be undertaken after the installation of the lining system	The term leak detection in Section 3 of the EIS report applied to geophysical (DC) survey is misleading.		
18		3.5	Seepage	No seepage analyses model and 2D sections through the proposed TMF have been provided. Seepage analyses are required to estimate phreatic surface for use within stability modelling.		
19		3.6	Perimeter Interceptor Channel	The criteria adopted for the selection of channel type and sizing should be provided. The channel should be lined	Tara Mine Response to Further Information Request 08/11/2017 - Item 4: "Any seepage passing through defects in the lining system will mix and be diluted with ground water. Ground water flow will be intercepted by the perimeter interceptor channel. The perimeter interceptor channel will discharge into the existing (Stage 5) east and west perimeter interceptor channel and will be pumped back into the active dam (Stage 5) from where it will be reclaimed to the processing plant. The interceptor channel would not intercept ground water flow if it were lined".	It appears that contamination may have occurred in the past through the existing unlined interceptor channel (See items 112,113 and 115). It is recommended that an alternative seepage collection system will be considered reporting to a lined peripheral channel
20		3.7	Embankment Stability Modelling	In the document there is no reference to the criteria adopted for the analysis such as required Minimum Factor of Safety and seismic parameters. ICOLD recommendation for the selection of seismic parameters should be applied		
21		3.7.3	Geotechnical parameters	The tabulated geotechnical parameters should refer to laboratory and site investigation. Reference should be included to relevant GSI data. A sensitivity analysis should be undertaken to assess any potential variation in the parameters for soil foundation and tailings material. There is no indication on interface strength for the proposed composite liner. This will need to be evaluated based on laboratory tests on soil liner bedding and geosynthetics material selected for project use.		
22	Appendix B.6.1 - Boliden Tara Mines Ltd (April 2016) EIS - TSF Extension, Stage 6, ICW and associated works	3.7.4	Stability modelling	The type C protection and geosynthetics composite layers have not been included in the model. It is not clear why the model shows various elements/zone for random fill and type A materials as the parameters adopted are identical. The analysis should address both short term (following construction) and long term scenarios (TMF development and closure).The stability of the main embankment of the TMF should be evaluated at three different stages: (i) following completion of Phase I embankment and prior to tailings disposal, (ii) at end of Phase I and following construction of Phase II, and (iii) once the TMF dam has reached its final estimated design height.	Slope Stability Analysis provided	

IEL Application Documents Review

amec foster wheeler

PROJECT DOC. NO.:	
PROJECT NAME:	**Assessment of proposed extension to Tailings Management Facility at Boliden Tara Mines**
CLIENT:	**EPA Environmental Protection Agency**
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Item No.[(1)]	Document Title	Section	Report/Document Excerpt	AmecFW Comment/ Question/ Request	EPA Response/Further Information Received	AmecFW Final Comment/Request
23	Appendix B.6.1 - Boliden Tara Mines Ltd (April 2016) EIS - TSF Extension, Stage 6, ICW and associated works	3.7.5	In the statistically unlikely event of an earthquake, the factor of safety is 0.99 which under these conservative conditions, is acceptable.	Although the scenario associated with a factor of safety of 0.99 is stated to be "statistically unlikely" the result of pseudo-static analysis indicates that the seismic stability of the dam may not conform to the minimum stability criteria.	Dynamic Response Analysis provided (See Appendix to Tara Mines Response to Further Information Request 08/11/2017)	
24		3.8	This type of perimeter dam used for tailings storage, which has no external catchment area, is normally operated without spillways.	Although the construction of the starter embankment (Phase I) and subsequent downstream raise should ensure that sufficient retention volume will be available reference should be made to the criteria adopted to determine the minimum design freeboard in the absence of emergency spillway	Tara Mine Response to Further Information Request 12/09/2017 - Item 4: "Spillways will be installed at the end of the life of the facility as was the case at Galmoy and Lisheen facilities to protect the dam walls from being overtopped in the long term at closure"	Perimeter dam may be designed and operated with no emergency spillway. However, the design will need to incorporate sufficient freeboard to contain design storm rainfall. Duration and return period should be selected based on Best practice and international guidelines.
25		3.9	During the operation of Phase 1 and Phase 2 the tailings level will be filled to a point leaving a 'free board' of 1 metre	In absence of emergency spillway the adopted design pond level of 1 m below the crest during operations is considered insufficient.	Tara Mine Response to Further Information Request 08/11/2017 - Item 2: "Water levels in the facility are controlled by continually pumping water back (reclaiming) to the processing plant for reuse or further treatment and discharge. In the event of a pump failure no water would be pumped to or from the facility. The facility will operate with a minimum free board of 1 metre, meaning there will be reserve capacity to store 1000mm of water. Based on the OPWs Flood Studies Database (Web Portal - http://opw.hydronet.com) available data for the Navan area would suggest that during a 1 in 500 year rainfall event (AEP: 0.2%) over a continuous period of 600 hour (25 days) the maximum potential rainfall depth would be 268.1mm c. 27% of the available storage provided by the 1 metre free board.	Freeboard should be validated based on the theoretical greatest precipitation (Probable Maximum Precipitation PMP) for a suitable given duration. The PMP is determined for very long return period and although generally not defined is considered to be in order of 100,000 years or greater
26		3.9	To prevent damage of the lining at the point of discharge and to provide surcharge for the base, the basin should be filled with a minimum of 1 m of water equating to approximately 430,000 m3.	Alternative to the proposed 1 m water cover geomembrane protection should be considered		
27		3.9	Figure 3.20 Line protection - tyre arrangement	A more detailed description of the proposed return water system should be provided. Figure 3.20 of the EIS report shows a concrete platform 2 m from the toe of the slope (adjacent) to the 500 g/m^2 geotextile. The design criteria and requirement for a concrete platform need clarification. Details of liner/concrete seal should be provided.		
28		7.3.2	Existing Road Network. Thereafter, traffic generated by the TMF is expected to operate on national roads which are designed to accommodate such traffic without producing any additional adverse environmental effects. As such, these are not considered in this report.	Need clarification. From the document would appear that an assessment on the existing road based on two alternative route has indeed been undertaken		
29	Appendix B.6 - 2 Meath County Council Notification of Decision to Grant Permission (Planning ref NA/160408)	Schedule of Conditions. Item 3		The document suggests that the Passive Treatment System for TSF closure will not be part of the current planning application. The development of the TSF should be addressed together with the water treatment facility to avoid the risk that the TSF will be constructed and developed without suitable planning for water treatment during operation and at closure		
30		Schedule of Conditions. Item 9		Unclear. A comprehensive seepage and slope stability analyses should be part of the current application and IEL Review. Point b) and point j) seems identical. The Operation Maintenance and Surveillance manual should address all aspect of TSF development and operation		
31		Schedule of Conditions. Item 10		The independent consultant should have proven experience on TMF design, construction operation and closure		
32	Appendix B.6 -3 Planners Final Grant for each planning permission granted since last Licence Review Application in 2010					
33	Appendix B.6-4 Boliden Tara Mines Ltd 2016 STAGE 6 TMF Natura Impact Statement	Section 2.2.1	The existing TSF is constructed as a ring-dike configuration, enclosed by earth-fill embankment walls. The embankment walls are constructed of low permeable glacial clay till and armoured with a layer of coarse material on the upstream slope.	Need clarification. As from other documents would appear that armour will be placed on the downstream slope only		
34			The Stage 5 extension was a further upstream extension. This 4 meter vertical raise too the overall height of the facility to C 22 metres. The proposed Stage 6 extension will be constructed in two phases. Phase 1 will be a later extension to the north of the existing facility and will extend to a height of 14 metres and will tie in to the northern wall of the existing dam.	More details are needed of the proposed interface between existing upstream wall and the proposed Stage 6 extension		
35		3.1.2	The upstream slope of phase 1 will be constructed with a slope of 2H:1V and will be keyed into the northern embankment wall of the existing facility. The crest elevation will be 59.29 m AOD (14 metres above ground level).	As per Item 13 above for ease of liner installation and subgrade preparation purposes a 3H:1V slope should be considered		
36			The crest width of the dam walls for all phases is 6 m and the maximum wall height will be approximately 22 m.	For safety reason a wider crest (min 8 m) may be advisable		
37			Sections through the dam wall are presented in Drawing 6.5 and the section locations are shown in Drawing 6.6. Much of the dam wall footprint is within the existing areas which have been previously borrowed for Stage 5	No drawings provided	Feasibility Study drawings provided in response to request for information	
38			The upstream sector of the proposed dam, Figure 3.4, will consist of a 6m wide unit of clayey glacial till (Type A1 and/or Type A2). The footprint of the dam wall will be constructed with a 1m minimum thickness of Type D2 rock which acts as a drainage blanket	No Figure 3.4 included	Feasibility Study drawings provided in response to request for information	
39		2.3	Construction materials will be sourced for a number of potential sources, including: On site „borrow pits" Onsite stockpiles Third party licenced facilities The main mine site at Knockumber (surplus mine rock)	A report addressing geotechnical and geochemical characterisation for all materials should be provided		
40	Appendix B.6-4 Boliden Tara Mines Ltd 2016 STAGE 6 TMF Natura Impact Statement	2.3.1	Passive treatment system (Integrated Constructed Wetland) has been designed and will be constructed (approximately 10 years) to take discharge from the capped stage 5 area and the operational Stage 6 area. The ICW will be in place during operation of the Stage 6 area and throughout the decommissioning phase of the Stage 5 and Stage 6 areas.	Alternative options should be considered in the event that ICW will be unsuitable to treat water from the TSF		
41		2.4.4	It was observed that the extreme volumes of rain in early November resulted in a large body of water on Stage 5b of the TSF, and activity shifted from Stage 5a to 5b (with little or no roosting on 5b during October, when there was very little standing water present).	The comment on "large body of water" raises concern on TSF operation.		
42		4.4.3	Once the Stage 5 and Stage 6 areas have been capped, there is potential for groundwater seepage and surface water run-off to carry heavy metals, suspended solids and other contaminants to the River Blackwater.	Need clarification		
43		4.6.3	The construction of the ICW will come after the closure of Stage 6 and will include a retention pond	It is recommended that the ICW construction will commence prior and in preparation of Stage 6 closure		
44	Appendix B.6 - 5 NIS – Development of Wind Turbine at Knockumber					

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DATE.:	**30-Dec-17**
PROJECT NO.:	**7879130116**

Item No.[1]	Document Title	Section	Report/Document Excerpt	AmecFW Comment/ Question/ Request	EPA Response/Further Information Received	AmecFW Final Comment/Request
45	Appendix B.6 - 6 NIS – Discharge to River Blackwater	Section 7.5	All water from the process plant is pumped to the tailings facility for treatment prior to return of treated water to the reclaim pond.	This need clarification. No water treatment undertaken at the TSF		
46	Appendix B.6 - 7 NIS – Excavation of Material in Simonstown Borrow Area					
47	Appendix B.6 - 9 NIS – Development of Mine Return Air Shaft, RAR 5N					
48	Appendix B.6 - 10 NIS – Mining into Liscartan					
49	Appendix B.9 Site Notice for application to the EPA for review of industrial emission licence					
50	Appendix B.10 SEVESO III Classification					
51	Appendix B.13 Variations/Adjustments to conditions or schedules of the existing licence					
52	Attachment C Management of the Activity					
53		Section D.1 Effluent Discharge	All water from the process plant is pumped to the TSF	This need clarification. No water treatment undertaken at the TSF		
54		Section D.1 Effluent Discharge	Water from the Reclaim Water Pond decants, via a controlled overflow, to a Clear Water Pond (Discharge pond)	Need clarification. From the schematic and Section "Water Treatment Plant (Lamella)" the TSF return water is pumped to the Reclaim Water Pond 1 and then discharged to Reclaim Pond 2, mixed with mill processing pant and normal mine water and treated before pumped to the clear water pond		
55	App. D Licence review - Phase 1 and Phase 2 Hydrological and site investigations					
56	Attachment G Resource Use and Energy Efficiency					
57	Attachment H Materials Handling					
58	Appendix H - 1 Bund Integrity Test Report Appendix H - 2 Weekly Bund Inspection Check Sheet Appendix H – 3 Hazardous Waste Handling: UN Number and class Appendix H - 4 Hazardous Waste Management Procedure Appendix H - 5 Non Hazardous Waste Management Procedure					
59	Appendix H – 6 Extractive Waste Management Plan	1.3	The Plan shall be reviewed at least once every five years thereafter in a manner agreeable to the Agency and amended where there are substantial changes to the operation of the waste facility or to the waste accumulated or deposited	This will need to be updated addressing Stage 6 TMF		
60		7.0	Management of Mine Waste	The current Operation, Maintenance and Surveillance Manual will also need to be updated		
61		8.6	Seepage and Supernatant Control	As above		
62	Appendix H - 7 PRTR_2015 Worksheet for Treatment and Transfer of waste					
63	Attachment I Existing Environment & Impact of the Activity	Table I.8	Tailings Deposition Plan	No tailings deposition plan included for review	Tailings discharge line layout and typical spigot arrangement provided (See Tara Mines Response to Further Information Request 12/09/2017)	
64		Table I.8	A layer of coarse material will be placed on the upstream side of the raise to protect the slope against wave scour from the ponded water (Rip rap used on upstream side slopes to prevent water erosion).	This need clarification		
65		Table I.8	Tailings supernatant water is pumped to the mill. An unlined ditch, which surrounds the embankment perimeter, collects seepage water via a blanket of finger drains and intercepts flow from under the dam. The interceptor ditch feeds several collection sumps from which excess water is pumped back to the tailings pond, if necessary.	The interceptor channel should be lined		See comment to Item 19
66		Table I.8	A probabilistic risk assessment has been undertaken previously for the overall TMF. A number of failure scenarios were examined and it was concluded that a failure of a dam wall with an associated release of pond water and mobile tailings solids was the only major accident scenario for the TMF.	Similar analysis should be undertaken for Stage 6 TMF	Dam break Analysis provided (See Tara Mines Response to Further Information Request 12/09/2017)	
67	Appendix J – 1: Environmental Emergency & Preparedness Response Procedure	2.3				
68	Appendix J – 2: Fire Water Risk Assessment					
69	Appendix J – 3: MAPP Major Accident Prevention Policy					
70	Appendix J – 4: Internal Emergency Plan for the TMF					
71	Attachment K Remediation, Decommissioning, Restoration and Aftercare					
72	Appendix K – 1: ELRA Knockumber Mine Site					
73	Appendix K – 2: ELRA TMF					
74	Appendix K – 3: CRAMP	1.2	The facility serves as containment for mine tailings to settle and consolidate, as well as a storage dam for water which is re-circulated to the processing plant for reuse.	**The TSF should not be used as water storage**		
75		2.2.2	Managed deposition of tailings before closure will provide a valley profile that is required for the cap and the tailings will beach at slopes of between 0.1% and 0.5%. This will allow surface water drainage and runoff to be confined to the decant structure and into the interceptor channel.	Capping system should ensure that there will be no ponding water and prevent infiltration		
76		2.3	The tailings facility serves as a water storage dam, as well as a mill tailings repository. The principal water streams that enter the Randalstown facility comprise underground mine drainage, surface drainage from the plant and mill process water and a small amount of seepage water collected in the perimeter interceptor channel	Inflows to the TMF also include water from slurry tailings and precipitation. **The facility should not be used as water storage**		
77			The Stage 6 unlined perimeter interceptor channel will discharge into the existing TMF east and west perimeter interceptor channels during operation. An unlined perimeter interceptor channel surrounds the Stage I, II and III embankment walls collecting seepage water via a blanket of finger drains and intercepts flow from under the dam. The internal drainage system for Stage 4 and Stage 5 is directed to the perimeter interceptor channel by means of manholes, pipework and chutes. The perimeter interceptor channel feeds two collection sumps from which all water is pumped back to the tailings pond. The main sump is at chainage 2125m in the southern sector of the perimeter interceptor channel where the ground level is at its lowest on the site. In the perimeter interceptor channel are a number of weirs where the flow rates are monitored on regular basis. The fall on the perimeter interceptor channel is approximately 1 in 300 to the sumps.	The interceptor channel collecting seepage from the TSF embankments should be lined		See comment to Item 19
78			The interface between the in situ tailings and the overlying blanket material is more complicated because of the variability of the tailings deposits. The drainage blanket filter material will in some areas take flow from the fine tailings, and in others, from the sand sized tailings. In order to maintain the practical aspects of the design, a filter fabric, Terram 2000, have been used to separate the drainage material and underlying tailings. The fabric will also improve stability during the placement of the initial layers of compacted fill on the underlying soft tailings deposits.	Assume the section refers to the capping system. The main aim of this should be to minimise risk of ponding water and prevent infiltration into discharged tailings		
79			The drainage system must be able to convey the seepage flows. This is easily satisfied by the chimney drain. The embankment consists of relatively uniform sandy to silty clay till placed as a homogeneous mass without segregation of the coarse particles and compacted to at least 95% of the standard Proctor compaction dry unit weight, the upper bound permeability of the fill is unlikely to exceed 10^{-9} m/s	Is the estimated permeability based on laboratory tests?		
80		2.3	It is proposed to install an inert soil cap cover over the existing Randalstown TSF and the proposed Stage 6 TSF. The cap will: Provide a productive land asset that could be used for agriculture; managed sheep farming and/or wildlife conservation purposes; Minimise the possibility of long term exposure of tailings and therefore tailings dusting; Minimise contaminant runoff from the surface; Reduce the migration of contaminants upwards to the surface and; Reduce the time frame between the post closure active phase, passive phase and finally the stable phase.	The TSF capping should aim to reduce infiltration and water ponding rather than runoff		
81		2.6	To accommodate the 45 minute 1 in 10,000 year storm event	Reference should be provided to the criteria adopted for the selection of the storm event		
82		3.2.2	Further investigations which included geophysical and high quality coring investigations, indicated that there are no significant karstic fractures present in the rock encountered beneath the tailings facility.	This seems in disagreement with other documents reviewed		

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83	Appendix K – 3: CRAMP	3.2.8	The quality of the water monitored in I.C.P. 1 E shows lightly alkaline characteristics. Values of conductivity are well above the minimum thresholds, with values reaching 2021 µS/cm which is reflected by the high sulphate values with a maximum value of 1846 mg/l recorded. Suspended solids and sulphate values are generally exceeding the EPA limits. Also elevated values of zinc, lead, nickel, manganese and aluminium were recorded. The water quality in I.C.P 1 W indicates alkalinity and conductivity values exceeding the minimum thresholds, with values reaching 3193 µS/cm which is reflected by the sulphate values with a maximum value of 1977 mg/l recorded. Suspended solids values are generally low, with some elevated recordings as the maximum of 186 mg/l in June 2007. Sulphate values exceed the minimum guideline limits with a maximum value of 1977 mg/l recorded. Also, elevated values of zinc, lead, nickel, manganese and aluminium were recorded.	This seems to confirm the requirement for a lined interceptor channel		See comment to Item 19
84	Attachment L Statutory Requirements					
85	2.1 List to Statutory Bodies					
86	2.2 List of Local Residents					
87	2.3 List of Attendees at Public Consultation Meeting					
88	3.1 Integrated Constructed Wetland Design - Vesi Environmental Design	Section 3.4	The below table shows sulphate concentration of 700mg/l from the ICW, however lower concentrations are expected from the ICW. This value has been used for the purpose of the calculation to show that there is capacity in the river to receive these concentrations even at high flow rates from the ICW, without exceeding the drinking water standard of 187.5mg/l.	There may be still concern on suitability of this system for water treatment		
89			Maps highlight that the site is prone to flooding, while local knowledge is that there has been no flooding on the site. However a Stage 1 and Stage 2 Flood Risk Assessment has been undertaken by IE Consulting for the site, see Appendix C for further details. The study found that the 'Overall, the flood risk to and from the proposed ICW development is LOW'.	This is subject to upsize of existing culvert structures		
90		Appendix A		No drawings included in the document provided		
91	4.1A NPWS Derogation DER – Bat 2016-2015					
92	4.1B NPWS Derogation DER – Badger 2016-2023					
93	4.2 List of Flora observed during surveys					
94	4.3 Results of Winter Bird Survey					
95	4.4 Results of Bat Survey					
96	4.5 Flight Maps of Whooper Swans and Golden Plover observed during winter Bird Survey					
97	4.6 Results of bat surveys					
98	7.1 Traffic Data Survey					
99	7.2 Roads Structural Evaluation					
100	8.1A Flood Risk Assessment (TSF Stage 6 site & environs)	Section 3	On the basis of the PFRA screening maps it is therefore probable that a full FRA will be called for within the planning application for the proposed extension at the Tara Mines facility due to the presence on a possible flood plain.	Scoping report only. A more detailed flood risk assessment is required.		
101	8.1B Water Framework Directive Assessment	1.2	As part of the proposed extension Blake's stream would be diverted to the east into a disused channel along the eastern boundary prior to entering the Simonstown stream.	An analysis should be undertaken to confirm that the capacity of the disused channel will be sufficient to contain the diverted flow without flooding		
102		4.2.1.5	The interceptor channels contain contaminated water from the TMF; sampling has shown that when groundwater levels are lower than the water levels in the interceptor channel it has a negative effect on sulphate levels in the groundwater. This trend in turn affects surface water quality. Migration measures are proposed regarding the amount of dewatering with respect to water levels in the interceptor.	Interceptor channels containing contaminated TMF water need to be lined to minimise risk of any potential impact to groundwater		See comment to Item 19
103	9.1 Landscape Designation Map (including viewpoint locations)					
104	9.1 Two Zone of Theoretical Visibility (ZTV) Maps					
105	9.1 Six Viewpoints Sheets, refer to Figures 9-1 to 9-9. The viewpoint sheet include sketch photomontage of the proposed development for four of the chosen viewpoints					
106	EIS Stage 6 Extension to the TSF			See Appendix B 6.1 to Attachment B for comments		
107	EIS Appendix – 8.1B			See EIS Appendix – 8.1B for comments		
108	Existing Environment & Impact of the Activity			See Attachment I		
109	EIS Stage 6 Extension to the TSF			See Appendix B 6.1 to Attachment B		
110	Current IEL Licence					
111	Amendment to IEL					
112	Inspectors Report on a Licence Review	Schedule C8	There is evidence of contamination of groundwater with sulphate to the south west of the TMF, i.e. downstream of the TMF. This indicates that, historically, some seepage has escaped the interceptor channel and moved away from the TMF.	The interceptor channel should be lined		See comment to Item 19
113			There is also some evidence of contamination of groundwater with other parameters such as zinc, iron and lead at levels occasionally higher than the Groundwater Threshold Value.	As above		See comment to Item 19
114	Technical amendment A to IEL					
115	Appendix I - 1 Review of 2015 Hydro-Environmental Monitoring Data at TMF	4.2.1	*(Sulphate)* Concentrations in the channel generally have not met the guideline value (187.5 mg/l), which is as expected, given the nature of the intercepted waters. The interceptor channel collects water from the internal drainage system within the embankment of the TMF, horizontal seepage from the TMF, local runoff and groundwater.	This seems to confirm the requirement for a lined channel		
116		4.4.2	The following additional parameters demonstrated minor exceedances of guideline values on some occasions in surface water during 2015: antimony, arsenic, chloride and lead.	Exceedances of guidelines values should be further investigated		
117		5.1	Sulphate concentrations remained below the guideline value at 70% of all bedrock boreholes, and showed an increase compared to 2014, most notably at BR1, located on the southern boundary of the TMF	As above		
118			Sulphate concentrations at OB4-P1 and BR12 also show increases of over 10%; the mechanism by which sulphate concentrations have reached elevated levels here is unclear at this time.	As above		
119	Appendix I - 2 Risk Screening and Technical Assessment Report for TMF	Limitation	The work described in this Report was undertaken between 24 January 2014 and 4 March 2015 and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances.	It should be updated to include the proposed Stage 6		
120	Appendix I – 3 Pollution Reduction Plan	3.3	As of March 2016, a pollution reduction plan has not yet been prepared for the ERBD. However it is understood that an inventory of emissions, discharges and losses is currently under consultation. Therefore it is not possible at this time to conduct a review of the pollution reduction plan or of "specific objectives… targets and deadlines" and "particular measures…to prevent and limit environmental pollution by priority substances", as required under condition 6.14 of the IE licence No. P0516-03.	The current assessment should be updated once the Pollution Reduction Plan will be made available		
121		4.3	Condition C.2.2 of the IE licence requires that emissions to water at SW1 are monitored for cadmium, lead and mercury on a weekly basis (Ref. 1). This has been conducted by Tara Mines since 2001. There have been no exceedances of the emission limit values for cadmium, lead or mercury at SW1 since monitoring began.	Need clarification. From Section 4.4.2, Appendix I-1 seems that some exceedance occurred		
122	Appendix I – 3 Pollution Reduction Plan	4.4	The minimum detection limits (MDL's) used by the laboratory exceed the EQS AA for cadmium and lead and therefore may mask exceedances	This will need to be addressed		
123	Appendix I - 4 Water Framework Directive			See EIS Appendix – 8.1B for comments		
124	Golder Associates. Technical Memo to Boliden Tara Mines Ltd. Stage 6 TMF Options Study. July 2015. No. 1532091.501			Memo identifying technical issues only associated with TSF expansion and/or construction of a new facility. No options study included in the document. No TSF options scoring and ranking addressing technical, environmental and socio-economical accounts.		

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125	Golder Associates (2016). Boliden Tara Mines: Design for the Stage 6 Tailings Management Facility. Report No. 1532091.502/A.1	2.4	Palaeokarsts are present in the Randalstown area and investigations were previously carried out on this subject for the Stage 4 dam raise project….For Stage 6, some initial geophysics was undertaken to investigate the potential for excavating the rock within the basin of the facility which indicated some anomalies. We would propose undertaking a resistivity survey over the entire footprint and a microgravity survey over any anomalies found where the Pale Beds underly the site. Micro gravity is the best technique to determine any areas of mass deficiency representing palaeokarstic features.	A comprehensive GSI of the site should be undertaken prior to construction as part of the TSF design to fully address foundation conditions		
126		3.0	The depth and relative strength condition of the underlying bedrock (References 3.4 and 3.5) was also investigated by geophysics in the northern and seven fields borrow area together with a limited amount in the Simonstown borrow area.	As above. Further site investigation (geotechnical drilling, sampling and laboratory testing) is required		
127		3.4	Site Work and borrow materials	High level estimates of material availability and excavatability only. No geotechnical characterisation of the proposed material and TSF foundation based on detailed GSI provided.		
128		4.2	Groundwater	No data provided on any planned/ongoing groundwater level monitoring at the TSF site		
129		5.1	Based on a review of historic data on earthquakes over the past 1,000 years within 1,000 km of the site, and broad estimates of attenuation, a design acceleration of 0.03g would provide for a 1 in 1,000 year event. Even up to a 1 in 10,000 year event, equivalent to the maximum credible earthquake (MCE), the acceleration should not exceed 0.06g.	More info on the criteria adopted for the selection of design seismic earthquakes should be provided.		
130			The design criteria for the site have been evaluated using seismic data of the region to derive the Design Base Earthquake (DBE) and the Maximum Credible Earthquake (MCE). These are equated to a peak ground acceleration (PGA) for the site. This procedure follows international guidelines as set out by the International Commission on Large Dams (ICOLD) (Reference 5.2).	Consideration should be given to the latest ICOLD Bulletin 148 (2016) Selecting seismic parameters for large dams - Guidelines		
131		6.0	Design	Insufficient or no information provided on water management. No TSF Water Balance Model included. No indication on adopted design criteria for freeboard and storm events		
132		6.1	The ratio of tailings volume to construction volume indicates the additional volume gained in Phase 1 by filling the existing northern and seven fields borrow areas and borrowing the remaining material to construct the walls.	Data (table and graph) showing tailings rate of raises should be included in the report		
133			Once the first phase is complete, the basin area will be sterilised to any future borrowing by the placement of the lining system. It will therefore be necessary to remove all available material within the basin area and any addition materials found would be stored on the downstream side of Phase 1 or as ramps and ancillary structures.	Table 4 reports Phase II dam volume will be 0.95Mm³. This suggest that significant volumes of borrow material from Phase I basin will need to be placed on temporary stockpiles until Phase II construction will commence. More detail on how this will be achieved should be provided.		
134		6.2	The upstream slope will be constructed with a slope of 2H:1V and for the first phase, will be keyed into the existing Stage I, II, III and Stage 4,	see comment on Appendix 6B.1 Section 3.1.2		
135		6.3	Fill material	see comment on Appendix 6B.1 Section 3.2		
136		6.10	Permanent surcharge	see comment on Appendix 6B.1 Section 3.3.1		
137		6.12	Seepage	see comment on Appendix 6B.1 Section 3.5		
138		6.13	Perimeter Interceptor Channel	see comment on Appendix 6B.1 Section 3.6		
139		6.14	Embankment Stability Modelling	see comment on Appendix 6B.1 Section 3.7		
140		6.14.2	Geotechnical Parameters	see comment on Appendix 6B.1 Section 3.7.3		
141		6.14.3	Stability Modelling	see comment on Appendix 6B.1 Section 3.7.4		
142		6.14.4	Results of Stability Modelling	see comment on Appendix 6B.1 Section 3.7.5		
143		6.15	Spillway	see comment on Appendix 6B.1 Section 3.8		
144		6.16	Appendices	No Drawings of Trial pit logs provided	Trial pit logs provided in response to request for further information	

Note 1. EPA Document List Reference:
(i) Licence review application documentation (P0615-04)
(ii) Project description and engineering design
(iii) Water Framework Directive Assessment
contamination in the vicinity of the TMF
(v) EIS for TMF extension Stage 6
(vi) Current industrial emissions licence (Register No. P0516-03) and the Inspectors Report for that licence application.
(viii) Any other documentation related to the industrial emissions licence that is deemed necessary to the assessment.

Attachment 2
Response to Further Information Requests

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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12 September 2017

Reg No: P0516-04

Dear Mr. Walsh,

I refer to your application for a licence review.

I am to advise in accordance with Regulation 10(2)(b)(ii) of the EPA (Industrial Emissions) (Licensing) Regulations 2013, that the following information is required in support of the application under Regulation 9 of the Regulations:

1. The NIS states that "the footprint of the Stage 6 facility is confined to the existing northern and seven fields borrow areas. Virtually all the area is exposed indicating rock or glacial till over the site". The EIS states that "...a resistivity and microgravity survey would be undertaken to delineate the presence of any palaeokarstic features..."
    a. Please provide a report of a comprehensive study of palaeokarst features and their potential impact on Stage 6 TMF stability. The study and report should detail the following as a minimum; site investigation plan, geotechnical logs, soil and rock laboratory testing, tailings geotechnical characterisation, geological plan and sections, and geotechnical parameters.
    b. Table 5.1 of the EIS details the geotechnical parameters adopted in the stability modelling. Please compare these modelling parameters to the parameters obtained from the study requested in paragraph 1a above. A sensitivity analysis (undertaken to assess any potential variation in parameters for soil foundation, tailings and embankment construction material), should be included in the report requested in paragraph 1a above.
2. The EIS states that the "physical and chemical characteristics of the deposited tailings will remain unchanged from those deposited previously" and the NIS states that "the tailings are expected to be non-acid generating". Please provide an updated assessment of potential for acid generation to include consideration of the construction materials to be used.

Note: Any ***telephone enquiries*** in relation to the above should be directed to **Dr. Magnus Amajirionwu** at the number above.
All ***written communications and replies*** should be directed to Elizabeth Leacy, Office of Environmental Sustainability, EPA, PO Box 3000, Johnstown Castle Estate, County Wexford.

3. The EIS refers to two alternatives used to assess the stage 6 TMF options for mine waste disposal namely; slurry and paste. This is not satisfactory. Please provide a more detailed report on the assessment of tailings disposal options from conventional slurry to dry stack. The selection of the preferred option should evaluate environmental and technical impacts and clearly demonstrate the selection process through scoring and ranking, using, for example, the multiple account analysis methods.

4. It is noted that, as part of the EIS, a preliminary appraisal was carried out to address flood risk within the stage 6 TMF and environs. Section 3.9 of the EIS states that "there is adequate control of the tailings water level which can be achieved by adjusting the discharges into the TMF and removal of tailings water by pumping from the TSF to the plant site". Clarify why neither an emergency spillway nor the capability to store probable maximum precipitation of appropriate duration (months, not hours), is provided.

5. The likelihood of seepage through the liner is discussed in section 3.5 of the EIS. However, no seepage analyses model and 2D sections through the proposed TMF have been provided, which are required to estimate phreatic surface for use in stability modelling.

   a. Please provide a seepage analyses model and 2D sections through the proposed TMF as part of the stability analysis.

   b. Provide explanation why there is no allowance for an overliner and underliner drainage as part of seepage control during operation.

6. Provide a slope stability analysis that addresses the following:

   a. Short term (following construction) scenario

   b. Long term (TMF development and closure) scenario

7. In relation to the description of the composite lining system:

   a. Provide specifications for the 500 and 1000g/m² geotextiles proposed

   b. Justify the need for the 1000g/m² geotextile (e.g. is HDPE puncture of concern)?

   c. Clarify the term carbon-rich as it applies to the geotextile

   d. Section 3 of the EIS made reference to leak detection. Clarify if a leak detection and collection system will be installed as part of the lining system.

8. It is stated that the Stage 6 TMF extension will be operated in a manner similar to the existing TSF by discharging the tailings from spigots on the dam crest.

   a. Provide a tailings deposition plan detailing the layout of the tailings pipeline, deposition points, decant location and technical specifications of the pipeline (including proposed pipe cross-section and long section).

   b. Provide an explanation why burying the tailings pipeline is preferred to the over-ground piping, in relation to containment in the event of leakage.

9. Three sources of water that are considered as process water include water ingress to the mine; water from processing plant; and surface runoff.

   a. Clarify the statement, *"All water from the process plant is pumped to the tailings facility"*.

Note: Any ***telephone enquiries*** in relation to the above should be directed to **Dr. Magnus Amajirionwu** at the number above.
All ***written communications and replies*** should be directed to Elizabeth Leacy, Office of Environmental Sustainability, EPA, PO Box 3000, Johnstown Castle Estate, County Wexford.

b. Provide a detailed explanation why collection systems for clean runoff and for seepage are not separate.

c. Provide a detailed explanation why the interceptor channel used to collect and discharge seepage water into the water treatment system is not fully lined.

10. It is proposed that the existing water treatment system will be used for both Stage 5 and Stage 6 TMF until an integrated constructed wetland system is put in place. Provide detailed information on the capability and suitability of the existing water treatment to accommodate the increased volumes following Stage 6 start-up and prior to Stage 5 decommissioning.

11. It is noted that no tailings flow slide analysis is provided in the EIS in relation to TMF dam failure. Provide an assessment of the potential impact on the environment in the event of a TMF dam failure.

In addition to the above please also provide an updated non-technical summary to reflect the information provided in your reply.

The requested information should be submitted to the Agency within ***eight weeks*** of the date of this notice, in order to allow the Agency to process and determine your application.

In the circumstances, you should make arrangements to have the required documents (1 signed original and 1 copy in hardcopy format, and 2 copies of all files in electronic searchable PDF format on CD-ROM) submitted to the Agency. Your response to this request should be directed to Elizabeth Leacy, Administration Officer, Office Environmental Sustainability.

It should be noted that the eight-week period within which the Agency is to decide the proposed determination will commence on the day on which this notice has been complied with. If you have any further queries please contact Dr. Magnus Amajirionwu at the number above.

Yours sincerely,

Dr. Magnus Amajirionwu
Environmental Licensing Programme
Office of Environmental Sustainability

Note: Any ***telephone enquiries*** in relation to the above should be directed to **Dr. Magnus Amajirionwu** at the number above.
All ***written communications and replies*** should be directed to Elizabeth Leacy, Office of Environmental Sustainability, EPA, PO Box 3000, Johnstown Castle Estate, County Wexford.

Appendix to FIR Item 3

- **Dynamic Response Analysis of Settlement of the Stage 6 Tailings Storage Facility due to a Seismic Event**

APPENDIX - DYNAMIC ANALYSIS

Golder Associates have undertaken numerous dynamic analysis in high seismic regions such as, Italy, Greece, Bulgaria, Serbia, Armenia and Turkey where the peak ground acceleration (PGA) is in excess of 0.2 g, to determine the settlement of a dam wall under seismic conditions. During seismic events, well-engineered and constructed dam walls do not fail due to slope stability issues but settle due to shaking.

To determine the settlement as a result of the maximum credible earthquake (MCE) impacting Stage 6 tailings facility, both finite element and empirical modelling was undertaken.

FINITE ELEMENT

The dam dynamic response analysis was undertaken using the finite element software package Midas GTS NX. Midas GTS NX is a comprehensive finite element analysis software package that can analyse a range of geotechnical design applications including dynamic analysis.

The dynamic response analysis was primarily focused on the prediction of the likely range of maximum and permanent deformation of the tailings dam under seismic loading. The analysis was undertaken based on the following assumptions:

- The analysis used isotropic elasto-perfect-plastic material model; and
- The analysis used drained shear strength properties for the tailings and fill material.

Geotechnical Parameters

Table 1 presents the shear strength parameters used for the drained tailings, the fill materials, the foundation material and the underlying bedrock. The shear strength parameters were chosen in accordance with the assessment undertaken in the previous 2D limit equilibrium analysis (Ref. 1).

Table 1: Shear Strength Parameters

Material	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction angle (°)
Drained Tailings	18	0	32
Random Fill	19	0	32
Material Type A1/A2	19	0	32
Material Type A2/A3	19	0	32
Material Type D2	21	0	35
Foundation Material	19	5	32
Limestone Bedrock	24	200	37

Table 2 presents the stiffness related parameters which are required for the finite element analysis. These parameters were chosen primarily based on Golders in-house previous experience and also the values reported in the technical literature.

Table 2: Stiffness Parameters

Material	Young's Modulus E (MPa)	Poisson's Ratio v
Tailings	30	0.3
Random Fill	50	0.3
Material Type A1/A2	50	0.3
Material Type A2/A3	50	0.3
Material Type D2	100	0.3
Foundation Material	150	0.3
Limestone Bedrock	1,000	0.25

Model Set-Up

The geometry of the finite element model is consistent with that used in the previous slope stability analysis. The finite element mesh is presented in Figure 1. Points A, B and C show the locations where the displacement results will be examined.

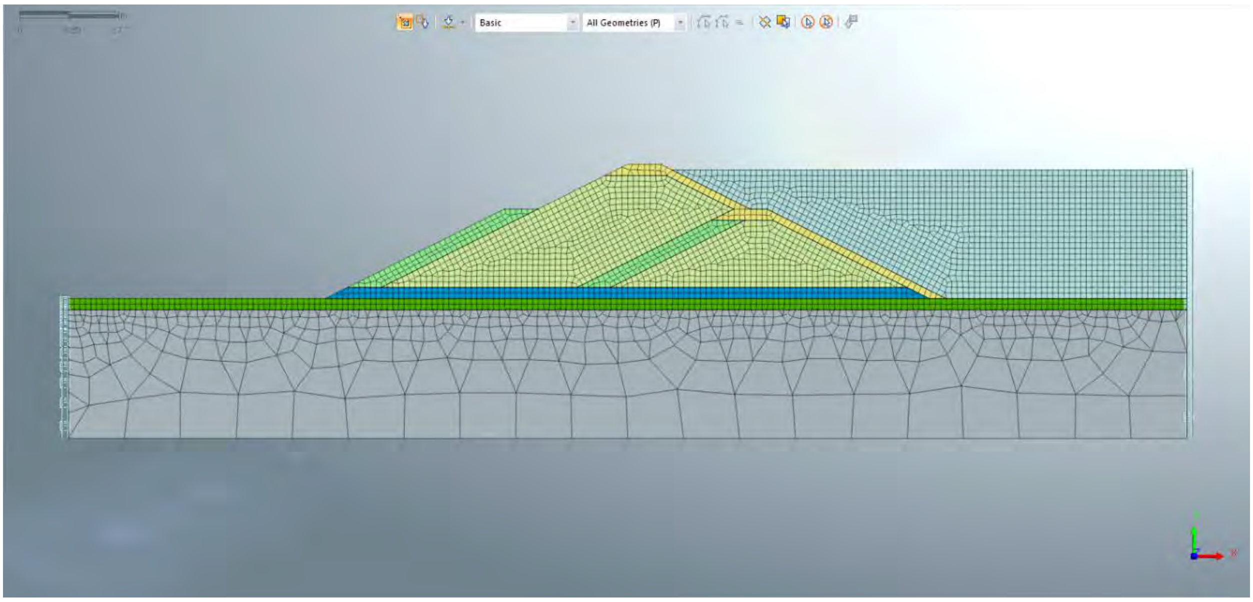


Figure 1: Finite Element Mesh

Ground acceleration data from three previously recorded earthquake events were used to develop the loading conditions for the current dynamic analysis study. These three earthquake events are:

- Ground Acceleration Time History 1: 1940 El Centro earthquake;
- Ground Acceleration Time History 2: 1979 Imperial Valley earthquake; and
- Ground Acceleration Time History 3: 1994 Northridge earthquake.

The Peak Ground Acceleration (PGA) of these earthquake were scaled down to 0.06g which is the PGA that the mine site is expected to potentially experience during 1 in 10,000 year event, i.e. equivalent to the Maximum Credible Earthquake (MCE). The processed ground acceleration time history adopted in the dynamic analysis are presented in Figures 2 to 4 all of which showing a PGA of 0.06 g.

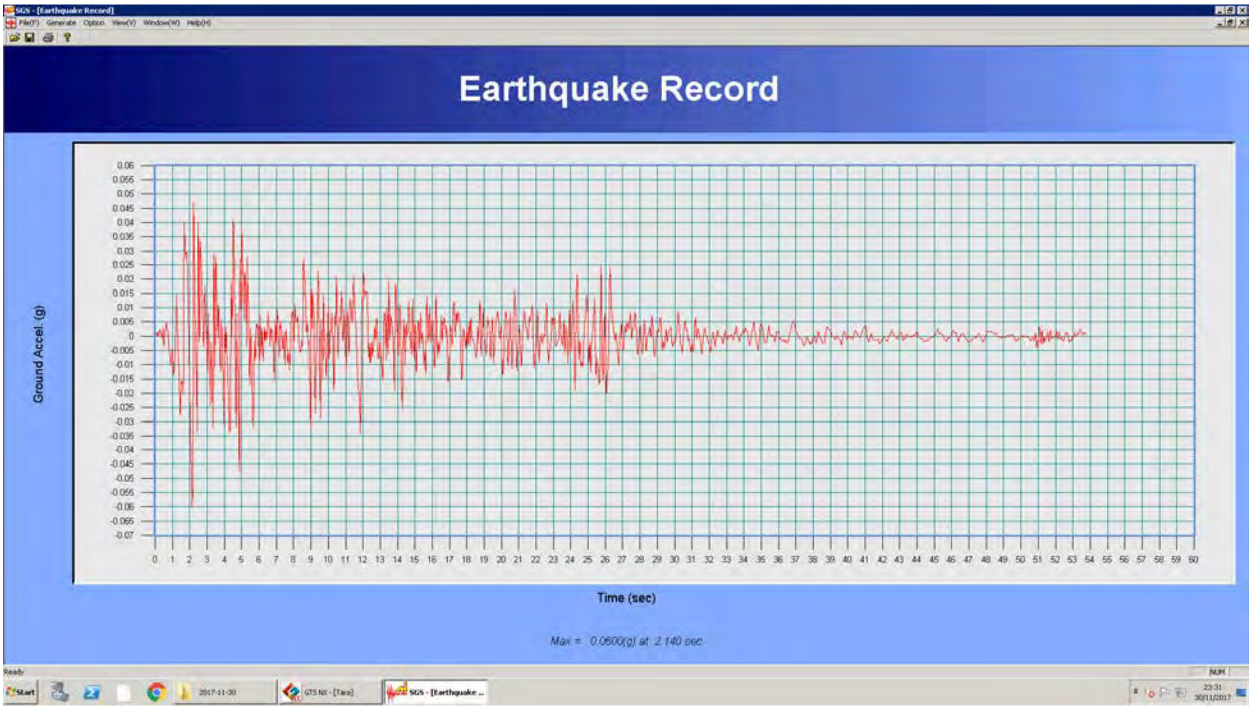


Figure 2: Ground Acceleration History 1

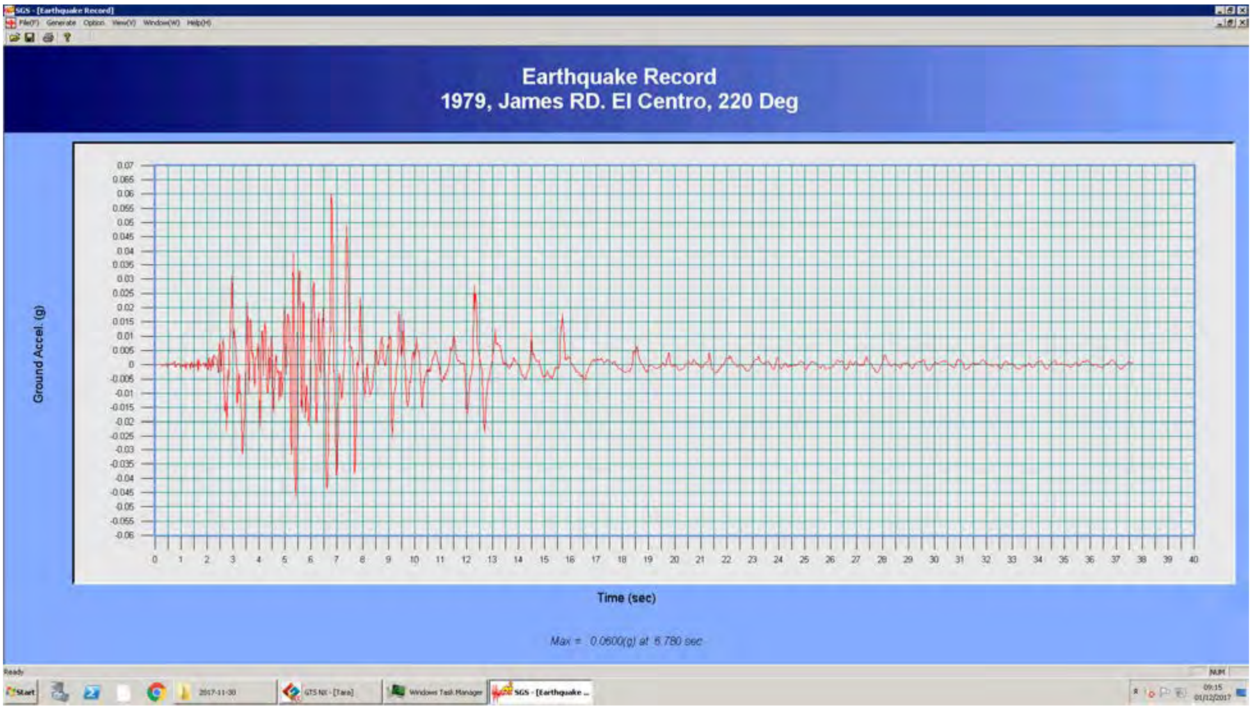


Figure 3: Ground Motion History 2

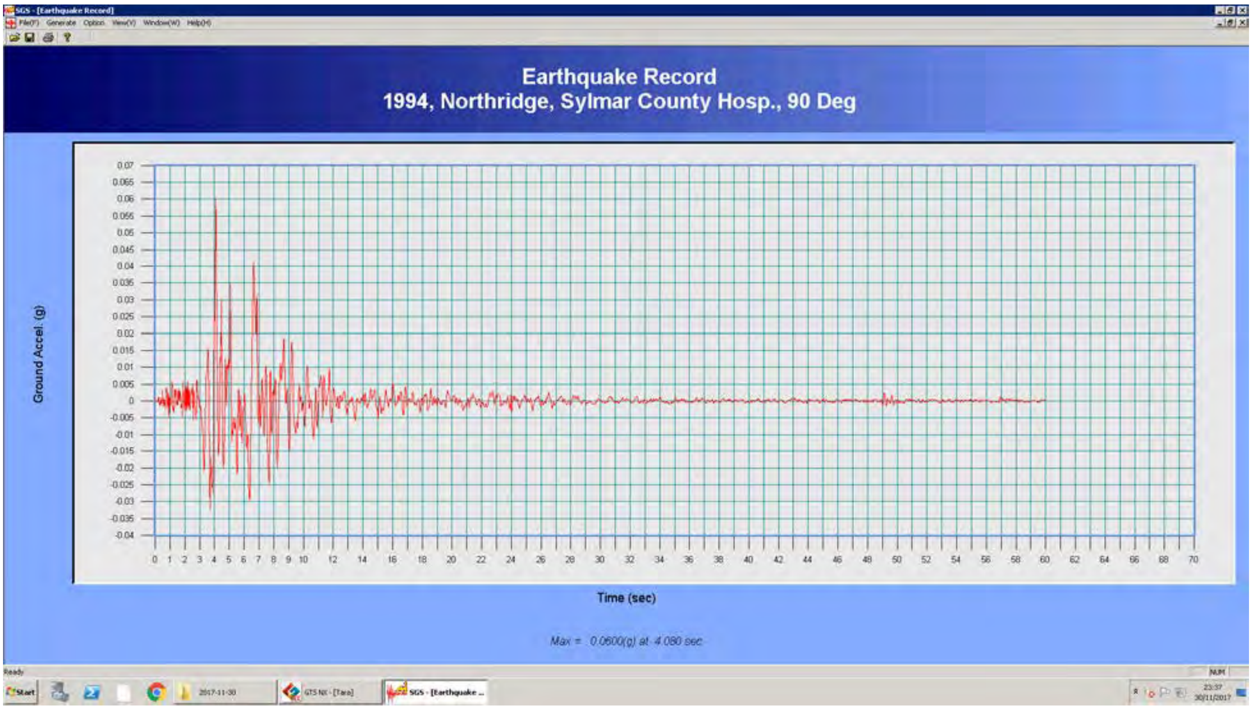


Figure 4: Ground Motion History 3

The numerical analysis consists of two phases. The initial stresses due to self-weight (i.e. static loading) were generated and activated in the first calculation phase. In the second calculation phase, seismic loadings were introduced at the model base by applying the above processed ground acceleration time history.

Model Results

Figures 5 and 6 show the horizontal and vertical stress distributions following the completion of the first calculation phase which only considers the static loading condition, i.e. self-weight. The figures show that the initial stress levels are consistent with the depth of the ground and unit weights of the materials included in the finite element model.

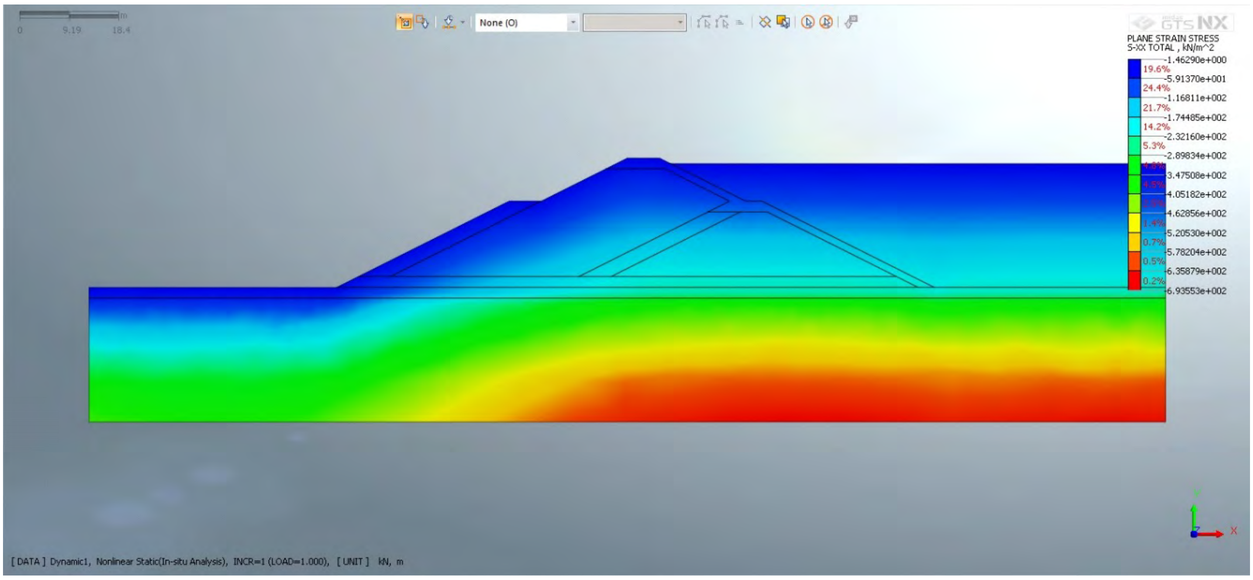


Figure 5: Initial Horizontal Stress Distribution

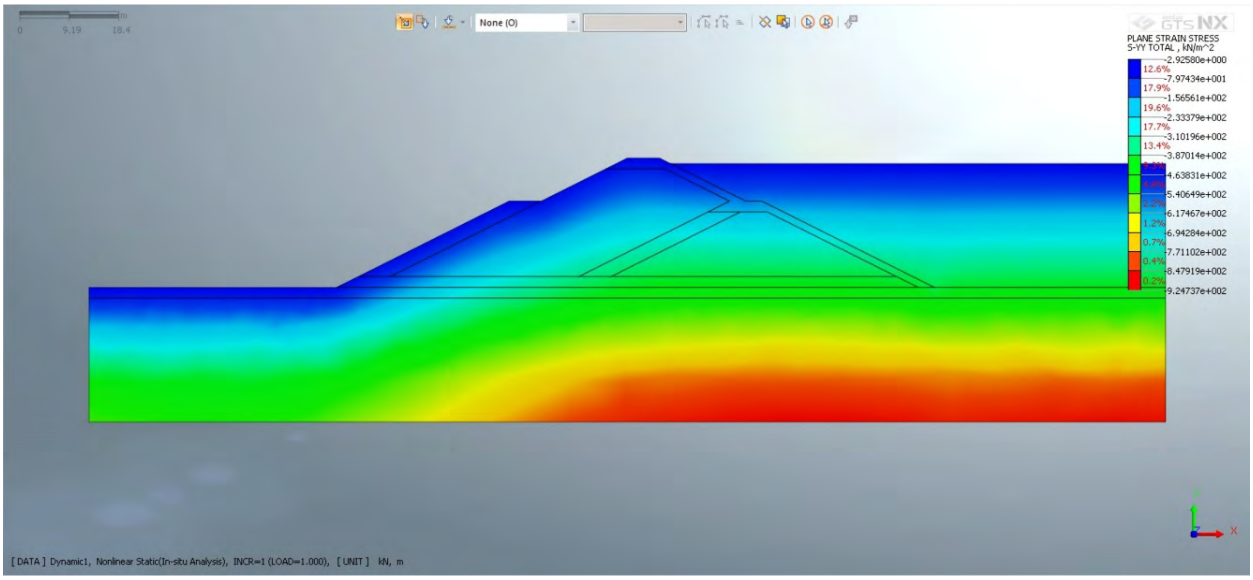


Figure 6: Initial Vertical Stress Distribution

Figures 7 to 10 present the results for the dynamic analysis using Ground Acceleration Time History 1 as the dynamic loading condition, i.e. Run 1.

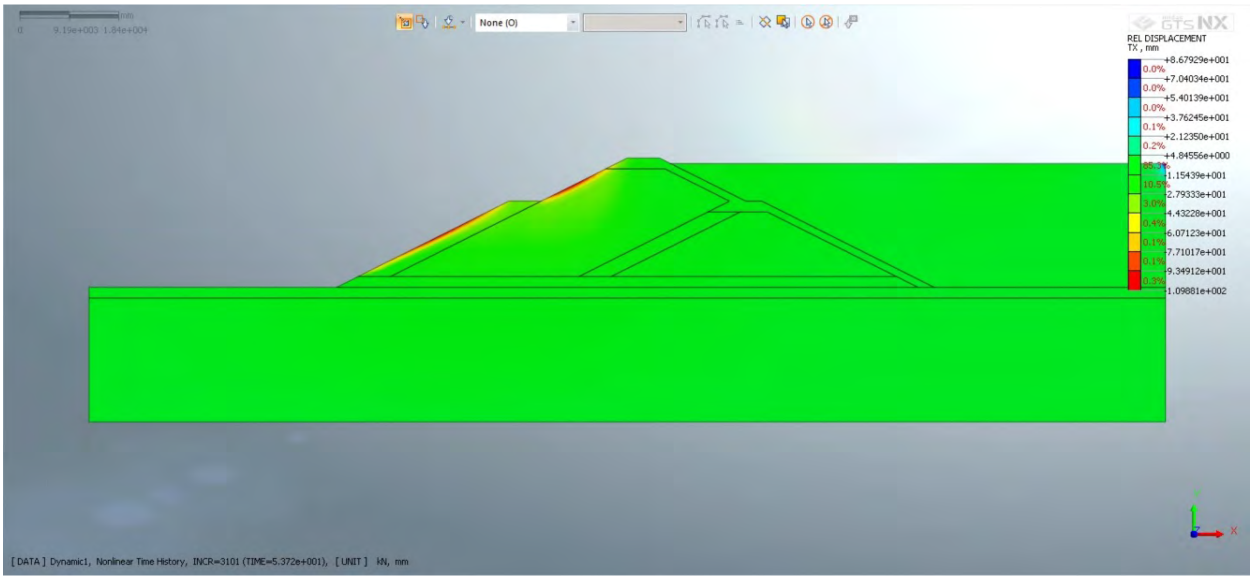


Figure 7: Run 1: Post-Earthquake Horizontal Displacement

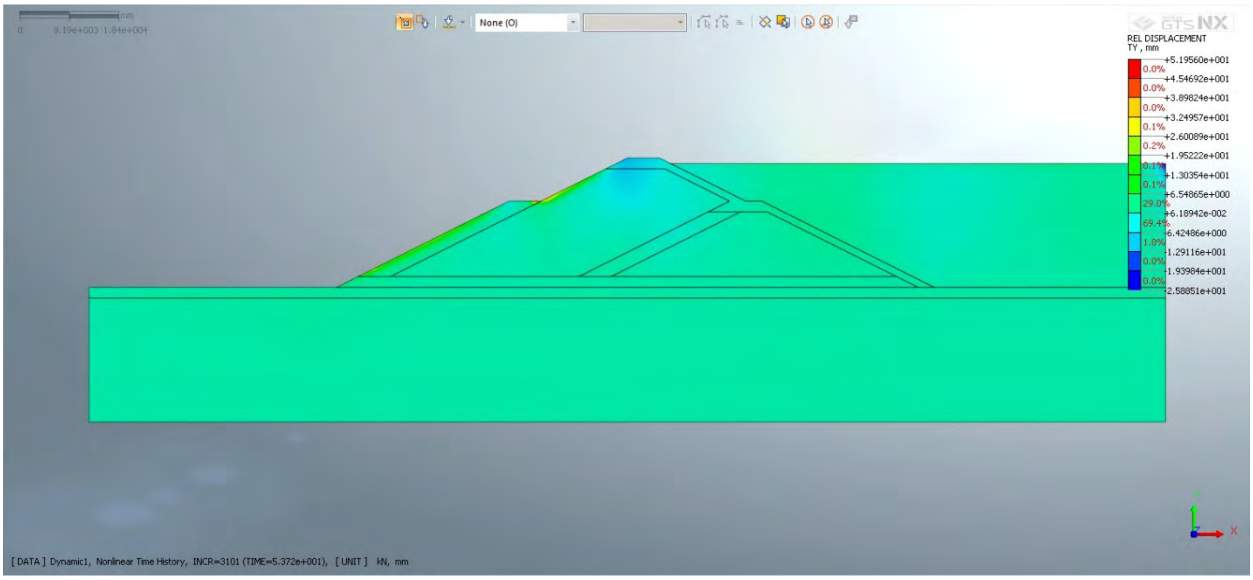


Figure 8: Run 1: Post-Earthquake Vertical Displacement

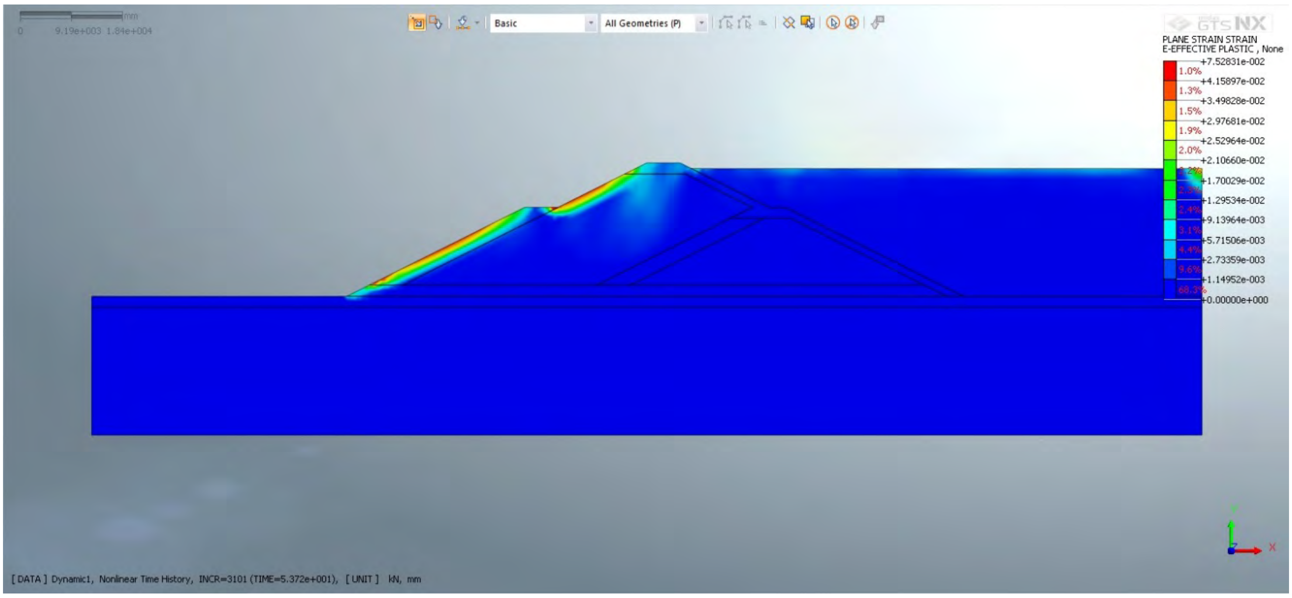


Figure 9: Run 1: Post-Earthquake Plastic Strain

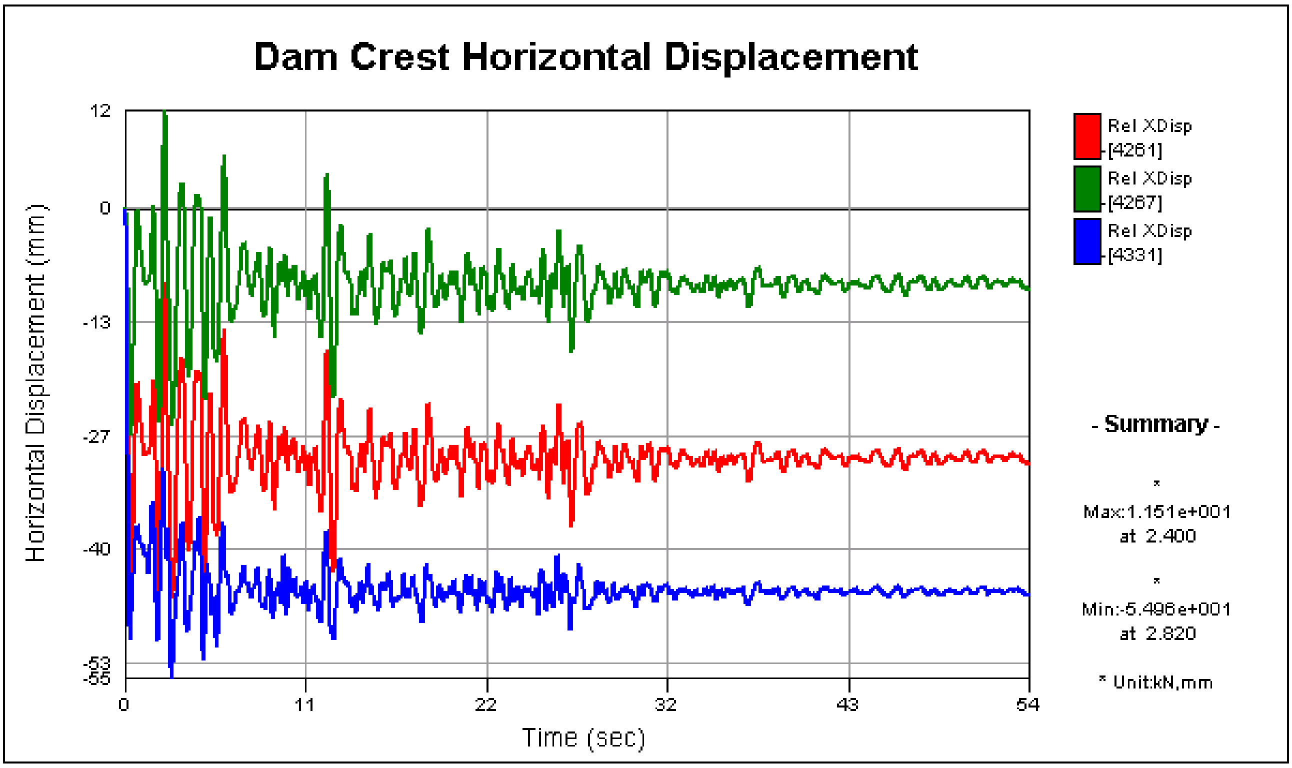


Figure 10: Run 1: Dam Crest Horizontal Displacement History Plot

Figures 7 and 8 show the predicted post-earthquake displacement in both horizontal and vertical directions at the final time step.

The level of displacements are generally at a very low level (up to 20 mm) with some slightly elevated values (20 to 110 mm) near the surface of the downstream face of the dam which is apparent in the horizontal displacement plot. The depth of this high displacement zone is generally very limited, i.e. less than 300 mm following further interrogation near the surface. This is understandable considering the model assumes zero cohesion for the fill material of the dam. Following the shake of an earthquake event (even with a not very high PGA), some movements or perhaps local slumping near the surface of the dam is to be expected and considered acceptable. The vast majority of the dam and the tailings would experience insignificant movements which is considered satisfactory. Figure 9 shows very small plastic strain concentration near the surface of the dam which further confirms the damage would be superficial. Figure 10 presents the dam crest horizontal displacement history during the shake.

Figures 11 to 14 presents the results for the dynamic analysis using Ground Acceleration Time History 2 as the dynamic loading condition, i.e. Run 2.

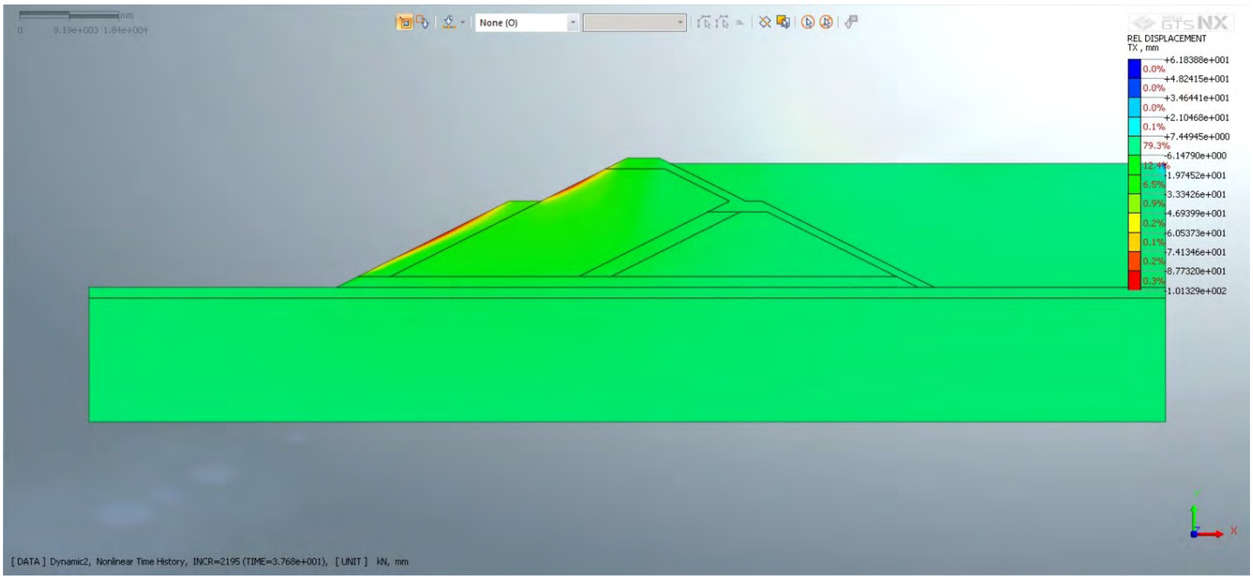


Figure 11: Run 2: Post-Earthquake Horizontal Displacement

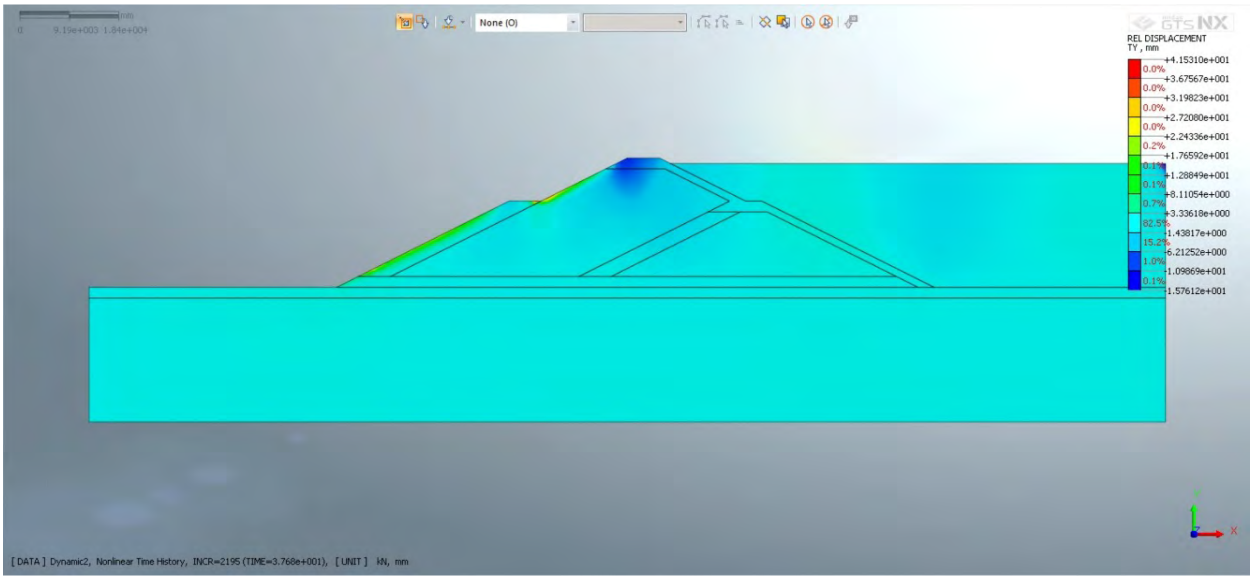


Figure 12: Run 2: Post-Earthquake Vertical Displacement

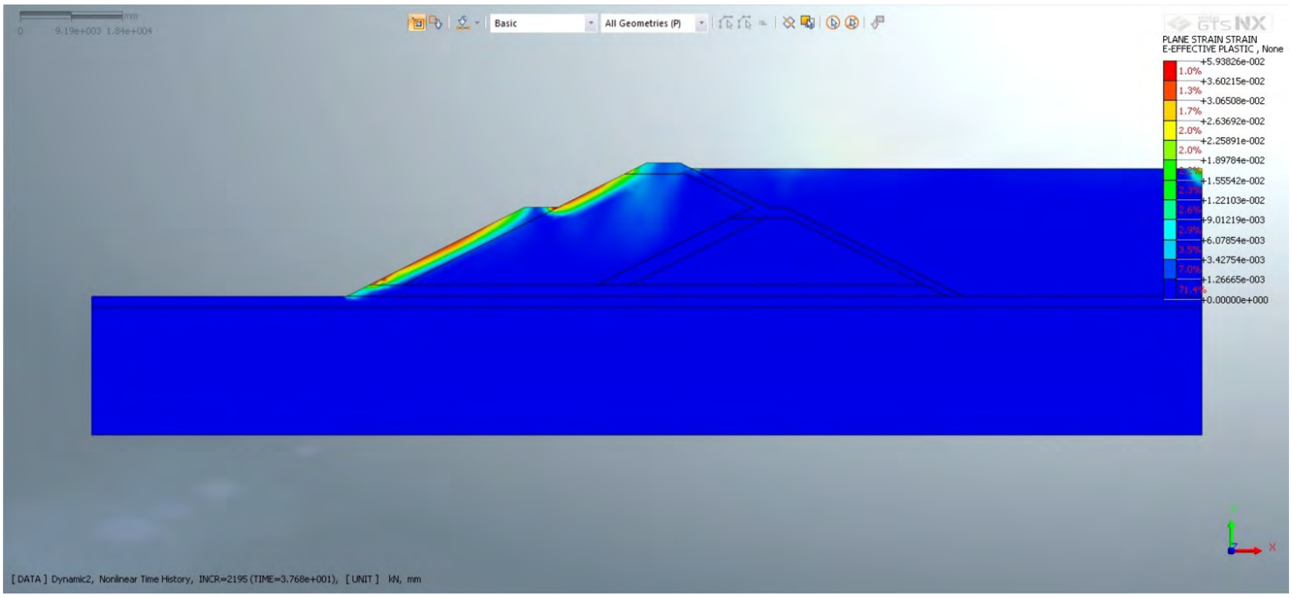


Figure 13: Run 2: Post-Earthquake Plastic Strain

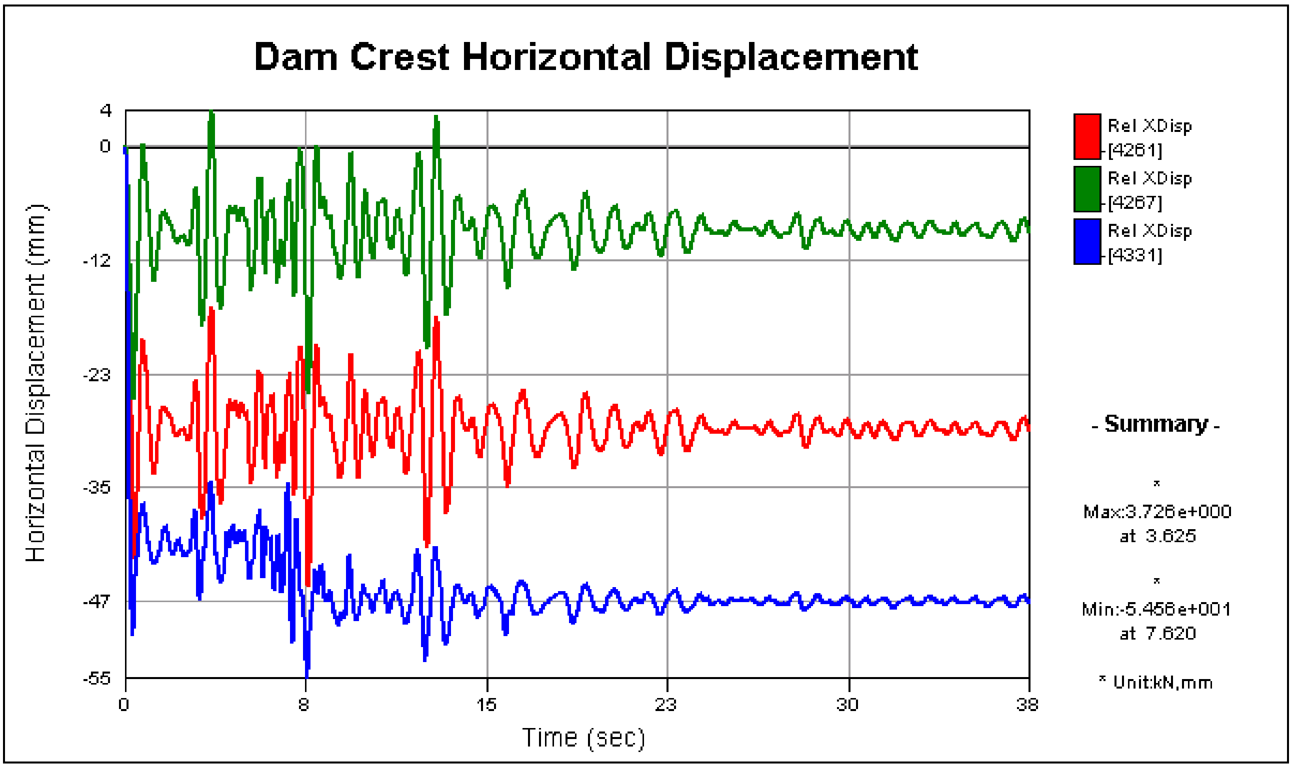


Figure 14: Run 2: Dam Crest Horizontal Displacement History Plot

Figures 15 to 18 presents the results for the dynamic analysis using Ground Acceleration Time History 3 as the dynamic loading condition, i.e. Run 3. These results are similar to those of Run 1.

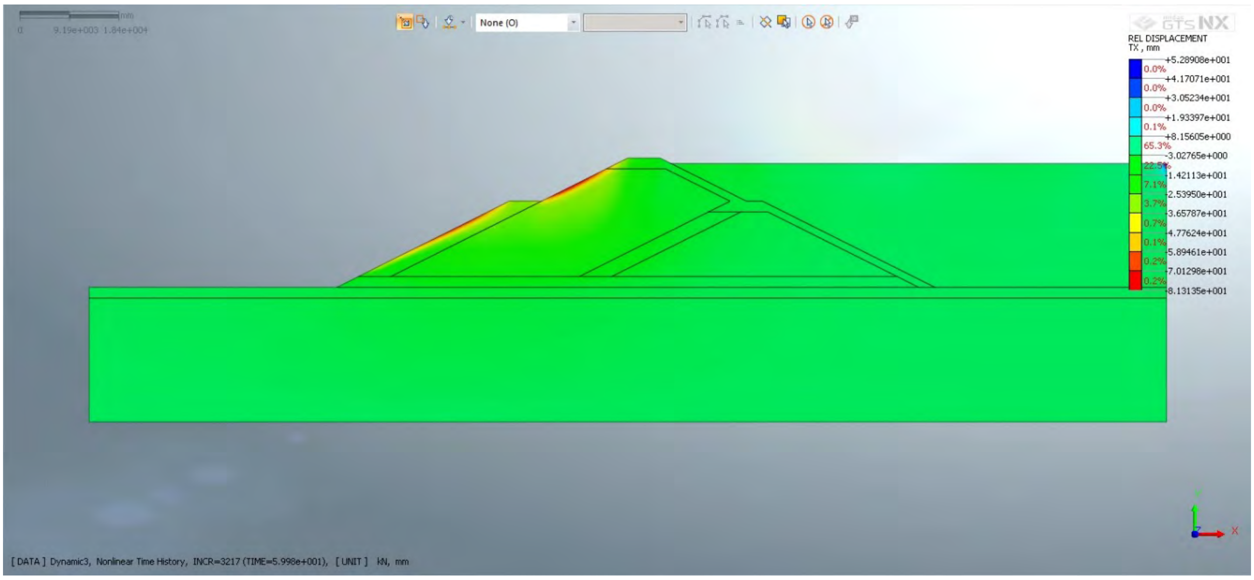


Figure 15: Run 3: Post-Earthquake Horizontal Displacement

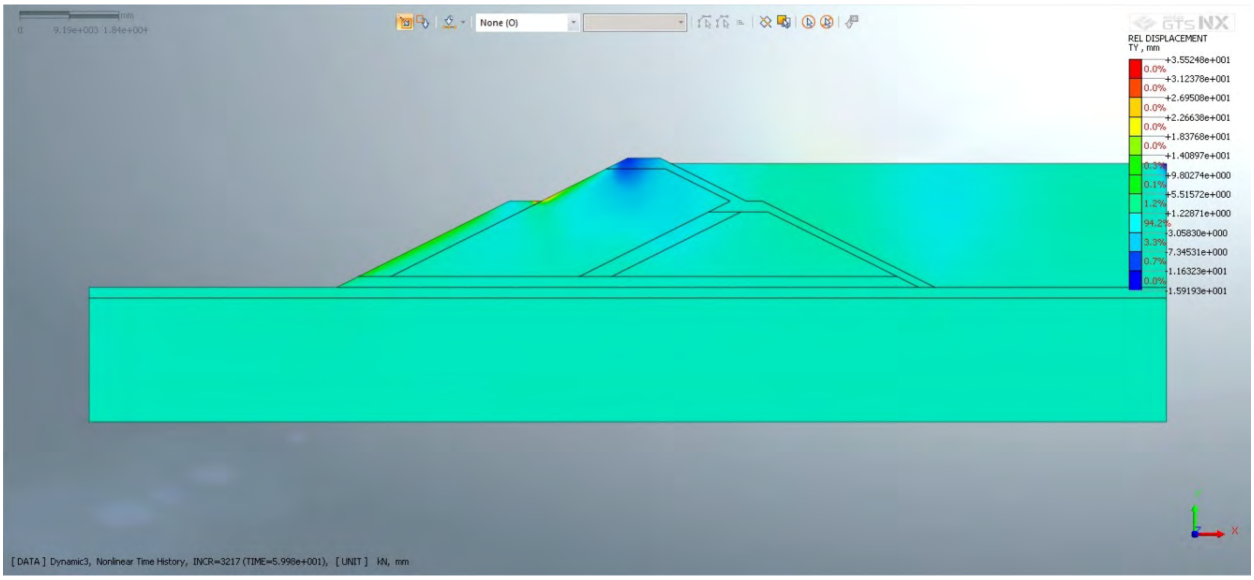


Figure 16: Run 3: Post-Earthquake Vertical Displacement

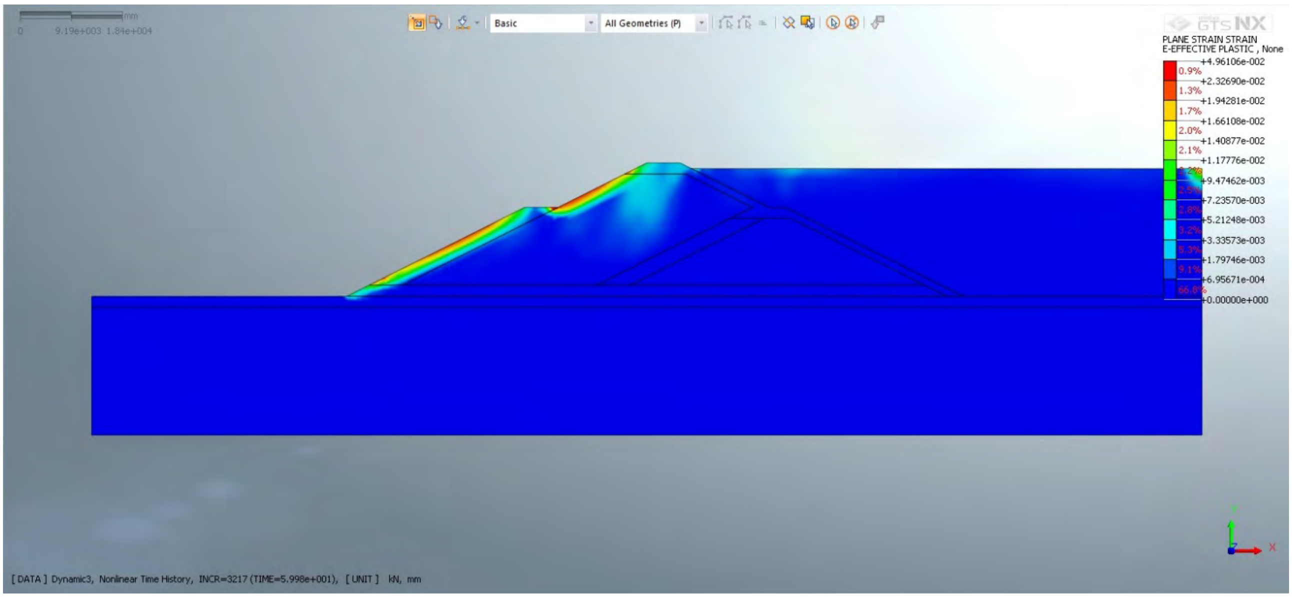


Figure 17: Run 3: Post-Earthquake Plastic Strain

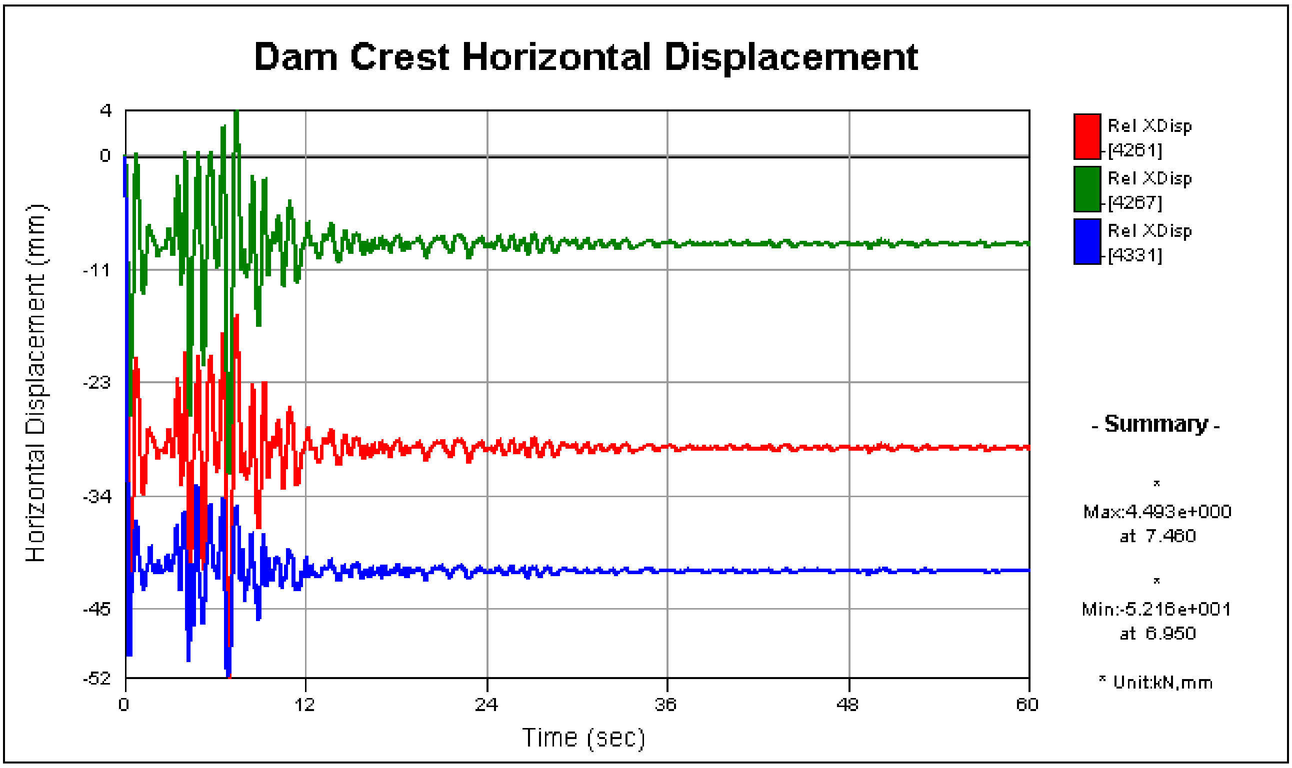


Figure 18: Run 3: Dam Crest Horizontal Displacement History Plot

Table 3 summarises the displacement results at the dam crest locations highlighted in Figure 1. The results include the maximum predicted displacements the dam will have experienced during the earthquake event and the permanent (i.e. irreversible) displacements following the completion of the earthquake events. It can be seen that the displacement results for each of loading conditions are fairly consistent. It can also be seen that the greatest permanent displacement values are less than 0.2% of the full dam height (24 m), which would likely cause only minor damages to the dam in accordance with the empirical method as discussed later.

The displacement results are therefore considered satisfactory.

Table 3: Summary of Dam Crest Displacements

Reference	Loading	Location	Horizontal Disp. (mm)		Settlement (mm)	
			Maximum	Permanent	Maximum	Permanent
Run 1	Time History 1	A	45.5	29.9	13.8	13.8
		B	26.5	9.5	7.8	7.8
		C	54.0	45.0	3.8	3.8
Run 2	Time History 2	A	45.1	29.2	13.4	12.9
		B	26.0	8.7	7.6	6.5
		C	54.6	46.9	4.0	3.5
Run 3	Time History 3	A	52.2	29.4	13.6	13.0
		B	31.9	9.0	7.5	6.4
		C	52.0	41.6	3.3	3.0

Summary and Conclusions

Dynamic response analysis was carried out for the Tara Stage 6 tailings dam using the finite element programme Midas GTS NX. Three difference sets of ground acceleration time history were used in the analysis to cover a wide range of response spectrum in ground motion simulation. The analysis results indicated that the level of deformation of the tailing dam during and after a MCE event would not impact the integrity of the dam wall and therefore considered satisfactory.

EMPIRICAL METHODS

Two methods were adopted for the empirical evaluation of settlement due to a seismic event.

The first empirical method was developed by Bray and Travasarou (Ref. 2). It is a simplified semi empirical

relationship for estimating permanent displacements due to earthquake – induced deviatoric deformations. It utilises a nonlinear fully coupled stick slip sliding block model to capture the dynamic performance of an earth dam, natural slope, compacted earth fill or municipal solid-waste landfill.

This methodology calculates the level of vertical deformation which may occur in an embankment following or during a seismic event.

There are four steps in the process:

1) Use available data to determine the average Shear Wave Velocity (Vs) for materials within the embankment;

2) Determine the Yield Acceleration (kY) and Depth of the Critical Slip Plane (H) from Limit Equilibrium;

3) Determine Spectral Acceleration (Sa) from earthquake records based on a calculated Natural Period

4) (Ts): and

5) Using the Bray - Travasarou equation, calculate values of seismic deformation.

The equation used is:

$$\ln(D) = -1.10 - 2.83\ln(ky) - 0.333(\ln(ky))^2 + 0.566\ln(ky)\ln(Sa(1.5Ts)) + 3.04\ln(Sa(1.5Ts)) - 0.244(\ln(Sa1.5Ts)))^2 + 1.50Ts + 0.278(M - 7) \pm \varepsilon$$

Where:

- D = Vertical Displacement (cm);
- Ky = Yield acceleration (taken as the horizontal seismic coefficient for a FOS of 1 from pseudo-static limit equilibrium modelling using a fully-softened soil strength model;
- Sa = Spectral acceleration from earthquake time record (g) at a period of 1.5 Ts;
- M = Earthquake magnitude (which acts as a measure of the earthquake duration);
- ε = Standard deviation of 0.66; and
- Ts = Natural period of Embankment (s) = 4H/Vs or 2.6H/Vs (Figure 5).

Figure 19: Calculation for Natural Period

The steps and calculations are presented at the end of Appendix A and a summary of the results using this method are given below.

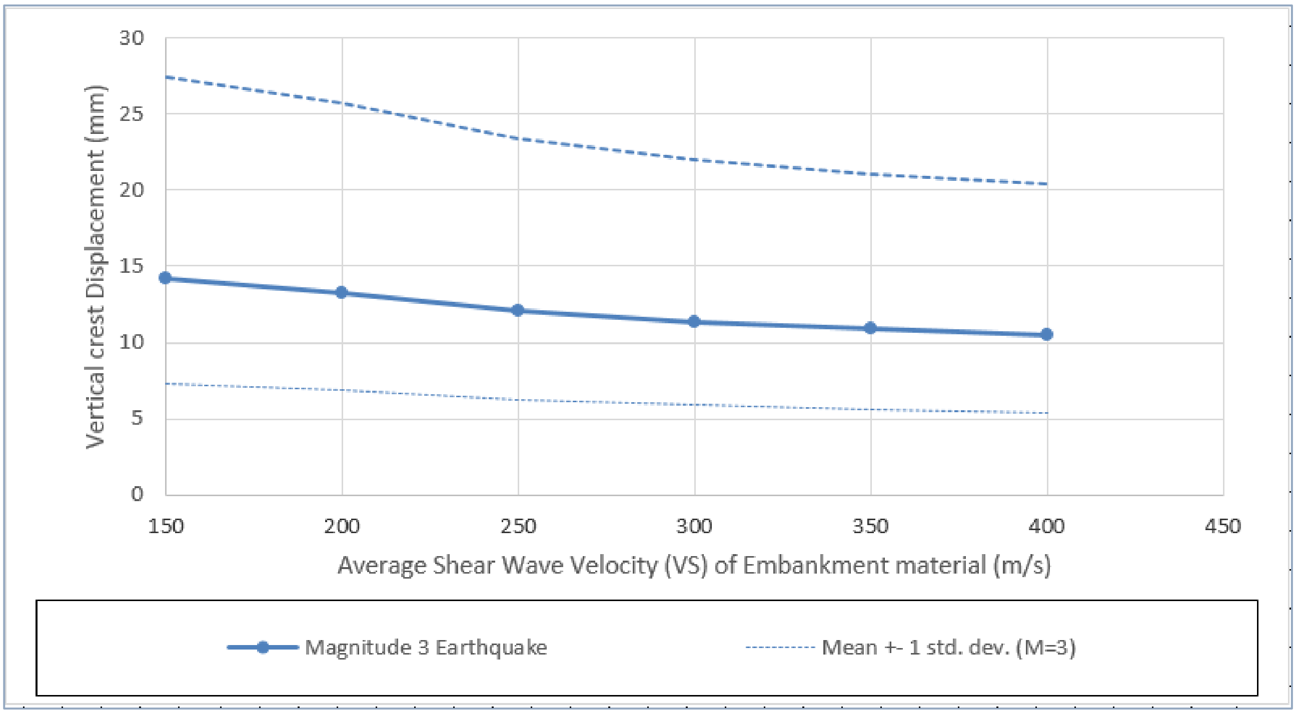


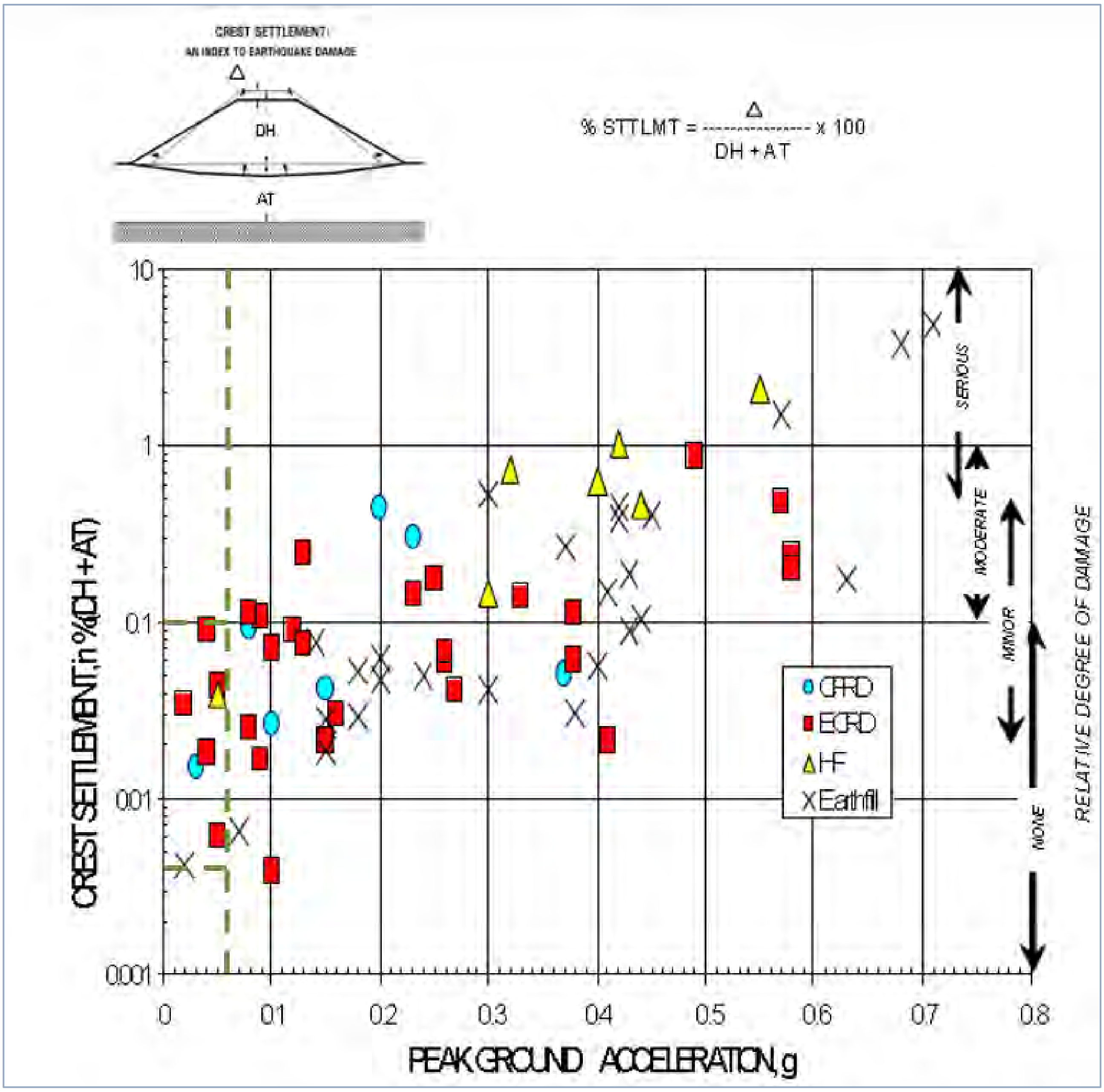
Figure 20: Crest Settlement

For a magnitude of 3, the expected crest settlement is likely to be of the order of 11 mm to 14 mm with a standard deviation of between a lower bound value of 5 mm and an upper bound value of 27 mm. If the magnitude was increased to 4, the expected crest settlement would be in the order of 14 mm to 18 mm and for a magnitude of 5, the expected crest settlement would be in the order of 18 mm to 25 mm

The second empirical method adopted was developed by Swaisigood (Ref 3) and presents a review of case histories of embankment dam behaviour during earthquake events. The results of this empirical study have shown that the most important factors that appear to affect dam crest settlement during earthquake include the peak ground acceleration at the site and the earthquake magnitude. A chart was prepared to summarize the relationship between the amount of measured settlement and the peak ground accelerations experienced in the incidents that were studied.

An important outcome of the study was that it was found that there is ample evidence that well-built dams can withstand moderate shaking with peak accelerations up to at least 0.2 g with no harmful effects

In addition, an empirical equation was formulated as an aid in estimating the amount of deformation to be expected. The results of the study as presented as a chart is given below.



CRFD are concrete face rock fill dams, ECRD are earth core rock fill dams and HF are hydraulic fill (sand) dam. Stage 6 dam would be classified as a clay faced rock fill dam and therefore could be expected to behave somewhere between an earth fill dam and rockfill dam.

Both the equation and chart were used to estimate the potential range of settlement that could be experienced at Stage 6 as a result of an MCE earthquake.

From the equation, the amount of settlement is 0.7 mm. From the chart, and represented by the green dashed line, the settlement is between 0.3 mm and 28 mm. The calculations are presented at the end of Appendix A.

Summary and Conclusions

Both the empirical dynamic analyses indicated settlements of similar range and not exceeding 27 mm compared to the dynamic response analysis using the finite element programme Midas GTS NX of 14 mm. The analysis results indicated that the level of deformation of the tailing dam during and after a MCE event would not impact the integrity of the dam wall and therefore considered satisfactory.

Ref. 1 Golder Associates (2016), Design for the Stage 6 Tailings Management Facility, Boliden Tara Mines, 1523091.503/B.0, March 2016

Ref. 2 Bray, J, D. and Travasarou, T., 2007, *Simplified Procedure for Estimating Earthquake-Induced Deviatoric Slope Displacements*, Journal of Geotechnical and Geoenviromental Engineering, ASCE.

Ref. 3 Swaisgood, J. R., 2003, *Embankment Dam Deformation Caused By Earthquakes*, Pacific Conference On Earthquake Engineering.

PROJECT	**Calculation of Seismic Settlement**		
Job No. 1532091		Made By: GJ	Date: 20/11/2017
Project Tara Stage 6 design		Checked:	Sheet: 1
		Reviewed:	of: 6

INTRODUCTION

The methodology adopted for this calculation sheet is a generalisation of Newmark's approach, that was proposed by Bray and Travasarou (2007)[1].
It is a simplified semiempirical predictive relationship for estimating permanent displacements due to earthquake-induced deviatoric deformations. It utilizes a nonlinear fully coupled stick-slip sliding block model to capture the dynamic performance of an earth dam, natural slope, compacted earth fill, or municipal solid-waste landfill
This methodology calculates the level of vertical deformation which may occur in an embankment following/during a seismic event.

The four steps involved in this process are:

1. Use available data to determine the average Shear Wave Velocity (Vs) for materials within the embankment
2. Determine the Yield Acceleration (kY) and Depth of the Critical Slip Plane (H) from Limit Equilibrium modelling when the pseudo-static FOS =1
3. Determine Spectral Acceleration (Sa) from earthquake records based on a calculated Natural Period (Ts) of the embankment
4. Using the Bray - Travasarou equation, calculate values of seismic deformation

The Bray and Travasarou (2007)[1] Equation used is as follows:

$$\ln(D) = -1.10 - 2.83\ln(ky) - 0.333(\ln(ky))^2 + 0.566\ln(ky)\ln(Sa(1.5Ts)) + 3.04\ln(Sa(1.5Ts)) - 0.244(\ln(Sa1.5Ts)))^2 + 1.50Ts + 0.278(M-7) \pm \varepsilon$$

Where

- D = Vertical Displacement (cm)
- ky = Yield acceleration (taken as the horizontal seismic coefficient for a FOS of 1 from pseudo-static limit equilibrium modelling using a fully-softened soil strength model
- Sa = Spectral acceleration from earthquake time record (g) at a period of 1.5Ts
- M = Earthquake magnitude (which acts as a measure of the earthquake duration)
- ε = Standard deviation of 0.66
- Ts = Natural period of Embankment (s) = 4H/Vs or 2.6H/Vs (Figure 1)
  - Where
    - H = Height of the sliding mass. Taken as the height of the deepest slice from the limit equilibrium modelling (m)
    - Vs = The average shear wave velocity of the embankment material (m/s)

The outputs from this calculation includes mean values of vertical settlement ± 1 standard deviation

Limitations:

$0.02 \geq Ky \leq 0.4$ g
$0 \geq Ts \leq 2.0$
$0.002 \geq Sa(1.5Ts) \leq 2.7$

1. Bray, J,D. and Travasarou, T., 2007, *Simplified Procedure for Estimating Earthquake-Induced Deviatoric Slope Displacements* , Journal of Geotechnical and Geoenviromental Engineering, ASCE

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Step 1: Determine Yield Acceleration and Depth of Sliding Mass

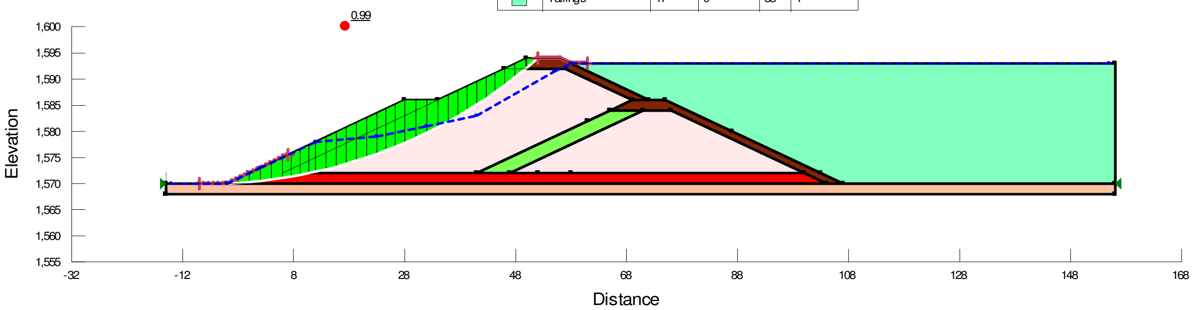
In order to calculate the yield acceleration, Slope/W, a limit equilibrium slope stability software package, was used. This modelling was used to determine the horizontal pseudo-static seismic coefficient which returned a FOS of 1 against failure of the embankment.

Modelling was carried out using the Morgenstern-Price method, along with entry and exit slip surfaces.

Model Parameters

Name	Tara Stage Design	
Elevation	##### masl	
FoS	0.99	
Yield Acceleration (ky) =	**0.060**	
Depth of Critical Slip Plane (H) =	**24**	m

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
	Foundation Material	19	5	32	1
	Material Type A1 / A2	19	0	32	1
	Material Type A2 / A3	19	0	32	1
	Material Type D2	21	0	35	1
	Random Fill	19	0	32	1
	Tailings	17	0	33	1



Step 2: Determine Shear Wave Velocity and Natural Period

shear wave velocity, Vs (m/s)	150	200	250	300	350	400
Natural Period, Ts (s)	**0.42**	**0.31**	**0.25**	**0.21**	**0.18**	**0.16**

Table 3.1: Ground types

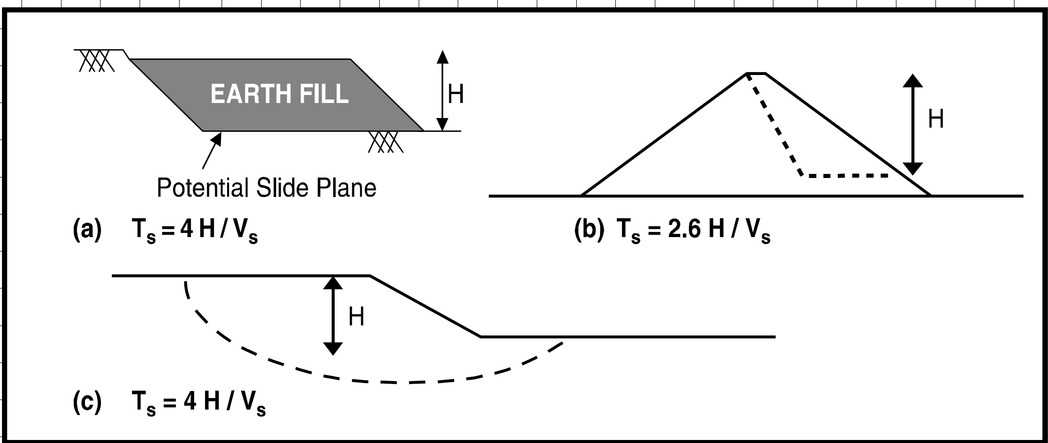
Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	_	_
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with v_s values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with v_s > 800 m/s.			
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	_	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1			

From: EuroCode 8 EN 1998-1

A single wave velocity was chosen to represent the average shear velocity of the materials within the embankment. The estimate was based on typical shear wave velonity as reported in Table 3.1, and from Golder experience from measurements in similar types of embankments

The natural period of the embankment was calculated based on the shear wave velocity, the depth of the failure surface within the embankment, and the shape of the embankment, and the failure surface within the embankment. Standard relationships, as reported in Rathje and Bray 2001, were used.

Figure 1: Calculation for Natural Period



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Step 3: Determine Spectral Acceleration based on Natural Period of Embankment

Seismic Parameters

Design ground acceleration on Type A Ground (ag) = 0.06 g YES

Natural Period (Ts) =	0.42	0.31	0.25	0.21	0.18	0.16
1.5 Ts (s) =	0.62	0.47	0.37	0.31	0.27	0.23
Sa (g)	0.17	0.17	0.17	0.17	0.17	0.17

Ground Type (A to E) = C

Soil Factor (S) = 1.15 T_B = 0.20 T_C = 0.60 T_D = 2.00

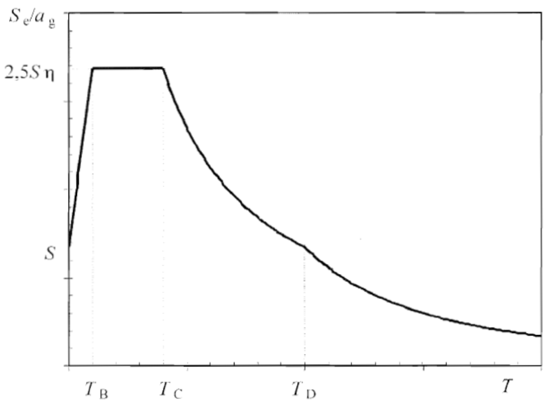
Viscous Damping Ratio = 5 % (Assumed)

Daming Correction factor 1

$$\eta = \sqrt{10/(5+\xi)} \geq 0{,}55$$

Table 3.2: Values of the parameters describing the recommended Type 1 elastic response spectra

Ground type	S	T_B (s)	T_C (s)	T_D (s)
A	1,0	0,15	0,4	2,0
B	1,2	0,15	0,5	2,0
C	1,15	0,20	0,6	2,0
D	1,35	0,20	0,8	2,0
E	1,4	0,15	0,5	2,0



$$0 \leq T \leq T_B : S_e(T) = a_g \cdot S \cdot \left[1 + \frac{T}{T_B} \cdot (\eta \cdot 2{,}5 - 1)\right]$$

$$T_B \leq T \leq T_C : S_e(T) = a_g \cdot S \cdot \eta \cdot 2{,}5$$

$$T_C \leq T \leq T_D : S_e(T) = a_g \cdot S \cdot \eta \cdot 2{,}5\left[\frac{T_C}{T}\right]$$

$$T_D \leq T \leq 4\text{s} : S_e(T) = a_g \cdot S \cdot \eta \cdot 2{,}5\left[\frac{T_C T_D}{T^2}\right]$$

Figure 3.1: Shape of the elastic response spectrum

The ground motion spectral acceleration at 1.5 times the natual preiod of the embankment (Sa(1,5Ts) is used in the calculation of displacement. the amount of calculated seismic displacement is correlated to the spectral acceleration of the input earthquake ground motion at the degraded period of the slope, with displacement increasing significantly as Sa (1.5Ts) increases .

The spectral acceleration graph was estimated based on the horizontal elastic response spectrum presented in Eurocode 8 (1998-1)

PROJECT	**Calculation of Seismic Settlement**			
Job No.	1532091	Made By: GJ	Date:	20/11/2017
		Checked: RSW	Sheet:	5
		Reviewed:	of:	6

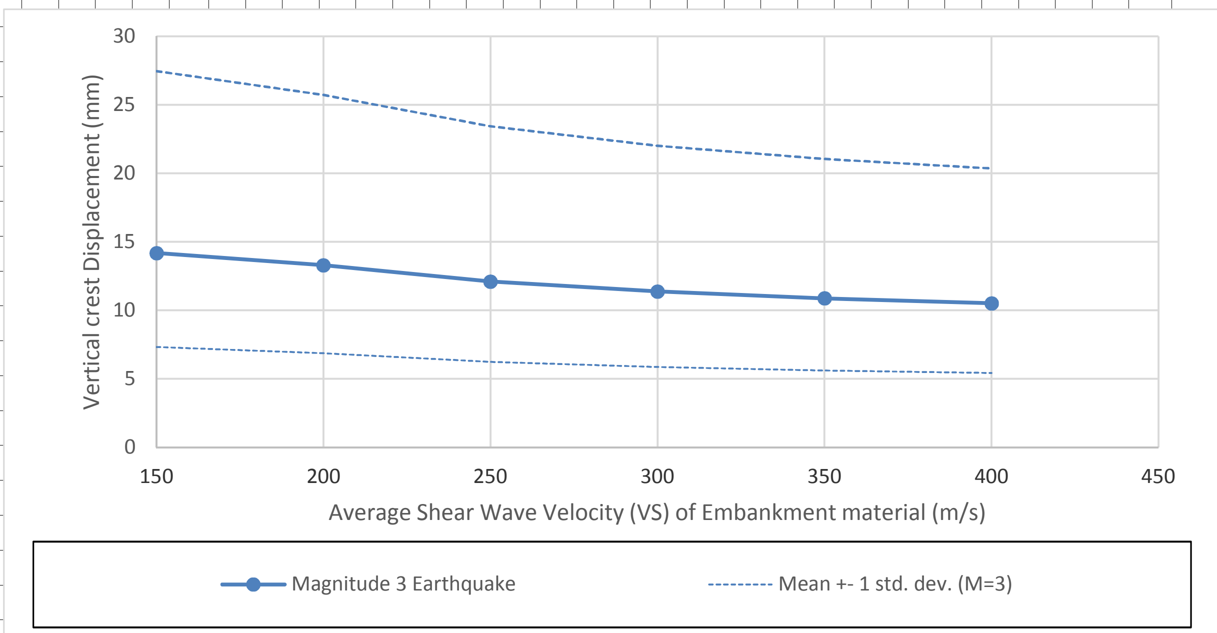
Step 4: Calculate Vertical Deformations Following Seismic Event

Summary of Parameters									**Parameter within Model Limitations**
Magnitude of Earthquake	M		3	-					
Yield Acceleration	ky		0.06	g					YES
Depth of Sliding Mass	H		24.00	m					
Velocity of Sliding Mass	V		250	m/s					
Standard Deviation	SD		0.66	-					
Natural Period, Ts (s)	**0.42**	**0.31**	**0.25**	**0.21**	**0.18**	**0.16**			YES
1.5 Ts	0.62	0.47	0.37	0.31	0.27	0.23			
Spectral Acceleration, Sa (g)	0.17	0.17	0.17	0.17	0.17	0.17			YES

Mean Value						
ln(D)	0.35	0.28	0.19	0.13	0.08	0.05
Displacement (mm)	**14**	**13**	**12**	**11**	**11**	**11**

Mean Value - 1 SD (Lower Bound)						
ln(D) - SD	-0.31	-0.38	-0.47	-0.53	-0.58	-0.61
Displacement (mm)	**7**	**7**	**6**	**6**	**6**	**5**

Mean Value + 1 SD (Upper Bound)						
ln(D) + SD	1.01	0.94	0.85	0.79	0.74	0.71
Displacement (mm)	**27**	**26**	**23**	**22**	**21**	**20**



Seismic Embankment deformation based on Swaisgood (2003)

Embankment height = 24 m
foundation depth = 4 m
Design Earthquake = 0.06 g
Earthquake Magnitude = 3

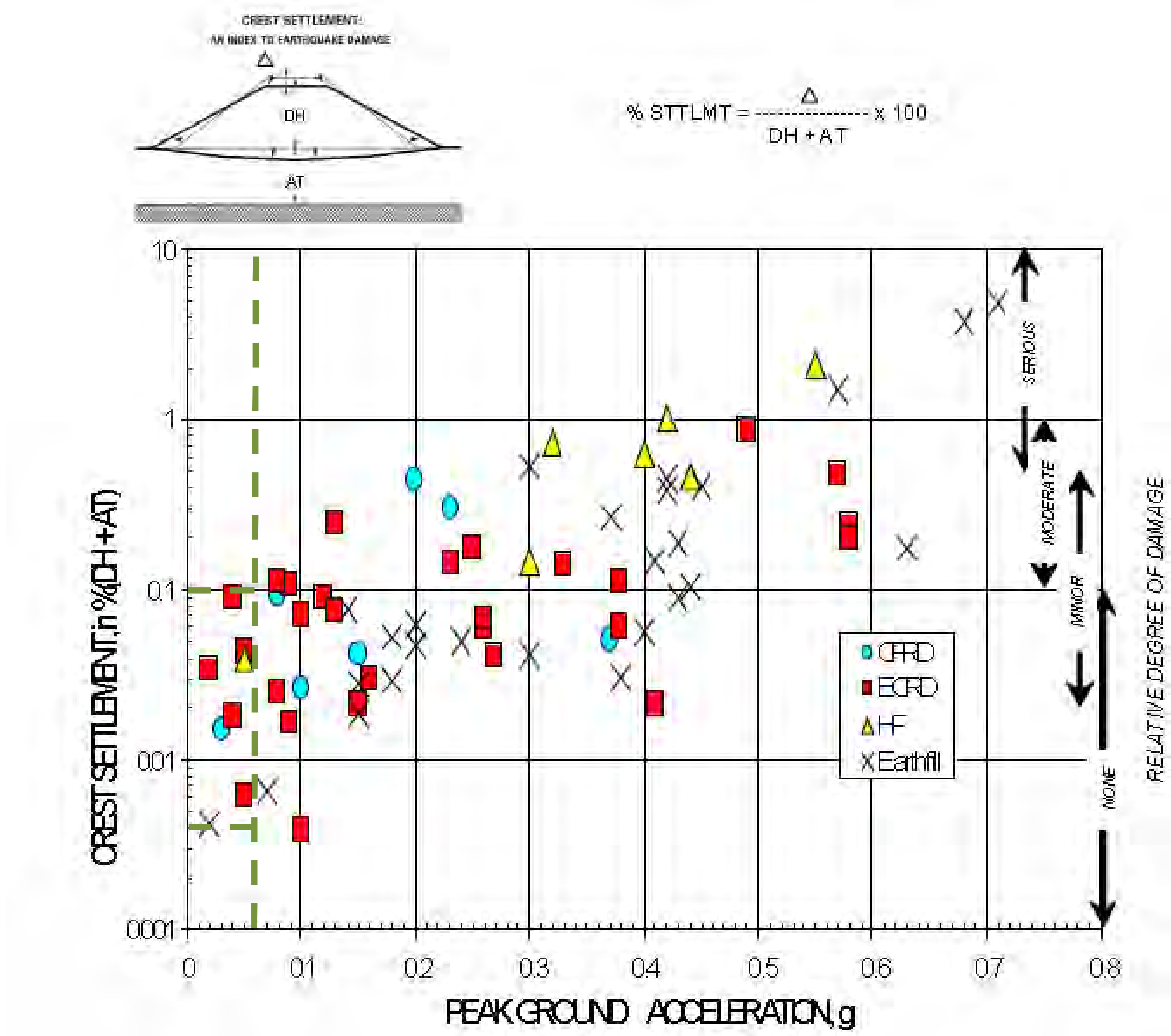
From equation:

% settlement = 0.00267 %
Settlement = 0.7 mm

$$\% \text{ Settlement} = e^{(6.07\ PGA\ +\ 0.57\ M\ -8.00)}$$

From Case History Graph

% settlement between 0.1 and 0.001 % (read off graph for design PGA)
Settlement between 28.0 and 0.3 mm



Response to Further Information Request (FIR)

12/09/2017

Response to Further Information Request 12/09/2017

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Item 1

The NIS states that "the footprint of the Stage 6 facility is confined to the existing northern and seven fields borrow areas. Virtually all the area is exposed indicating rock or glacial till over the site". The EIS states that " ... a resistivity and microgravity survey would be undertaken to delineate the presence of any palaeokarstic features... "

a. *Please provide a report of a comprehensive study of palaeokarst features and their potential impact on Stage 6 TMF stability. The study and report should detail the following as a minimum; site investigation plan, geotechnical logs, soil and rock laboratory testing, tailings geotechnical characterisation, geological plan and sections, and geotechnical parameters.*

b. *Table 5.1 of the EIS details the geotechnical parameters adopted in the stability modelling. Please compare these modelling parameters to the parameters obtained from the study requested in paragraph 1a above. A sensitivity analysis (undertaken to assess any potential variation in parameters for soil foundation, tailings and embankment construction material), should be included in the report requested in paragraph 1a above.*

Response to Item 1(a)

The approach taken to investigate the presence of possible palaeokrast features was to use a combination of tried and tested Geophysical methods; EM31, Electrical Resistivity Imaging (ERI), Seismic Refraction and Micro-Gravity.

Micro-Gravity is an industry wide method used to specifically target the presence of possible palaeokarst features, and was successfully used at Lisheen and Galmoy Mines on their Tailings Management Facilities.

The Geophysical investigations and follow-up intrusive investigations based on the findings of the Geophysics are provided in the following reports;

- Golder Associates (May 2017). Boliden Tara Mines Limited: Stage 6 Footprint Geophysical Surveys. Report reference 1775908.R01.B0
- Golder Associates (May 2017). Boliden Tara Mines Limited: Possible Borehole Locations – Pale Beds – Stage 6 ('Borrow Area'). Report reference 1775908.R02.B0
- Golder Associates (September 2017). Boliden Tara Mines Limited: Stage 6 Footprint Palaeokarst Investigation and Grouting

The investigation did not identify any large voids beneath the footprint of the Stage 6 facility that might pose a risk to the integrity of the facility and is presented in Appendix to FIR item 1.

Response to Item 1(b)

The successful backfilling of the paleokarstic features with grout as outlined in the report provides a foundation equal to the fractured limestone without any paleokarstic features. Therefore, the design parameters for the foundation rock were not changed.

It should be noted that no palaeokarstic features were found beneath the footprint of the dam wall.

Item 2

The EIS states that the "physical and chemical characteristics of the deposited tailings will remain unchanged from those deposited previously" and the NIS states that "the tailings are expected to be non-acid generating". Please provide an updated assessment of potential for acid generation to include consideration of the construction materials to be used.

Response to Item 2

An updated assessment of potential for acid generation in deposited tailings at the Randalstown TSF is presented in Appendix to FIR item 2.

The tailings have a high net neutralisation potential and results (past and on-going) indicate a considerable buffering capacity of the tailings to neutralise any acid generation

- Significant reductions in tailings pH or alkalinity are not expected to occur over time
- Acid mine drainage from the Randalstown tailings facility is not expected to be a significant environmental issue

All construction material to be used in construction of Stage 6 will have a neutralising potential ratio, determined on the basis of static test EN 15875, of greater than 3.

Item 3

The EIS refers to two alternatives used to assess the stage 6 TMF options for mine waste disposal namely; slurry and paste. This is not satisfactory. Please provide a more detailed report on the assessment of tailings disposal options from conventional slurry to dry stack. The selection of the preferred option should evaluate environmental and technical impacts and clearly demonstrate the selection process through scoring and ranking, using, for example, the multiple account analysis methods.

Response to Item 3

Surface paste disposal was one of the options considered for increasing the tailings storage of the TMF previously for stages 4 and 5. It was proposed to construct these stages as a dome on the existing facilities. Paste has the benefit of increasing the density of the deposited tailings and thereby reducing the volume of material to be stored. Also, the dome shape would increase the storage capacity for a given dam wall crest height and the inherent strength of recently deposited paste would have resulted in potentially lower costs for rehabilitation of the surface at closure.

Surface paste tailings disposal has significant advantages over conventional disposal of slurried tailings particularly when;

- reclamation of water has to be maximised such as in semi and arid areas;
- the reclaim water has significant value in terms of added chemicals which otherwise would have to be added in the process;
- space is a premium and the dam foot print is to be minimised; and
- the terrain is steep and tailings paste can be deposited down valley and above the containment dam wall thus maximising storage;

The distance of the TMF from the mill site is some 5km and at the limit for positive displacement pumps and therefore the paste plant for surface disposal of tailings paste would have to be located at the TMF site. The tailings would be pumped as a slurry to the TMF as currently undertaken and then processed through the paste plant and pumped to the facility using positive displacement pumps.

Stages 4 and 5 could have been domed from a central stack at the middle of the dividing wall originally between Stages I, II and III. This would not be the case for Stage 6 where the paste would initially be discharged from the crest until nearly full and then a central discharge tower constructed which could be used to form a dome. The tower required would be founded on fill above tailings and therefore subject to potential differential settlements.

The paste plant would operate 24hrs/day and the plant, the discharge points and eventually the tower would need to be adequately lit to allow for continuous observation/access.

The pasted tailings would form a slope between 2.5% and 5% depending on the final moisture content at discharge. Thus for a slope of 2.5%, the central tower height would need to be about 10m high for the paste to reach the Stage 6 crest wall at a distance of 400 m. Normally, the slope gradient will decrease as the distance from the discharge point increases and more discharge points may be required.

To prevent dusting of the paste an extensive system of sprinklers would be required and operated frequently during dry and windy periods. The exposed beaches would be subject to extensive dusting unless continually saturated. The sprinkler system would have to be continuously raised as paste is deposited. The sprinkler water and rainfall runoff from the slopes, which would be contaminated, would be collected around the upstream perimeter of the Stage 6 dam wall crest via a constructed channel. The water collected would be discharged into Stage 5. An emergency facility to hold slurried tailings would also be required when the paste plant is maintained or for some reason was non-operational. The facility would again be the existing Stage 5.

Tara Mines use the coarse fraction of the tailings (sands) for hydraulically back filling stopes underground as part of the mining operation. This procedure also reduces the amount of tailings discharging to the TMF. The fine tailings (slimes) are discharged into the TMF. When backfilling underground is not required, the total tailings (sand and slimes) are discharged directly to the TMF. Surface disposal of paste needs to be reasonably consistent in order that the geotechnical/fluid properties can be reliably used for design of the disposal facility. Therefore, the sand and slimes component of the tailings combined would have different rheological and geotechnical properties than each of the materials if separated. This would mean that the backfilling underground at Tara would also have to be paste and therefore a backfill plant would be required at the mill site as well as at the TMF.

There are a number of negative key issues relating to paste disposal in Stage 6 as discussed above. These are given below;

- potential for dusting of the paste surface;
- requirement for two paste plants at the TMF site and also to replace Tara's existing backfilling operation underground using cyclone coarse sands with paste; and
- operating the paste plant at the TMF site 24 hours a day, seven day a week with the associated noise and lighting.

Filter cake disposal has many of the advantages and disadvantages that apply to paste disposal. It is by far the safest option for tailings disposal and is reasonably commonly used in arid climates where water is a premium, the reclaimed water has a value and the filter cake can be dried in the heat and compacted. In Ireland, trafficking on filter cake, when wet, is very problematic. At Aughinish, where filter cake is produced, it is wetted up to form paste and pumped to the facility. The filter cake plant would have to be located at the TMF site and the material could either be placed by a conveyor system or trucks. The filter cake plant site, road ways and the placement areas would need to be lit up continuously.

Either paste or filter cake disposal operations would impact the neighbours due to light and noise pollution for the life of the facility. These options have been discussed with the stakeholders during previous consultation meetings and none would prefer a plant operating at the tailings sites 24 hours a day seven days a week. Currently, with slurry disposal, there is the minimum of activity on the TMF.

It was considered therefore that the negative aspects of surface paste or filter cake disposal outweighed the benefits and these methods of disposal were rejected in favour of conventional slurry discharge into Stage 6.

Item 4

It is noted that, as part of the EIS, a preliminary appraisal was carried out to address flood risk within the stage 6 TMF and environs. Section 3.9 of the EIS states that "there is adequate control of the tailings water level which can be achieved by adjusting the discharges into the TMF and removal of tailings water by pumping from the TSF to the plant site". Clarify why neither an emergency spillway nor the capability to store probable maximum precipitation of appropriate duration (months, not hours), is provided.

Response to Item 4

The stage 6 TMF is classified as a perimeter dam with no external catchment area. The facility will be operated with a 1 m freeboard. It is normal to operate a perimeter dam with no spillway and has been the case with Stages 1, 2, 3, 4 and 5 of the facility.

Similarly, tailings facilities at the Galmoy and Lisheen were operated without a spillway.

A spillway is not required because the majority of the water discharged into the facility is controlled by pumping and managed by Tara Mines. Thus the facility is operated by a 1m freeboard and if exceeded Tara mines has the option to stop pumping into the facility or increase pumping from the facility provided discharge criteria is meet.

The 1 m freeboard would accommodate the total average annual rainfall over the last 50 years (856 mm) and the maximum annual rainfall over the last 50 years (1136 mm).

Spillways will be installed at the end of the life of the facility as was the case at Galmoy and Lisheen facilities to protect the dam walls from being overtopped in the long term at closure (Refer to Section 6.15 of *Design for the Stage 6 Tailings Management Facility* report submitted as part of this IE License Review).

Item 5

The likelihood of seepage through the liner is discussed in section 3.5 of the EIS. However, no seepage analyses model and 2D sections through the proposed TMF have been provided, which are required to estimate phreatic surface for use in stability modelling.

a) *Please provide a seepage analyses model and 2D sections through the proposed TMF as part of the stability analysis.*

b) *Provide explanation why there is no allowance for an over liner and underliner drainage as part of seepage control during operation.*

Response to Item 5 (a)

Seepage from the TMF will be controlled by the low permeability composite lining system, and the low permeability of the tailings retained by the facility. On the upstream dam wall face there is Type A1 and A2 low permeability glacial till. Experience of a large number of quality assured and controlled geomembrane installations indicates the likely presence of between 2 and 5 leaks per hectare and these defects are generally less than 10 mm^2 in size.

Seepage calculations have been based on the design equations given in References 1 and 2 below for the worst case, when the facility is filled with tailings.

Ref 1 Leakage through Liners Constructed with Geomembranes. Part II. Composite Liners. J. P. Giroud, et al., Geotextiles and Geomembranes, 8(4) pp71-111 1989.

Ref 2 Rate of Leakage through a Composite Liner due to Geomembrane Defects. J. P. Giroud, et al., Geotextiles and Geomembranes, 11(1) pp1-28 1992

These equations also over estimate seepage flow from a lined tailings facility as any defect is choked by the tailings particles reducing the seepage significantly.

The volume of seepage flowing laterally through the dam wall via the GCL and some nominal defects in the lining system for a constant head of 20m (Phase 2) would be an average of about 1.5 m^3/day with a 10% probability of the seepage being less than 0.25 m^3/day and a 10% probability being greater than 5 m^3/day. The range represented in the figure below, is based on a number of variables including infiltration rate based on the range of vertical permeability values of the tailings, the range of defects in the lining per hectare, the effective permeability of the composite lining and head acting on the lining.

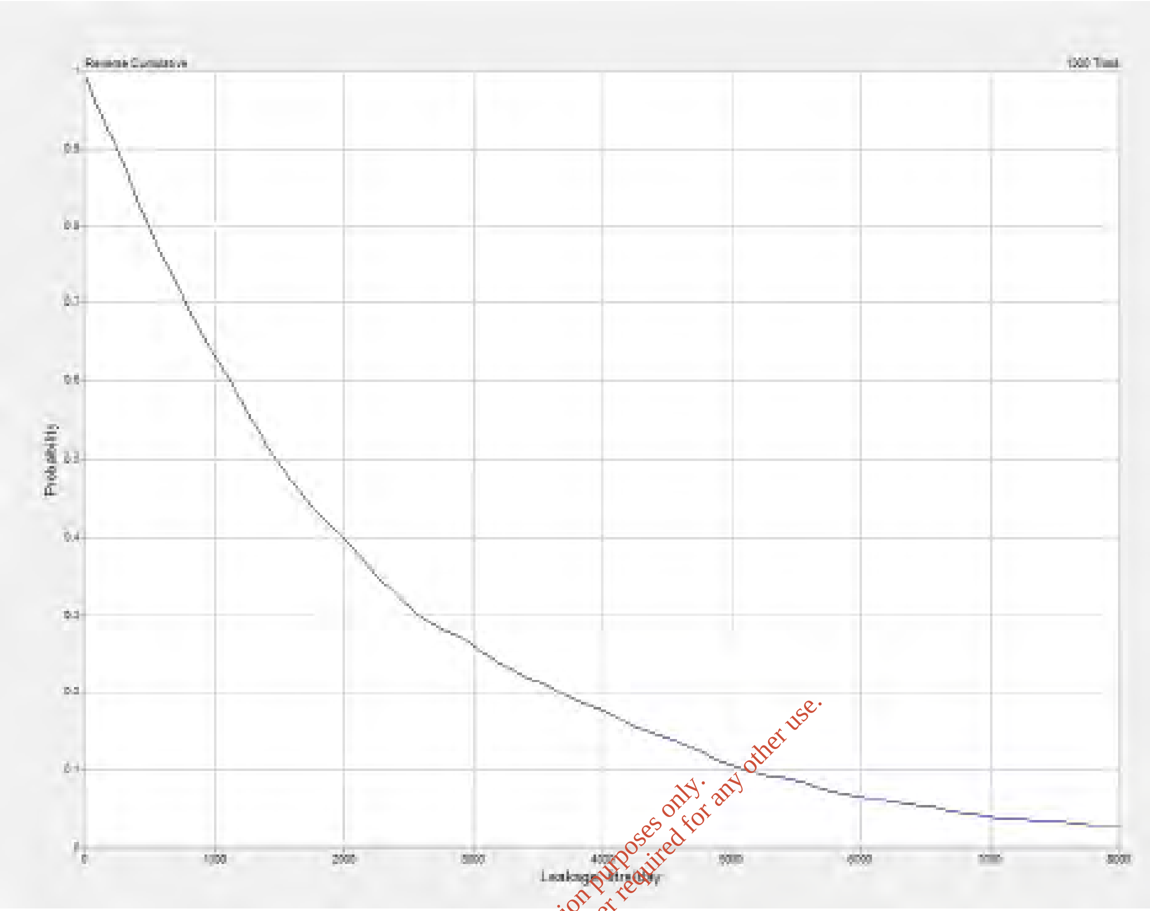

Figure 1: Probability of Seepage from Composite Lining System

The dam wall incorporates a basal granular drainage blanket and the downstream dam shell has been modified to be granular. Thus any seepage through the dam wall will be directed to the drainage blanket. Seepage through the basin will pass into the underlying limestone. It is not therefore not appropriate to undertake a seepage model under these circumstances.

Response to Item 5 (b)

Neither the main composited lined cells at Lisheen or the Phase 1 Extension and Phase 2 cells at Aughinish had over or under drainage systems.

Overdrainage:

There are a number of reasons why an overliner was not proposed detailed below:

- Unlike domestic land fill facilities, the tailings are a very low permeability material. Placing a drainage blanket above the lining would allow the drainage water to find and recharge any defects in the lining system.

- Most damage to a lining system in landfills is a consequence of placing the drainage blanket.
- The water storage capacity of the drainage system is relatively small and the recharge to the system via the low permeability tailings is slow. Thus pumps, which would have to pump over the dam wall would rapidly pump the drainage system followed by a long pause as the drainage blanket recharged.
- The basin area of the TMF is significantly greater than those used at domestic land fill sites. These are typically 1 Ha to 5 Ha. The basin area of the TMF is 43 Ha and would be difficult to shape with constant grades to a sump.
- Seepages are comparatively very low compared to the adjoining tailings facilities (Stages 1 to 5) which are lined with glacial till or clay blanket.

Underdrainage

Much of the footprint of the Stage 6 TMF is bed rock ranging from Lower Palaeozoic in age through to Lower Carboniferous Limestone.

The Lower Palaeozoic rocks are divided into four main rock types, consisting of Lower Palaeozoics, Red Beds (Old Red Sandstone), Mixed Beds and Pale Beds. The rocks are predominantly siltstones, sandstones, shales and greywackes with quartz conglomerate horizons. These Lower Palaeozoic rocks occur at rock head level to the east and north of the tailings facility and in a 500 m wide zone beneath the site, to the west side of the Randalstown fault. The fault cuts from northeast to southwest across the site.

The Pale Beds or the Meath Formation comprise a variety of pelletal, oolitic and bioclastic calcarenites which locally contain quartz sand and darker argillaceous layers. They are a dominantly massive group and are characterised by their low shale content. The base of the Pale Beds is defined by a pale micritic limestone known as the Micrite Unit, which varies greatly in thickness. The Pale Beds vary from 0 m to 140 m thick across the Randalstown area.

All rocks are fractured and the mass permeability exceeds the seepage derived from the low permeability of the tailings combined with any defects in the HDPE component of the composite lining. Thus an underliner drainage system would not collect the seepage and the seepage would pass vertically downwards and be diluted by the ground water.

A limited underdrainage system is incorporated to control groundwater during construction and particularly during the winter months in which the water table will rise. The main drainage system which exits in the north-west corner of the site will be monitored for water quality.

Item 6

Provide a slope stability analysis that addresses the following.

a) Short term (following construction) scenario.

b) Long term (TMF development and closure) scenario.

Response to Item 6(a)

Short term stability analysis was undertaken using a cohesion of 40 kPa and 60 kPa with no increase in strength with loading and with factors of 0.13 and 0.25 increase with increasing effective overburden pressure. Further analysis was undertaken using effective strength parameters and excess pore pressure as ru values. Results are presented in Attachment of FIR item 6.

Stability Modelling Results Short Term

Case	Condition	Location	FOS
1	Short term undrained shear strength of Type A1 and A2 materials 40kPa.	Upstream	
2	Short term undrained shear strength of Type A1 and A2 materials 60kPa.	Upstream	
3	Short term undrained shear strength of Type A1 and A2 materials 40kPa increasing strength factor of 0.13.	Upstream	
4	Short term undrained shear strength of Type A1 and A2 materials 40kPa increasing strength factor of 0.25.	Upstream	
5	Short term undrained shear strength of Type A1 and A2 materials 60kPa increasing strength factor of 0.13.	Upstream	
6	Short term undrained shear strength of Type A1 and A2 materials 60kPa increasing strength factor of 0.25.	Upstream	
7	Short term effective shear strength of Type A1 and A2 materials 32 degrees ru 0.25	Upstream	
8	Short term effective shear strength of Type A1 and A2 materials 32 degrees ru 0.45	Upstream	

Response to Item 6(b)

Long-term downstream embankment stability, with tailings level 1 m below the crest were undertaken for the HDPE liner intact and an assumed phreatic surface was drawn down through the embankment by the downstream drainage blanket and the rock used in downstream construction.

Stability analysis were undertaken in the long term assuming the HDPE had failed, the drainage system was no longer operational and the phreatic surface exits the dam wall in the slope at one third of its height. This is a very extreme scenario which is unlikely to develop. Further analyses were undertaken for the long term using pseudo-static conditions corresponding to a 0.06 g acceleration for the liner intact.

Results of the stability analyses are presented in the *Design for the Stage 6 Tailings Management Facility* report Section 6.14.4. This report is given again as Attachment to FIR item 6:

Stability Modelling Results Long Term

Case	Condition	Location	FOS
1	Long-term, tailings 1m below crest, phreatic surface at the toe of the dam. Static condition	Downstream	1.63
2	Long-term, tailings 1m below crest, phreatic surface at the toe of the dam. Ground Acceleration 0.06g. Pseudo static condition.	Downstream	1.38
3	Long-term, tailings 1m below crest, phreatic surface exists 1/3 dam height. Static condition.	Downstream	1.16
4	Long-term, tailings 1m below crest, phreatic surface exists 1/3 dam height. Ground Acceleration 0.06g. Pseudo static condition.	Downstream	0.99

Item 7

In relation to the description of the composite lining system:

(a) Provide specifications for the 500 and 1000g/m^2 geotextiles proposed

(b) Justify the need for the 1000g/m2 geotextile (e.g. is HDPE puncture of concern)?

(c) Clarify the term carbon-rich as it applies to the geotextile.

(d) Section 3 of the EIS made reference to leak detection. Clarify if a leak detection and collection system will be installed as part of the lining system.

Response to Item 7 (a)

A 1000 g/m2 non-woven needle punched geotextile is required to protect the GCL and HDPE geomembrane from the underlying Type C material which in turn is placed on top of the Type B material. A carbon rich 500 g/m2 non-woven needle punched geotextile is required in the anchor trench and on the surface of the HDPE to protect this material from the surcharge and movement of pipe work.

The physical and mechanical properties of the 1000 grm/m2 and 500 grm/m2 non-woven needle punched geotextile are presented in the *Design for the Stage 6 Tailings Management Facility* report Section 6.7.2:

Non-Woven Geotextile Properties

Parameter	Specification 1000 g/m²	Specification 500 g/m²
CBR Puncture Resistance	Minimum 10,000 N	Minimum 5,000 N
Wide Width Tensile Strength	Minimum 75 kN/m	Minimum 40 kN/m
Elongation at break	Minimum 50%	Minimum 50%
Thickness	Minimum 8.0 mm	Minimum 5.0 mm
Mass per unit area	Minimum 1000 g/m²	Minimum 500 g/m²

Response to Item 7 (b)

The use of 1000 g/m2 is a conservative approach but ensures with the protection layer that neither the GCL or HDPE would be punctured by any sharp protrusion present in the sub grade material.

Response to Item 7 (c)

This is a term to describe a black non-woven 500 grms/m² geotextile which has better resistance to ultra violet light if it were exposed.

Response to Item 7 (d)

A leak detection survey using DC electric current will be undertaken after the installation of the lining system and prior to commissioning. This geophysical method was used successfully for the Lisheen and Aughinish cells. An electric current is passed between two electrodes, one placed in either water ponded in the cell or by a water spray jetted onto the lining and the other in the peat outside the cell. With the geomembrane intact, the water in the cell will be electrically isolated from the external environment. The resulting potential field, measured as a difference between two non-polarising electrodes, is small but uniformly distributed over the geomembrane. If the geomembrane is defective, current will flow through the point of leakage and the measured potential will peak around the position of the defect.

Data acquisition is performed within the cell on a predetermined grid marked on the geomembrane at 2.0 m spacing. Two or more sets of data are obtained simultaneously, with information automatically stored on data loggers where possible. The results are processed and plotted on site, then overlaid on the plan of the cell to allow the immediate detection and location of the defect. The voltage used is 240 V and there is a strict safety protocol to follow to ensure no connection is made between the personnel, the ground and the water during the data gathering phase.

As the leak detection survey proposed will find all defects no permanent leak detection system will be installed underneath the lining. It should be noted that once tailings are placed in the facility no repairs of the lining system could be undertaken beneath the tailings. It also should be noted that at 2 m intervals, as per the leak detection survey, the amount of permanent cable to be installed over the entire TMF footprint would be in the order of 600 km.

A perimeter interceptor channel will be installed although virtually all the water collected would be surface water runoff from the dam wall and ground water.

Item 8

It is stated that the Stage 6 TMF extension will be operated in a manner similar to the existing TSF by discharging the tailings from spigots on the dam crest.

a) Provide a tailings deposition plan detailing the layout of the tailings pipeline, deposition points, decant location and technical specifications of the pipeline (including proposed pipe cross-section and long section).

b) Provide an explanation why burying the tailings pipeline is preferred to the over-ground piping, in relation to containment in the event of leakage.

Response to Item 8(a)

The tailings deposition systems for the Stage 6 crest are detailed in Figure 2, including spigot locations and long section (figure 3). The main header pipeline carrying the tailings is 800 mm OD, 559 mm ID, PE100 and SDR17. The spigot spacings will be at 75m. The tailings discharge pipe line at the spigots is 200 mm OD, 176 mm ID, PE 100 and SDR17. A typical spigot point is presented in Figure 4 below

During normal operation, tailings are cycloned to produce a coarse fraction used as backfill hydraulic fill for the mine. The fine fraction is pumped to the TSF. On occasion when hydraulic fill is not required by the mine, the processing plant tailings are pumped in total to the TSF.

Discharge of the total tailings fraction is from a single point, through a dedicated 800 mm OD pipeline of specification as described above. Discharge of this fine fraction occurs from 3 to 4 spigots at any one time for a period of one week and the tailings are deposited in layers. Discharge is rotated systematically along the dam wall crest.

The reclaim pump system is located in the south east corner and the water will be pumped back into the existing reclaim water pumping system.

Response to Item 8(b)

The header pipeline is buried on the crest to prevent excessive movement due to temperature related expansion/contraction of the pipe, protection from vehicle damage and to act as a landscape berm.

The fact that the pipeline is buried has no application to containment in the event of a leakage.

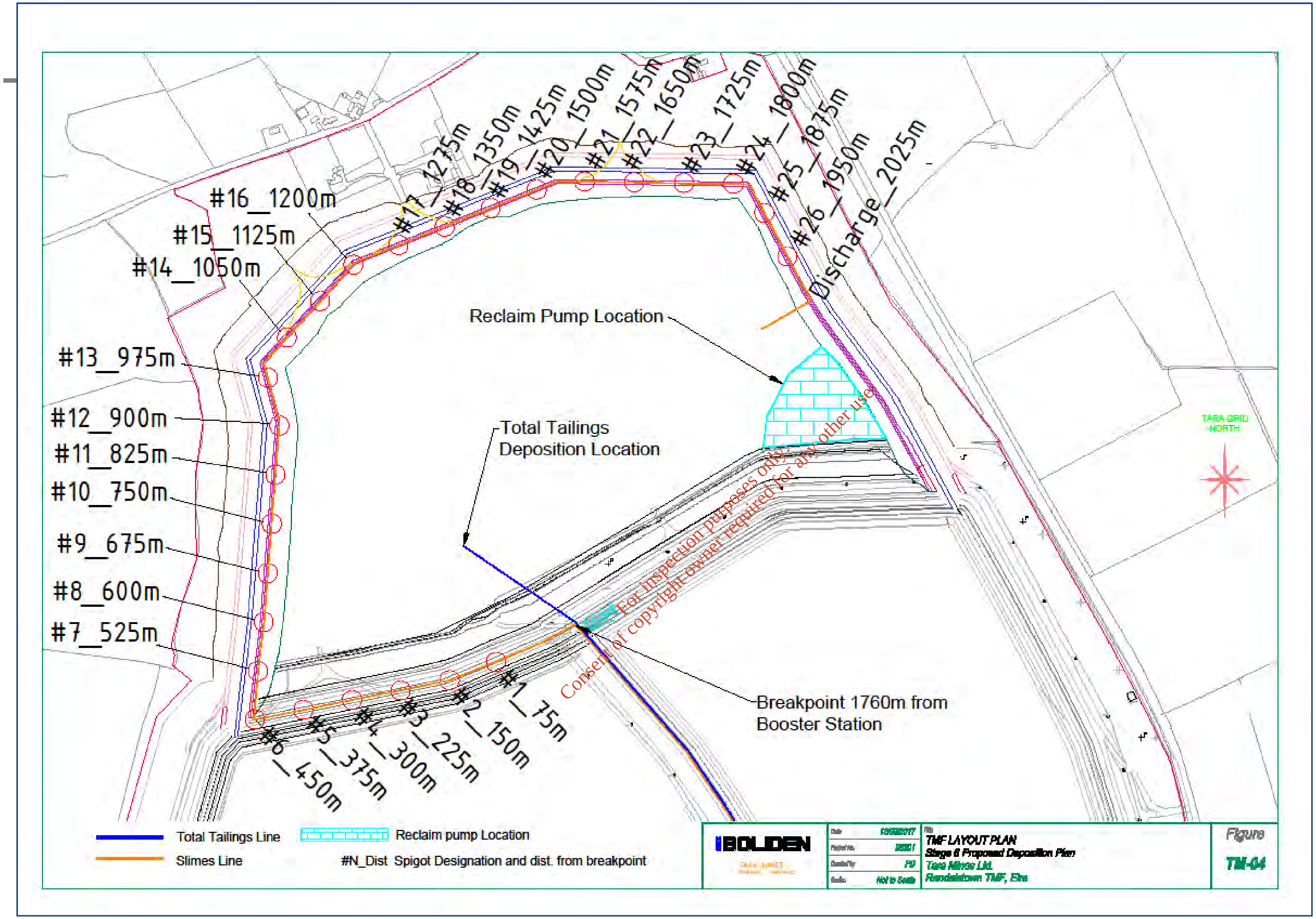

Figure 2 Stage 6 Tailings Deposition Plan

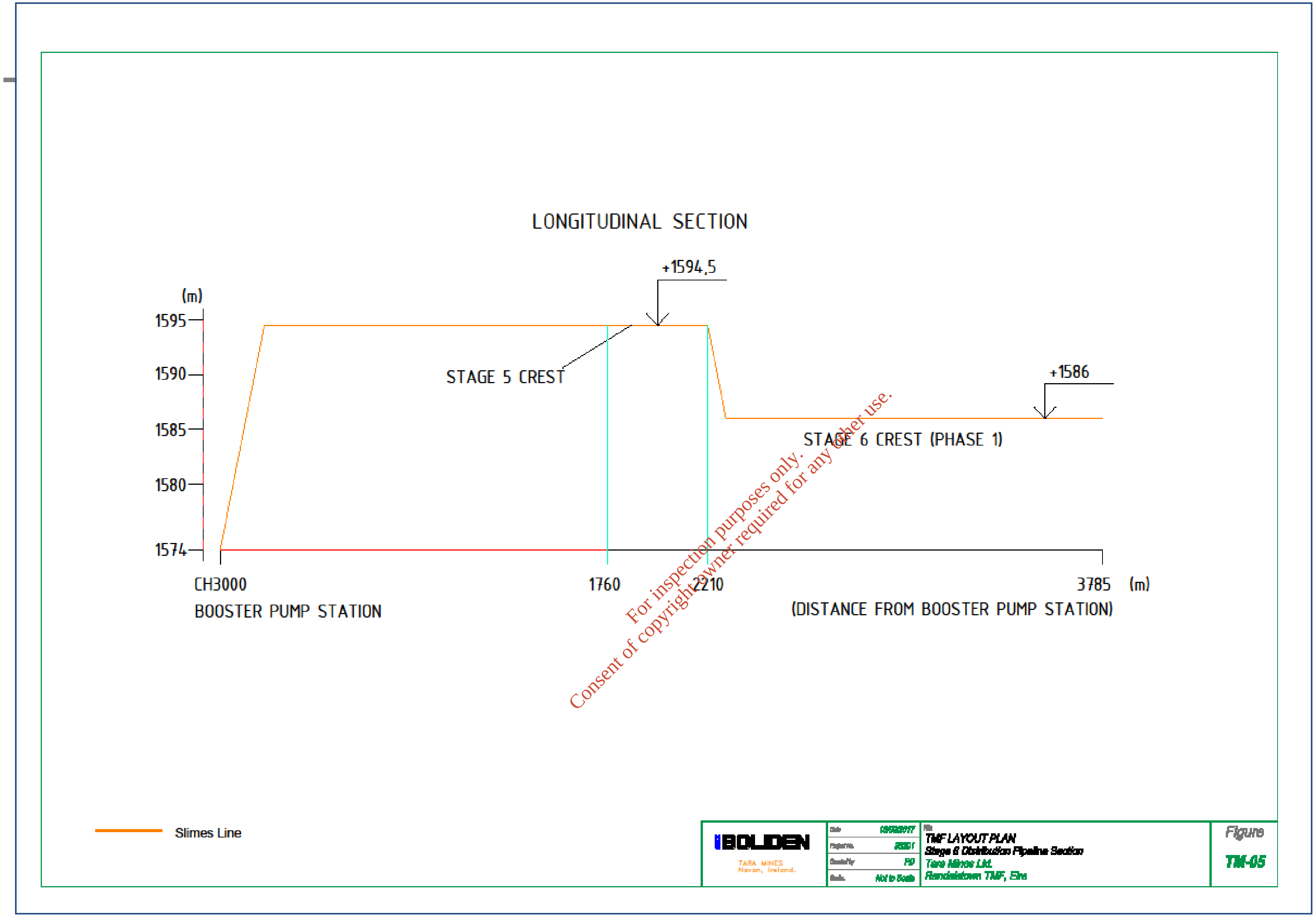

Figure 3 Stage 6 Layout Longitudinal Section

Figure 4 Typical Spigot Point

Item 9

Three sources of water that are considered as process water include water ingress to the mine; water from processing plant; and surface runoff.

(a) Clarify the statement, "All water from the process plant is pumped to the tailings facility".

(b) Provide a detailed explanation why collection systems for clean runoff and for seepage are not separate.

(c)Provide a detailed explanation why the interceptor channel used to collect and discharge seepage water into the water treatment system is not fully lined.

Response to Item 9(a)

The concentrator / processing water system is a closed loop system. All water streams (process water, storm water, runoff) drains centrally to the Mill tailings box and are pumped to the tailings storage facility as part of the 'tailings stream' for treatment and is subsequently returned to the reclaim pond on site for re-use.

This water is then either reused in the concentrator or further treated and blended in the sediment-aeration ponds prior to discharge to the River Boyne at Emission Point Reference SW1.

Response to Item 9(b)

As explained in response to item 5, as the facility is composite lined, the seepage is very low and virtually all the water collected in the perimeter interceptor channel will be derived from rainfall and ground water. Much of the water emanating from the basal drainage blanket will have derived from rainfall infiltrating the downstream shoulder of the dam wall.

Response to Item 9(c)

Water collected from the perimeter interceptor channel will be pumped back to the tailings facility. The interceptor channel will not be operated for water storage.

However, if monitoring indicates contaminates in excess of the discharge limits in the interceptor channel then the perimeter interceptor would be lined.

Item 10

It is proposed that the existing water treatment system will be used for both Stage 5 and Stage 6 TMF until an integrated constructed wetland system is put in place. Provide detailed information on the capability and suitability of the existing water treatment to accommodate the increased volumes following Stage 6 start-up and prior to Stage 5 decommissioning.

Response to Item 10

Process water flow from the TSF will not increase with the commissioning of Stage 6 as the combined inputs to both systems will remain the same.

All process water eminating from the TSF will continue to enter the water management system as at present. A wetlands water treamtment system will be utilised on decommissioning of Stage 5.

Item 11

It is noted that no tailings flow slide analysis is provided in the EIS in relation to TMF dam failure. Provide an assessment of the potential impact on the environment in the event of a TMF dam failure.

Response to Item 11

A dam break analysis for the existing and Stage 6 tailings facility has been undertaken and is presented in Appendix to FIR item 11.

Appendix to FIR Item 1

- Stage 6 TMF Footprint Palaeokarst Site Investigation and Grouting Works (Golder Associates)

September 2017

BOLIDEN TARA MINES LTD

Stage 6 TMF Footprint Palaeokarst Site Investigation and Grouting Works

Submitted to:
Boliden Tara Mines Ltd
Knockumber
Navan
Co Meath

REPORT

Report **Number** 1782163.R01.A0

Distribution:

Boliden Tara Mines - one copy
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Golder Associates

Study Limitations

IMPORTANT: This section should be read before reliance is placed on any of the opinions advice, recommendations or conclusions herein set out.

a) This report has been prepared for and at the request of Boliden Tara Mines Ltd ("the Client or Tara") for the purpose of undertaking a drilling investigation to its appointment of Golder Associates Ireland Limited (Golder) to act as Consultant;

b) Save for the Client no duty is undertaken or warranty or representation made to any party in respect of the opinions, advice, recommendations or conclusions herein set out;

c) Regard should be had to the agreements between Golder and the Client from the proposal and the subsequent Terms of Appointment issued by Golder;

d) All work carried out in preparing this report has used, and is based upon Golder's professional knowledge and understanding of the current relevant Irish, UK and European Community legislation.

   Changes in the legislation may cause the opinion, advice, recommendations or conclusions set out in this report to become inappropriate or incorrect. However, in giving its opinions, advice, recommendations and conclusions, Golder has considered pending changes to environmental legislation and regulations of which it is currently aware. Following delivery of this report, Golder will have no obligation to advise the Client of any such changes, or of their repercussions;

e) Golder acknowledges that it is being retained, in part because of its knowledge and experience with respect to engineering and environmental matters. Golder will consider and analyse all information provided to it in the context of its knowledge and experience and all other relevant information known to Golder. To the extent that the information provided to Golder is not inconsistent or incompatible therewith, Golder shall be entitled to rely upon and assume, without independent verification, the accuracy and completeness of all such information and Golder shall have no obligation to verify the accuracy and completeness of such information;

f) The content of this report represents the professional opinion of experienced engineering and environmental consultants, Golder does not provide specialist legal advice and the advice of lawyers will be required;

g) If the scope of the work includes borings, trial pits, or engineering interpretation of such information attention is drawn to the fact that special risks occur whenever engineering and related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing programme implemented in accordance with a professional Standard of Care may fail to detect certain conditions. The environmental, geologic, geotechnical, geochemical and hydrogeological conditions that Golder interprets to exist between sampling points may differ from those that actually exist. Passage of time, natural occurrences, and activities near the Site may substantially alter discovered conditions;

h) In the conclusion section of this report, Golder has set out its findings and provided a summary and overview of its advice, opinions and recommendations, however, other parts of this report will often indicate the limitations of the information obtained by Golder and therefore any advice, opinions or recommendations set out in the conclusion section ought not to be relied upon until considered in the context of the whole report; and

i) The contents of this report includes confidential information and should not be disclosed to third parties without prior written approval from Golder.

Table of Contents

1.0 BACKGROUND AND INTRODUCTION

Golder Associates (Golder) was retained by Boliden Tara Mines Ltd (Tara) to investigate potential palaeokarst features, interpreted during recent geophysics survey works (Electrical Resistivity Imaging (ERI), Seismic Refraction, EM31 Electromagnetic-Conductivity and Micro-Gravity), within the footprint of the proposed Stage 6 Tailings Management Facility (TMF) (the ‘Site’). The ‘Site’ is located to the north of the existing TMF at Randalstown, Co. Meath (Figure 1).

Figure 1: Aerial Photograph of the Proposed Stage 6 TMF (Northern and Seven Fields Borrow Area)

The footprint of the Stage 6 TMF is confined to the existing ‘Northern and Seven Fields Borrow Areas’. During the development phases of previous raises of the main TMF, the Site was used as a Borrow Area for construction material and occupies some 40 hectares.

The bedrock underlying the proposed Stage 6 TMF footprint comprises of two main units:

- Pale Beds (Carboniferous Limestones); and
- Non-calcareous Lower Palaeozoic (LP) sediments (Rathkenny Formation).

The geological map of the area (supplied by Tara) in Figure 2 below shows that the majority of the footprint to the east (including the area known as the Seven Fields Borrow Area) is underlain by black mudstone, siltstone and greywacke of the Rathkenny Formation, which is Lower Palaeozoic in age.

Pale Beds (PB) are understood to underlie much of the south-western part of the Site and present a potential risk for palaeokarst features; a number of anomalies were interpreted from the recent geophysical survey works which are the focus of this site investigation. Karst is defined as a geological feature formed by the dissolution of soluble rocks, and palaeokarst is a term used for ancient and inactive karst areas that have been buried or filled by later sediments.

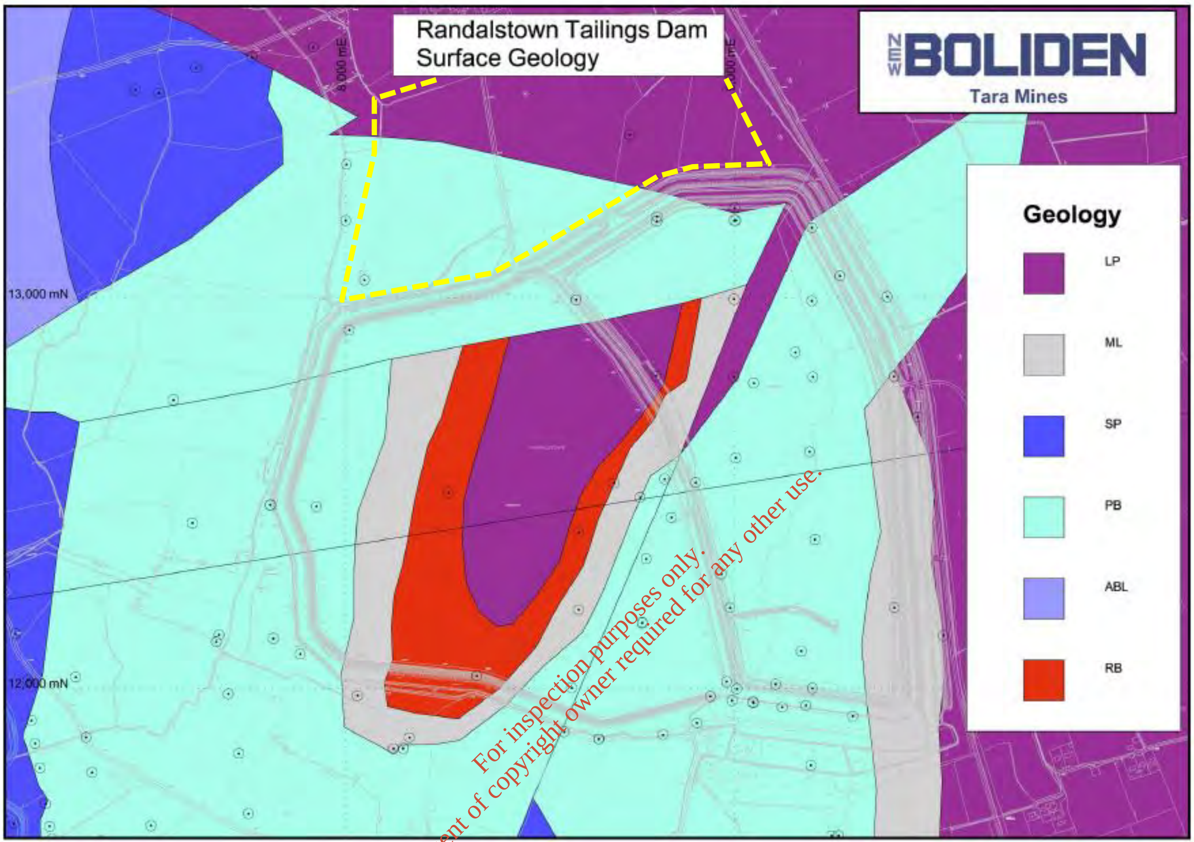

Figure 2: Geological Map of area around Tara TMF, Stage 6 TMF footprint is located to the north of the existing TMF (highlighted by yellow dashed line)

Golder have successfully undertaken surveys to locate and assess potential palaeokarst features at the Tara TMF and also at the Galmoy TMF in Co. Kilkenny, the Lisheen TMF in Co. Tipperary and at Aughinish Alumina Plant in Co. Limerick using a number of geophysical survey methods.

2.0 BOREHOLE TARGETING

The geophysical surveys undertaken over the proposed extension footprint for Stage 6 ('Borrow Area') of the TMF at Randalstown consisted of the following surveys (Golder Associates Report References 1775908.R01.B0 and 1775908.R02.B0):

- Seismic Refraction Survey – consisting of 102 profiles;
- Electrical Resistivity Imaging Survey (ERI) – consisting of 15 profiles,
- Micro-Gravity Survey – consisting of 2699 stations; and
- EM31 Electromagnetic-Conductivity Survey.

Results from the **Micro-Gravity** survey identified a number of gravity lows (Figure 3), indicating the possible presence of areas with *'low density sub-crop material'.* These gravity low areas may be due to palaeokarstic features within the underlying Pale Beds limestones. Modelling of the Micro-Gravity and comparison with the ERI pseudosections and Seismic Refraction profiles indicates that heavily weathered, fractured (and palaeokarstic) bedrock conditions may exist in the underlying Pale Bed limestones from near surface to depths of typically 40 to 50 m bgl. Five locations for boreholes, centred on the anomalies, were selected to test for the presence of palaeokarst features.

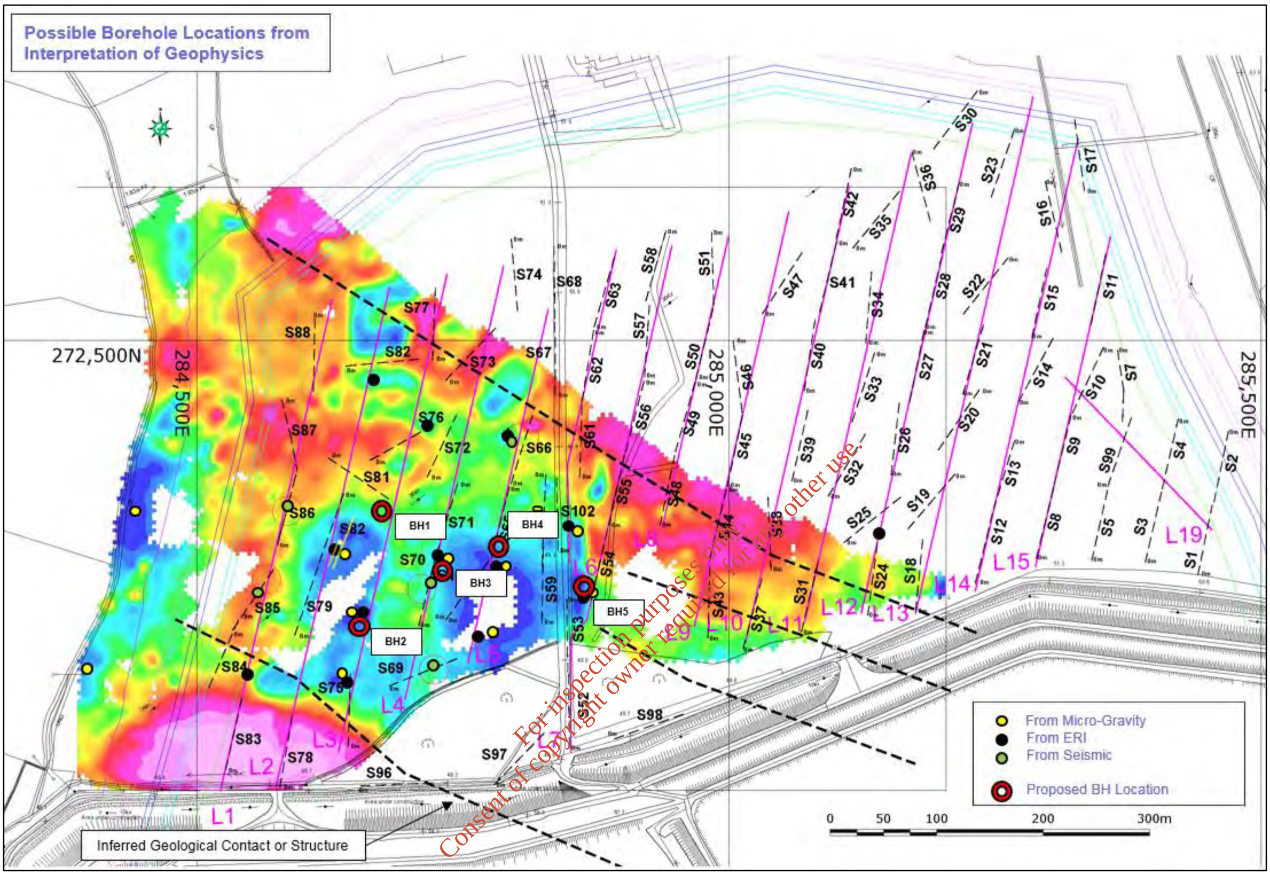

Figure 3: Residual Bouguer Gravity Map with Borehole Locations (red circles)

None of the anomalies interpreted are located beneath the dam wall footprint, all five are located in the south-west section of the base of the proposed Stage 6 TMF.

Previous site investigations (trial pitting) indicated that a thin layer of glacial till varying in thickness from 0.5 m to 5.0 m overlies much of the Site. In some instances overburden thicknesses in excess of 5 m occur, particularly overlying the Pale Beds in the western part of the Site. This material typically consists of grey clayey silty sands and gravels with boulders, and gravelly sandy clayey silts with boulders, and weathered brown clayey silty sands and gravels with occasional boulders. As the grey till approaches the underlying bedrock surface, the boulder content typically increases to over 50% of the material.

Figure 4 below presents the locations of the investigative boreholes plotted over a recent aerial photograph of the proposed Stage 6 extension to the TMF.

Figure 4: Location of Boreholes (plotted over recent aerial photograph of the Stage 6 TMF footprint)

Table 1 below presents the northing and easting coordinates for the boreholes in Irish National Grid along with the estimated depth of overburden from the seismic survey data.

Table 1: Coordinates for Proposed Borehole Locations in Irish National Grid

Borehole ID	Easting	Northing	Estimated Depth of Overburden from Geophysics
BH1	284634.2	272291.4	3.5 m
BH2	284653.1	272241.0	5.5 m
BH3	284733.0	272291.0	4.0 m
BH4	284783.4	272323.6	4.0 m
BH5	284870.9	272256.9	4.0 m

3.0 DRILLING AND CAMERA SURVEY RESULTS

The borehole drilling works were conducted by JS Drilling Ltd of Thomastown, Co Kilkenny with attendance provided by a Golder. Borehole locations were determined by an interpretation of the geophysical survey data and centred on the anomalies. A Golder geologist supervised the drilling works and completed geotechnical logs (to BS 5930:1999 + A2 2010) for each of the boreholes, which are provided in Appendix A. Following drilling each borehole, a camera survey was completed to assess for the presence of palaeokarst features.

A brief summary of each borehole is described below:

- **BH1** – Upper 6.0m comprised of made ground/overburden. Palaeokarst from 6m -17 m, in-filled with sands, gravels, and pebbles/cobbles, including a 2.5m section of weathered limestone. Water strike at 14.5m. Limestone bedrock encountered at 17.0m, with the borehole being terminated at **23.5m** (in bedrock).
- **BH2** – Upper 1.7m comprised of made ground/overburden. Palaeokarst from 1.7m - 40.3m, in-filled with sands, silts, clays, and gravels/cobbles. End of borehole at **40.3m** due drill rods becoming stuck.
- **BH3** - Upper 1.0m comprised of glacial till. Palaeokarst from 1.0m - 33.5m, in-filled with clays and gravels, becoming increasingly clay rich with depth. End of borehole at **33.5m** due to loss of air (very stiff clays).
- **BH4** – Upper 2.0m comprised of made ground/overburden. Weathered limestone from 2.0m - 18.5m, becoming less weathered at depth. Palaeokarst in-filled with clays, silt, sand, and rounded gravels from 18.5m - 23m. Limestone bedrock from 23.0m - 26.5m, becoming fractured at depth. Palaeokarst in-filled with clay and sand from 26.5m - 31m. End of borehole at **31m** due to drill rods becoming stuck.
- **BH5** – Upper 3.0m comprised of made ground, with glacial till between 3m -10m. Palaeokarst in-filled with clays, silts, and sands from 10m - 17m. End of borehole hole at **19.5m** due to drill rods becoming stuck.

4.0 GROUTING WORKS

Following from an assessment of the borehole logs and the camera surveys, the boreholes were decommissioned using gravity grouting techniques, proceeding from the bottom of the borehole to the top of the borehole. Four of the boreholes were infilled with a bentonite / cement grout mix to between 4m and 7 m below ground level and capped with a concrete plug while BH4 was infilled with the bentonite / cement grout mix to ground level.

The grout design mix selected had a ratio by weight of 8:3:1 for water: sodium bentonite powder: cement, respectively.

The supply water for the grout was filled into a tanker vehicle from a water tank used for the on-site truck wash. The grout was mixed in a high shear colloidal mixer to fully wet all the cement and bentonite particles prior to being pumped through the rods into the borehole. The percentage grout consumption ranged from 126% to 300% of the estimated extracted volume of the borehole by drilling. Additional grout consumption beyond 100% is attributed to minor voids created in the subsurface during the drilling of the boreholes. Table 2 provides a summary of the grouting works undertaken.

Table 2: Tara Mines Stage 6 Grouting Works

Borehole ID	Borehole Diameter (mm)	Borehole Total Depth (m) when drilled	Depth to top of Grout (m)	Volume of Grout Placed (m^3)	Est. Volume of Borehole for Grouting (m^3) ($V = d\pi r^2$)	% Grout Consumption	Concrete Volume used for Plug (m^3)
BH1	**100**	**23.5**	7	0.35	0.14	150	0.5
BH2	**100**	**40.3**	3.9	0.62	0.274	126	0.4
BH3	**100**	**33.5**	5.7	0.52	0.223	133	0.5
BH4	**100**	**31**	0	0.79	0.204	287	0
BH5	**100**	**19.5**	5	0.44	0.11	300	2.5

5.0 CONCLUSIONS

Five boreholes (BH1 to BH5) were drilled to depths of between 19.5m and 40.3 m centred over the interpreted geophysical anomalies to test for the presence of possible palaeokarst features in the underlying bedrock. The findings of the palaeokarst investigative drilling were in agreement with the results of the geophysical survey, indicating that the anomalies interpreted comprised of **infilled palaeokarst features**.

The boreholes intersected between ca. 1.0m - 6.0 m of glacial till/overburden underlain by weathered limestone and palaeokarst features infilled with sediments including clay/silt, sand, and rounded gravels (limestone and calcareous sandstones). Three boreholes were terminated before reaching bedrock due to drill rods becoming stuck. BH3 was terminated due to loss of air in stiff clays, and BH1 was terminated in limestone bedrock. Following drilling works, the boreholes were decommissioned with a bentonite-cement grout and capped with concrete.

The palaeokarst investigation did not identify any large voids beneath the footprint of the Stage 6 TMF Facility that might pose a risk to the integrity of the Stage 6 TMF Facility.

6.0 REFERENCES

1) Golder Associates (May 2017). Boliden Tara Mines Limited: Stage 6 Footprint Geophysical Surveys, 1775908.R01.B0

2) Golder Associates (May 2017). Boliden Tara Mines Limited: Possible Borehole Locations – Pale Beds – Stage 6 ('Borrow Area'), 1775908.R02.B0

Report Signature Page

GOLDER ASSOCIATES IRELAND LIMITED

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VAT No.: 8297875W

APPENDIX A

Geotechnical Borehole Logs

BOREHOLE LOG

Project				BOREHOLE No
Stage 6 - Karst features Site Investigantion				BH1
Job No: 1782163 - Karst SI	Date:	Ground Level (m): 1574.02	Co-Ordinates (Tara Mine Grid): E 8,216.8 N 13,272.8	
Contractor: JS Drilling				Sheet: 1 of 2

SAMPLES & TESTS: Depth	Type No	Test Result	Water	STRATA: Reduced Level	Legend	Depth (Thickness)	DESCRIPTION	Geology	Instrument/ Backfill
						(3.00)	MADE GROUND		
				1571.02		3.00			
						(2.80)	BOULDER CLAY		
				1568.22		5.80			
						(2.70)	PALEOKARST CAVITY - gravelly with rounded limestone pebbles BOULDER CLAY		
				1565.52		8.50			
						(4.50)	weathered LIMESTONE		
				1561.02		13.00			
			1			(3.50)	PALEOKARST CAVITY - gravelly BOULDER CLAY some cobbles		
				1557.52		16.50	PALEOKARST CAVITY - sands and gravels		
				1557.02		17.00	Competant grey LIMESTONE BEDROCK		
						(6.50)			

Boring Progress and Water Observations: Date	Time	Depth	Casing Depth	Casing Dia. mm	Water Dpt	Chiselling: From	To	Hours	Water Added: From	To	GENERAL REMARKS
											End of Hole at 23.5m - competant BEDROCK

All dimensions in metres Scale 1:143.75	Client: New Boliden - Tara Mines	Method/ Plant Used: Beretta T44	Logged By: MBD

AGS3 UK BH TEST.GPJ GINT STD AGS 3_1.GDT 19/9/17

BOREHOLE LOG

Project				BOREHOLE No
Stage 6 - Karst features Site Investigantion				**BH1**
Job No 1782163 - Karst SI	Date	Ground Level (m) 1574.02	Co-Ordinates (Tara Mine Grid) E 8,216.8 N 13,272.8	
Contractor JS Drilling				Sheet 2 of 2

SAMPLES & TESTS			Water	STRATA				Geology	Instrument/ Backfill
Depth	Type No	Test Result		Reduced Level	Legend	Depth (Thickness)	DESCRIPTION		
				1550.52					

Boring Progress and Water Observations						Chiselling			Water Added		GENERAL REMARKS
Date	Time	Depth	Casing Depth	Casing Dia. mm	Water Dpt	From	To	Hours	From	To	End of Hole at 23.5m - competant BEDROCK

All dimensions in metres Scale 1:143.75	Client New Boliden - Tara Mines	Method/ Plant Used Beretta T44	Logged By

AGS3 UK BH TEST.GPJ GINT STD AGS 3_1.GDT 19/9/17

BOREHOLE LOG

Project				BOREHOLE No
Stage 6 - Karst features Site Investigantion				**BH2**
Job No: 1782163 - Karst SI	Date:	Ground Level (m): 1574.11	Co-Ordinates (Tara Mine Grid): E 8,220.2 N 13,186.1	
Contractor: JS Drilling				Sheet: 1 of 1

SAMPLES & TESTS Depth	Type No	Test Result	Water	Reduced Level	Legend	Depth (Thickness)	DESCRIPTION	Geology	Instrument/ Backfill
				1572.41		1.70	MADE GROUND		
				1571.11		3.00	PALEOKARST CAVITY - sands and pebbles		
				1567.91		(3.20) 6.20	PALEOKARST CAVITY - very fine grey silts and lac clays		
				1566.81		7.30	PALEOKARST CAVITY - boulder clay with cobbles		
			1	1565.11		9.00	PALEOKARST CAVITY - gravelly boulder clay with cobbles		
				1564.11		10.00	PALEOKARST CAVITY - gravelly boulder clay with cobbles		
				1535.61		(28.50) 38.50	PALEOKARST CAVITY - clay with sands and gravels		
				1533.81		40.30	PALEOKARST CAVITY - dead sand		

Boring Progress and Water Observations: Date	Time	Depth	Casing Depth	Casing Dia. mm	Water Dpt	Chiselling: From	To	Hours	Water Added: From	To

GENERAL REMARKS

End of Hole at 40.3m - rods becoming stuck

All dimensions in metres Scale 1:251.875	Client: New Boliden - Tara Mines	Method/ Plant Used: Beretta T44	Logged By

BOREHOLE LOG

Project				BOREHOLE No
Stage 6 - Karst features Site Investigantion				**BH3**
Job No: 1782163 - Karst SI	Date:	Ground Level (m): 1571.37	Co-Ordinates (Tara Mine Grid): E 8,294.3 N 13,245.7	
Contractor: JS Drilling				Sheet: 1 of 1

SAMPLES & TESTS				STRATA					
Depth	Type No	Test Result	Water	Reduced Level	Legend	Depth (Thickness)	DESCRIPTION	Geology	Instrument/ Backfill
			▼1	1570.37		1.00	Boulder black LIMESTONE		
			▼2	1558.37		(12.00) 13.00	PALEOKARST CAVITY - clay with boulders		
				1557.17		14.20	PALEOKARST CAVITY - gravel, with lots of water inflow (a "slurry")		
				1550.37		(6.80) 21.00	PALEOKARST CAVITY - orangy/brown clay		
				1548.27		(2.10) 23.10	PALEOKARST CAVITY - stiff clay		
				1545.17		(3.10) 26.20	PALEOKARST CAVITY - stiff clay, minor clasts		
				1539.67		(5.50) 31.70	PALEOKARST CAVITY		
				1539.17		32.20	PALEOKARST CAVITY - very stiff grey clay		
				1537.87		33.50	PALEOKARST CAVITY - very stiff grey clay		

Boring Progress and Water Observations						Chiselling			Water Added	
Date	Time	Depth	Casing Depth	Casing Dia. mm	Water Dpt	From	To	Hours	From	To

GENERAL REMARKS

End of Hole at 33.5m - rods pulled due to loss of air. Very stiff clays

All dimensions in metres Scale 1:209.375	Client: New Boliden - Tara Mines	Method/ Plant Used: Beretta T44	Logged By

AGS3 UK BH TEST.GPJ GINT STD AGS 3_1.GDT 19/9/17

BOREHOLE LOG

Project				BOREHOLE No
Stage 6 - Karst features Site Investigantion				BH4
Job No: 1782163 - Karst SI	Date:	Ground Level (m): 1572.54	Co-Ordinates (Tara Mine Grid): E 8,336.5 N 13,276.7	
Contractor: JS Drilling				Sheet: 1 of 1

SAMPLES & TESTS: Depth	Type No	Test Result	Water	STRATA: Reduced Level	Legend	Depth (Thickness)	DESCRIPTION	Geology	Instrument/ Backfill
				1570.54		(2.00) 2.00	MADE GROUND		
				1567.24		(3.30) 5.30	fractured LIMESTONE with silts		
				1564.24		(3.00) 8.30	LIMESTONE - very heavily weathered in areas		
				1560.84		(3.40) 11.70	As above, but harder with depth		
				1560.04		12.50	As above, but harder with depth		
				1554.04		(6.00) 18.50	As above, but harder with depth		
			1	1549.54		(4.50) 23.00	PALEOKARST CAVITY - clays, silts, sands and rounded gravels		
				1549.04		23.50	very hard LIMESTONE		
				1547.04		(2.00) 25.50	very hard LIMESTONE		
				1546.04		26.50	soft - broken highly fractured LIMESTONE		
				1541.54		(4.50) 31.00	PALEOKARST CAVITY - clay filled with minor sand		

Boring Progress and Water Observations: Date	Time	Depth	Casing Depth	Casing Dia. mm	Water Dpt	Chiselling: From	To	Hours	Water Added: From	To

GENERAL REMARKS

End of Hole at 31.0m - rods becoming stuck

All dimensions in metres Scale 1:193.75	Client: New Boliden - Tara Mines	Method/ Plant Used: Beretta T44	Logged By

BOREHOLE LOG

Project				BOREHOLE No
Stage 6 - Karst features Site Investigantion				BH5
Job No 1782163 - Karst SI	Date	Ground Level (m) 1573.66	Co-Ordinates (Tara Mine Grid) E 8,435.6 N 13,235.1	
Contractor JS Drilling				Sheet 1 of 1

SAMPLES & TESTS			Water	STRATA				Geology	Instrument/ Backfill
Depth	Type No	Test Result		Reduced Level	Legend	Depth (Thickness)	DESCRIPTION		
				1570.66		(3.00) 3.00	MADE GROUND		
				1569.66		(1.00) 4.00	BOULDER CLAY		
				1566.66		(3.00) 7.00	BOULDER CLAY		
				1563.66		(3.00) 10.00	silty BOULDER CLAY		
			1	1562.66		(1.00) 11.00	PALEOKARST CAVITY - wet silts		
				1559.66		(3.00) 14.00	PALEOKARST CAVITY - clay/silts, increase in water		
				1556.66		(3.00) 17.00	PALEOKARST CAVITY - grey/brown coarse sand		
				1554.16		(2.50) 19.50	PALEOKARST CAVITY - sands and gravels		

Boring Progress and Water Observations						Chiselling			Water Added	
Date	Time	Depth	Casing Depth	Casing Dia. mm	Water Dpt	From	To	Hours	From	To

GENERAL REMARKS

End of Hole at 19.5m - rods becoming stuck

All dimensions in metres Scale 1:121.875	Client	New Boliden - Tara Mines	Method/ Plant Used	Beretta T44	Logged By

BOLIDEN TARA MINES - STAGE 6 PALAEOKARST REPORT

September 2017
Report No. 1782163.R01.A0

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Appendix to FIR Item 2

- Assessment of potential for acid generation in deposited tailings

An Assessment of Potential for acid generation in deposited Tailings at Randalstown

Physical Composition

The tailings comprise slurry containing approximately 10-15% solids. The solids are composed of particles, with a significant percentage being less than 11 microns in size, and 90% less than 44 microns.

Chemical Composition

The chemical composition of the tailings solids reflects a combination of the chemistry of the host rock, the ore mineralogy and the metallurgical processes.

Chemical Reagents

A number of chemical reagents are added during mineral processing. Some of the reagents are consumed or degraded in the process circuit. Small residual amounts may enter the tailings stream and be deposited in the TMF, however they are present in low concentrations and the organic component degrades rapidly.

Element Analysis

The primary economic minerals occurring within the orebody are galena and sphalerite. Secondary minerals include pyrite, marcosite, baryte, and some sulphosalts. These secondary minerals, together with residual amounts of galena and sphalerite, occur in the tailings that remain after minerals processing. As mineralisation has occurred within a Lower Carboniferous limestone host rock, the greater mass of tailings comprises calcitic and dolomitic limestone.

Selective analyses of metals, metalloids, and non-metal components of the tailings are routinely performed by an external accredited laboratory as part of Tara Mines IEL.

Results of the analyses for 2016 are presented in Table 1:

The analyses are undertaken monthly for zinc, lead, arsenic, iron copper, mercury, cobalt, magnesium, sulphate and sulphide. Cyanide and pH are monitored weekly.

The tailings samples comprise significant concentrations of calcium and magnesium representative of the calcitic and dolomitic limestones from which they are derived. They also contain a few trace metals in concentrations which exceed 5 x crustal abundance. These include zinc, lead, arsenic, mercury and copper. The near-neutral pH indicates metal mobility will generally be low.

Table 1 Tailings Solid Chemistry 2016

Parameters		pH	Total Cyanide (mg/kg)	Weak Acid Dissociable Cn	Zinc (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Iron (mg/kg)
Tailings Solids	Average	7.9	<1.1	<3.4	2,410	1,690	531	21,173
	Minimum	7.7	<1.1	<3.4	1,470	733	302	13,300
	Maximum	8.3	<1.1	<3.4	3,130	2,590	832	30,300
	Median	8.0	<1.1	<3.4	2,420	1.640	442	20,600
Parameters		**Copper (mg/kg)**	**Mercury (mg/kg)**	**Cobalt (mg/kg)**	**Calcium (mg/kg)**	**Magnesium (mg/kg)**	**Sulphate (mg/l)**	**Sulphide (mg/kg)**
Tailings Solids	Average	75	<1.00	12.9	196,727	14,709	6,573	21,327
	Minimum	37	<1.00	9.0	175,000	8,900	3,400	11,900
	Maximum	126	<1.00	17.0	223,000	25,300	10,000	37,700
	Median	71	<1.00	13.0	194,000	13,900	6,500	19,500

Host Rock Chemistry & Mineralogy

A samples mineralogical composition is a critical aspect in the prediction of its acid generation, acid neutralisation, and metal leaching potential.

Tailings sample was submitted for XRD analyses in August 2015 to determine its mineralogical composition. The sample was found to contain the following:

Major abundance: Calcite (49.4%)

Moderate abundance: Quartz (16.2%), Dolomite (11.5%)

Minor abundance: Mica (8.3%), Barite (5.2%), K-feldspar (3.8%), Pyrite (2.7%), Albite (2.4%)

Trace abundance: Galena (<0.5%), Sphalerite (<0.5%)

The sulphur concentration likely to result from metal sulphides and sulphates within the tailings, particularly barite ($BaSO_4$) and pyrite (FeS_2), together with residual amounts of sphalerite (ZnS) and galena (PbS).

Acid-Base Accounting (ABA) and Acid Generation Potential

The generation of acidic conditions within deposited tailings or waste rock is generally encountered when pyrite is exposed to atmospheric oxygen and water. Pyrite oxidation is a complex, stepwise process, one end product of which is sulphuric acid. The associated reduction in pH of the waste mobilises metals as soluble salts which, with sulphuric acid, may cause severe environmental impacts if allowed to drain or run off from a tailings facility, in an uncontrolled manner. Acid rock drainage (ARD) can significantly compromise ground and surface water quality, and surface reclamation success, even if neutralisation reactions have occurred before discharge.

The results of ABA testing on tailings samples in 2016 are presented in Table 2.

Although tailings at Tara Mines contain both pyrite and trace amounts of its more reactive polymorph, marcasite, the geochemical and physical characteristics of the tailings mitigate against the formation of ARD.

At the Randalstown facility, oxidation of pyrite within the tailings is suppressed as a consequence of the fine texture and saturated condition of the tailings, both of which will restrict oxygen diffusion below the surface. Furthermore, the Carboniferous Limestone matrix of the tailings offers significant and excess neutralisation capacity should any pyrite oxidise to produce acid-sulphate tailings water.

Although no single standard exists for interpretation of ARD potential using ABA results, the MEND (2009) guidance report presents screening criteria for ARD potential that have gained widespread acceptance. These criteria indicate that where an NPR > 2, the material is expected to be non-acid generating.

Using 2016 data the median NPR is ~9.0 and is well in excess of 2; therefore the tailings are expected to be non-acid generating.

Furthermore, criteria based on the NNP is summarised in the GARD Guide (INAP, 2012). Material with an NNP >20kg $CaCO_3$/t is expected to be non-acid generating.

Using 2016 data the median tailings NNP is 526 kg $CaCO_3$/t and therefore classified as non-acid generating in terms of this criteria.

At present, there is no visible evidence of acid seepage from the Randalstown facility, or ponding of acidic water on the surface of the dam. Under conditions of net acid generation potential, ARD is usually detected as a yellow to ochre-red drainage, containing oxy-hydroxides of metals, particularly of iron, aluminium, and manganese. The absence of such drainage, and a tailings water median pH of 8.3, suggests that ARD is not being generated in the Randalstown tailings facility.

Based on the previous work and the ongoing monitoring it is concluded that Tara Mine's tailings at Randalstown have a high net neutralisation potential:

- Significant reductions in tailings pH or alkalinity are not expected to occur over time
- Acid mine drainage from the Randalstown tailings facility is not expected to be a significant environmental issue

The results indicated a considerable buffering capacity of the tailings to neutralise any acid generation.

Table 2 2016 ABA testing on tailings samples

	Acid Potential (AP)	Neutralisation Potential (NP)	Neutralisation Potential Ratio (NPR)	Net Neutralisation Potential (NNP)	Total C	Total Sulphur	Sulphate Sulphur	Sulphide Sulpher (Calc)	C organic	C inorganic
	kgCaCO3/t ore	kgCaCO3/t ore	unity	kgCaCO3/t ore	%	%	%	%	%	%
Jan-16	66	560	8.45	494	6.88	2.84	0.72	2.12	0.16	6.72
Feb-16	76	571	7.49	495	6.91	3.24	0.80	2.44	0.17	6.74
Mar-16	50	604	12.09	554	7.69	2.29	0.69	1.60	0.20	7.49
Apr-16	72	586	8.15	514	7.46	3.00	0.70	2.30	0.15	7.31
May-16	66	613	9.29	547	7.97	2.79	0.68	2.11	0.13	7.84
Jun-16	81	615	7.56	533	7.98	3.30	0.70	2.60	0.14	7.84
Jul-16	47	603	12.96	557	7.66	2.26	0.77	1.49	0.22	7.44
Aug-16	70	553	7.89	483	7.41	3.14	0.90	2.24	0.14	7.27
Sep-16	70	602	8.60	533	7.69	2.88	0.65	2.23	0.13	7.56
Oct-16	63	603	9.60	540	7.49	2.65	0.65	2.00	0.15	7.34
Nov-16	73	594	8.16	521	7.43	3.08	0.75	2.33	0.1	7.33
Dec-16	78	615	7.91	537	8.20	3.16	0.67	2.49	0.1	8.10
Average	**67.59**	**593.25**	**9.01**	**525.67**	**7.56**	**2.89**	**0.72**	**2.16**	**0.15**	**7.42**

Appendix to FIR Item 6

- Results of short term stability analysis
- Design for the Stage 6 Tailings Management Facility *(Golder Associates)*

REPORT

March 2016

BOLIDEN TARA MINES

Design for the Stage 6 Tailings Management Facility

Submitted to:

Boliden Tara Mines Ltd

Knocknumber

Navan

Meath

Report Number. 1532091.502/A.1

Distribution:

Boliden Tara Mines Ltd - 1 copy (pdf)

Golder Associates (UK) Ltd - 1 copy

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1.0 INTRODUCTION

This report presents the design of the proposed Stage 6 tailings management facility (TMF) at Boliden Tara Mines Ltd (Tara). Stage 6 is required to supplement the diminishing storage capacity of the main TMF and will allow for progressive closure of the existing Stage 5A and 5B facilities.

Tara Mines is Europe's largest zinc and lead mine located near the town of Navan in Co. Meath. The main orebody is hosted in Lower Carboniferous limestone and the process produces large quantities of tailings and approximately 1.15 Mt of tailings, which represents 60% of the total, were discharged into Stage 5A in 2015 whilst the remaining tailings were placed underground as backfill. Historically, approximately 48% to 52% of the mine tailings are discharged into the tailings facilities. For future estimates, the tailings discharge rate has been taken as 1.1Mt/y.

The existing facilities have been built in five key stages during the period between 1974 and present. Drawings 1.1 and 1.2 show the site location and Drawing 1.3 shows the layout plan for the existing tailings facilities, Stages 5A and 5B and the proposed Stage 6 location. All drawings are presented in Appendix A. Stages I and II were constructed to an elevation of 57.29 m AOD (Above Mine Datum) filled and the tailings surface temporarily re-vegetated in 1988 (Drawing 1.4). Stage III was constructed between 1985 and 1987 to an elevation of 57.29 m AOD and was filled in March 2003. Construction of Stage 4A, a raised facility over the existing tailings in Stages I and II to an elevation of 63.29 m AOD, began in late summer of 1998 and was completed in July 2000. The Stage 4A tailings facility was filled by the end of 2006. The construction of Stage 4B to an elevation of 63.29 m AOD, which is founded on the Stage III tailings, commenced in the summer of 2003 and the dam walls were completed in 2006. Stage 4B has been filled. Construction of Stage 5A above Stage 4A to an elevation of 67.29 m AOD has been completed and tailings deposition into 5A commenced in July 2013. To date the total capacity of the tailings facilities, Stages I, II, III, 4A, 4B and 5A is approximately 40.3 Mt and based on an average dry density of 1.42 t/m^3 equates to a volume of 28.4 Mm^3.

Tara Mines had completed the construction of Stage 5B in October 2015 which was constructed on the tailings of Stage 4B to a crest elevation of 67.29 m AOD. Stage 5B will provide additional tailings storage of 4.6 Mt (3.2 Mm^3).

An option study (Ref 1.1) and conceptual designs for Stage 6 were presented to Tara (Reference 1.2) in 2015. The decision by Tara was to adopt a new facility located along the northern sector of the existing facilities (Drawing 1.3) and confined within the northern and seven fields borrow areas (Drawing 1.4). These borrow areas have been extensively used for the construction of Stages 4B, 5A and 5B. Approximately 1.2 Mm^3 of material has been removed from the borrow area including some 300,000 m^3 of weathered rock.

The partially excavated borrow areas are shown in Figure 1 which is an aerial photograph of the borrow sites.

The northern boundary of the TMF footprint was restricted to a distance of at least 100 m from the public road.

The Stage 6 facility provides a potential struck storage volume of approximately 9.6 Mm^3 or 13.6 Mt at a crest elevation of 67.29 m AOD.

Figure 1: Aerial Photograph of the Northern and Seven Fields Borrow Area

2.0 GEOLOGY

2.1 Regional Geology

The bedrock geology underlying the Randalstown area is described in the Golder Associates palaeokarst report (Reference 2.1)

Rocks underlying the immediate area of the tailings impoundment range from Lower Palaeozoic in age through to Lower Carboniferous (Dwg. 2.1) as evaluated by Tara Mines geological department. From the Geological Survey of Ireland (GSI) website both borrow areas consist of the Lower Palaeozoic rocks termed the Rathkenny Formation also shown on Drawing 2.1. These are divided into four main rock types, consisting of Lower Palaeozoics, Red Beds (Old Red Sandstone), Mixed Beds and Pale Beds. These units are described briefly below. The Randalstown Fault cuts from northeast to southwest across the site.

The Lower Palaeozoic rocks consist predominantly of siltstones, sandstones, shales and greywackes with quartz conglomerate horizons. These Lower Palaeozoic rocks occur at rock head level to the east and north of the tailings impoundment and in a 500 m wide zone beneath the site, to the west side of the Randalstown fault.

The Red Beds, which are Lower Carboniferous in age, consist of dark red interbedded conglomerates and sandstones and unconformably overly the Lower Palaeozoic. The Red Beds are assumed to be thin in this area. Exploration boreholes drilled in this area encountered between 0 m to 12 m of Red Beds.

The Mixed Beds is a collective term for two units, which are the Laminated Beds and the Muddy Limestone and also termed the Liscarton Formation. The Laminated Beds consist of dark laminated siltstones, mudstones and shales with local sandstones and calcarenites. The thickness of the laminated beds beneath the basin area of the tailings facility, range from 0 m to 40 m. The overlying Muddy Limestone consists of dark, well bedded, argillaceous and crinoidal limestones with local coarser, bioclastic strata which are microconglomeratic in nature. The thickness of this unit in the tailings area ranges from 0 m to 10 m.

The Pale Beds or the Meath Formation comprise a variety of pelletal, oolitic and bioclastic calcarenites which locally contain quartz sand and darker argillaceous layers. They are a dominantly massive group and are characterised by their low shale content. The base of the Pale Beds is defined by a pale micritic limestone known as the Micrite Unit, which varies greatly in thickness. The Pale Beds vary from 0 m to 140 m thick across the Randalstown area.

The Pale Beds have distinctive marker horizons within them, such as nodular shaley units and silty horizons. Extensive fracturing and leaching of this horizon is common (Reference 2.1) but cavity formation is almost wholly restricted to those sections of the Pale Beds which do not have a cover of the Upper Dark Limestone (UDL). The UDL is a more argillaceous unit compared to the Pale Beds, and as such is less prone to the chemical action of the groundwater. In the tailings area the Pale Beds are not covered by the UDL.

2.2 Quaternary Deposits

The whole region was glaciated by ice sheets, in excess of 800 m thick, which covered Ireland during the Munsterian and Midlandian stages, approximately 15,000 years ago (Ref. 2.2 and 2.3). These left behind Quaternary overburden deposits in the area of the tailings impoundment consisting of three main soil types. The basal unit is a Quaternary glacial till consisting of consolidated lower grey silty clay to clayey silt with sand, gravel and some cobbles and boulders. This is directly overlain by the upper brown weathered glacial till also consisting of silty clay to clayey silt with sand, gravel with some cobbles and boulders. This is essentially a weathering of the underlying grey material and as such tends to have a higher clay content. Overlying some areas of the glacial till are lenses of possibly alluvial or out-wash granular materials comprising silt, sand and gravel.

The general thickness of overburden deposits recorded at Randalstown varies from about 1 m to 8 m and follows the somewhat random profile of the bedrock surface.

2.3 Structure

The major Randalstown Fault, running diagonally across the main tailings site area, trends in a northeast to southwest direction and brings the Pale Beds directly into contact with the Lower Palaeozoic rocks (Drawing 2.1 and Ref. 2.1). This is a reverse fault which dips to the northwest at a steep 75° angle in the tailings area. It is possible that associated with this structure is a zone of strong and extensive shearing, fracturing and subsequent calcite vein infilling.

Several minor faults are reported to exist beneath the tailings dam, notably along the Carboniferous/Lower Palaeozoic contact at the northern end of Stage II (Ref. 2.1).

The limestones within the tailings pond are believed to be draped about the northwest flank of a complex southwest plunging anticline of Lower Palaeozoic rocks.

2.4 Karstification

In carbonate rocks, the secondary permeability, where water moves through fissures, fractures, joints or along bedding planes, may be increased by solution during ground water movement. This process is termed karstification, and leaves interconnected cavities in the ground, and creates distinctive topographical features

(Reference 2.4). During the formation of some karst features, the development of a solution cavity in the underlying limestone may induce the overlying overburden material to migrate or slump into the cavity. This could result in the formation of a sinkhole, also termed doline, at the ground surface. The concerns of this risk relate to the foundation failures that may be induced by karstification, associated with the development of sinkholes.

Karstic features may be considered as either 'active', i.e. forming at the present time, or may have formed in the past and are now inactive, termed 'palaeokarst'. For karstification to be active at the site, there must be groundwater movement. A palaeokarst system is one in which the conditions which promote karstification are no longer present.

Palaeokarsts are present in the Randalstown area and investigations were previously carried out on this subject for the Stage 4 dam raise project (Reference 2.5). The outcome of these investigations indicated that the karsts at the tailings area comprises an immature palaeokarst system. It was termed an immature system because the individual cavities are small and are unlikely to be interconnected. It was considered as a palaeokarst due to the pre-glacial infill materials, such as sand, rock fragments and clay material, and also because the thickness of the overburden deposits indicate that there has been no active karstification in the Randalstown area within the past 15,000 years.

For Stage 6, some initial geophysics was undertaken to investigate the potential for excavating the rock within the basin of the facility which indicated some anomalies. We would propose undertaking a resistivity survey over the entire footprint and a microgravity survey over any anomalies found where the Pale Beds underly the site. Micro gravity is the best technique to determine any areas of mass deficiency representing palaeokarstic features. These types of survey were undertaken at Galmoy and Lisheen with considerable success.

3.0 SITE CONDITIONS

3.1 General

The footprint of the Stage 6 facility is confined to the existing northern and seven fields borrow areas. Virtually all the area is exposed indicating rock or glacial till over the site. It is anticipated that rock which can be excavated by a tracked excavator, ripped or removed by pneumatic hammer (breakable) will be used in construction of the dam walls and drainage. The foundation of the dam walls will either be glacial till or bedrock.

Some locations within the northern borrow area have been restored using topsoil or ameliorated soil and these materials will be removed and stockpiled within the mine boundary and outside the footprint of the facility for capping of Stage 5A. Topsoil stockpiles are also present mainly around the perimeter of the borrow area and they will remain in place if outside the Stage 6 footprint. Any topsoil stockpiles within the basin area will be removed to outside the dam or used for capping of Stage 5A.

A number of site investigations have been undertaken to evaluate the extent and suitability of the glacial till for construction of Stage 5B (References 3.1 and 3.2) in the northern and seven fields borrow areas and for the Simonstown borrow area (Reference 3.3) used in the construction of Stage 4. The depth and relative strength condition of the underlying bedrock (References 3.4 and 3.5) was also investigated by geophysics in the northern and seven fields borrow area together with a limited amount in the Simonstown borrow area.

3.2 Bedrock

The bedrock underlying the proposed Stage 6 footprint are the Pale Beds or Lower Palaeozoic rocks (Drawing. 2.1). Much of the area exposed in the north east sector of the Northern borrow area and the Seven Fields borrow area are Lower Palaeozoic rocks which are generally non calcareous with Pale Beds in the south west sector of the Northern borrow area which are calcareous.

Some removal of the weathered rock material has been undertaken during the construction of Stage 5B to a depth of at least 2 m below rock head level. The strength of the exposed rock is variable and dependent on the degree of weathering and structure. Where the rock has been removed by pneumatic hammer, the material is moderately strong to strong and would be suitable for the drainage protection materials.

3.3 Glacial Till

Above the bedrock is a thin layer of glacial till generally varying in thickness from 0.5 m to 5.0 m and is typically grey clayey silty sands and gravels with boulders and gravelly sandy clayey silts with boulders which is termed Type A2 material and weathered brown clayey silty sands and gravels with occasional boulders which is termed Type A1 material. As the grey till approaches the underlying bedrock surface the boulder content increases considerably to over 50% of the material.

Occasionally, there are bands and lenses of silty fine sand/fine sandy silt (Lacustrine Deposits) or sands and gravels within and above the glacial till and these materials are referred to as Type A3 material.

3.4 Site Work and Borrow Materials

3.4.1 Geophysics

A recent geophysical survey was undertaken in the basin area of Stage 6 consisting of electromagnetic conductivity, seismic refraction and electrical resistivity imaging. The surveys were undertaken to;

- Evaluate the nature and extent of overburden across the basin area for use as material for construction;
- Evaluate the nature and extent of 'rippable-breakable' rock for use as material for construction; and
- Evaluate the potential quantities of overburden and viable rippable–breakable rock available within the proposed footprint of the 'basin' area to be used in construction of the new facility.

The electromagnetic conductivity (EM31) survey is used to assist in the delineation of variations in the thickness of overburden. The seismic refraction survey is used to investigate areas of overburden and potential rippable-breakable rock. The electrical resistivity imaging (ERI) survey is used to map and delineate changes in material type and to determine overburden and rock-fill properties. The results are discussed in Reference 3.5 and the estimated volumes are given below.

Table 1: Estimated Volumes from the Geophysical Surveys Above 1572 m AMSL.

Western Cell	**Estimated Volume (m^3)**	**% Adjustment**	**Adjusted Volume (m^3)**	**Estimated Excavatability**
Overburden	170,000	30	119,000	Diggable
Weathered Bedrock	44,000	25	33,000	Rippable
Bedrock	3,500	25	2,600	Breaking
Total	**217,500**		**154,600**	-
Eastern Cell	**Estimated Volume (m^3)**	**% Adjustment**	**Adjusted Volume (m^3)**	**Estimated Excavatability**
Overburden	365,000	30	255,500	Diggable
Weathered Bedrock	260,000	25	195,000	Rippable
Bedrock	59,000	25	44,200	Breaking
Total	**684,000**		**494,700**	-

The adjustment for the overburden material is for boulders and cobbles which are too large to use as construction fill. The adjustment used for the available rock is precautionary. The total volume available for construction not requiring blasting is 0.65 Mm^3.

For the purpose of the geophysical survey, the basin area within Stage 6 was divided into two cells separated by the main haul road running through the area. The cells are presented in Figure 2.

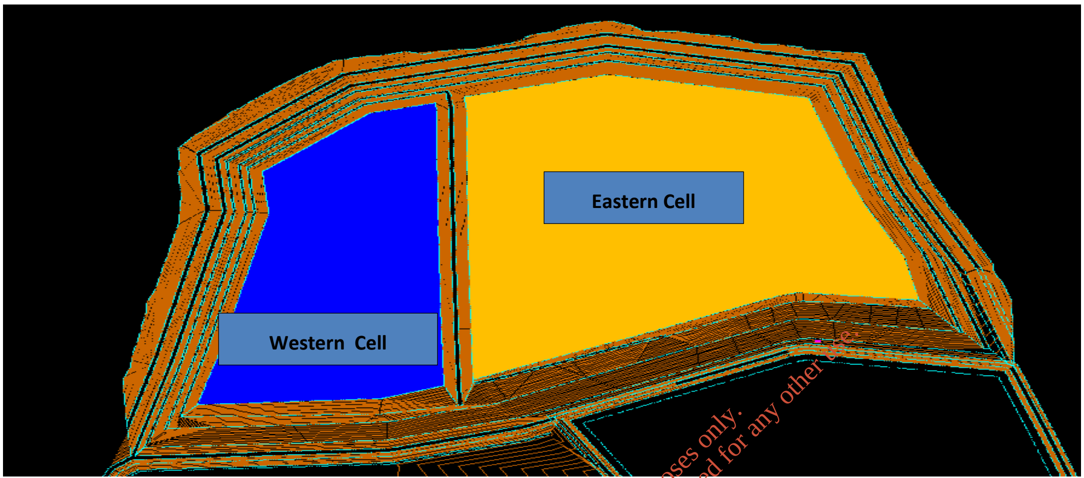

Figure 2: Western and eastern cells within the Stage 6 basin area.

A limited geophysical survey was also undertaken in the old Simonstown borrow area which was used extensively in the construction of Stage 4A. Two seismic profiles and a single ERI line were undertaken (Reference 3.5) to establish the depth of overburden material and rippable rock in the northern sector of the borrow area.

3.4.2 Trial Pitting Northern and Seven Fields Borrow Area

Twenty nine trial pits were excavated through the overburden material to near refusal either in bedrock or where hard digging due to the presence of numerous cobbles and boulders were observed within the basin area of Stage 6 in the northern and seven fields borrow areas. The location of the trial pits is given in Figure 3 and the logs presented in Appendix B and indicated that within the Stage 6 basin area of the western cell, the depth of overburden was generally between depths below ground level of 3.6 m and 5.0 m. In terms of elevation, the overburden extended to depths below 1570 m AMD and 1566.8 m AMD. In the eastern cell, overburden was found to depths of between 0.4 m and 3.5 m below ground level although in some areas the overburden has been removed completely to expose bedrock.

Table 2: Estimated Overburden Volumes from the Trial Pitting

Western Cell	**Estimated Volume (m^3)**	**% Adjustment**	**Adjusted Volume (m^3)**	**Comments**
Average Depth 4 m	520,000	30	364,000	Including material below an Elv. of 1570 m AMD
Average Depth 2 m	260,000	30	182,000	Material above an Elv. of 1570 m AMD
Eastern Cell	**Estimated Volume (m^3)**	**% Adjustment**	**Adjusted Volume (m^3)**	**Comments**

Western Cell	Estimated Volume (m^3)	% Adjustment	Adjusted Volume (m^3)	Comments
Average Depth 1.2 m	300,000	30	210,000	Above an Elv. of 1570 m AMD

Figure 3: Location of Trial Pits in the Northern and Seven Fields borrow area

3.5 Summary of Borrow Material

There are several sources of material that could be used for construction purposes for the dam wall and capping on land owned by Tara Mines and in the immediate vicinity of the existing TMF. The main sources of borrow material are:

- Within the basin area of Stage 6 which will need to be removed prior to completion of the first phase of construction; and
- The material outside of the TMF footprint and within the northern and seven fields borrow areas.

There are some discrepancies between the overburden evaluated by the geophysics and the trial pitting and it can be assumed that the latter is a more robust method of evaluation. In summary, the overburden material including diggable weathered bedrock within the basin area of Stage 6 is estimated to be between 392,000 m^3 and 574,000 m^3 depending on the depth achieved. This assumes that the depth of excavation in the western cell is approximately between 2 m and 4 m and generally above an elevation of between 1568 m AMD and 1572 m AMD. Assuming and average value (3m depth), the material available is 483,000 m^3. Where overburden is taken to depth and particularly where ground water is encountered, these excavations will be backfilled with boulders and cobbles removed from the glacial till.

From the geophysics, an estimate for the rippable rock volume is 228,000 m^3 and the volume of breaking rock with a pneumatic hammer is approximately 46,800 m^3.Therefore the total material available within the basin area of the TMF is approximately 757,000 m^3.

Table 3: Estimated Available Borrow Materials

Location	**Estimated Volume (m^3)**			
	Overburden Diggable	**Rippable Rock**	**Breakable Rock**	**Total**
TMF Basin Area	483,000	228,000	46,000	**757,000**
Outside TMF Footprint	329,000	175,000	37,000	**541,000**
Total	**812,000**	**403,000**	**83,000**	**1,298,000**

The remaining borrow area outside of the dam footprint would be used after the completion of Phase 1 construction.

The bulk of any short fall in borrow materials for Phase 2 construction would be obtained from land adjacent to the tailings facility owned by Tara and subject to planning. Additional materials such as drainage or protection material would be imported from local quarries together with any recycling of imported material from construction sites.

4.0 HYDROLOGY AND GROUNDWATER

4.1 Hydrology

The Randalstown tailings facility is located in a topographically flat area at approximately 50 m above sea level. There are four main drainage regimes in the vicinity (Dwg 4.1).

The Yellow River, to the west of the tailings facility, is close to the site and flows south. The Yellow River joins the Blackwater River about 0.75 km south west of the site.

The Blackwater River flows south east and into the River Boyne approximately 4 km downstream.

The Simonstown stream originally crossed the tailings site and was diverted during the construction of Stage I into a channel on the eastern side of Stages I and II. The stream flows into the Doug River which in turn flows into the Blackwater River.

4.2 Groundwater

Two hydrogeological units exist at the site:

- Quaternary sands, gravels and clays with an average thickness of 8 m beneath the tailings pond; and
- Lower Palaeozoic greywacke and Lower Carboniferous limestone bedrock.

The units are expected to be in hydraulic connection naturally. Hydraulic conductivity for Quaternary sands and gravels is likely to be of the order of 1E-4 m/s and 1E-5 m/s. Areas of high clay content are expected to have significantly lower hydraulic conductivity as represented for the clayey glacial till materials and as low as 1E-9 m/s. The hydraulic conductivity range for the bedrock hydrogeological unit is likely to be 1E-4 m/s and 1E-5 m/s (Reference 4.1) although results obtained from the two deep borehole investigations (Reference 3.1), indicated lower permeabilities at around 1E-6 m/s. The permeability of the rock will be dependent on frequency of fissuring and fissure infilling.

Groundwater flow in the Quaternary hydrogeological unit is expected to be restricted by the laterally discontinuous nature of the high hydraulic conductivity lenses.

Groundwater flow in the bedrock is expected to be locally very fast through faults, fissures and solution features in the limestone. High flows were recorded from the fissured bedrock (Reference 4.1).

Local groundwater flow is to the south west towards the Yellow River. Both hydrogeological units are expected to be in hydraulic connection with the Yellow River. A bedrock spring flows into the river near the north western edge of the Stage III tailings facility.

There are two private wells which draw water from bedrock in the Randalstown area and make contact with the Quaternary hydrogeological unit. Groundwater flow is expected to be to the south and southwest across the region, towards the Yellow and the Blackwater Rivers and River Boyne.

Groundwater is already encountered in the Northern and Seven Fields borrow areas and drainage measures have been installed to drain the site. During the summer season, the groundwater drops and rises in winter time. It is expected that over much of the basin area, rock will be exposed and therefore it would be prudent to place the lining system during late summer and early autumn.

5.0 SEISMICITY

5.1 Seismic Hazard

Ireland is characterised by very low levels of seismic activity. There have been no known occurrences of severe shaking over the past 10 centuries. The largest earthquake of recent time to shake the area was the magnitude 5.4 (Richter Scale) Wales earthquake of 1984, about 400 km from the site. The last reported earthquake in Ireland was in Wicklow on 28th April 1992 with a magnitude of 1.4 which is a very small event. The seismicity of Ireland is very low, particularly in the western part of the country and virtually the whole of Ireland is practically free of earthquakes (Reference 5.1).

Based on a review of historic data on earthquakes over the past 1,000 years within 1,000 km of the site, and broad estimates of attenuation, a design acceleration of 0.03g would provide for a 1 in 1,000 year event. Even up to a 1 in 10,000 year event, equivalent to the maximum credible earthquake (MCE), the acceleration should not exceed 0.06g.

The design criteria for the site have been evaluated using seismic data of the region to derive the Design Base Earthquake (DBE) and the Maximum Credible Earthquake (MCE). These are equated to a peak ground acceleration (PGA) for the site. This procedure follows international guidelines as set out by the International Commission on Large Dams (ICOLD) (Reference 5.2). The DBE equates to an earthquake event that usually has a return period equal to 10 to 50 times the life of the facility (500 years) and when occurring will not affect the performance of the structure. The MCE has a return period of some 10,000 years and when occurring will not cause total failure of the embankment wall but will result in severe damage i.e. slumping of the crest. The MCE is particularly applicable to the long term situation such as the close-out phase of the facility.

5.2 Seismic Vulnerability

Stage 6 will be constructed using the downstream method and therefore not vulnerable to the earthquakes anticipated for this site.

The DBE has been taken as 0.03g which is very low and would have little or no effect on any of the dam walls constructed. The MCE has been taken as 0.06g and has been used to determine the pseudo static stability of the dam walls. It is a very conservative method as it assumes a horizontal force in one direction whereas the action is both forwards and backwards and for a brief period of time at its peak. The normal consequence of seismicity is settlement of an engineered, constructed and compacted dam wall rather than dam failure. The MCE has been used in the long term stability analysis as a horizontal force acting on the stack wall of the TMF. This is termed the pseudo-static method of stability analysis and is a very conservative approach.

6.0 DESIGN

6.1 General

The adjoining cell is located along the northern sector of the of the existing TMF facility (Drawing 1.2 and 1.3) and confined within the northern and seven fields borrow areas. It is proposed to raise the dam in two phases (Dwg. 6.1), the first phase to 1586 m AMD and the second phase to 67.29 m AOD. External ramps will be provided (Dwg. 6.2) for access from the main haul roads. The total construction volumes and storage volumes for various elevations are presented in the following table.

Table 4: Struck Storage and Construction Volumes at given Crest Elvs.

Phases	Crest Elevation m AMD	Tailings Struck Storage Acc. Vol. m^3	Total Construction Acc. Volumes m^3	Ratio Tails/Con Vol. Ratio	Life in years
1	1586	5,300,000	533,800	10	6.5
2	1594	9,580,000	1,786,400	5.6	11.75

The ratio of tailings volume to construction volume indicates the additional volume gained in Phase 1 by filling the existing northern and seven fields borrow areas and borrowing the remaining material to construct the walls. The life in years has been based on a tailings discharge into the TMF of 1.1Mt/y tailings to TMF, a 0.5% beach slope and an average dry density of 1.42 t/m^3.

The main benefit of two phases is that the maximum amount of fill can be borrowed from the basin area to use in construction. Once the first phase is complete, the basin area will be sterilised to any future borrowing by the placement of the lining system. It will therefore be necessary to remove all available material within the basin area and any addition materials found would be stored on the downstream side of Phase 1 or as ramps and ancillary structures. The floor plan area of the TMF basin is approximately 38.5 Ha.

6.2 Dam Sections

The construction of the walls would be different from all previous dam walls forming the existing facility because of the design for a composite lining on the upstream face of the dam walls and basin area although the dam wall will be zoned (Dwg. 6.3) and the figure below.

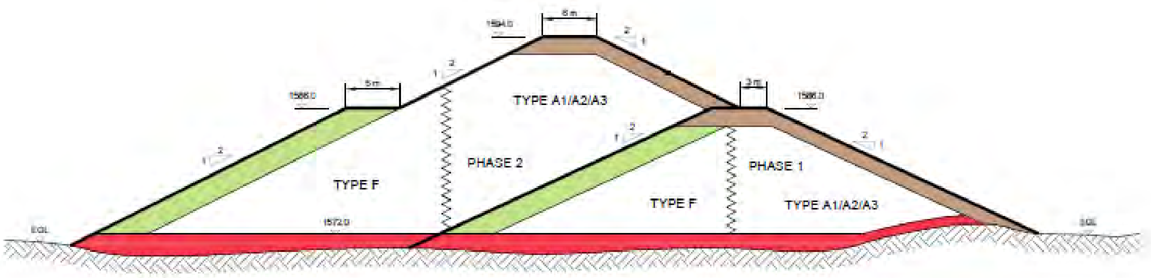

Figure 4: Typical Dam Section

The upstream slope will be constructed with a slope of 2H:1V and for the first phase, will be keyed into the existing Stage I, II, III and Stage 4, with a ramp down to 57.29 m AOD and a ramp up to 63.29 m AOD (Dwg 6.4A). The second phase will be keyed into Stage 5 at 67.29 m AOD. The overall downstream slope will be approximately 2.25H:1V consisting of two 2H:1V slopes with a 6m bench at 1586 m AMD for the second phase. This will allow access to Stages I, II and III by ramping down to 57.29 m AOD and Stage 4 by ramping upwards to an elevation of 1590.0 m AMD (Dwg 6.4B). The bench will also be used to install some of the monitoring instruments. The crest width of the dam walls for all phases is 6 m and the maximum wall height is approximately 20 m for the final elevation of 67.29 m AOD.

Sections through the dam wall are presented in Drawing 6.5 and the section locations are shown in Drawing 6.6. The current ground level is variable and generally between elevations of 1570 m AMD and 1580 m AMD. Much of the dam wall footprint is within the existing areas which have been previously borrowed for Stage 5.

The upstream sector of the dam (Dwg. 6.3) consists of a 6m wide unit of clayey glacial till (Type A1 and/or Type A2). The footprint of the dam wall will be constructed with a 1m minimum thickness of Type D2 rock which acts as a drainage blanket. On the lower parts of the downstream sector of the dam wall, a 6 m width of Type A2 glacial till will be placed. Between the upstream Type A1/A2 zone and the downstream Type A2 zone is an upstream core consisting of Type A material and a downstream core consisting of Type F material, a wethered limestone.

No chimney drainage system is needed for this structure since the basal Type D2 will act as a drainage blanket. The composite lining will minimise seepage through the dam wall provided it is not damaged during operations. Measures will be undertaken to prevent damage of the lining system during operations using protection measures as discussed later.

The existing northern dam wall, perimeter interceptor channel and finger drain channels would be stripped of topsoil and vegetation prior to receiving the protection material and lining system forming Stage 6. The existing manholes will be trimmed below ground level so there are no protrusions that could damage the lining system. To prevent the lining system collapsing into the manholes it is proposed to backfill them with uniform 50 mm cobbles (Type E). The open concrete chutes will also be backfilled with Type E material. The location of these structures are presented on aerial photographs in Appendix C.

Once the existing northern dam wall is lined, rainfall infiltration into the dam wall will be significantly reduced and the lower flow rates measured in the weirs of Stage 4 and Stage 5 will be applicable.

The finger drain channels and the perimeter interceptor channel at the base of the existing northern wall of the facility would also be backfilled with Type E material. A 300 mm diameter perforated pipe would be installed into the base of the perimeter interceptor channel on a bedding of Type C material.

A 100 mm layer of processed rockfill Type C material would be placed over the Type A materials on the upstream side of the new Stage 6 dam walls and on the northern face of the existing embankment wall (Dwg.6.7) to provide protection for the lining system. The maximum particle size of the Type C would be 20 mm and the material would be well graded. A 1,000 g/m^2 non-woven geotextile is placed on top of the Type C material prior to placement of the lining system. The adjoining wall would be cleaned of vegetation, trimmed to receive the 100 mm layer of Type C followed by the 1,000 g/m^2 non-woven geotextile. The Type C material on the dam walls would continue over the backfilled finger channels and backfilled perimeter interceptor channel. The Type C will intercept any seepage at the downstream toe of the northern dam wall and into the perimeter interceptor channel. Where Type C is placed on the Type E material backfill it will be separated by Terram 1000 geotextile or equivalent. Terram may also be required in soft areas on the borrow area floor and downstream toe of the existing northern dam wall. Once the Type C material is placed, the composite lining would be formed along the base, up the slope and anchored on the crest.

A perimeter roadway would be constructed and merge with the roads around the existing TMF. A new security fence is required along the north perimeter access road (Dwg 6.8) and tied into the existing fences on the eastern and western site boundaries.

A road surfacing material Type B, 200 mm thick would be required at the top of the dam crest and the lower perimeter road, intermediate bench at 1586 m AMD and any permanent ramps.

It is anticipated that at least 3 external ramps will be installed along the northern wall of Stage 6. The first ramp would be in a central location (Dwg.6.2) and be accessed via the main tarmac road from the site offices. Two other ramps would be located opposite the east and west sectors of the northern borrow area. These ramp would allow access to the remaining borrow materials and stockpiles to complete the second phase of Stage 6, the capping of Stage 5B and the eventual capping of Stage 6.

Temporary internal ramps will also be required but these would be removed systematically as the lining system is installed.

6.3 Fill material

6.3.1 General

The dam wall raise is constructed from several materials which include cohesive glacial till, granular glacial material and processed rock fill. It consists of the following material types:

- Type A1 and A2 Cohesive Glacial Till;
- Type A3 Glacial Granular Material;
- Type B Road Material;
- Type C Protection Material;
- Type D1 Backfilling Existing Borrow Area Drains;
- Type D2 Dam Footprint Drainage Blanket Material; and
- Type E 75 mm Coarse Drainage Backfill For Perimeter Interceptor Channel and Concrete Chutes.

6.3.2 Type A Materials

6.3.2.1 Type A1

Type A1 will be suitable material complying with the following:

- Material Type A shall be glacial silty sands and gravels obtained from the borrow area with a Plasticity Index greater than 10%;
- The moisture content shall be between -2% and +4% of optimum as measured in the Standard Proctor method and the material shall be free of all unsuitable material and compacted to 95% of Standard Proctor in 300 mm lifts; and
- Maximum particle size is 200 mm in the minimum dimension.

6.3.2.2 Type A2 Material

Type A2 will be suitable material complying with the following:

- Material Type A2 shall be glacial silty sands and gravels obtained from the borrow area with a Plasticity Index less than 10% but greater than 4%;
- The moisture content shall be between -2% and +4% of optimum as measured in the Standard Proctor method and the material shall be free of all unsuitable material and compacted to 95% of Standard Proctor in 300 mm lifts; and
- Maximum particle size is 200 mm in the minimum dimension.

6.3.2.3 Type A3 Material

Type A3 will be suitable material complying with the following:

- Material Type A3 shall be glacial silty sands and gravels obtained from the borrow area with a Plasticity Index less than 4%;
- The moisture content shall be between -2% and +4% of optimum as measured in the Standard Proctor method and the material shall be free of all unsuitable material and compacted to 95% of Standard Proctor in 300 mm lifts; and
- Maximum particle size is 200 mm in the minimum dimension.

6.3.3 Granular Rock Material

6.3.3.1 General

There is a requirement for a large quantity of granular rock material which will be either imported or derived from quarrying in the borrow area and these are discussed below.

6.3.3.2 Type B Road Surface Material

The specification for this material which conforms to the 804 specification is tabulated below.

Table 5: Type B Grading Envelope

Sieve Size (mm)	Coarse (% passing)	Fine (% passing)
63	100	
31.5	90	80
16	85	55
8	65	35
4	50	22
2	40	15
1	35	10
0.5	20	0
0.063	7	0

The material will be compacted with four passes of a 10 tonnes smooth vibratory roller.

6.3.3.3 Type C Protection Material

The specification for this material is tabulated below.

Table 6: Type C Material

Sieve Size (mm)	% Passing
20	100
6.3	60-95
1.18	35-80
0.300	15-60
0.075	0-30

This will be nominally compacted with a smooth roller on the basin floor. The protection material placed on the dam wall side slopes will also be nominally compacted with a smooth roller winched down from the crest or by an alternative method agreed by the Engineer.

6.3.3.4 Type D1 Backfilling Existing Borrow Area Drains

The specification for this material is tabulated below.

Table 7: Type D1 Grading Envelope

Sieve Size (mm)	Coarse (% passing)	Fine (% passing)
250	100	
100	100	30
75	60	10
50	40	0
20	15	0
10	10	0
1	6	0

This material will be placed and nominally compacted with the construction plant.

6.3.3.5 Type D2 Dam Footprint Drainage Blanket Material

The specification for Type D2 material is that it is granular and 100% passing 250 mm. The material will be placed in maximum lift size of 500mm and compacted with a 10 tonnes vibratory roller using 6 passes.

6.3.3.6 Type E Coarse Drainage Material

This material is uniformly graded at 50 mm diameter.

6.4 Fill Material Quantities

The volumes of material for construction are tabulated as follows.

Table 8: Material Quantities

Description	Unit	1st Stage Qty	2nd Stage Qty	Total Qty
Total Dam Fill Volumes	**m3**	**533,800**	**1,173,400**	**1,707,200**
Type A1/A2 Upstream Wall Construction	m3	105,500	110,600	**216,100**
Type A 2 Downstream Wall Construction	m3	107,900	111,900	**219,800**
Type B Road Surfacing	m3	4,900	5,100	**7,400**
Type C Protection Material	m3	52,280	7,400	**59,700**
Type D1 Drainage	m3	600		**600**
Type D2 Dam Footprint Drainage	m3	85,400	98,900	**184,300**
Type A1/A2/A3 Upstream Core	m3	117,500	426,000	**543,500**
Type F Downstream Core	m3	117,500	426,000	**543,500**
Type E Coarse Drainage	m3	11,500		**11,500**
Total Construction Volumes	**m3**	**600,500**	**1,185,900**	**1,786,400**

The total dam fill volume excludes Type B, Type C, Type D1 and Type E material which is typically imported although could be produced on site from crushing and grading strong rock as previously undertaken for Stage 5B.

6.5 Site Preparation

There is a considerable amount of site preparation that is required to develop this site of which some could be undertaken pre-construction while other activities would be done during construction.

Blakes Stream cuts across the Northern borrow area and the Seven Fields borrow area and is located in the basin area of the proposed Stage 6 facility. It enters the site in the north east corner and exits the site in the south west corner via a settling pond complex before entering the Yellow River. It is proposed to divert Blakes Stream to the east as it enters the site (Dwg 6.9) and into a disused channel which runs along the eastern boundary prior to entering the Simonstown Stream. It will be necessary to compare the invert levels of Blake's Stream and the existing channel to determine the optimum location for the two to join.

There are a number of trees that will require removal from the site. The majority are immediately north of the existing northern dam wall but also occur around the Contractors compound as well as the central site road and along established drainage ditches. All vegetation will be removed from the footprint of the proposed Stage 6 TMF.

There are several power lines that cross the site. These are shown on Drawing 6.10. A 10 KV power line runs along the downstream toe of the existing northern dam wall. This will require realignment. Another power line carrying 38 KV follows the eastern boundary of the seven fields borrow area and this will need to be realigned further to the east beyond the footprint of the TMF. A power line crosses diagonally from north east to south west of the seven fields and the northern borrow area. This is a 38 KV line and will need to be moved.

The Contractors compound will require removal and the septic tanks removed and backfilled with compacted fill or left and backfilled with concrete. Fencing along the downstream side of the existing northern wall should be removed from site into a suitable landfill.

The elevations within the existing borrow area forming the footprint Stage 6 is variable and the Drawing 6.11 is a recent survey showing the cut and fill depths to an elevation of 1572 m AMD. After removal of the materials from the borrow area some regarding of the surface will be required to receive the lining system. The existing drainage system will be backfilled with Type D1 material to prevent ponding during the placement of the lining system. Boulders from Types A1 and A2, and Type D2 material will be used to fill hollows.

Type D2 material will be used to bring the level of the subgrade to an approximate elevation of 1571 m AMD within the footprint of the dam wall. On subgrade above 1571 m AMD, a 1m layer of Type D2 will be placed. Any unsuitable materials in the basin area will be removed and stockpiled outside the TMF footprint and used for capping restoration.

Groundwater may be an issue and it may be difficult to remove all water from the excavation and some boulders and Type D2 material may have to be placed into water to raise the excavation level prior to installation of the lining system. Care is required as the lining system will be placed during the summer when the water table is at its lowest. However, as the water table rises during the approach of autumn and winter, it is important to surcharge the liner to prevent the lining lifting. The most practical method is to place the tailings into the facility soon after the lining is placed or mine water and at the end of summer.

After regarding of the floor area, a 100 mm layer of Type C is placed on top of the floor where the lining system is to be placed in the basin area. In soft areas, Terram 1000 would be placed prior to Type C placement.

Generally, prior to the preparation of the foundations, a resistivity and microgravity survey would be undertaken to delineate the presence of any palaeokarstic features in the limestone bedrock. Some anomalies result from rapid changes in the thickness of the glacial till above the bedrock or highly weathered and fractured near surface bedrock. Any anomalies, if found, would be investigated by drilling. However, as discussed in Sections 2 and 3, the majority of the Stage 6 footprint is founded on Palaeozoic rocks which are non-calcareous rocks and it is only the south west corner of the Northern borrow area where limestone may be present as part of the Pale Beds. The geophysical work undertaken in the borrow area to determine the excavatability of the bedrock indicated the possibility of palaeokarst in five locations as presented below.

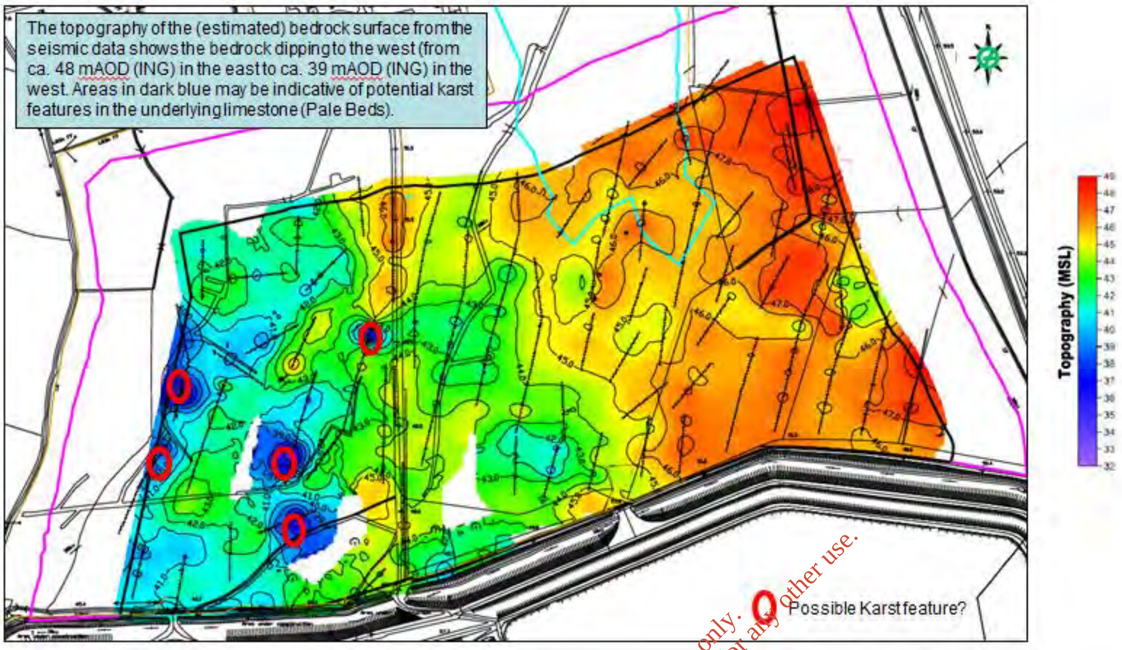

Figure 5: Possible Palaeokarstic Features (Ref.3.5)

6.6 Composite Lining

The TMF incorporates a composite lining system which consists of high density polyethylene (HDPE) geomembrane over a geosynthetic clay liner (GCL). The composite lining overlies a1000 g/m^2 which in turn overlies 100 mm of Type C protection material as shown in section on Drawing 6.12.

6.6.1 High Density Polyethylene (HDPE)

The HDPE will be 2 mm thick, double textured and is placed directly over GCL on the 2H:1V upstream slopes of the dam wall. In the basin area the HDPE is 2 mm thick and smooth and is placed directly over the GCL. The HDPE and GCL are anchored along the dam crest at 1586 m AMD and along the existing north wall of Stage 4 at an elevation of 63.29 m AOD for the first phase of Stage 6. Similarly, the lining system is anchored along the dam crest at 67.29 m AOD for the second phase of Stage 6.

The geomembrane materials shall consist of high density polyethylene, produced from new resins and containing no fillers, plasticisers or additives of any kind with the exception of carbon black.

The geomembrane shall comply with the requirements set out in the table below for 2.0 mm double textured and smooth geomembrane.

Table 9: HDPE Properties

Parameters	Properties	
Material	Double Textured 2 mm	Smooth 2 mm
Thickness (minimum average)	nom. (mil)	
■ Lowest individual of 10 values	-10%	-10%
Density mg/l (minimum.)	0.940 g/cc	0.940 g/cc
Tensile Properties (minimum average)		
■ Yield strength	29 kN/m	29 kN/m

Parameters	Properties	
■ Break strength	21 kN/m	53 kN/m
■ Yield elongation	>12%	>12%
■ Break elongation	>100%	>700%
Tear Resistance (minimum average)	250 N	249 N
Puncture Resistance (minimum average)	500 N	640 N
Stress Crack Resistance	300 hr.	300 hr.
Carbon Black Content (range)	2.0 - 3.0%	2.0 - 3.0%

The geomembrane installation will be independently supervised and will be subjected to a strict CQA procedure.

6.6.2 Geosynthetic Clay Liner (GCL)

The GCL is placed beneath the HDPE geomembrane and over the Type C sub-base material on the upstream dam slopes and basin area of the facility.

The GCL shall be Bentofix or an approved equivalent and the grade shall be 3600 g/m^2 dry weight with a maximum permeability of 5E-11 m/s. The GCL shall consist of a layer of natural sodium bentonite clay encapsulated between two polypropylene textiles (geotextile) and have the following properties:

Table 10: GCL Properties

Parameter			Properties
Bentonite Layer	Swell Index, Minimum		24 ml/2g
	Fluid Loss, Maximum		18 ml
	Sodium Bentonite, Minimum		3600 g/m^2
Geotextile Mass (Minimum Average Roll Value)	Slit-Film Woven		105 g/m^2
	Nonwoven Needle Punched		200 g/m^2
Index Flux (Maximum)			8x10^{-9} m^3/m^2/s
Hydraulic Conductivity (Maximum)			5x10^{-11} m/s
Peel Strength (Minimum)			240 N/m
Strip Tensile Strength (Minimum)	Machine Direction	Tensile Strength	8 kN/m
		Elongation	8%
	Across Machine Direction	Tensile Strength	8 kN/m
		Elongation	8%
Hydrated Internal Shear Strength (Minimum)			24 kPa

For purposes of strength, performance, and integrity, the GCL shall be manufactured by mechanically bonding the geotextile using a needle-punching process. Needle-punched GCLs are those which, by the use of a needling board, have fibres of the non-woven geotextile pushed through the bentonite clay layer and integrated into a woven or non-woven geotextile.

The bentonite sealing compound or bentonite granules used to seal penetrations and make repairs shall be made of the same natural sodium bentonite as the GCL and shall be as recommended by the GCL Manufacturer. All GCL shall be free of damage or defect.

The GCL installation will be independently supervised and will be subjected to a strict CQA procedure.

6.7 Geotextile

6.7.1 General

Three types of geotextile material are required, a 1000 g/m^2 non-woven needled punched geotextile to protect the lining system from underneath, a carbon rich 500 g/m^2 non-woven needled punched geotextile to protect the lining system from above on the slope and a Terram 1000 or equivalent as a separation medium.

6.7.2 500 g/m^2 and 1000 g/m^2 Non-Woven Geotextile

A 1000 g/m^2 non-woven needle punched geotextile is required to protect the GCL and HDPE geomembrane from the underlying Type C material which in turn is placed on top of the Type B material. A carbon rich 500 g/m^2 non-woven needle punched geotextile is required in the anchor trench and on the surface of the HDPE to protect this material from the surcharge and movement of pipe work.

The physical and mechanical properties of the 1000 grm/m^2 and 500 grm/m^2 non-woven needle punched geotextile are given below.

Table 11: Non-Woven Geotextile Properties

Parameter	Specification 1000 g/m^2	Specification 500 g/m^2
CBR Puncture Resistance	Minimum 10,000 N	Minimum 5,000 N
Wide Width Tensile Strength	Minimum 75 kN/m	Minimum 40 kN/m
Elongation at break	Minimum 50%	Minimum 50%
Thickness	Minimum 8.0 mm	Minimum 5.0 mm
Mass per unit area	Minimum 1000 g/m^2	Minimum 500 g/m^2

6.7.3 Terram 1000

A separation geotextile will be required in some glacial foundation areas exposed, to prevent the Type C material punching into any soft and wet material. It will not always be possible to remove these materials or prevent water accumulating on the surface of the glacial till particularly in localised depressions. The geotextile would also be used to separate the coarse drainage material (Type D1 and Type E) and finer material. The separation textile would be Terram 1000 or equivalent.

6.8 Geofabric Material Quantities

The areas of material for construction are tabulated as follows.

Table 12: Material Quantities

Description	Unit	Phase 1 Qty	Phase 2 Qty	Total Qty
1000 g/m^2 Geotextile	m^2	529,262	74,255	**603,517**
500 g/m^2 Geotextile	m^2	99,262	74,255	**173,517**
Terram 1000	m^2	176,421	24,752	**201,172**
GCL	m^2	529,262	74,255	**603,517**
HDPE (Smooth) 2 mm	m^3	430,000		**430,000**
HDPE (Textured) 2 mm	m^3	99,262	74,255	**173,517**

6.9 Anchor Trench

The geosynthetics will be fixed in an anchor trench excavated along the crest of the dam wall stages as shown in section in Drawing 6.12. The trenches will be excavated with rounded shoulders where the geotextile and geomembrane lining will adjoin the trench in order to avoid sharp curvatures in the membrane material. The trench will be backfilled with screened Type C material and compacted in layers not exceeding 150 mm deep.

6.10 Permanent Surcharge

A permanent surcharge is required on the exposed geomembrane to prevent the HDPE from being lifted and damaged by wind action and minimise damage from pipe movements. It also acts as a ladder if someone accidently falls into the facility. The surcharge will consist of car tyres in filled with Type C material and placed on the carbon rich 500 g/m^2 non-woven needle punched geotextile. Each line of surcharge shall be a maximum of 2 m centres longitudinally and anchored on the crest and the weights consisting of car tyres shall be a maximum of 1.5 m apart down slope and where applicable on the lining placed on the floor of the tailings and a minimum distance of 1 tyre width beyond the downstream toe. The two tyres at the toe of the slope and 1 tyre width beyond will be tied together (Dwg 6.13). The tyres will be attached by suitable rope with a minimum life of 10 years.

6.11 Leak Detection

A leak detection survey using DC electric current will be undertaken after the installation of the lining system. This geophysical method was previously used. An electric current is passed between two electrodes, one placed in either water ponded in the cell or by a water spray jetted onto the lining and the other in the peat outside the cell. With the geomembrane intact, the water in the cell will be electrically isolated from the external environment. The resulting potential field, measured as a potential difference between two non-polarising electrodes, is small but uniformly distributed over the geomembrane. If the geomembrane is defective, current will flow through the point of leakage and the measured potential will peak around the position of the defect.

Data acquisition is performed within the cell on a predetermined grid marked on the geomembrane at 2.0 m spacing. Two or more sets of data are obtained simultaneously, with information automatically stored on data loggers where possible. The results are processed and plotted on site, then overlaid on the plan of the cell to allow the immediate detection and location of the defect.

The voltage used is about 240 V and there is a strict safety protocol to follow to ensure no connection is made between the personnel, the ground and the water during the data gathering phase.

It is also anticipated that some difficulties will arise in physically walking on the flooded geomembrane. The surface of the geomembrane forming the basin area will be extremely slippery and to overcome this problem the operators use specialised waterproof clothing and footwear developed in the sailing industry.

6.12 Seepage

Seepage from the TMF will be controlled by the low permeability composite lining system, and the low permeability of the tailings retained by the facility. Experience of a large number of quality assured and controlled geomembrane installations indicates (Reference 6.1) the presence of between 2 and 5 leaks per hectare and these are generally less than 10 mm^2 in size.

Seepage calculations have been based on the design equations given in References 6.1 and 6.2 and for the worst case, when the facility is filled with tailings.

The volume of seepage flowing laterally through the dam wall via the GCL and some nominal defects in the lining system for a constant head of 20m (Phase 2) would be an average of about 1.5 m^3/day with a 10% probability of the seepage being less than 0.25 m^3/day and a 10% probability of greater than being 5 m^3/day. The range represented in the figure below, is based on a number of variables including infiltration rate based on the range of vertical permeability values of the tailings, the range of defects in the lining per hectare, the effective permeability of the composite lining and head acting on the lining.

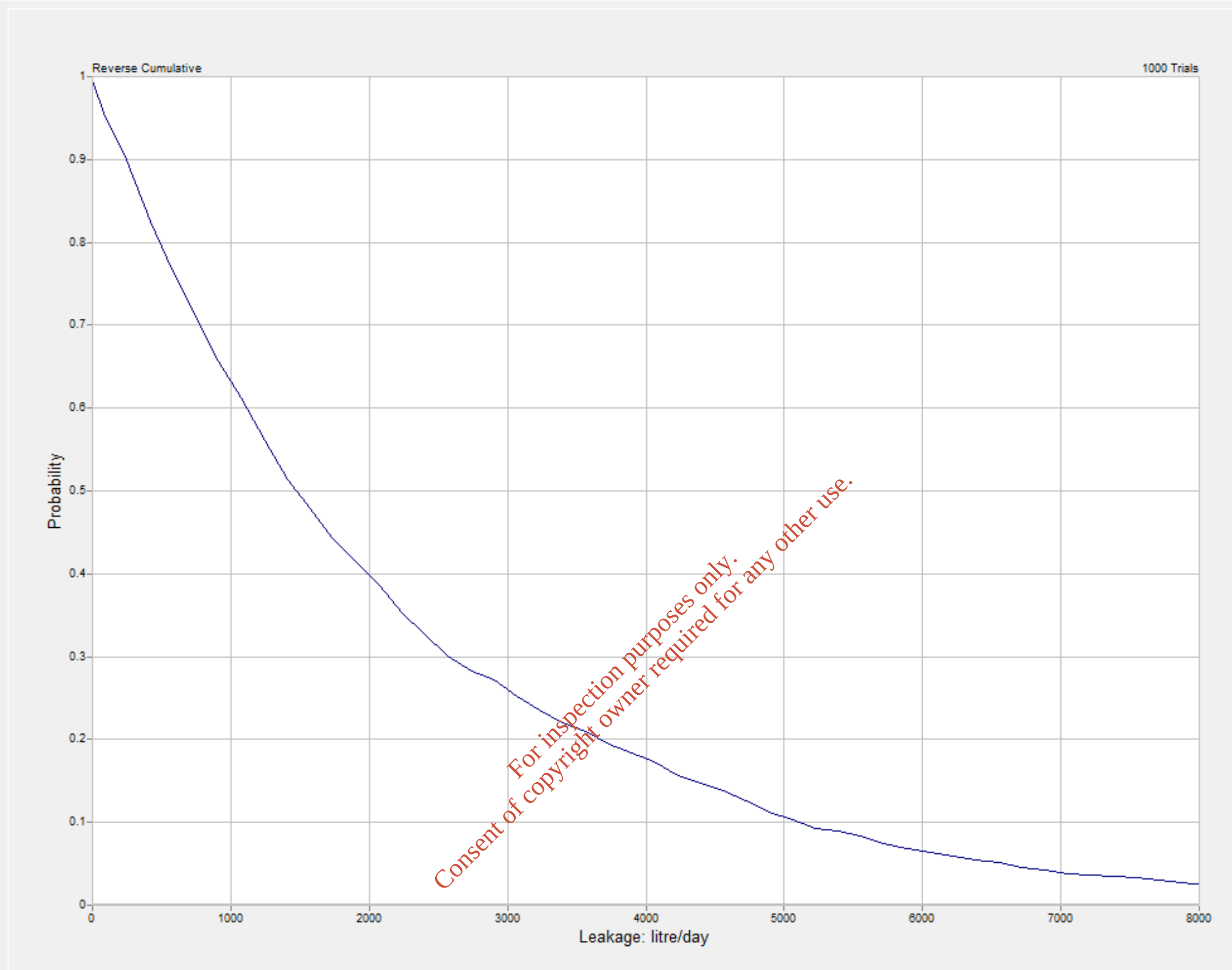

Figure 6: Probability of Seepage from Composite Lining System

6.13 Perimeter Interceptor Channel

The regional groundwater flow is from the north east to the south west and the minimal seepage passing through defects in the lining system will mix and be diluted with the ground water. The perimeter interceptor channel (Drawing 6.8) will collect surface water runoff from the dam walls, perimeter road and borrow areas. This seepage will be insignificant when compared with the clean surface water runoff from the dam walls and surrounding land.

During winter, sections of the perimeter interceptor channel will intercept the groundwater as it rises and this will be monitored for quality. It is expected that water quality will be suitable for discharge into the environment directly but initially it will be collected.

The final profile of the channel will be fixed during construction after the removal of unsuitable materials and also after borrowing suitable material. The perimeter interceptor channel will discharge into the existing east and west perimeter interceptor channel. The longitudinal profile is considerably variable and generally between 1569 m AMD and 1580 m AMD as shown on Drawing 6.14, which is the profile for the second phase. The plan showing the chainage of the longitudinal profile is shown on Drawing 6.15. Because of the presence of low spots there could be issues with potential ponding in the channel unless pumping is undertaken from these low points. The eastern sector of the Stage 6 perimeter interceptor channel has a low spot at about 1573 m AMD which is 1.8m below the Stage I and II eastern perimeter interceptor channel where it would join. The western sector of the Stage 6 western perimeter interceptor channel has a low spot at 1569 m AMD which is 0.5 m below the Stage III perimeter interceptor channel where it would join.

Where practicable the low spots will be backfilled and high spots removed and the channel depth will be dependent on achieving where possible, gravity flow to the two outlets which are the existing interceptor channels. Also, any low spots in the borrow area adjacent to the perimeter access road will also be backfilled with boulders and cobbles rejected from the Type A glacial materials. It is not anticipated that the channel in the glacial till or bedrock will be significantly deeper than 1 m and the side slopes would vary from 1H:2V to 1H:1V to 3H:2V depending on the material excavated.

For Phase 1, the road and perimeter interceptor channel could be raised and constructed in fill used for the next phase (Dwg 6.16). However, that could result in ponding in low spots against the construction fill and also water from the channel seeping into the fill.

6.14 Embankment Stability Modelling

The stability analysis for the new cell was carried out using commercially available limit-equilibrium slope stability software, SLOPE/W version 7.15 (Reference 6.3). The analytical method used was Morgenstern and Price method of slices, which satisfies both force and moment equilibrium. The stability analysis indicates that the dam walls have adequate Factor of Safety (FoS) under the modelled conditions. Details of the modelling approach and the results are presented below.

6.14.1 Model Geometry

The model geometry is based on a typical cross-section of perimeter dam wall at full height (67.29 m AOD) including the bench at 1586.0 m AMD. The Stage 6 height is approximately 20 m above the glacial till/bedrock foundation level. The modelled sub-surface conditions are based on the geotechnical investigation information at the site of the existing TMF.

6.14.2 Geotechnical Parameters

The geotechnical strength parameters adopted in the stability modelling are presented in the following table and the geometric configuration presented in Figure 7.

Table 13: Geotechnical Parameters for Stability Analysis

Material Type	Unit Weight (kN/m^3)	Effective Strength	
		c' (kPa)	ø' (deg)
Type A	19	0	32
Type D1 and D2	21	0	37
Tailings	18	0	32
In-situ Glacial Till	20	5	32
Limestone Bedrock*	-	-	-

*Limestone bedrock was considered impenetrable by slope failure.

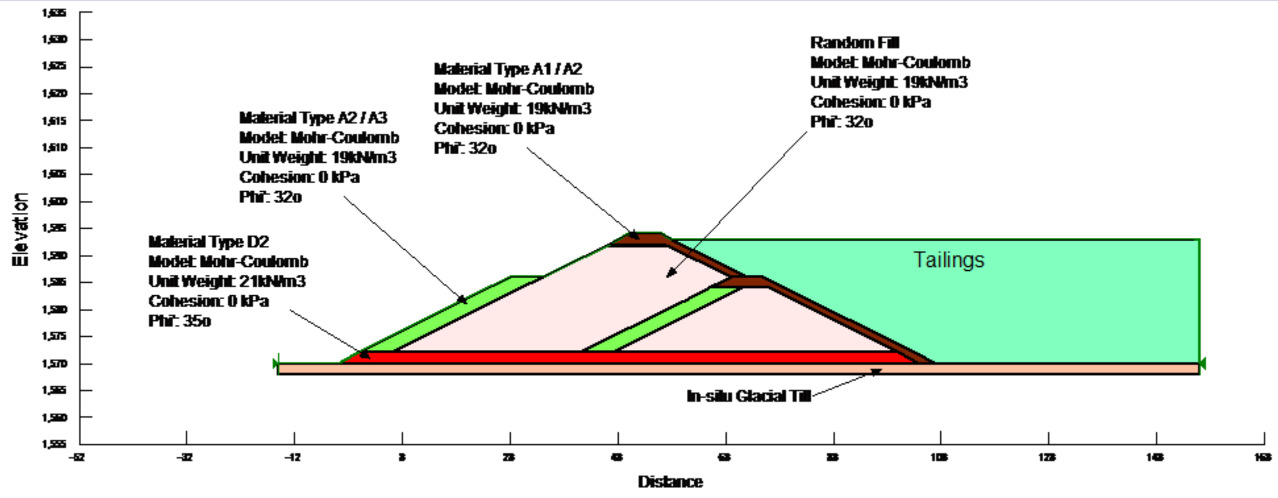

Figure 7: Model with material details

Effective strength parameters are typically used to assess long-term stability (after closure), whereby the excess pore pressures developed in any fine grained soils have dissipated.

6.14.3 Stability Modelling

The stability of the TMF wall for each option was considered under the following conditions:

Long-term downstream embankment stability, with tailings level 1 m below the crest. The HDPE liner was assumed to be intact and an assumed phreatic surface was drawn down through the embankment by the downstream drainage blanket and the rock used in downstream construction.

Long-term downstream embankment stability, with tailings level 1 m below the crest. The HDPE liner was considered to undergo complete failure and the drainage system was no longer free draining and the phreatic surface exits the dam wall in the slope at one third of its height. This is a very extreme scenario which is unlikely to develop.

Further analyses were undertaken using pseudo-static conditions corresponding to a 0.06 g acceleration for the liner intact.

6.14.4 Results of Stability Modelling

The results of the stability analyses are presented in Table 14 below in the form of the FoS for the most critical slip surface and in Figures 8 to 11. The required minimum FoS was exceeded under all conditions analysed.

Table 14: Stability Modelling Results

Case	Condition	Location	FOS
1	Long-term, tailings 1m below crest, phreatic surface at the toe of the dam. Static condition	Downstream	1.63
2	Long-term, tailings 1m below crest, phreatic surface at the toe of the dam. Ground Acceleration 0.06g. Pseudo static condition.	Downstream	1.38
3	Long-term, tailings 1m below crest, phreatic surface exists 1/3 dam height. Static condition.	Downstream	1.16

4	Long-term, tailings 1m below crest, phreatic surface exists 1/3 dam height. Ground Acceleration 0.06g. Pseudo static condition.	Downstream	0.99

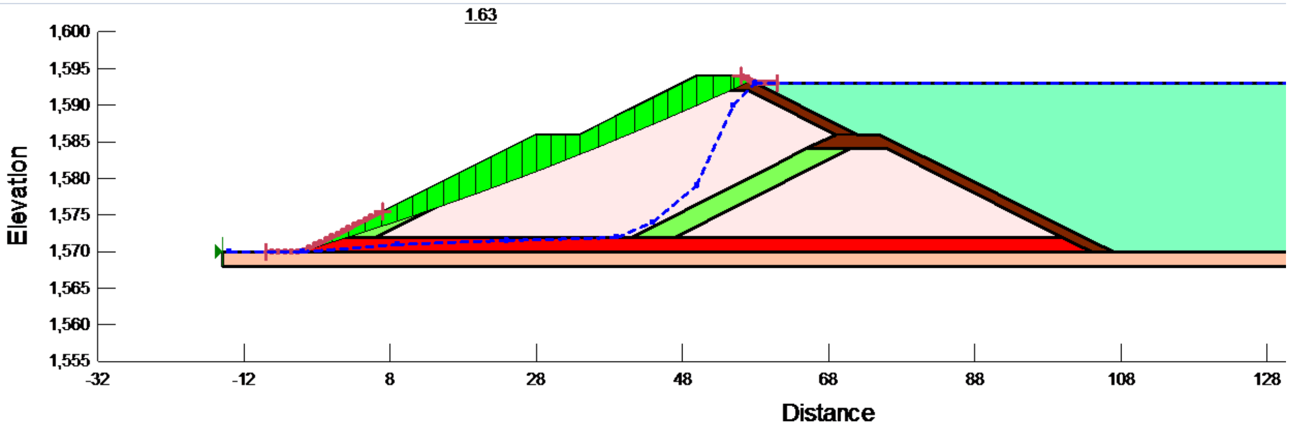

Figure 8: Static Analysis with Drainage Blanket operational (Phreatic Surface at the Dam toe)

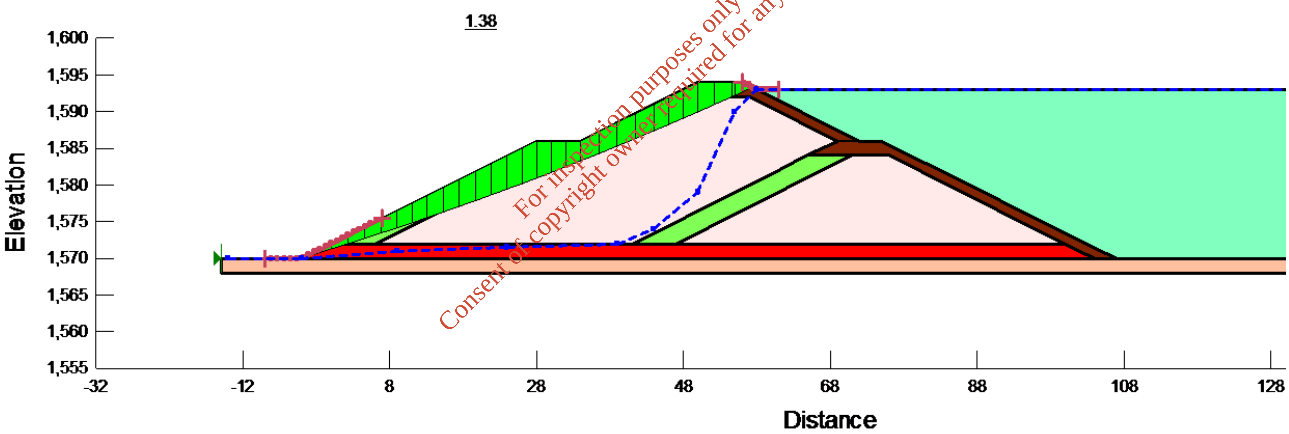

Figure 9: Pseudo – Static analysis with Drainage Blanket operational (Phreatic Surface at the Dam toe)

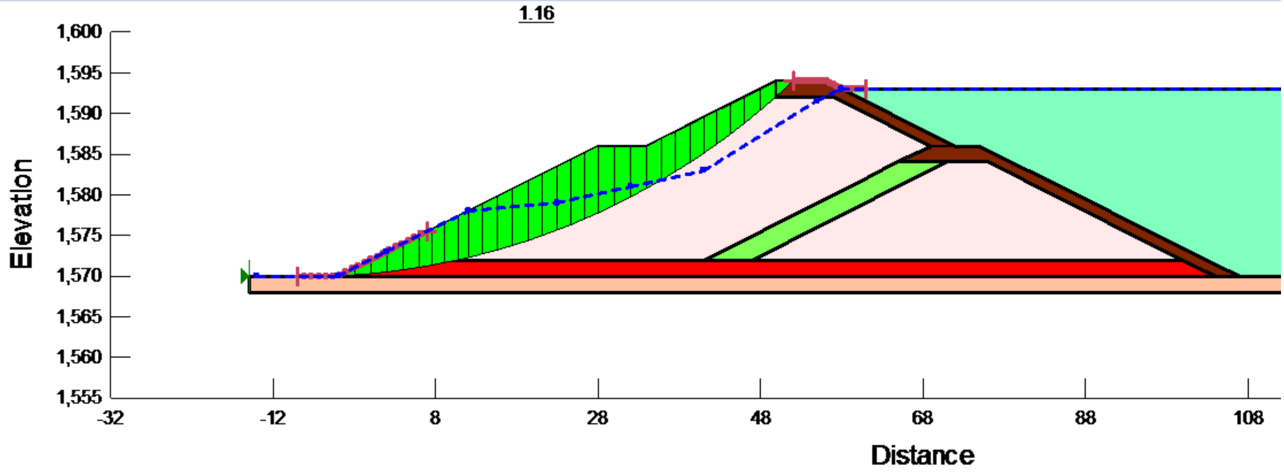

Figure 10: Static Analysis with Drainage Blanket blocked (Phreatic Surface at 1/3 Dam height)

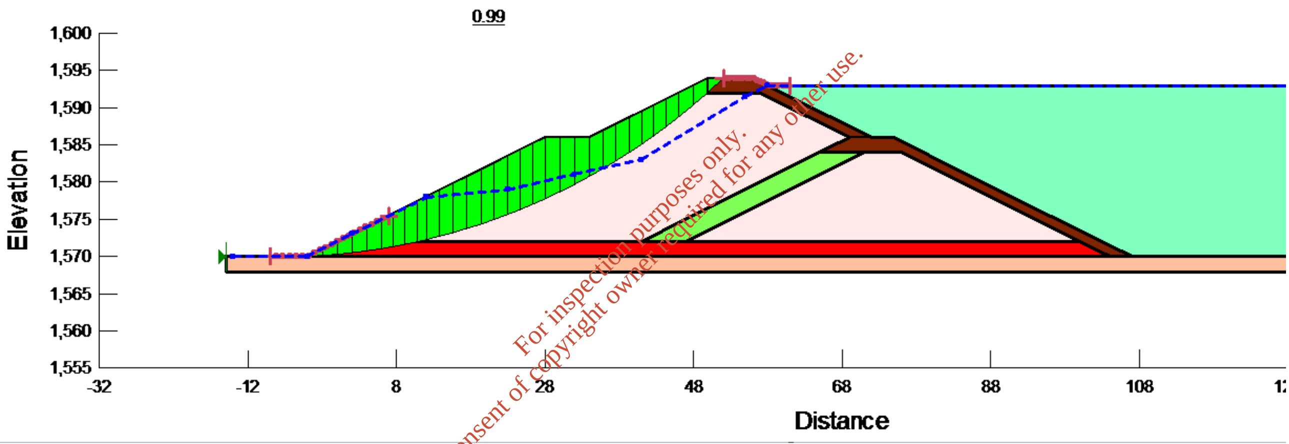

Figure 11: Pseudo - Static Analysis with Drainage Blanket blocked (Phreatic Surface at 1/3 Dam height)

The factor of safety for the static and pseudo-static cases for the internal drainage system operational are satisfactory. Where the drainage system is non-operational, the factor of safety for the static condition is satisfactory. However, if an earthquake occurs, then the factor of safety is 0.99 which under these conservative conditions, is acceptable. As the dam wall incorporates a downstream drainage blanket and an upstream zone of Type A1 and A2 low permeability material together with the lining system, it is very unlikely that the phreatic surface would exit at a point one third of the dam height.

6.15 Spillway

This type of perimeter dam used for tailings storage, which has no external catchment area, is normally operated without spillways. There is always adequate control on the tailings water level which can be achieved by adjusting the discharges into the TMF and removal of tailings water by pumping from the TMF to the plant site. However, a spillway is required post-closure to control water levels and discharges.

The spillway will be constructed prior to closure of the new cell. The level of the tailings water in the TMF will be dependent on the discharge from the mill into the facility, water reclaim from the facility and the effective rainfall. Both the discharge and reclaim are controlled by the mill operators and can be adjusted at short notice. The probable maximum precipitation (PMP) for this area will be of the order of 250 mm over 24 hours which is readily retained within the freeboard of the facility.

The spillway will be located and designed in detail closer to the end of the life of the Stage 6 facility. The cap of Stage 5 adjacent to the northern wall will be at about 67.29 m AOD. Ideally, the spillway would be located in the south east corner of the Stage 6 dam wall where the reclaim pumps are located. For premature closure the wall would be cut down to accommodate a lower tailings level. The water will be discharged into the eastern perimeter interceptor channel. However, the final location will be dependent on the location of the return water pumps which will ensure the lowest tailings level and the location of the sand ramp where the shortest route from the mill is also the south east corner of Stage 6. If this was chosen for the sand line, then the return pumps and spillway would be located in the south west corner of the Stage 6 dam wall.

7.0 OPERATIONS

7.1 General

Stage 6 is composite lined and special care will be required from the operators in order to prevent damage to the lining system. Generally, the typical causes of damage are from dropping equipment on the lining, dropping and dragging pipelines or the installation and movement of the return water pumps.

Stage 6 will be operated similar to the existing TMF by discharging the tailings from spigots from the dam crest. The spigots would be open sequentially and the tailings will be discharged uniformly over the TMF. The discharge points should be every 50 m rather than currently 70 m and two tailings lines should be operated around the facility in opposite directions. Unlike the main Stage 5 operation, there will be a considerable depth between the crest and the basin floor initially. A slotted discharge pipe from the valve to the floor of the basin will be required (Dwg. 7.1). The slotted discharge pipe will be anchored on top of the in filled tyre surcharge which is place directly on 500 g/m^2 carbon rich geotextile which in turn is placed on the lining. Alternatively to slots, the end of the pipe could be cut off as the tailings rises although this would be a more hazardous operation as the operator would have to climb down the dam slope using the tyres supporting the pipe with a chain saw

The tailings will be placed to a final elevation of 1593.0 m AMD (Phase 2) and it is expected that the tailings will beach at a slope gradient of about 0.5% towards the reclaim pumps. The beach slope will be checked during operations. During Phase 1 and Phase 2, the tailings level should not exceed a depth less than 1m below the dam crest. The pond water level should be kept to 1.5m below the crest during operations particularly where the water is against the lining and at the corners of the facility. Spray from waves in the corners can be problematic and where possible a tailings beach should be developed to prevent this occurrence.

Where the reclaim pumps are located, a continuous protection of in filled tyres will be required some 20 m wide. This is illustrated on Drawing 7.1. This will need to be further detailed after discussions with yourselves on the method to be adopted particularly if a barge is to be used. The optimum location of the reclaim pumps is firstly along the existing northern wall in the south east sector where the future spillway can discharge into the eastern perimeter interceptor channel. The second option is along the existing northern wall but in the south west sector where the future spillway can discharge into the western perimeter interceptor channel. The existing northern wall is preferable as the composite lining and lining protection can be installed for all two phases from the beginning. This is further discussed in Section 8.

The sand line also poses a potential challenge as this would be discharged from a 600 mm diameter pipe. Again the liner will be protected with a minimum 20 m wide continuous in filled tyre protection as indicated in Drawing 7.1. Ideally this should be located on the existing northern wall where the composite lining and lining protection can be installed for both the phases from the beginning. This is further discussed in Section 8. During previous operations, the sand line has been extended into the facility because of the higher beach slope generated by the depositing sands. The other issue relates to discharging from the base of the facility. It would be possible to slot the pipe as per the normal spigot lines. But it is likely that the sand from the total tailings would form a delta at the discharge point and at a higher elevation than the surrounding settled slimes which could then be prone to dusting. The deposited sand could be redistributed by placing a slimes spigot adjacent to the sand line. It would also be possible to construct a berm into the facility, on the tailings at a later stage of the life of Phase 1 and also for Phase 2 if the sand line had to be extended into the facility.

To prevent damage of the lining at the point of discharge and to provide surcharge for the base, the basin should be filled with a minimum of 1 m of water equating to approximately 430,000 m^3.

7.2 Piezometer and Groundwater Monitoring

The groundwater monitoring system for the TMF is presented on Drawing 7.2 and indicates piezometers and monitoring wells at 5 locations. The monitoring wells will be located beyond the downstream toe and adjacent to the perimeter access road but subject to any anomalies indicated by the resistivity and microgravity survey which would indicate the presence of any water bearing fissures. The piezometers would be installed into the foundations and above the drainage blanket at the base of the dam fill from the crest at 1586 m AMD for the first phase of Stage 6. These would then be replaced during the construction of the second phase of Stage 6 with two piezometers installed on the crest and two piezometers on the intermediate bench. The construction of the piezometers and wells are shown on Drawings 7.3.

The water level and water quality sampling will be undertaken in accordance with the IPPC license.

7.3 Settlement Monitoring Points

Settlement of the dam wall will be undertaken at seven locations as shown on Drawing 7.2 and the construction shown on Drawing 7.3

8.0 CONSTRUCTION

8.1 General

Unlike Stages 4 and 5, there is no time restraint for placing the construction materials because there will be little to no excess pore pressure development in the foundation glacial tills compared to Stages 4 and 5 founded on tailings. Therefore, there is no restriction on the rate of rising of the dam wall or on the size or number of trucks. We would expect the size of dump trucks to be 40 tonnes rather than the 25 tonnes used to build the Stage 5B raise. We would also expect the dozers spreading on the dam wall to be the size of a D8. Using larger plant and increasing the number of dump trucks will significantly increase productivity.

The total bulk volume of fill to be removed from within the basin area of Stage 6 is 757,000 m^3. The total bulk volume of construction material to build Phase 1 is 530,000 m^3 plus 27,000 m^3 towards ramp construction and a further 200,000 m^3 to allow for capping of Stage 5A. For the second phase of Stage 6, to an elevation of 1594.0 m AMD the volume of construction fill material is 1,170,000 m^3. A further 300,000 m^3 is required for capping of Stage 5B. Assuming a construction season per year of 30 weeks, the average volume of material placed for the construction of Stage 6 only for a given number of seasons is tabulated below.

Table 15: Average Production Values For Construction of Stage 6

Construction Fill Vol. m^3 Phase 1 1586 m AMD	**557,000**	**557,000**	**557,000**	**557,000**	**557,000**
Season	1	1.5	2	2.5	3
Weeks	30	45	60	75	90
Average Vol. m^3/week	18,567	12,378	9,283	7,427	6,189
Construction Fill Vol. m^3	**1,170,000**	**1,170,000**	**1,170,000**	**1,170,000**	**1,170,000**

Phase 2 67.29 m AOD					
Season	1	1.5	2	2.5	3
Weeks	30	45	60	75	90
Average Vol. m^3/week	39,000	26,000	19,500	15,600	13,000

To place a weekly average of above 18,000 m^3 of construction fill would be optimistic although very much subject to the weather conditions, plant levels and distance to the borrow areas. During the construction of Stage III, the maximum fill rate per week achieved was 24,000 m^3 although the overall average over the season was nearer 15,000 m^3/week and that was over a relatively dry construction season. Over two seasons, the average was closer to 12,000 m^3/week and for three seasons the average reduced to 10,000 m^3/week.

8.2 Phase 1 Construction

If construction commenced in the spring of 2018, the earthworks could be completed by mid-summer of 2019, a total of 45 weeks and requiring an average weekly production rate of 12,378 m^3/week. This would allow a further 15 weeks to complete the remaining lining over the basin area, the dam walls and install the pumps and pipeline for discharge by the beginning of 2020.

The total area to be lined is about 530,000 m^2 of which about 81% is on the basin floor. Liner production is again dependent on the weather and is impacted by rainfall, wind and temperature. Placing lining on the basin floor is quicker than placing liner on the side slopes because of the greater length of roll that can be placed and the less welds required. We would expect an average weekly production rate of at least 20,000 m^3 for installation of the lining system based on four crews. This equates to a 27 week construction duration. Thus, sections of the wall and floor will need to be prepared by the beginning of the 2019 construction season to allow commencement of lining installation.

The lining will need to extend onto the existing dam wall to Stage 4 at an elevation of 63.29 m AOD as there is no bench at 1586 m AMD, the crest elevation of Stage 6 Phase 1.

The maximum number of seasons if work commenced in the spring of 2017 is essentially 2.5 which would equate to 3,400 m^3/week which is reasonable. This operation will be impacted by excess pore pressure development in the tailings so a slow construction pace is required.

8.3 Phase 2 Construction

The volume of fill required to construct Phase 2 is 1,170,000 m^3 plus an additional 300,000 m^3 of material to cap Stage 5B.

From Table 15, the weekly construction rate for 3 seasons is nearly 13,000 m^3 which should be achievable.

The area of the dam wall to be lined is 74,000m^2 which should be completed in about 7 weeks.

The Phase 1 facility needs to be operational during the construction of Phase 2. During the earthworks phase of construction, the pipes discharging into Phase 1 of Stage 6 will be located at edge of the Phase 1 crest. There is a provision of 3m between the upstream crest edge of Phase 1 and the upstream toe of Phase 2. However, once the Phase 2 earthworks is complete, the pipes are removed (dragged up the dam wall face) prior to preparation of the slope for receiving the composite lining. During this stage of the operation, the composite lining would need to have been placed on the existing northern dam wall (dividing wall between existing facility and Stage 6) so that tailings discharge can continue into the facility while the composite lining is being installed on the new dam walls of Phase 2.

Both the reclaim pump and sand line location require continuous tyre protection (Dwg. 7.1) of the composite lining system. The reclaim pumps and sand line will need to operate continuously and it would be appropriate to locate them on the existing northern wall and install the composite lining plus protection to the final dam crest height of 67.29 m AOD. The pipelines for these operations are currently operating on Stage 5 at an elevation of 67.29 m AOD and will need to be brought down the existing northern wall to the Stage 4 crest at 63.29 m AOD. The Phase 1 of Stage 6 is at a crest elevation of 1586 m AMD.

9.0 CLOSURE

Stage 6 will be capped in accordance with the procedures developed for capping Stages 5A and 5B (Reference 10.1). This will include approximately 350 mm of capping material. The arrangement of drainage and shape of the cap will need to be detailed once the location of the sand line and reclaim pumps are determined by Tara Mines. The spillway arrangements will be engineered once the facility is approaching closure. A detailed design of the closure is currently being prepared separately.

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Report Signature Page

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APPENDIX A

Drawings

Drawing No. 1.1 – Site Location Plan

Drawing No. 1.2 – Mine Site and Randalstown Tailings Facility Location Plan

Drawing No. 1.3 – Plan of Stage 6 Raise

Drawing No. 1.4 – Plan of Dam Stages and the Northern and Sevenfields Borrow Areas

Drawing No. 2.1 – Randalstown Tailings Dam Surface Geology

Drawing No. 4.1 – Principal Drainage Flowpaths in the Randalstown Vicinity

Drawing No. 6.1A – Stage 6 TMF Layout Plan Phase 1

Drawing No. 6.1B – Stage 6 TMF Layout Plan Phase 1 and 2

Drawing No. 6.1C - Stage 6 TMF Layout Plan Phase 1, 2 and 3

Drawing No. 6.2 – Permanent Ramp Locations

Drawing No. 6.3 – Typical Dam Wall Section

Drawing No. 6.4A – Western and Eastern Connections Details Phase 1

Drawing No. 6.4B – Western and Eastern Connections Details Phase 2

Drawing No. 6.5 – Stage 6 Sections Through Dam Wall Phase 1 and 2

Drawing No. 6.6 – Stage 6 Plan Showing Chainage of Sections

Drawing No. 6.7 – Typical Section of Existing Northern Dam Wall

Drawing No. 6.8 – Perimeter Roadway, Fence and Interceptor Channel.

Drawing No. 6.9 – Diversion of Blakes Stream

Drawing No. 6.10 – Existing Powerlines

Drawing No. 6.11– Survey of the Borrow Area Within the Footprint of Stage 6 Showing Cut and Fill Depth to 1573 mAMD

Drawing No. 6.12 –Typical Composite Lining System Detail

Drawing No. 6.13 – Tyre Ballast for Embankment Slopes

Drawing No. 6.14 – Longitudinal Profile Along Perimeter Interceptor Channel

Drawing No. 6.15 – Plan Showing Perimeter Interceptor Channel Chainage

Drawing No. 6.16 – Raised Perimeter Roadway and Interceptor Channel Constructed in the Next Phase

Drawing No. 7.1 – Pipeline and Reclaim Pump and Sand Line Protection

Drawing No. 7.2 – Piezometer and Monitoring Location Plan and Section

Drawing No. 7.3 – Instrumentation Details

APPENDIX B

Trial Pit Logs

APPENDIX C

Aerial Photograph

Photos showing locations of finger channels on the downstream side of the existing northern wall to be backfilled

Photos showing locations of chutes and manholes on the downstream side of the existing northern wall to be backfilled

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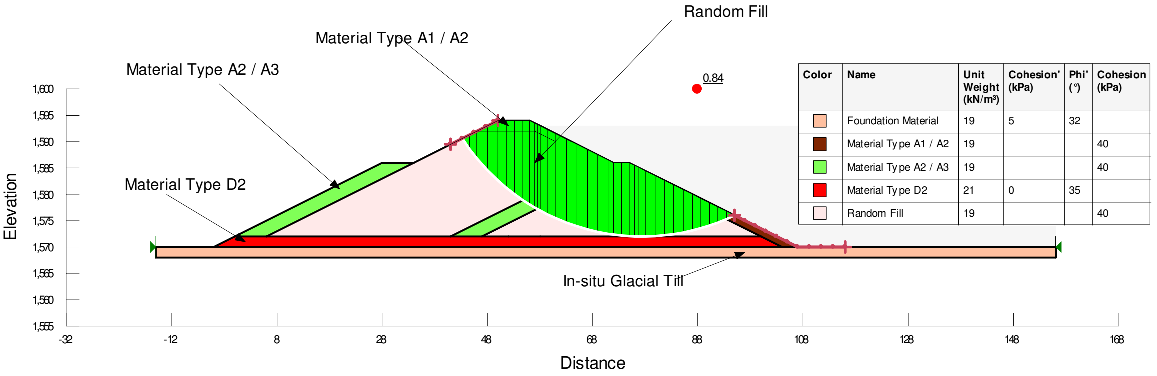
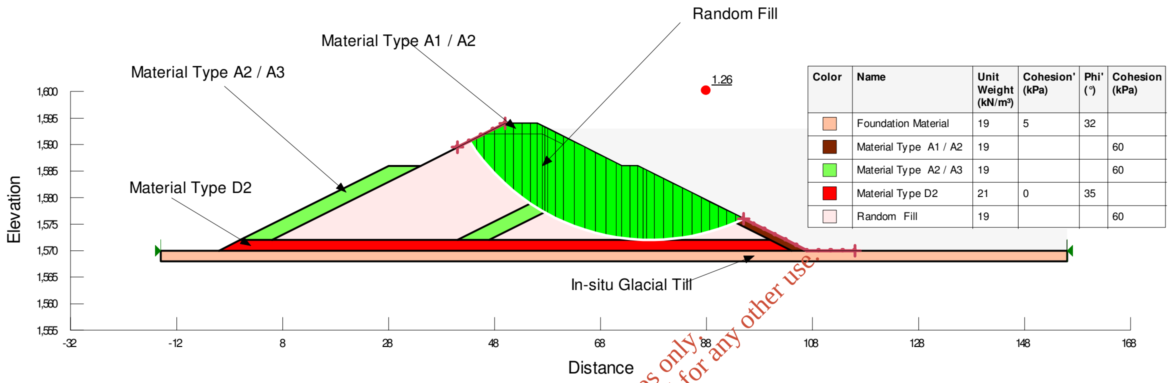


Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Cohesion (kPa)
	Foundation Material	19	5	32	
	Material Type A1 / A2	19			40
	Material Type A2 / A3	19			40
	Material Type D2	21	0	35	
	Random Fill	19			40

Case 1



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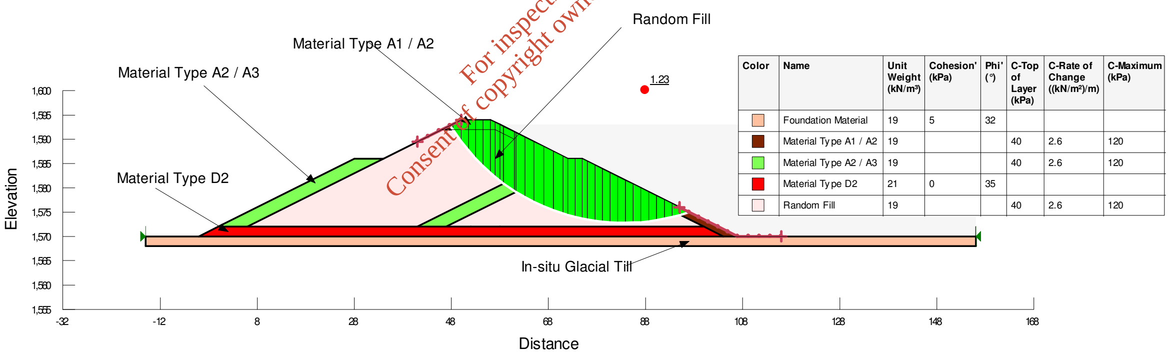
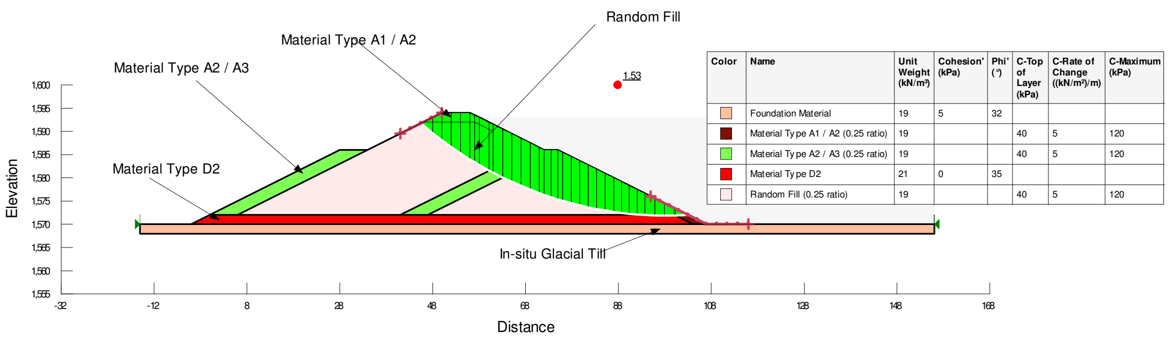
	Material Type A2 / A3	19			60
	Material Type D2	21	0	35	
	Random Fill	19			60

Case 2



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)
	Foundation Material	19	5	32			
	Material Type A1 / A2	19			40	2.6	120
	Material Type A2 / A3	19			40	2.6	120
	Material Type D2	21	0	35			
	Random Fill	19			40	2.6	120

Case 3



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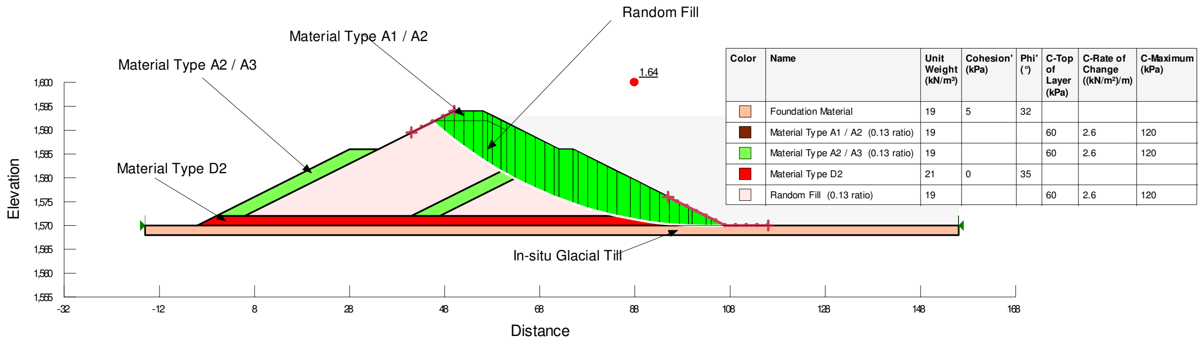
	Foundation Material	19	5	32			
	Material Type A1 / A2 (0.25 ratio)	19			40	5	120
	Material Type A2 / A3 (0.25 ratio)	19			40	5	120
	Material Type D2	21	0	35			
	Random Fill (0.25 ratio)	19			40	5	120

Case 4



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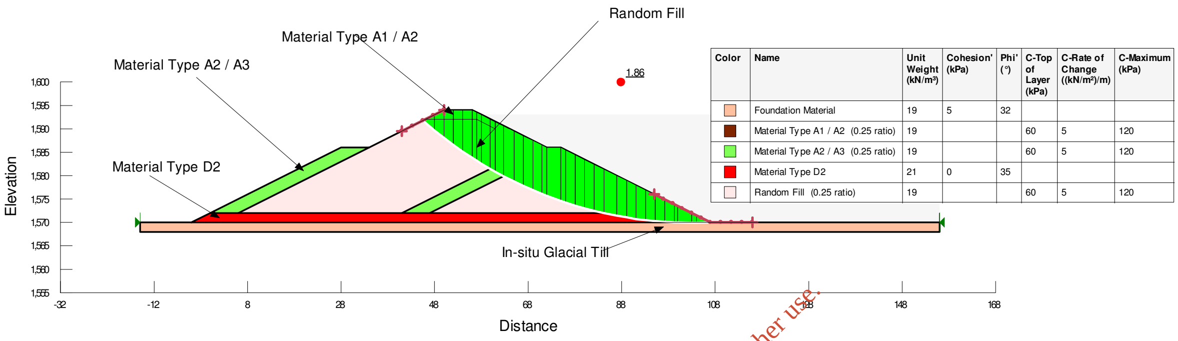
	Foundation Material	19	5	32			
	Material Type A1 / A2 (0.13 ratio)	19			60	2.6	120
	Material Type A2 / A3 (0.13 ratio)	19			60	2.6	120
	Material Type D2	21	0	35			
	Random Fill (0.13 ratio)	19			60	2.6	120

Case 5



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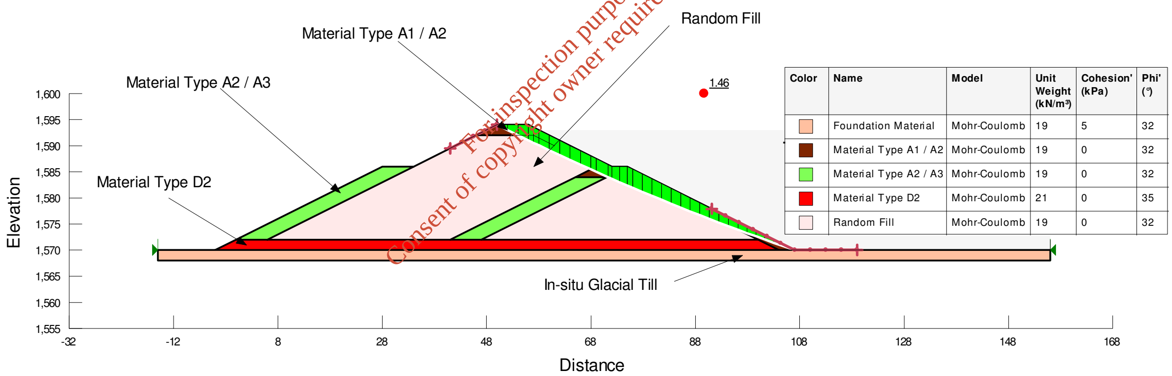
	Foundation Material	19	5	32			
	Material Type A1 / A2 (0.25 ratio)	19			60	5	120
	Material Type A2 / A3 (0.25 ratio)	19			60	5	120
	Material Type D2	21	0	35			
	Random Fill (0.25 ratio)	19			60	5	120

Case 6



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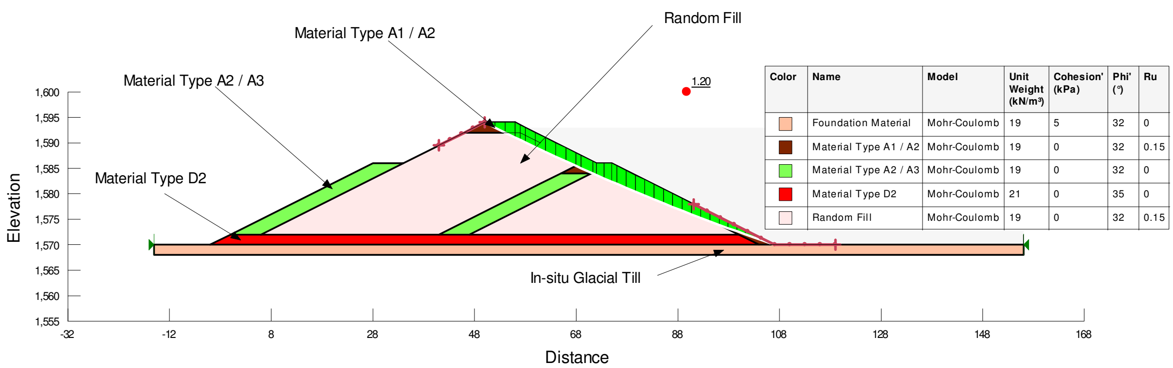
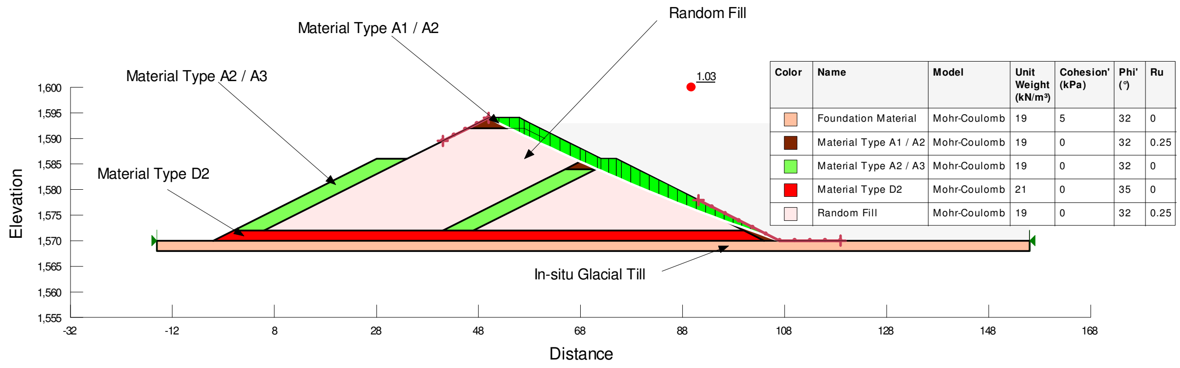
	Material Type A1 / A2	Mohr-Coulomb	19	0	32
	Material Type A2 / A3	Mohr-Coulomb	19	0	32
	Material Type D2	Mohr-Coulomb	21	0	35
	Random Fill	Mohr-Coulomb	19	0	32

Case 7



Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Ru
	Foundation Material	Mohr-Coulomb	19	5	32	0
	Material Type A1 / A2	Mohr-Coulomb	19	0	32	0.15
	Material Type A2 / A3	Mohr-Coulomb	19	0	32	0
	Material Type D2	Mohr-Coulomb	21	0	35	0
	Random Fill	Mohr-Coulomb	19	0	32	0.15

Case 8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Random Fill
Material Type A2 / A3
Material Type D2
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Elevation
Distance
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1,585
1,580
1,575
1,570
1,565
1,560
1,555
-32
-12
8
28
48
68
88
108
128
148
168
Color | Name | Model | Unit Weight (kN/m³) | Cohesion' (kPa) | Phi' (°) | Ru
Foundation Material | Mohr-Coulomb | 19 | 5 | 32 | 0
Material Type A1 / A2 | Mohr-Coulomb | 19 | 0 | 32 | 0.25
Material Type A2 / A3 | Mohr-Coulomb | 19 | 0 | 32 | 0
Material Type D2 | Mohr-Coulomb | 21 | 0 | 35 | 0
Random Fill | Mohr-Coulomb | 19 | 0 | 32 | 0.25

Case 9

Appendix to FIR Item 11

- Tailings Management Facility Dam Break Study *(Golder Associates)*

July 2016

BOLIDEN TARA MINES LIMITED

Tara Tailings Management Facility
Dam Break Study

Submitted to:
Boliden Tara Mines Limited
Knockumber
Navan
Co. Meath
Ireland

Report **Number** 1651706.500/A.1

Distribution:

Boliden Tara Mines Limited - 2 copies (1 pdf)
Golder Associates (UK) Limited - 1 copy

REPORT

Golder Associates

Table of Contents

1.0 INTRODUCTION

Boliden Tara Mines Limited (Tara) has commissioned Golder Associates (UK) Limited to undertake a dam break analysis study for the Randalstown Tailings Management Facility (TMF) which includes Stages 5A, 5B and 6. The purpose of the study is to determine the extent of flooding and potential pathways of an uncontrolled discharge of tailings into the downgradient environment during operations and closure. The results of the dam break analysis will be used to aid in future emergency planning for the Site.

2.0 BACKGROUND

The TMF, which is raised above surrounding ground levels, has been developed in stages, initially commencing in 1974. Stage 5A and 5B have been constructed on top of the existing TMF, to a crest level of 1,594 m above sea level (asl) and Stage 6 (planned) will be located north of the existing TMF, also to a crest level of 1,594 m.

Each stage will hold approximately 500,000 m^3 of supernatant water during operation. At closure it is planned that an engineered cap and growth media will be placed above the tailings. Surface drains will manage surface water runoff so that the closed facility is effectively drained. Spillways will be installed at closure to manage the 1 in 10,000 year flood event. It is planned that the closure profile of Stage 5A and 5B will slope southwards towards a spillway from Stage 5A linking 5B. Another spillway will then discharge flood water from Stage 5B, to the Simonstown Stream, south of the TMF. The proposed Stage 6 spillway is located at the south-eastern corner of Stage 6, discharging to a perimeter drain.

Figure 1 presents the TMF layout, which includes the proposed Stage 6. Drawing 1 presents the location of the TMF and nearby watercourses.

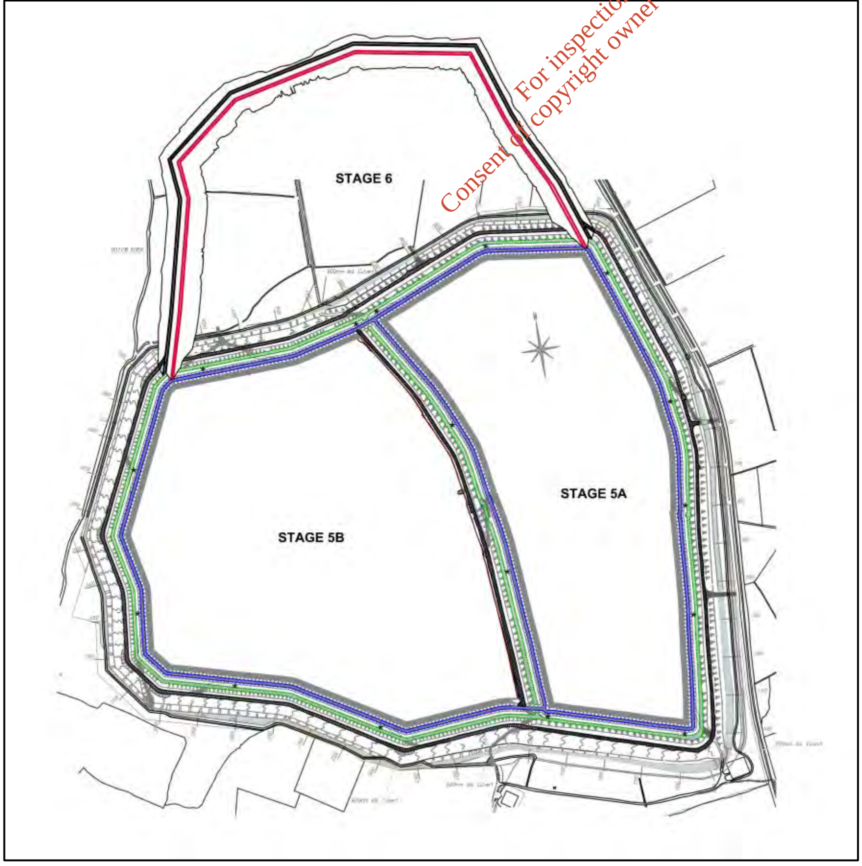

Figure 1: TMF Layout

3.0 DAM BREAK MODELLING

Due to the proximity of downstream identified receptors (residential properties) on all aspects (north, east, south and west) of the planned TMF, the critical (or 'worst case') scenario considered assumes failure occurs in the immediate proximity to nearby receptors. Drawing 2 and 3 presents the locations and details of the nearby receptors. Given the small catchment of the TMF, active management during operations, designed spillway capacity and proposed closure profile, the likelihood of overtopping is very small and therefore only piping failure has been considered in this study. Operational and closure failure scenarios have been considered for each TMF cell. Due to the number of nearby receptors, Stage 5B and Stage 6 consider two separate breach location scenarios. Stage 6 failure scenarios are located either side of a topographical high point. Five failure scenario locations have been considered during both operations and closure, totalling 10 failure scenarios and are as follows:

- Stage 5A – East;
- Stage 5B – West;
- Stage 5B – South;
- Stage 6 – North-west; and
- Stage 6 – North-east.

Sequential failure of multiple Stages has not been considered.

The aforementioned failure scenarios have been modelled using the following three steps:

- **Establish dam break parameters;**
  - Dam break geometry parameters have been estimated using the Froehlich Method (Froehlich, 2008). The parameters are a required input for determining dam break hydrographs.
- **Develop dam break hydrograph;**
  - Dam break hydrographs were determined using HEC-HMS (Hydrologic Engineering Centres Hydrologic Modelling System) software.
- **Assess potential impact downstream (flood routing);**
  - Dam break hydrographs were applied as boundary conditions to XPSWMM/TUFLOW (2D hydraulic model), providing a representation of downstream flood extents and time to inundation, based on the variable topography surrounding the TMF.

3.1 Dam Break Modelling Process

Dam break hydrographs have been estimated using the level pool routing function in HEC-HMS. Input parameters are provided in Section 3.1.1, which includes failure formation time and breach geometry.

3.1.1 Dam Break Parameters

Dam break parameters have been determined using the Froehlich method; an empirical model used to determine dam failure geometry. The Froehlich Method uses the following equation:

Average Breach Width = $0.27k_oV_w^{0.32}h_b^{0.04}$

Where:

k_o = 1.3, if overtopping failure, 1.0, if piping failure

V_w = Reservoir Volume Released (m^3)

h_b = Breach Height (m)

Side slope = 1.0, if overtopping failure, 0.7, if piping failure.

The dam break geometry for each scenario is presented in Table 1.

The volume of tailings released from the facility is based on the methodology presented in *Tailings mobilization estimates for dam breach studies* (Knight Piesold, 2015) and the Froehlich Method (2008). The mass of mobilized tailings is estimated assuming full mixing of supernatant water, with the tailings solids and interstitial water at a selected solids content. In this instance, instantaneous mixing at 65% solids content by mass has been applied, which is considered a conservative upper limit to Newtonian-like fluid behaviour. The supernatant water also includes the 24 hour 10,000 year return period rainfall event which is based on Met Eireann rainfall data for Randalstown. The Met Eireann rainfall frequency analysis data yields a 24 hour 10,000 year rainfall event of 210 mm (Figure 2).

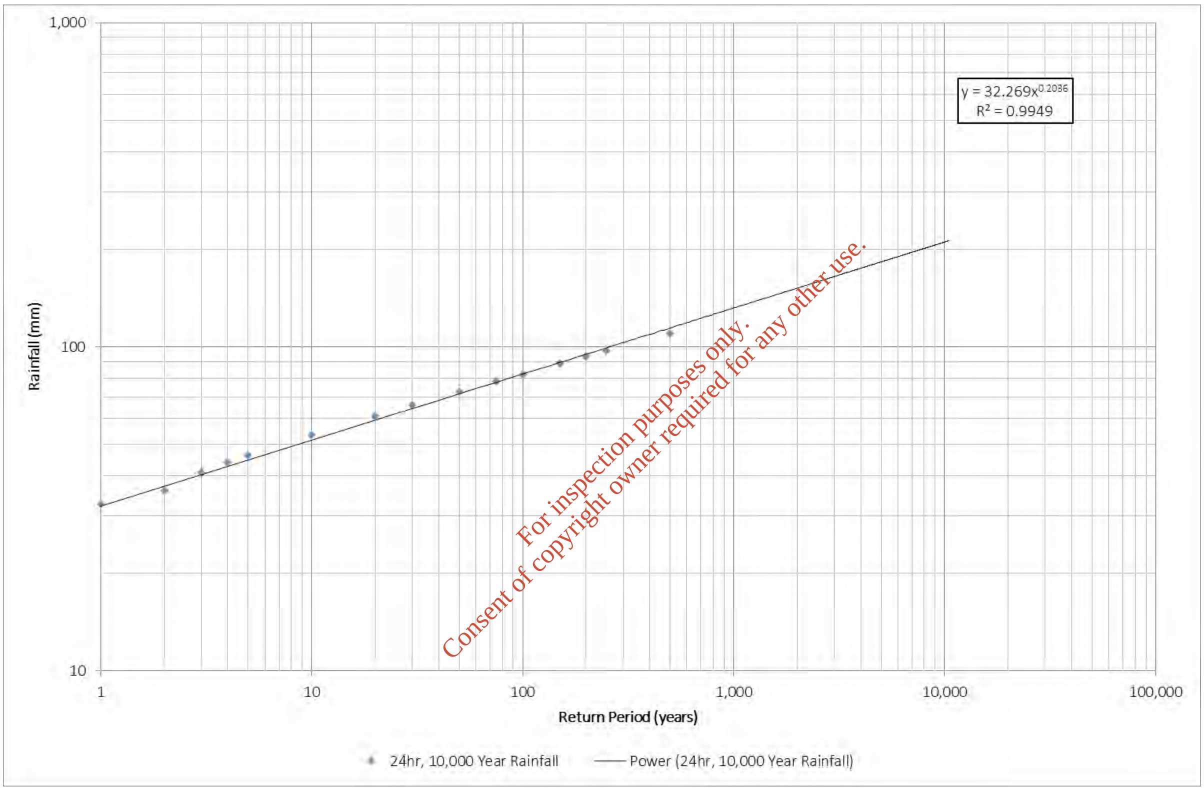

Figure 2: Rainfall Data

Failure formation time has been estimated using the equation developed by Froehlich (2008). The equation is presented below:

$$T = 0.0175\sqrt{\frac{Vw}{gHb^2}}$$

V_w = Reservoir Volume Released (m^3)

h_b = Breach Height (m)

g = gravity (m/s^2)

Breach depth is based on the current crest elevation of 1,594 masl, which also applies to the closure scenario. Breach formation times are presented in Table 1.

Table 1: Dam Break Parameters

Scenario	Total Volume Released (Mm^3) [1]	Supernatant Water (Mm^3)	24hr 10,000 yr Rainfall (Mm^3)	Breach height (m)	Failure Formation Time (hr)	Side Slope (1:H)	Breach Base Width (m)
Stage 5A, Operation	2.711	0.5	0.126	20	0.46	0.7	20.8
Stage 5A, Closure	0.547	-	0.126	20	0.21	0.7	6.9
Stage 5B, Operation	2.893	0.5	0.168	20	0.48	0.7	21.6
Stage 5B, Closure	0.729	-	0.168	20	0.22	0.7	8.9
Stage 6, Operation	2.694	0.5	0.122	20	0.46	0.7	20.8
Stage 6, Closure	0.530	-	0.122	20	0.2	0.7	6.7

1 Total volume releases includes supernatant water stored (500,000 m3), water stored in the tailings (estimated at 65% solids content) and the 24 hour 10,000 year return period rainfall event for Randalstown (210 mm depth).

3.2 Model Results – Dam Break Hydrographs

The level-pool routing function in HEC-HMS was used to generate dam break hydrographs based on the parameters presented in Table 1 (breach geometry and failure formation time). Figure 3 below presents the hydrographs derived from the HEC-HMS modelling that were subsequently applied to the XPSWMM/TUFLOW model as an upstream boundary condition.

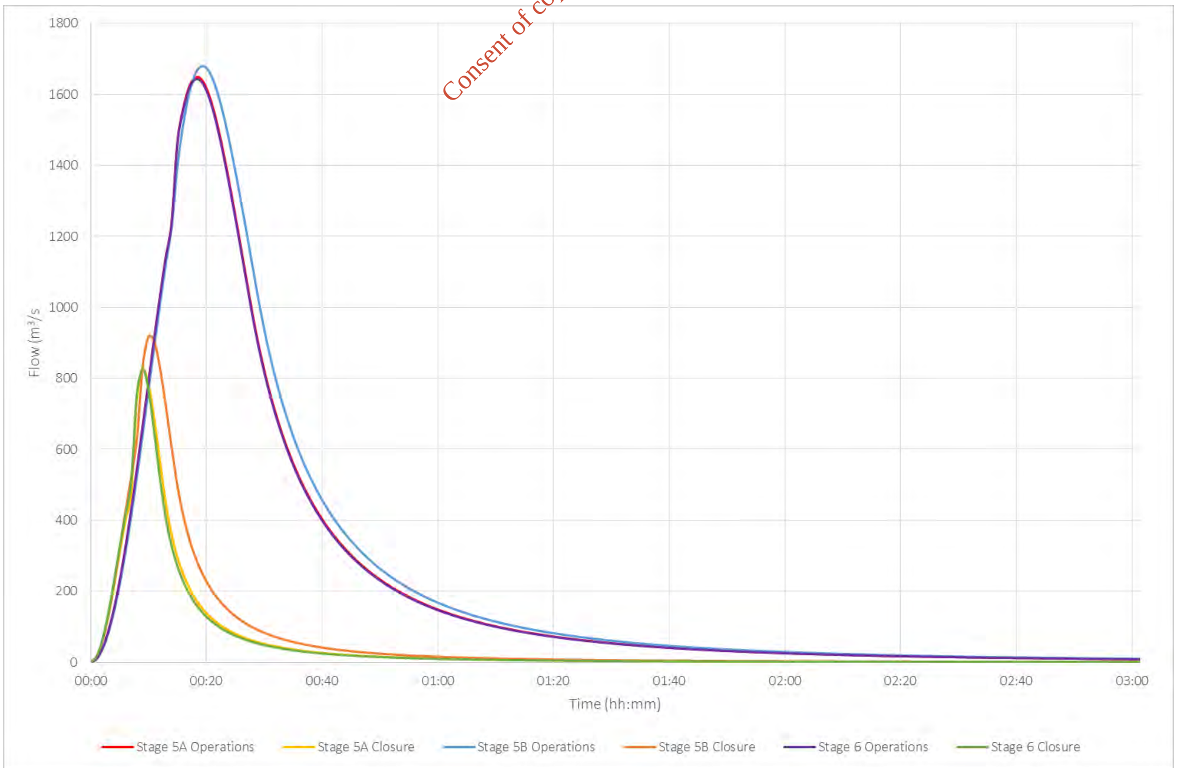

Figure 3: Dam Break Hydrographs

Peak flow is greater during operation due to the large volume of water contained within the TMF, primarily supernatant water. Note that dam break models are very sensitive to each of the input parameters, particularly the formation time; reducing the formation time of the failure and keeping all other parameters equal can lead to significantly higher peak flows.

3.3 Flood Routing

Flood routing downstream of a breach from the TMF has been modelled using XPSWMM/TUFLOW. TUFLOW is a 2D flood and tide simulation model. The 2D solution, which has been utilised to model flood routing of a dam break, simulates the hydrodynamics of floods based on the Stelling finite difference, alternating direction implicit (ADI) scheme that solves the full 2D free surface shallow water equations.

3.3.1 Model Inputs

The model was constructed using a grid where each point represents the modelled topography. The hydrographs applied to the model are presented in Figure 3. Flow is then calculated between each cell. Model inputs are provided in Table 2.

Table 2: TUFLOW Model Inputs

Parameter	Model Input	Comments	Sources
2D Grid	12 m Cell Size	Digital Elevation Model (DEM)	Tara
Time Step	3 seconds	-	-
Downstream Boundary Condition	Located approximately 3 - 4 km downstream, along River Blackwater.	Downstream boundary condition set to automatically calculate based on Manning's equation (Manning's is an empirical formula used for estimating open channel flow and is a function of channel velocity, flow area, surface roughness and channel slope.) and a downstream slope, derived from the DEM, of 0.005 m/m.	-
Upstream Boundary Condition	Hydrographs developed using HEC-HMS.	See Section 3.1.2.	-
Roughness	0.05	A relatively high Manning's coefficient (resistance of ground surface to the flow of water) was selected for the surrounding land use (arable and pasture) due to the presence of mobilised tailings.	HEC-RAS Hydraulic Reference Manual (HEC-RAS, 2010).

The Yellow River and Simonstown Stream have been modelled in 2D by cutting the stream into the DEM. The interceptor ditch circumnavigating the existing Stage 5A and 5B has been extended around the proposed Stage 6 of the TMF. A bund along the northern extent of the Site has also been incorporated into the model by raising ground levels by 2 m.

The River Blackwater is represented in the model by the data from the DEM. It is assumed the DEM provides the elevation of the water surface at the time of survey. It has therefore not been possible to fully assess the flow in the River Blackwater i.e. tailings and river flow. The likely impact on flows in the Blackwater have been quantified later in this report.

3.4 Model Results – Flood Routing

The maximum extent and depth of flooding is presented in Drawings 3 to 13.

Table 3 provides a summary of modelling results and flood propagation for various locations downstream of the TMF. These locations are presented in Drawings 3 to 13.

Table 3: Model Outputs

Section Line	West	South	East	RB1	RB2
Stage 5A, Dam Break East, Operation Phase, Drawing 4					
Peak Flow (m^3/s)	4	160	500	25	180
Available Flood Warning (minutes)*	53	15	5	53	60
Number of Properties Impacted	9 receptor locations (RH1 to RH6) and (RH83 to RH86)				
Stage 5A, Dam Break East, Closure, Drawing 5					
Peak Flow (m^3/s)	-	70	250	4	20
Available Flood Warning (minutes)*	-	13	4	60	75
Number of Properties Impacted	3 receptors locations (RH84, RH85 and RH86)				
Stage 5B Dam Break West, Operation Phase, Drawing 6					
Peak Flow (m^3/s)	1,170	21	-	580	360
Available Flood Warning (minutes)*	10	36	-	27	39
Number of Properties Impacted	1 receptor locations (RH18)				
Stage 5B Dam Break West, Closure Phase, Drawing 7					
Peak Flow (m^3/s)	560	16	-	135	84
Available Flood Warning (minutes)*	8	38	-	25	43
Number of Properties Impacted	1 receptor locations (RH18)				
Stage 5B Dam Break South, Operation Phase, Drawing 8					
Peak Flow (m^3/s)	27	1,400	-	50	240
Available Flood Warning (minutes)*	27	8		35	39
Number of Properties Impacted	7 receptor locations (RH1 to RH7)				
Stage 5B Dam Break South, Closure Phase, Drawing 9					
Peak Flow (m^3/s)	13	710	-	7	41
Available Flood Warning (minutes)*	29	6	-	35	45
Number of Properties Impacted	4 (RH3 to RH6)				
Stage 6 Dam Break North-west, Operation Phase, Drawing 10					
Peak Flow (m^3/s)	1,000	50	35	450	300
Available Flood Warning (minutes)*	24	55	37	42	55
Number of Properties Impacted	6 (RH18, RH19, RH23, RH24, RH48 and RH49)				
Stage 6 Dam Break North-west, Closure Phase, Drawing 11					
Peak Flow (m^3/s)	120	20	10	40	40
Available Flood Warning (minutes)*	23	60	39	54	92

Section Line	West	South	East	RB1	RB2
Number of Properties Impacted	4 receptor locations (RH18, RH19, RH48 and RH49)				
Stage 6 Dam Break North-east, Operation Phase, Drawing 12					
Peak Flow (m^3/s)	120	125	320	70	140
Available Flood Warning (minutes)*	36	39	24	75	93
Number of Properties Impacted	9 receptor locations (RH4 to RH6, RH48 to RH50, RH52, RH55 and RH84)				
Stage 6 Dam Break North-east, Closure Phase, Drawing 13					
Peak Flow (m^3/s)	39	53	56	12	25
Available Flood Warning (minutes)*	35	43	23	80	107
Number of Properties Impacted	3 receptor locations (RH4, RH5 and RH55)				

** From beginning of breach.*

The results of the modelling predicts a number of properties are likely to be at risk of inundation, particularly those in proximity to Stage 6, Yellow River and Simonstown River. A flood warning system will be adopted. Residents at high risk and / or incapacitated will have systems installed in their properties (light and alarm). The early warning system will also include text messages to residents, notifications to the emergency services and a localised siren. It is worth noting that a number of receptors are located in very close proximity to the TMF and are inundated in less than 15 minutes, particularly properties north of Stage 6. The presence of a bund along the north boundary of the Site will have a negligible impact to warning times for a dam break of the scale considered but could provide a tangible benefit for smaller releases from the TMF.

A failure along the northern boundary of Stage 6 presents the biggest risk to nearby properties. Stage 6, dam break north-west, operation scenario results indicate 10 properties are at risk and the peak flow entering the River Blackwater is approximately 450 m^3/s. Stage 6, dam break north-east, operation scenario results impacts 11 properties, however the flow entering the River Blackwater is attenuated to 140 m^3/s as tailings is conveyed along the eastern perimeter of the TMF.

During operation, a failure along the western embankment of Stage 5B presents the lowest risk but would still affect a single property and peak flow to the River Blackwater would be 580 m^3/s. At closure the property would still be affected, however peak flow to the River Blackwater decreases to 135 m^3/s.

Although the modelling results for all scenarios predicts limited flooding prior to reaching Navan, it is highly likely that such an increase in flow in the Blackwater would cause significant flooding as the Blackwater enters Navan, especially where hydraulic control structures such as bridges form constrictions.

3.5 Limitations

The analysis models the propagation of liquefied tailings as a Newtonian fluid (i.e. water). The viscosity of water is significantly lower than tailings, therefore the assessment is considered to be conservative for areas downstream. In addition, the model does not account for reduced pore water following capping and closure. Therefore dam break hydrographs and model outputs for the closure scenario are considered to be particularly conservative.

4.0 CONCLUSIONS

Only a piping failure of the TMF has been considered for dam break scenarios during operation and closure; as there is no catchment upstream of the TMF, and during closure the TMF will not hold any supernatant water. The introduction of spillways during closure will reduce the likelihood of a dam break by minimising the volume of water above the tailings. In addition, pore water in the tailings will reduce following capping, further reducing the likelihood of failure.

A failure of the TMF embankment in proximity to nearby properties and during operation represents the greatest risk to the public. During operation, a failure along the western embankment of Stage 5B presents the lowest risk but would still affect a single property and peak flow to the River Blackwater would be 580 m^3/s

In the event of a failure of the TMF, properties in proximity to Simonstown Stream, Yellow River and Stage 6 are particularly at risk of inundation. An early warning system will be implemented for those at risk, however residents will have very limited time in which to react.

Given the high consequence (on local residents) of a dam break failure in the immediate vicinity of the TMF facility at Tara as demonstrated in this study, we would recommended that future consideration is given to undertaking a further assessment based on non-Newtonian tailings dam breach (i.e. tailings viscosity, rather than assuming water). The software required to complete this type of study (Flow3D) is state-of-the-art and Golder is a leading provider in these types of assessments.

5.0 REFERENCES

1) Froehlich, 2008. Embankment Dam Breach Parameters and Their Uncertainties. ASCE, Journal of Hydraulic Engineering, Vol. 134, No. 12, December 2008.

2) Knight Piesold, 2015. Tailings mobilization estimates for dam breach studies. Proceedings Tailings and Mine Waste 2015. D, Fontaine & V, Martin.

3) USACE, 2010. HEC-RAS Hydraulic Reference Manual. Version 4.1.

4) USACE, 2014. Using HEC-RAS for Dam Break Studies. August 2014. TD-39.

Report Signature Page

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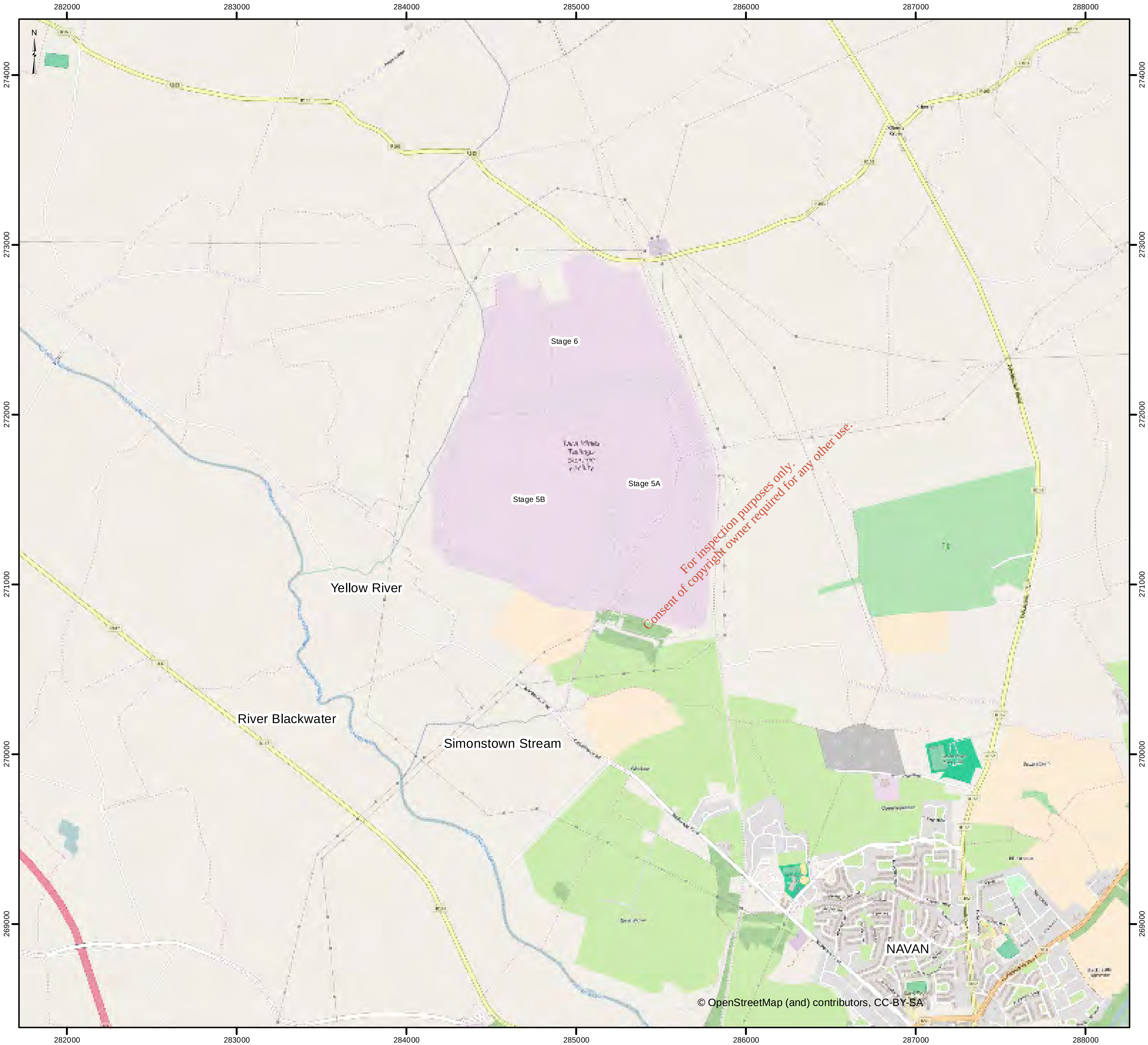
08 July 2016

BK/MG/ar

APPENDIX A

Drawings



LEGEND

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500

Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

PROJECT
TARA DAM BREAK STUDY 2016

TITLE
SITE LOCATION PLAN

CONSULTANT

Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0011	B	1

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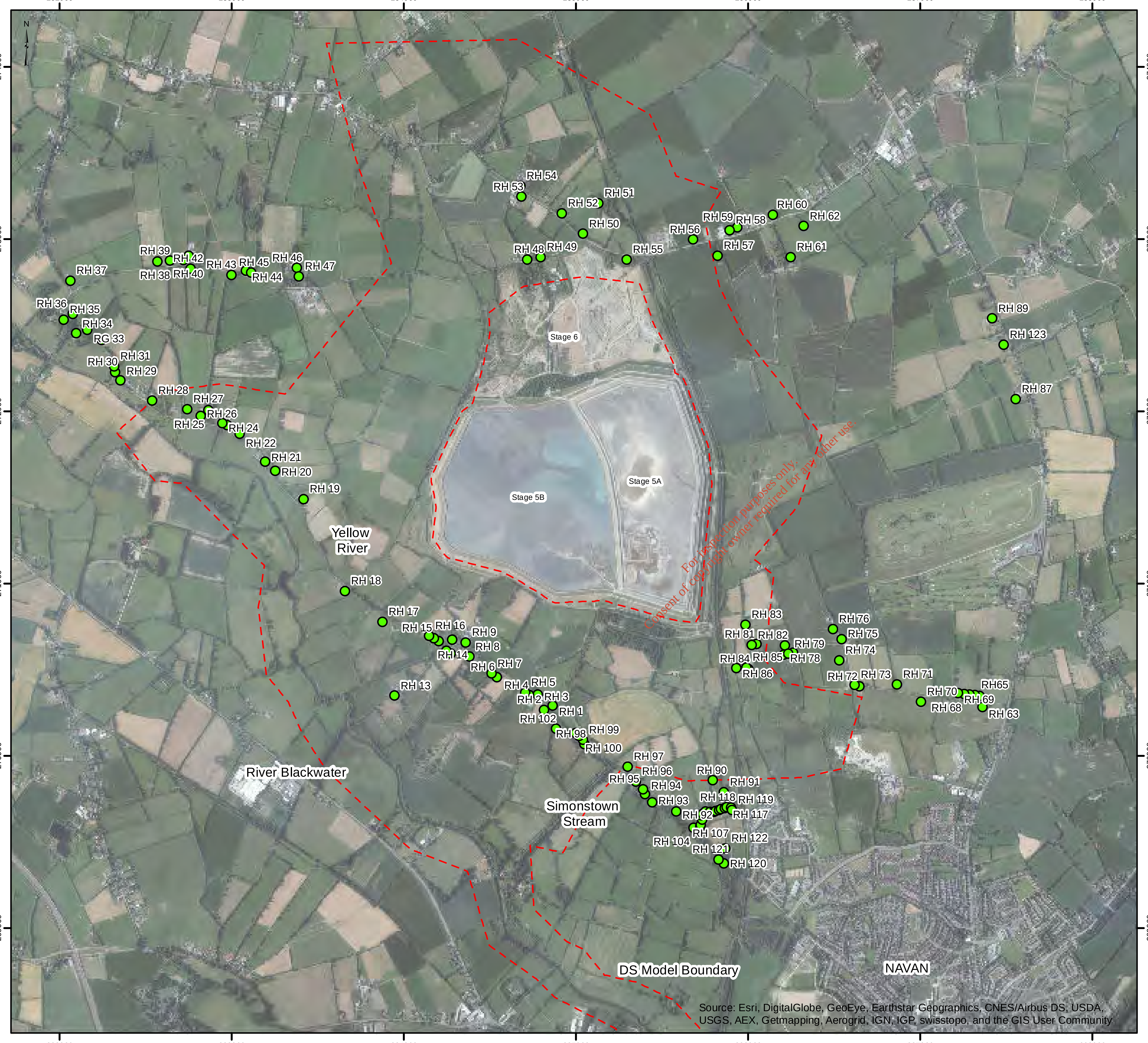
25mm



LEGEND

- Receptor
- Model Boundary

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

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Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

PROJECT
TARA DAM BREAK STUDY 2016

TITLE
RECEPTOR LOCATIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0001	A	2

Receptor Reference Number	Dwelling No	Name	Address	Address Line 1	Address Line 2	East	North
RH 1	1476	Paddy & Mary Gore	Randalstown	NAVAN		284866.719	270290.16
RH 2	1477	Joe & Geraldine Fitzpatrick	Randalstown	NAVAN		284815.000	270263.75
RH 3	1441	Siobhan & Lorcan O'Dowd	Randal Lodge, Randalstown	RANDALSTOWN	NAVAN	284780.156	270353.47
RH 6	1479	Richie & Grainne Cahill	Randalstown	DONAGHPATRICK	CO. MEATH	284543.156	270453.75
RH 7	706	Mrs. Smith	Randalstown	DONAGHPATRICK	CO. MEATH	284510.438	270475.91
RH 8	1443	Sarah & Nathan Doyle	Randalstown	RANDALSTOWN	NAVAN	284381.844	270574.97
RH 9	1444	Pat Kennedy	Randalstown	DONAGHPATRICK	CO. MEATH	284360.094	270656.81
RH 10	1442	Aidan & Sarah Kennedy	Randalstown	DONAGHPATRICK	CO. MEATH	284273.875	270592.38
RH 11	1480	Philip & Geraldine O'Dea	Randalstown	DONAGHPATRICK	CO. MEATH	284248.625	270608.94
RH 12	280	Mr. Ennis	Randalstown	RANDALSTOWN	NAVAN	284281.031	270673.22
RH 13	267	Brendan & Susan O' Neill	Mulleard	NAVAN		283947.000	270347.34
RH 14	1445	Vacant - Duignan's	Tatestown	DONAGHPATRICK	CO. MEATH	284204.219	270664.66
RH 15	707	Eimear & Karl Brennan	Tatestown	DONAGHPATRICK	CO. MEATH	284176.594	270680.81
RH 16	910	Dympna & M ichael Dolan	Tatestown	NAVAN		284146.750	270695.13
RH 17	713	Phillip & Mary Brady	Tatestown	NAVAN		283876.781	270775.09
RH 18	1446	Kevin & Geraldine Thompson	Riverview House, Tatestown	TATESTOWN	CO. MEATH	283659.188	270955.53
RH 19	1447	Jack Smith	Tatestown	NAVAN		283419.625	271488.28
RH 20	555	Dick & Eithne Brady	Tatestown Lodge, Tatestown	NAVAN		283252.719	271653.94
RH 21	1530	John & Majella Brady	Tatestown	TATESTOWN	CO. MEATH	283194.031	271707.31
RH 22	786	John & Mary Boyle	Tatestown	NAVAN		283047.188	271867.84
RH 23	1481	Joan & Pat O'Toole	Tatestown	NAVAN		282973.125	271919.78
RH 24	1411	Michael & Patsy Monaghan	Tatestown	NAVAN		282945.313	271929.03
RH 25	1412	Mrs Kelly	Tatestown	NAVAN		282866.063	272004.06
RH 26	1413	Paul & Joanne Fisher	Tatestown	NAVAN		282821.375	271972.88
RH 27	1482	John & Orla Molloy	Tatestown	NAVAN		282741.313	272010.81
RH 28	1414	Raymond Quail	Tatestown	NAVAN		282538.781	272061.31
RH 32	1483	Paul Byrne	Tatestown	NAVAN		282245.063	272414.31
RG 33	714	Aidan & Mary Jordan	Tatestown	NAVAN		282161.438	272471.63
RH 34	1494	Tom & Carol Noonan	Tatestown	DONAGHPATRICK	CO. MEATH	282097.719	272452.91
RH 36	553	Mr. & Mrs. Kevin Martin	Tatestown	DONAGHPATRICK	CO. MEATH	282076.031	272565.69
RH 37	1493	Mr. Eddie Joyce	Donaghpatrick	DONAGHPATRICK	CO. MEATH	282064.219	272758.09
RH 38	1431	Mr. Johnny Joyce	Donaghpatrick	DONAGHPATRICK	CO. MEATH	282568.000	272869.28
RH 39	1455	Thomas & Mandy Maree	Donaghpatrick	DONAGHPATRICK	CO. MEATH	282641.094	272873.59
RH 40	1531	John & Christina Maree	Donaghpatrick	DONAGHPATRICK	CO. MEATH	282719.531	272878.22
RH 41	1429	Mrs. Catherine Lally	Donaghpatrick	DONAGHPATRICK	CO. MEATH	282750.281	272903.41
RH 42	1430	Mr. Tommy Henehan	Donaghpatrick	DONAGHPATRICK	CO. MEATH	282762.781	272827.44
RH 43	1454	Dick Brady	Donaghpatrick	DONAGHPATRICK	CO. MEATH	282998.719	272790.47
RH 44	1428	Sean & Ann Lally	Donaghpatrick	DONAGHPATRICK	CO. MEATH	283082.531	272816.41
RH 45	1427	Thomas & Nora Lally	Donaghpatrick	DONAGHPATRICK	CO. MEATH	283113.125	272804.56
RH 46	1453	Peter Brady	Donaghpatrick	DONAGHPATRICK	CO. MEATH	283379.500	272831.78
RH 47	720	Dick Brady	Donaghpatrick	DONAGHPATRICK	CO. MEATH	283391.063	272781.88
RH 48	1426	John & Olive Kiely	Randalstown	DONAGHPATRICK	CO. MEATH	284719.063	272878.84
RH 50	1423	Renter	Woodview Lodge	RANDALSTOWN	NAVAN	285041.478	273029.91
RH 51	1422	Benny Sheridan	Woodview House	RANDALSTOWN	NAVAN	285131.969	273208.31
RH 52	178	Gabriel Caldwell	Randalstown	DONAGHPATRICK	CO. MEATH	284918.469	273148.72
RH 53	1451	Gerry Cauldwell	Randalstown	DONAGHPATRICK	CO. MEATH	284685.781	273245.19
RH 54	1421	Kevin Ward	Randalstown	DONAGHPATRICK	CO. MEATH	284677.781	273309.16
RH 55	1384	Willie Noonan	Randalstown	NAVAN		285296.469	272881.38
RH 56	1383	Padraic Heaney	Randalstown	NAVAN		285683.406	272996.75
RH 57	1450	Fiacra & Mary O'Cinneide	Randalstown	SILLOGUE	CO. MEATH	285823.750	272902.59
RH 59	1382	Cynthia & Eamonn Dempsey	Randalstown	SILLOGUE	CO. MEATH	285939.531	273068.13
RH 60	1380	Mrs. Rose Heaney	Randalstown	NAVAN		286147.531	273140.06
RH 61	1381	Mrs. Finnegan	Randalstown	NAVAN		286250.656	272895.56
RH 62	1449	Mr. & Mrs. Thomas Finnegan	Randalstown	SILLOGUE	NAVAN	286326.594	273074.94
RH 63	195	David Mullin	Proudstown	NAVAN		287365.719	270281.34
RH 64	190	Paul Mc Donagh	Proudstown	NAVAN		287348.125	270346.13
RH65	191	Brendan O'Reilly	Proudstown	PROUDSTOWN	CO. MEATH	287321.750	270350.91
RH 67	192	Gerry Mc Donagh	Proudstown	NAVAN		287289.781	270354.13
RH 68	193	Mike O'Shea	Proudstown	NAVAN		287257.781	270356.50
RH 69	194	Eric Brady	Proudstown	NAVAN		287223.406	270362.91
RH 70	1002	Paddy Markey	Proudstown	NAVAN		287008.344	270311.75
RH 71	796	Keith & Tracey Brady	Proudstown	NAVAN		286868.344	270412.59
RH 72	967	Michael Mc Ateer	Simonstown	NAVAN		286648.500	270399.94
RH 73	968	Tommy Mc Ateer	Simonstown	NAVAN		286621.688	270409.13
RH 74	282	Pat Conroy	Simonstown	NAVAN		286531.000	270551.84
RH 75	281	Mrs. Callaghan	Simonstown	NAVAN		286546.906	270675.53
RH 76	1003	Michael Clark	Simonstown	NAVAN		286495.031	270733.28
RH 77	1516	Tony & Rosaemary Curran	Simonstown	NAVAN		286265.125	270596.97
RH 80	969	Noel Clark	Simonstown	NAVAN		286216.625	270639.75
RH 81	970	Raymond & Caitriona Brady	Simonstown	NAVAN		286051.000	270646.09
RH 82	196	Derek & Ann Lister	Simonstown	NAVAN		286023.469	270640.28
RH 83	197	Brendan & Claire Brady	Simonstown	NAVAN		285988.188	270758.94

Receptor Reference Number	Dwelling No	Name	Address	Address Line 1	Address Line 2	East	North
RH 86	1005	Gerry Fitzpatrick	Simonstown	NAVAN		285935.000	270508.34
RH 87	1000	Tony Heanay	Proudstown	NAVAN		287558.188	272070.16
RH 89	1399	Jimmy Connolly	Proudstown	NAVAN		287421.000	272538.13
RH 90	787	John & Helen Burns	Windtown	NAVAN		285796.781	269854.78
RH 91	506	Eithne Cantwell	WIndtown	NAVAN		285861.188	269787.13
RH 92	507	John Sherlock	Linton House, Windtown	NAVAN		285585.094	269674.38
RH 93	508	Eamon & Ann Kearney	Windtown	NAVAN		285444.125	269727.44
RH 94	509	Joseph Downey	Windtown	NAVAN		285403.656	269773.69
RH 95	510	Andy & Geraldine O'Connor	Windtown	NAVAN		285391.438	269802.63
RH 96	511	Martina & Gabriel Hamilton	Windtown	NAVAN		285350.313	269848.88
RH 97	512	Mary & Ciaran Mangan	Rathaldron	NAVAN		285301.469	269934.34
RH 98	1440	Helen Duignan	Rathaldron	NAVAN		285051.875	270067.09
RH 99	1478	Bernie Ladd & Brian Collins	Rathaldron	NAVAN		285041.281	270089.69
RH 100	996	Jim Mc Hugh	Rathaldron	NAVAN		285018.688	270112.84
RH 101	997	Meath Disabilities Services	Shalimar House, Rathaldron	RATHALDRON	CO. MEATH	285000.188	270129.47
RH 102	708	Padraig & Louise Fitzsimons	Rathaldron	NAVAN		284887.031	270154.50
RH 103	489	O'Briens	1 Windtown	KINGDOM HALL	NAVAN	285701.813	269569.59
RH 104	490	Kingdom Hall	2 Windtown	NAVAN		285685.906	269578.47
RH 105	491	Mr. & Mrs. Muffit	3 Windtown	NAVAN		285724.188	269586.75
RH 106	492	Fr. Ray Husband	4 Windtown	NAVAN		285728.469	269596.53
RH 107	493	Mrs. Shiela Joyce	5 Windtown	NAVAN		285734.594	269626.53
RH 108	494	Mrs. Johnston	6 Windtown	NAVAN		285730.875	269651.31
RH 109	495	Mr. Wogan	7 Windtown	NAVAN		285737.000	269660.81
RH 110	496	Mrs. Mc Ateer	8 Windtown	NAVAN		285754.156	269674.88
RH 111	497	Mr. & Mrs. Markey	9 Windtown (Rosewood)	NAVAN		285779.281	269671.22
RH 112	498	Mr. Jack Meighan	10 Windtown	NAVAN		285803.000	269672.00
RH 113	499	Ms. Bridget & Kathleen Walsh	11 Windtown	NAVAN		285813.406	269676.28
RH 114	500	Mr. Cassidy (2 brothers)	12 Windtown	NAVAN		285834.250	269683.03
RH 115	501	Mrs. Baker	13 Windtown	NAVAN		285845.250	269687.31
RH 116	502	Mrs. Alexander	14 Windtown	NAVAN		285866.094	269694.03
RH 117	503	Mr. & Agnus Mc Govern	15 Windtown	NAVAN		285878.344	269698.94
RH 118	504	Mrs. Kathleen Markey	16 Windtown	NAVAN		285904.063	269696.50
RH 119	505	Mrs. Brennan	17 Windtown	NAVAN		285907.719	269683.03
RH 120	484	Derelict	Windtown	NAVAN		285860.000	269373.91
RH 121	485	Mr. & Mrs. John Lynch	Windtown	NAVAN		285830.688	269395.41
RH 122	486	Tom Hoskins	Windtown	WINDTOWN	CO. MEATH	285869.781	269458.91
RH 123	187	Mr. Colm Lynch	Windtown	NAVAN		287488.531	272386.59
RH 4	1700	Will Kearney	Randalstown			284728.220	270349.68
RH 5	1701	Richard & Caroline Brennan	Randalstown			284705.730	270366.00
RH 29	1703	Michael & Mary Corrigan	Tatestown			282353.470	272180.00
RH 30	1704	David & Annmarie Cassidy	Tatestown			282322.900	272227.39
RH 31	1705	Stephen Corrigan	Tatestown			282318.000	272259.69
RH 35	1706	George & Julie Mc Dermott	Tatestown			282023.380	272531.77
RH 49	1707	Robbie O'Brien	Randalstown			284797.600	272895.31
RH 58	1708	Brian & Marie Heaney	Randalstown			285895.600	273050.19
RH 78	1004	David Smith	Simonstown			286210.340	270585.25
RH 79	618	John & Ann O'Hare	Simonstown			286236.160	270590.47
RH 84	971 A	Patsy & Rita Brady	Simonstown			286003.160	270501.56
RH 85	971 B	Joe & Collette Mooney	Simonstown			285993.000	270510.85

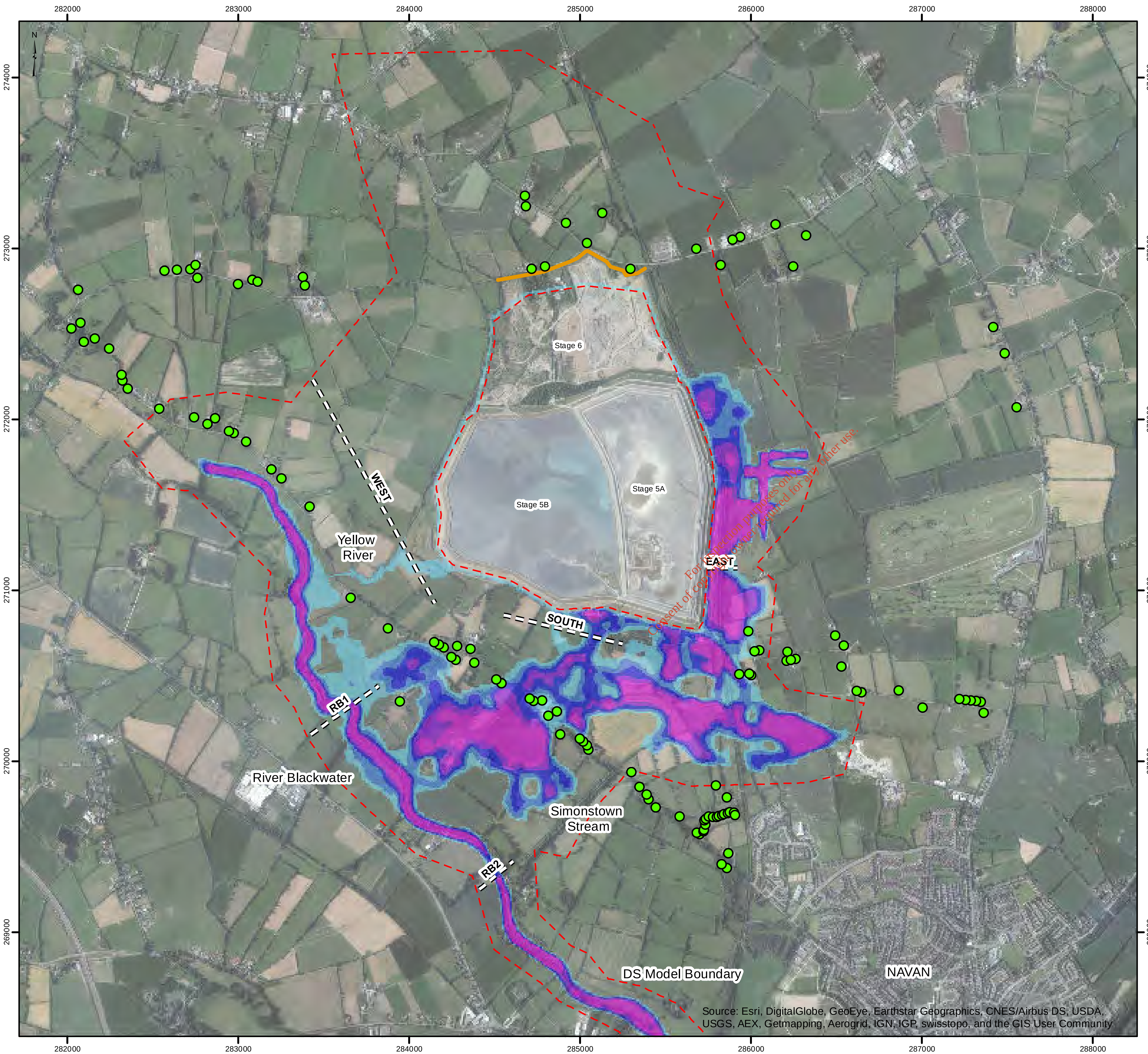
CLIENT
BOLIDEN TARA LTD

PROJECT
TARA DAM BREAK STUDY 2016

TITLE
SPREADSHEET OF RECEPTOR LOCATIONS

CONSULTANT		
Golder Associates	YYYY-MM-DD	06 JUL 2016
	DESIGNED	BK
	PREPARED	ECS
	REVIEWED	BK
	APPROVED	MG

PROJECT NO.	CONTROL	REV.	DRAWING
1651706	1001-DB-0013	A	3



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500

Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

PROJECT
TARA DAM BREAK STUDY 2016

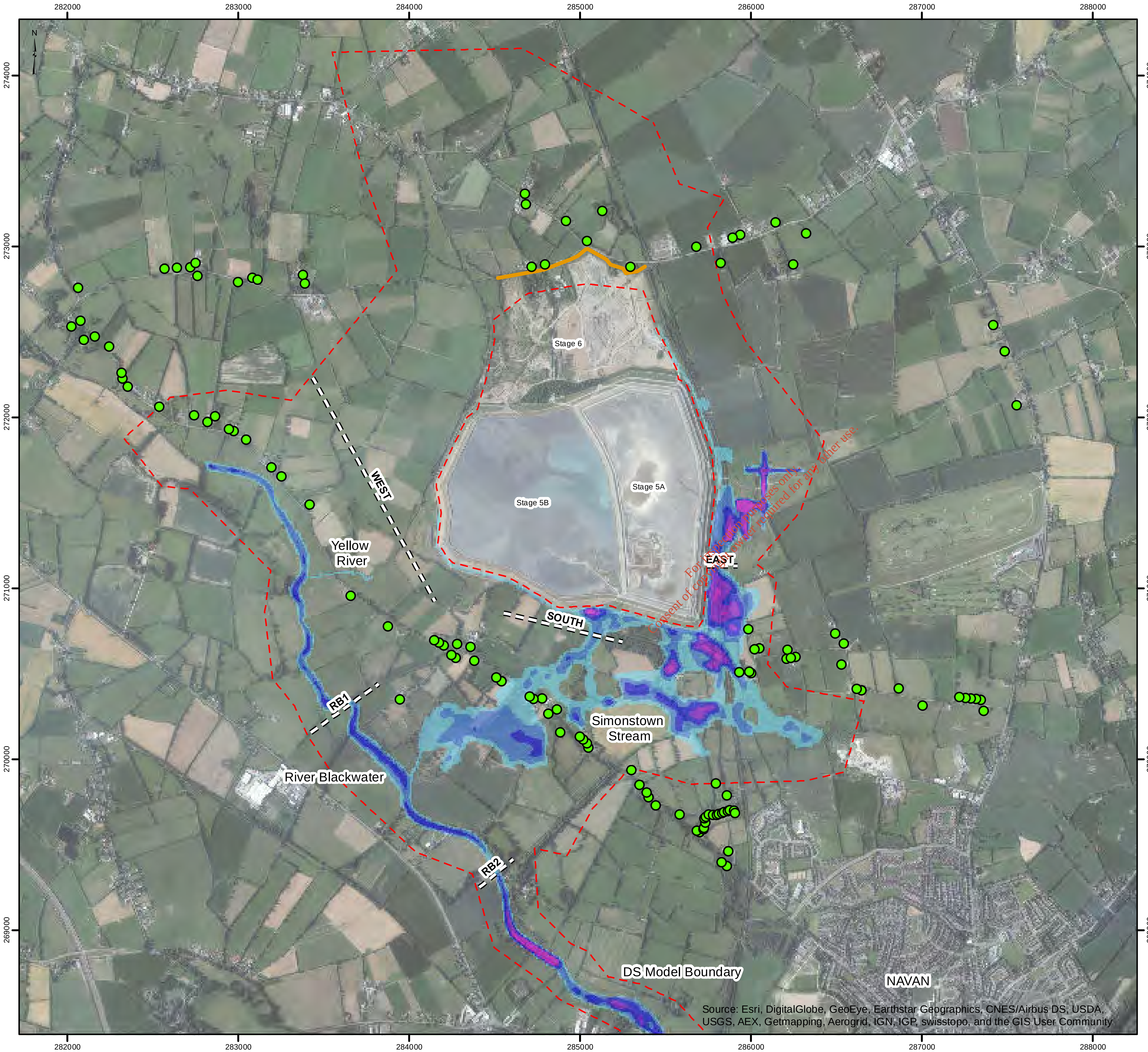
TITLE
STAGE 5A, DAM BREAK EAST, OPERATION PHASE

CONSULTANT

Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0001	B	4



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500
Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

PROJECT
TARA DAM BREAK STUDY 2016

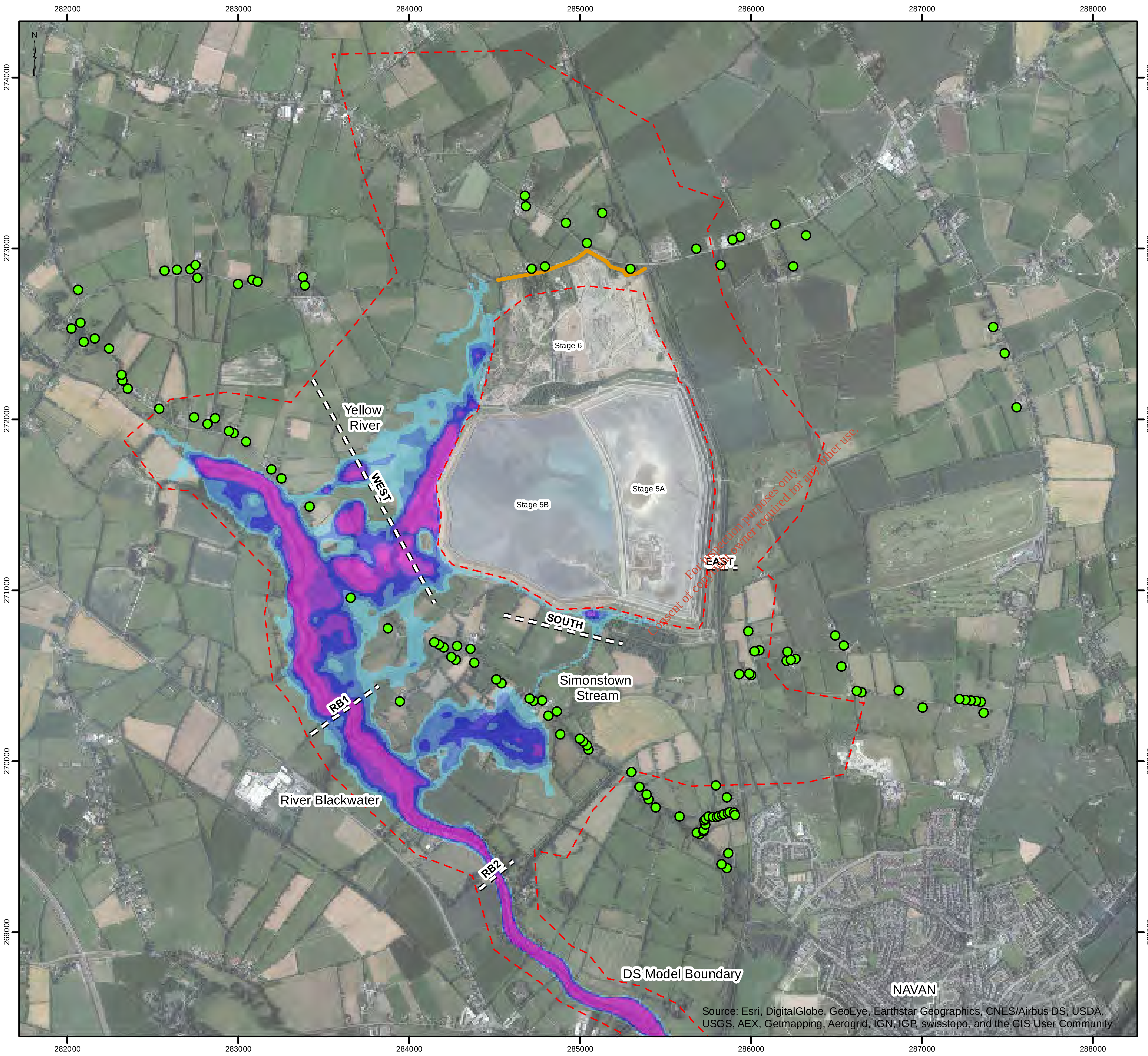
TITLE
STAGE 5A, DAM BREAK EAST, CLOSURE PHASE

CONSULTANT

Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0002	B	5



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500
Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

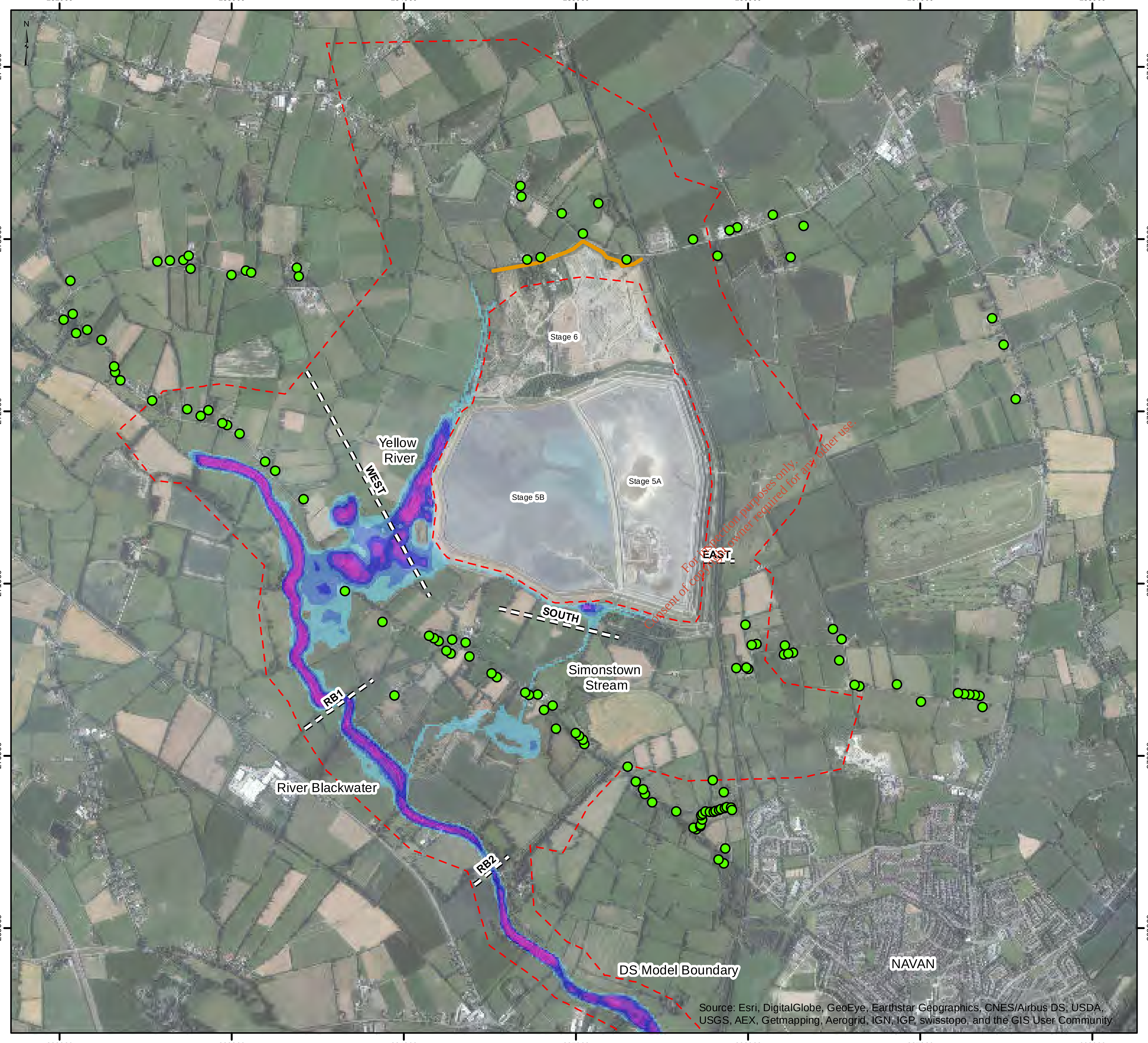
PROJECT
TARA DAM BREAK STUDY 2016

TITLE
STAGE 5B, DAM BREAK WEST, OPERATION PHASE

CONSULTANT
Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0003	B	6



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500
Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

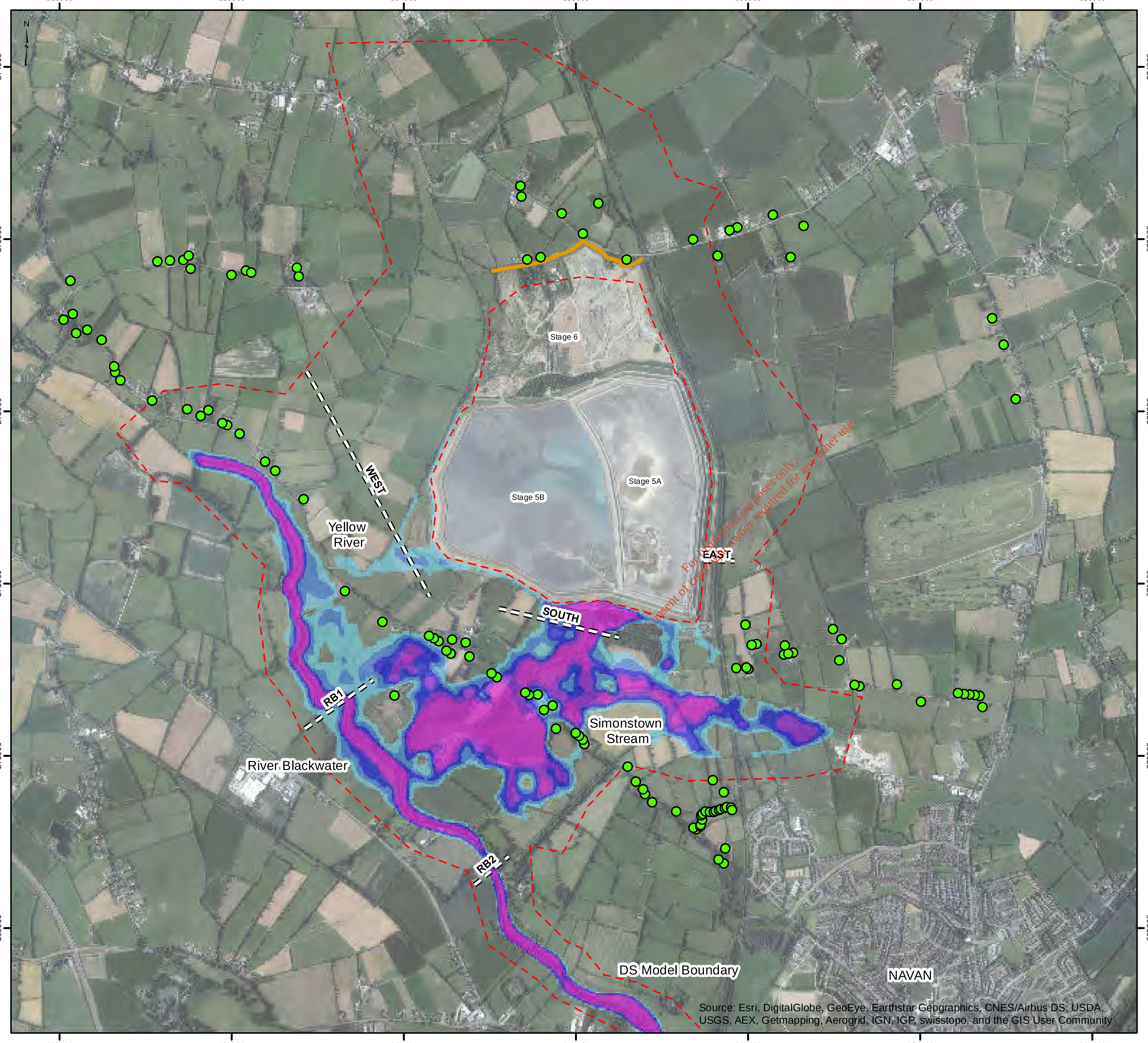
PROJECT
TARA DAM BREAK STUDY 2016

TITLE
STAGE 5B, DAM BREAK WEST, CLOSURE PHASE

CONSULTANT
Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0004	B	7



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500
Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

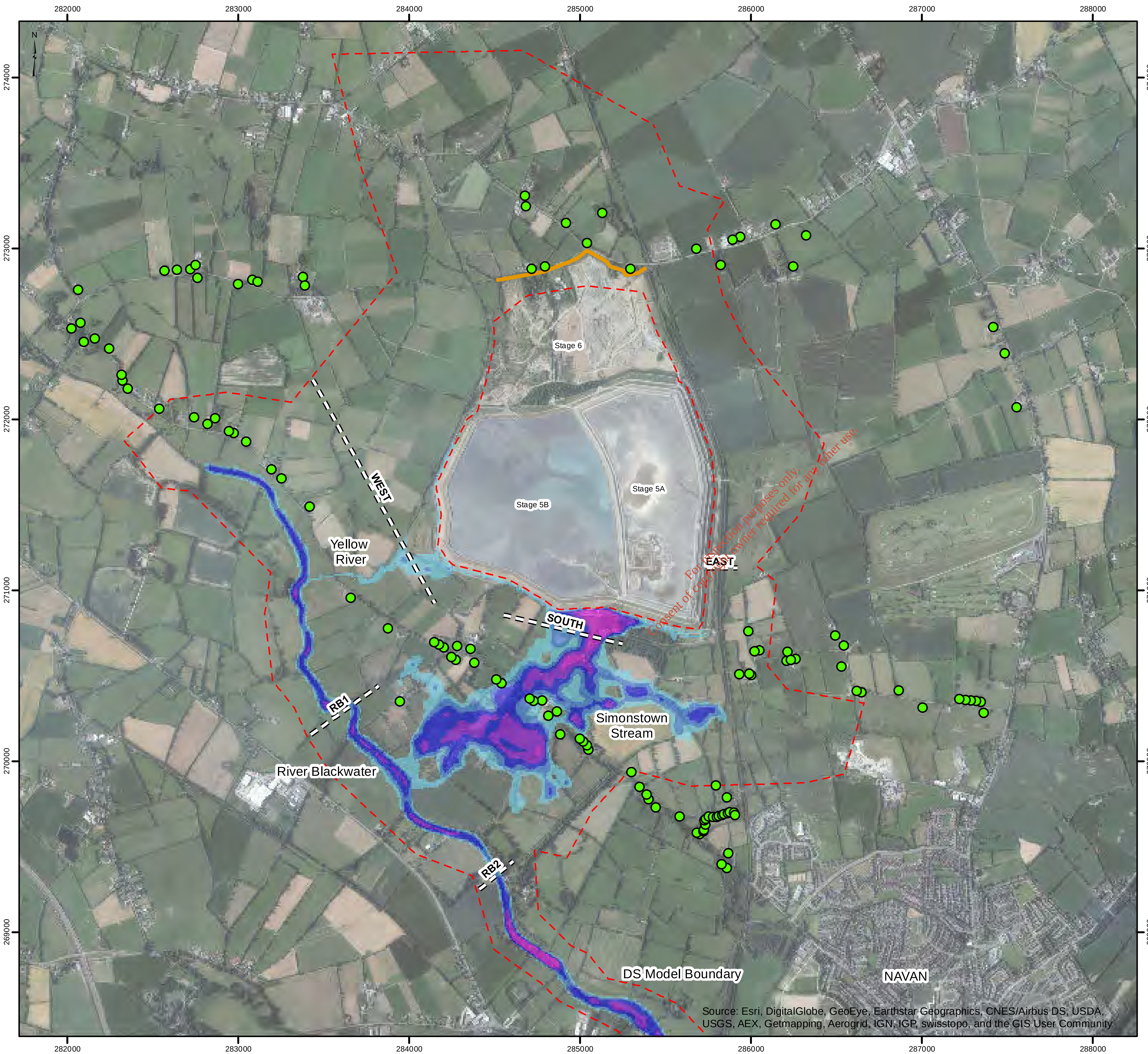
PROJECT
TARA DAM BREAK STUDY 2016

TITLE
STAGE 5B, DAM BREAK SOUTH, OPERATION PHASE

CONSULTANT
Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0005	B	8



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500
Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

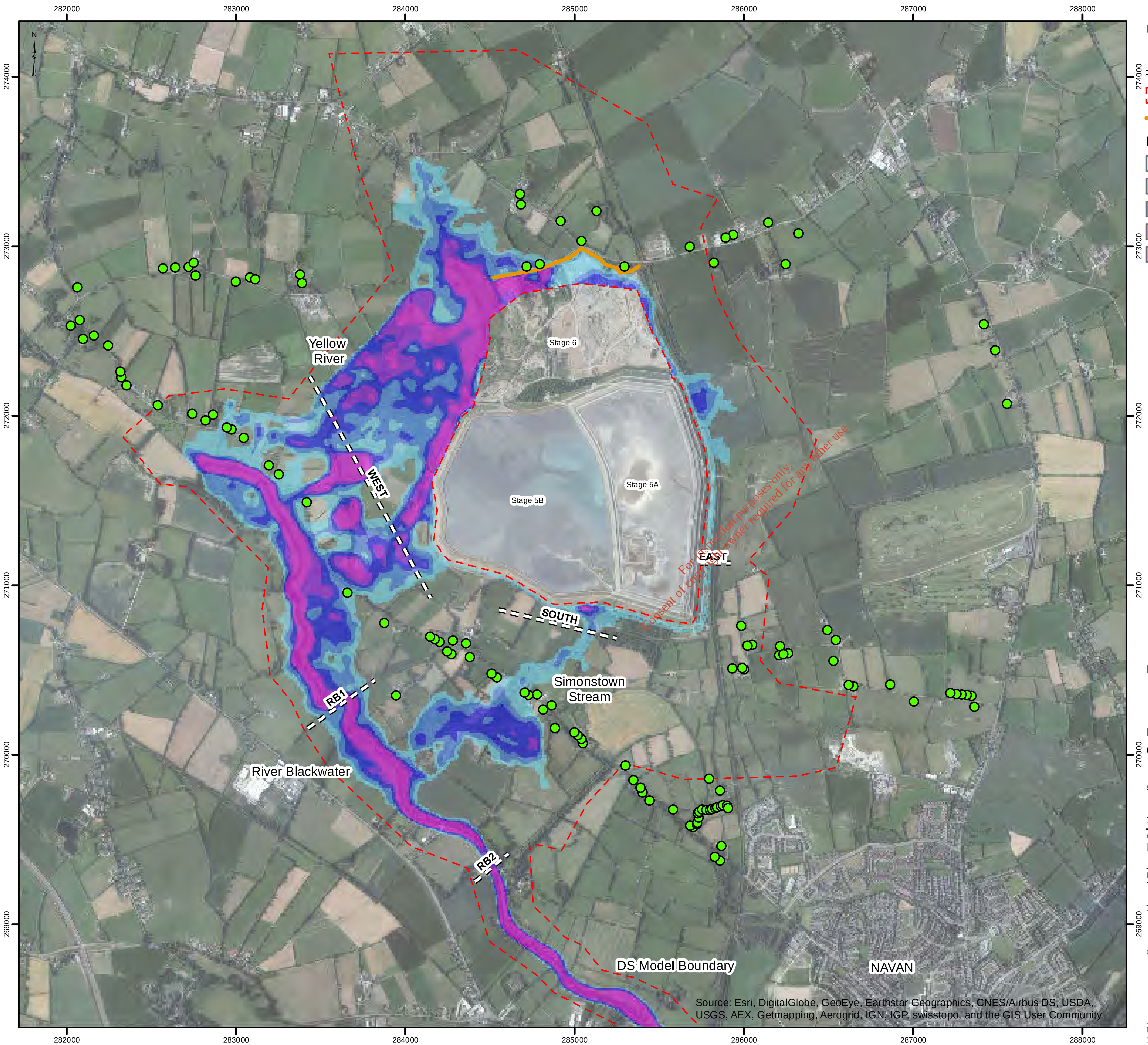
PROJECT
TARA DAM BREAK STUDY 2016

TITLE
STAGE 5B, DAM BREAK SOUTH, CLOSURE PHASE

CONSULTANT
Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0006	B	9



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500
Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

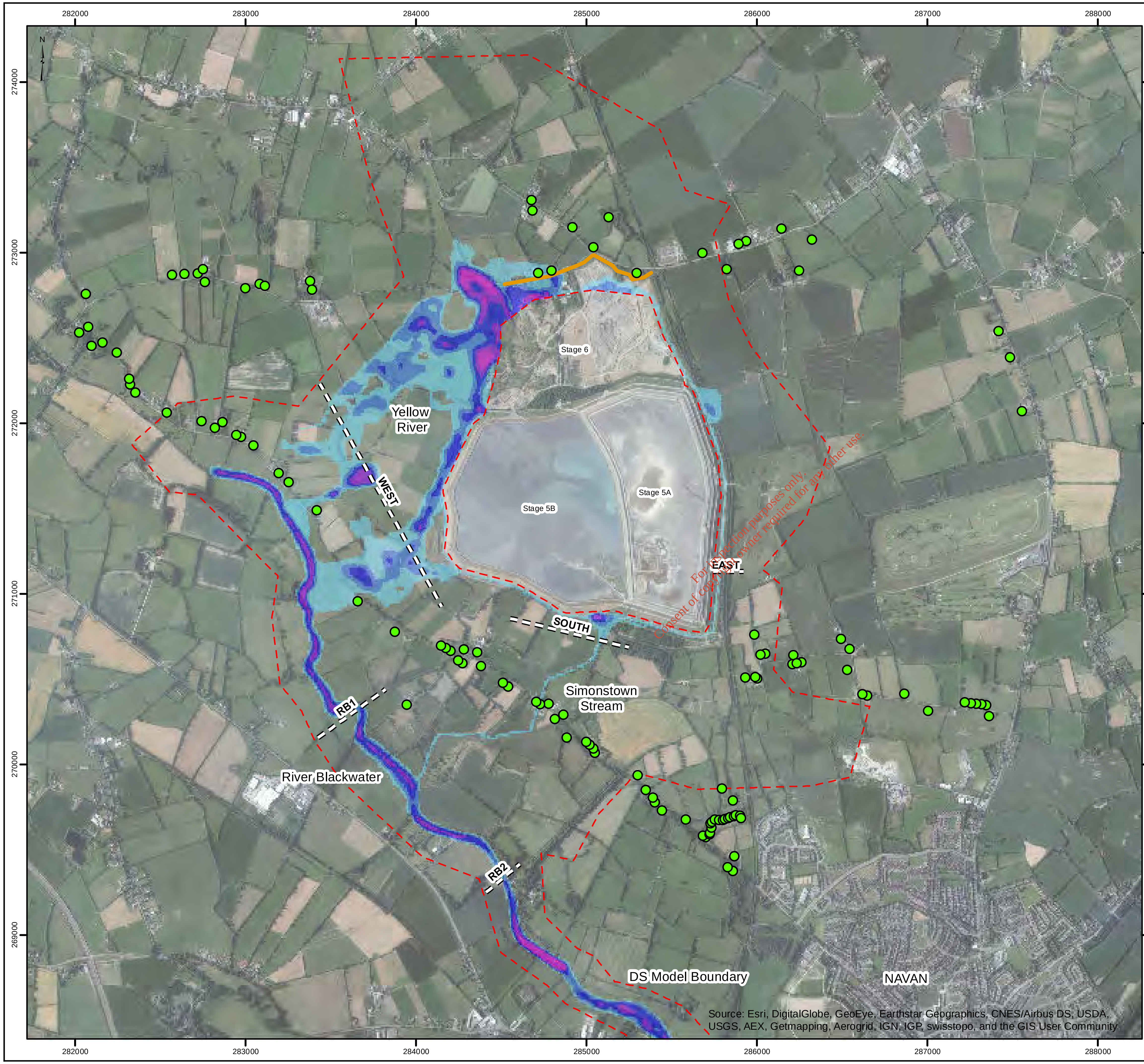
PROJECT
TARA DAM BREAK STUDY 2016

TITLE
STAGE 6, DAM BREAK NORTH-WEST, OPERATION PHASE

CONSULTANT
Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0007	B	10



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500
Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

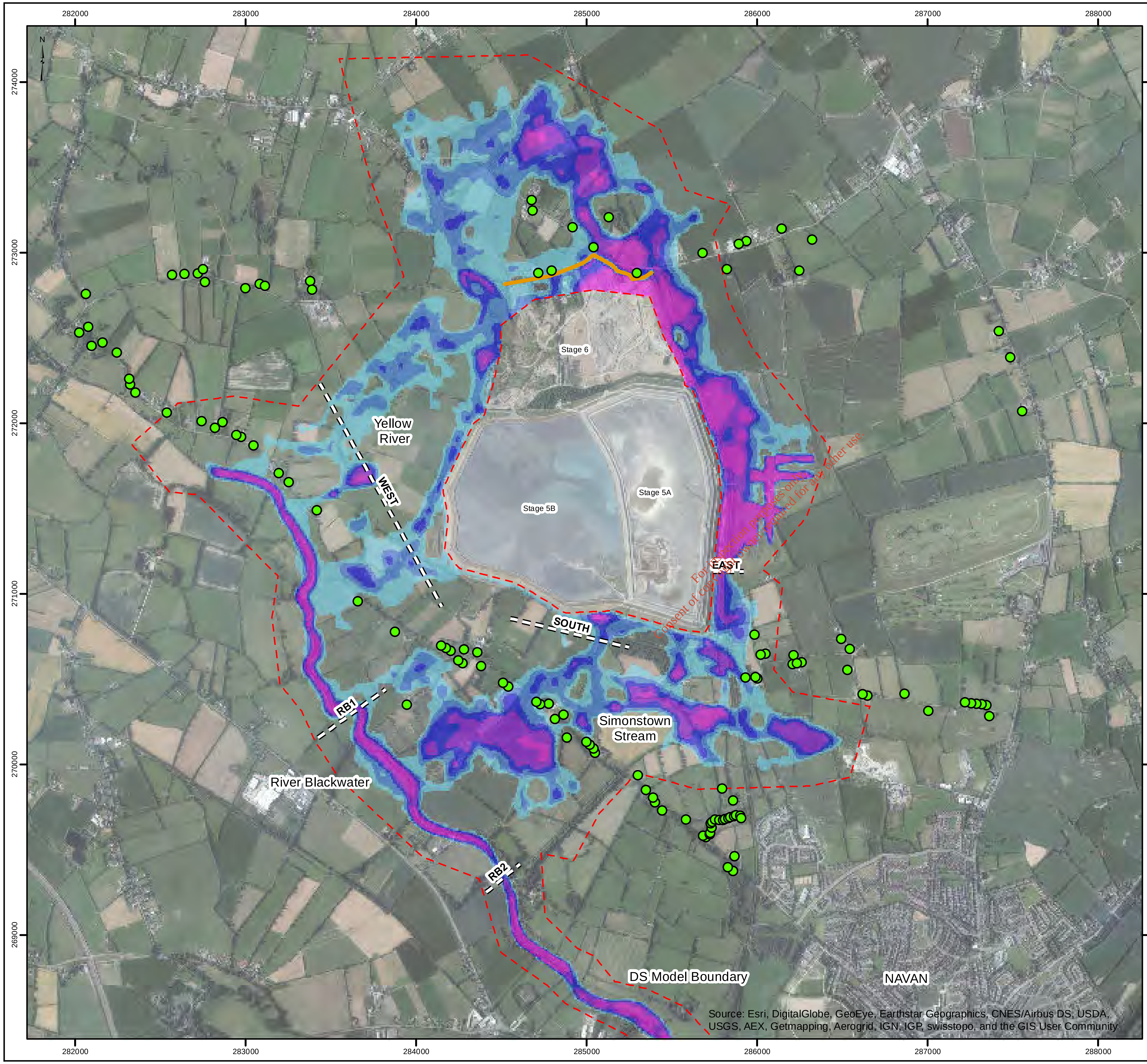
PROJECT
TARA DAM BREAK STUDY 2016

TITLE
STAGE 6, DAM BREAK NORTH-WEST, CLOSURE PHASE

CONSULTANT
Golder Associates

YYYY-MM-DD	08 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0008	B	11



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500 Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

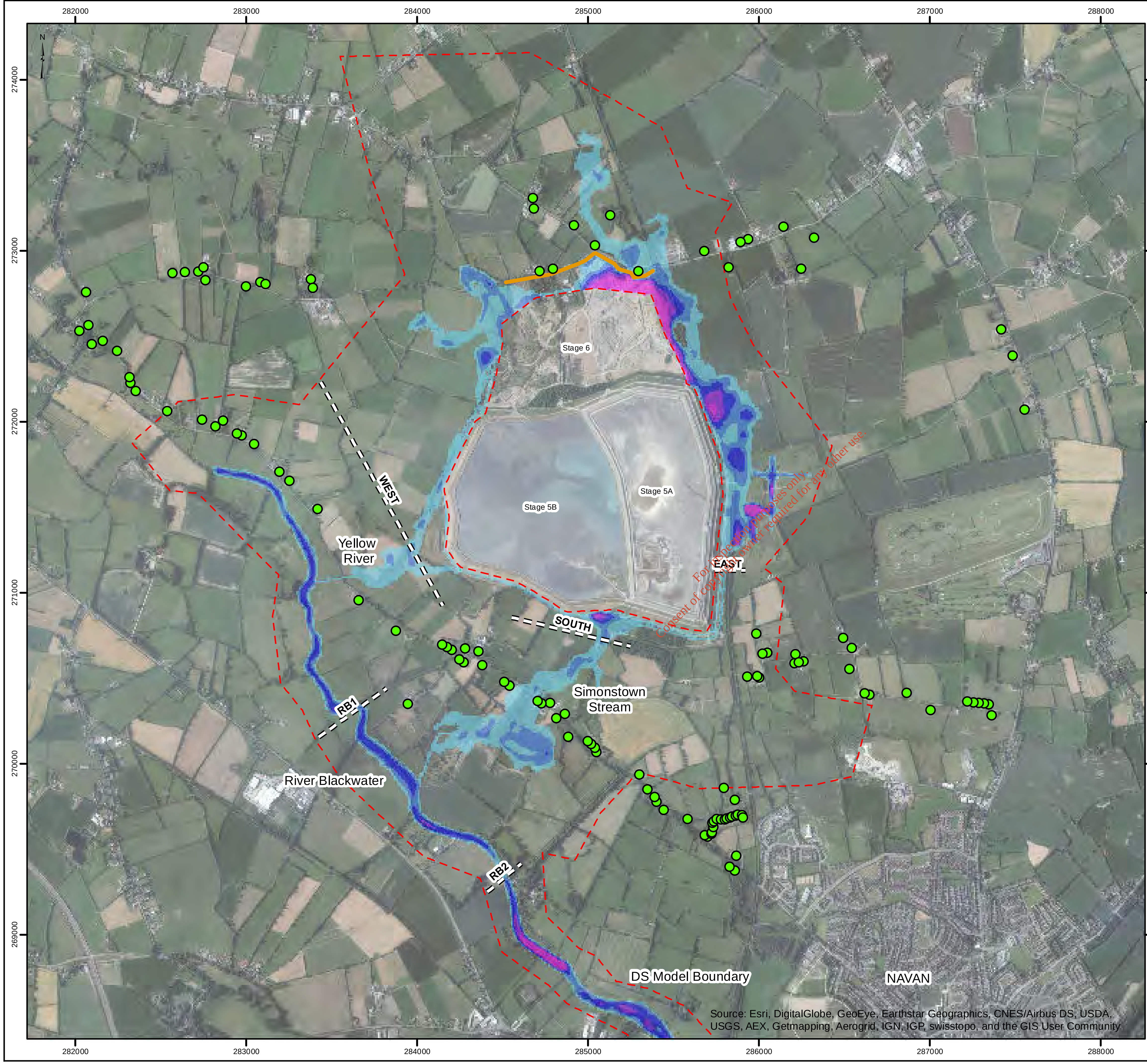
PROJECT
TARA DAM BREAK STUDY 2016

TITLE
STAGE 6, DAM BREAK NORTH-EAST, OPERATION PHASE

CONSULTANT
Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0009	B	12



LEGEND

- Receptor
- Section line (flow)
- Model Boundary
- North embankment

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0+

NOTES

REFERENCE

COORDINATE SYSTEM: TM65 IRISH GRID

500 250 0 500
Meters

1:22,000

CLIENT
BOLIDEN TARA LTD

PROJECT
TARA DAM BREAK STUDY 2016

TITLE
STAGE 6, DAM BREAK NORTH-EAST, CLOSURE PHASE

CONSULTANT
Golder Associates

YYYY-MM-DD	06 JUL 2016
PREPARED	ECS
DESIGN	RE
REVIEW	RE
APPROVED	MG

PROJECT No.	CONTROL	REV	DRAWING
1651706	1001-DB-0010	B	13

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm

APPENDIX B

Dam Break Video Files (CD)

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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Golder Associates

NEW BOLIDEN

Dr. Magnus Amajirionwu
Office of Climate, Licensing and Resource Use.
EPA Headquarters.
Po Box 3000,
Johnstown Castle Estate.
County Wexford.

11th December 2017

Ref: P0 516-04

Dr. Amajirionwu,

Please find response to your request for further information dated November 8th 2017consisting of 2 hard copies and 2 copies on CD-ROM in electronic searchable PDF format.

The content of the electronic file on the accompanying CD-ROM is a true copy of the original.

Yours sincerely,

Paschal Walsh

Paschal Walsh
EHS Manager
Boliden Tara Mines DAC

Response to Further Information Request 08/11/2017

Table of Contents

Item 1

You have included a list of advantages and disadvantages for various alternative tailings disposal method. Please provide a detailed methodology for selecting the most favourable option based on technical, environmental and socio-economic ranking.

Response to Item 1

An evaluation of alternative tailings disposal methods for the Stage 6 development of the Randalstown Tailings Storage Facility (TSF) was undertaken. The objective was to identify and select the most suitable method considering all aspects of the development lifecycle.

Multiple Account Anaylsis (MAA) was chosen as the framework for alternatives evaluation. The MMA process followed and overall outcome is presented in Appendix to FIR item 1.

Item 2

Your correspondence did not clarify the capability to store probable maximum precipitation of appropriate duration (months, not hours). Please demonstrate how the current design incorporates sufficient freeboard to contain design storm rainfall. All duration and return periods used in the design should be selected based on best practice and international guidelines, and this requirement should be demonstrated in your response.

Response to Item 2

As stated in previous correspondence the TMF is classified as a perimeter dam with no external catchment area. What this means is that no external water flows/drains into the facility.

Water can only enter in two ways;

1. As tailings carrying water (pumped from the processing Plant)
2. As precipitation

Water levels in the facility are controlled by continually pumping water back (reclaiming) to the processing plant for reuse or further treatment and discharge.

<u>In the event of a pump failure no water would be pumped to or from the facility.</u>

The facility will operate with a <u>minimum</u> free board of 1 metre, meaning there will be reserve capacity to store 1000mm of water.

And since, in the event of a pump failure there will be no water pumped to the facility then the only way water can enter is as precipitation.

Based on the OPWs Flood Studies Database (Web Portal - http://opw.hydronet.com) available data (Ref Table 1 and Figure 1 below) for the Navan area would suggest that during a 1 in 500 year rainfall event (AEP: 0.2%) over a continuous period of 600 hour (25 days) the maximum potential rainfall depth would be 268.1mm ***c. 27% of the available storage provided by the 1 metre free board.***

The 1000mm of free board would actually provide adequate storage for the

- **Total Annual Average** rainfall over the last 50 years (856 mm) and
- **87% of the Total Maximum Annual** rainfall over the last 50 years (1136 mm) (*not taking account of loss to evaporation which would be c. 40%).*

In other words there is a minimum of 11 months storage capacity at any time.

There is no scenario where the above would not be adequate. The pumps would have to be turned off 11 consecutive months during which time there was the worst recorded rainfall and no loss to evaporation.

Closure Phase

Once the facility is filled the remaining stored water will be pumped off and the closure plan would be enacted.

The closure plan includes provision for a spillway as the reclaim pump will no longer be in operation (Ref; EIS Section 3 Project Description Section 3.8).

Table 1 Rainfall data

Met Eireann
Return Period Rainfall Depths for sliding Durations
Irish Grid: Easting: 285140, Northing: 271549,

	Interval		Years													
DURATION	6months,	1year,	2,	3,	4,	5,	10,	20,	30,	50,	75,	100,	150,	200,	250,	500,
5 mins	2.5,	3.5,	4.0,	4.7,	5.2,	5.6,	6.9,	8.3,	9.2,	10.4,	11.6,	12.4,	13.8,	14.8,	15.6,	N/A ,
10 mins	3.5,	4.8,	5.5,	6.6,	7.3,	7.8,	9.5,	11.5,	12.8,	14.6,	16.1,	17.3,	19.2,	20.6,	21.8,	N/A ,
15 mins	4.1,	5.7,	6.5,	7.7,	8.5,	9.2,	11.2,	13.5,	15.0,	17.1,	19.0,	20.4,	22.6,	24.3,	25.6,	N/A ,
30 mins	5.5,	7.4,	8.4,	9.9,	11.0,	11.7,	14.2,	17.0,	18.8,	21.3,	23.5,	25.2,	27.8,	29.8,	31.4,	N/A ,
1 hours	7.2,	9.7,	10.9,	12.8,	14.1,	15.0,	18.0,	21.4,	23.6,	26.6,	29.2,	31.2,	34.2,	36.5,	38.5,	N/A ,
2 hours	9.5,	12.6,	14.2,	16.5,	18.0,	19.2,	22.9,	26.9,	29.5,	33.1,	36.2,	38.5,	42.1,	44.8,	47.1,	N/A ,
3 hours	11.2,	14.7,	16.5,	19.1,	20.8,	22.1,	26.3,	30.8,	33.7,	37.6,	41.0,	43.6,	47.6,	50.6,	53.0,	N/A ,
4 hours	12.6,	16.4,	18.4,	21.2,	23.1,	24.5,	29.0,	33.8,	36.9,	41.2,	44.9,	47.6,	51.8,	55.0,	57.7,	N/A ,
6 hours	14.8,	19.2,	21.4,	24.6,	26.7,	28.3,	33.3,	38.7,	42.1,	46.8,	50.9,	53.9,	58.6,	62.1,	64.9,	N/A ,
9 hours	17.4,	22.4,	24.9,	28.5,	30.9,	32.7,	38.3,	44.3,	48.1,	53.2,	57.7,	61.1,	66.1,	70.0,	73.1,	N/A ,
12 hours	19.6,	25.0,	27.8,	31.7,	34.2,	36.2,	42.2,	48.7,	52.8,	58.3,	63.1,	66.7,	72.1,	76.2,	79.5,	N/A ,
18 hours	23.1,	29.2,	32.3,	36.7,	39.6,	41.8,	48.5,	55.7,	60.2,	66.3,	71.5,	75.5,	81.4,	85.9,	89.5,	N/A ,
24 hours	25.9,	32.7,	36.0,	40.8,	43.9,	46.2,	53.5,	61.2,	66.1,	72.6,	78.2,	82.4,	88.7,	93.5,	97.3,	110.3,
2 days	32.5,	40.0,	43.7,	48.9,	52.2,	54.7,	62.4,	70.5,	75.5,	82.2,	87.9,	92.1,	98.5,	103.2,	107.0,	119.8,
3 days	38.1,	46.3,	50.3,	55.9,	59.5,	62.1,	70.3,	78.7,	83.9,	90.9,	96.7,	101.1,	107.6,	112.4,	116.3,	129.2,
4 days	43.2,	52.1,	56.3,	62.3,	66.0,	68.8,	77.4,	86.2,	91.6,	98.8,	104.8,	109.3,	116.0,	120.9,	124.9,	138.1,
6 days	52.6,	62.4,	67.2,	73.7,	77.8,	80.9,	90.1,	99.6,	105.4,	113.1,	119.5,	124.3,	131.2,	136.4,	140.6,	154.3,
8 days	61.1,	71.9,	77.1,	84.1,	88.5,	91.8,	101.7,	111.8,	117.9,	126.0,	132.8,	137.8,	145.1,	150.5,	154.8,	169.0,
10 days	69.2,	80.8,	86.3,	93.9,	98.6,	102.0,	112.5,	123.2,	129.6,	138.1,	145.1,	150.3,	157.9,	163.5,	168.0,	182.7,
12 days	76.9,	89.3,	95.2,	103.1,	108.1,	111.8,	122.8,	133.9,	140.6,	149.4,	156.7,	162.1,	170.0,	175.8,	180.4,	195.6,
16 days	91.7,	105.5,	111.9,	120.7,	126.1,	130.1,	142.0,	154.0,	161.3,	170.7,	178.5,	184.3,	192.6,	198.8,	203.6,	219.6,
20 days	105.9,	120.9,	127.8,	137.2,	143.1,	147.4,	160.2,	173.0,	180.6,	190.6,	198.9,	204.9,	213.7,	220.2,	225.3,	242.0,
25 days	123.0,	139.3,	146.9,	157.1,	163.4,	168.0,	181.8,	195.4,	203.6,	214.2,	223.0,	229.3,	238.6,	245.4,	250.8,	268.3,

NOTES:
N/A Data not available
These values are derived from a Depth Duration Frequency (DDF) Model
For details refer to:
'Fitzgerald D. L. (2007), Estimates of Point Rainfall Frequencies, Technical Note No. 61, Met Eireann, Dublin',
Available for download at www.met.ie/climate/dataproducts/Estimation-of-Point-Rainfall-Frequencies_TN61.pdf

OPW Flood Studies Update Web Portal - http://opw.hydronet.com

Rainfall Frequency Tool
Duration = 25 days = 600 hours

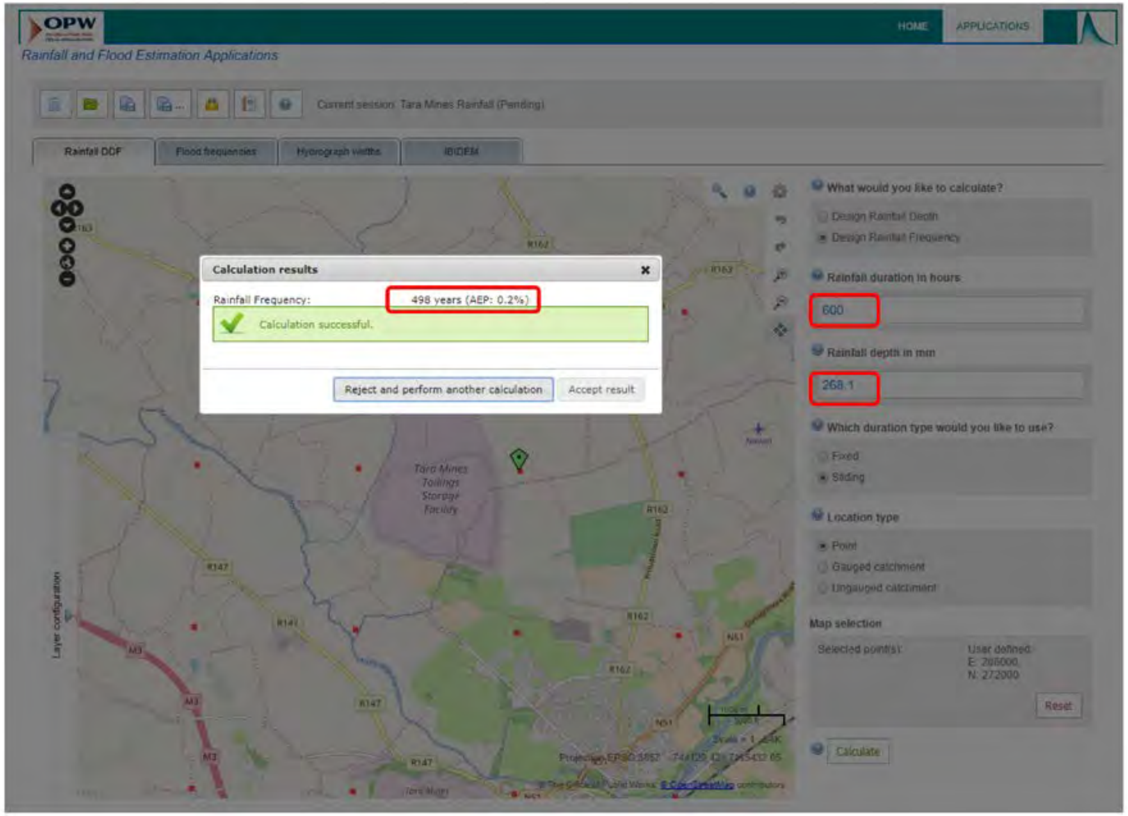

Figure 1 OPW Rainfall and Flood Estimation data

Item 3

Your correspondence referred to "a very extreme scenario which is unlikely to develop." The analyses suggest that although "unlikely" it is possible that the embankment will be unstable. Please provide a comprehensive (dynamic) analysis undertaken to confirm that the proposed embankment will be stable under "all" conditions.

Response to Item 3

Comprehensive (empirical dynamic) analysis to determine the settlement of the stage 6 dam walls under seismic conditions has been undertaken By Golder Associates and is presented in Appendix to FIR Item 2.

Dynamic response analysis was carried out using the finite element programme Midas GTS NX. Three different sets of ground acceleration time history were used in the analysis to cover a wide range of response spectrum in ground motion simulation.

The analysis results indicate the level of deformation of the tailings dam during and after a maximum credible earthquake (MCE) event would not impact the integrity of the dam wall and therefore is considered satisfactory.

In addition **Pseudo Static Stability** analysis carried out based on a MCE with a peak ground acceleration (PGA) of 0.06g is 1E-4 or a 1 in 10,000 year event (occurrence) or as given 'very unlikely' to occur. This analysis is presented in the *BTM Design for the Stage 6 TMF* document.

Item 4

On why the interceptor channel used to collect and discharge seepage water into the water treatment system is not fully lined, it was stated that "if monitoring indicates contaminates in excess of the discharge limits in the interceptor channel then the perimeter interceptor would be lined. " Please confirm that the TMF design includes lining of the interceptor channel to prevent any potential contamination.

Response to Item 4

The Stage 6 facility will be composite lined with a 2mm HDPE geomembrane and a geosynthetic clay liner (GCL) designed to contain both the tailings solids and water (the lining system will undergo a leak detection survey prior to commissioning).

Any seepage passing through defects in the lining system will mix and be diluted with ground water. Ground water flow will be intercepted by the perimeter interceptor channel. Refer to Figure 2

The perimeter interceptor channel will collect surface water runoff from the dam walls, perimeter road and borrow areas. Seepage volumes will be insignificant when compared with the clean surface water runoff from the downstream slopes of the embankment walls and surroundings (Ref EIS Section 3 Project Description, Section 3.6).

During winter, sections of the perimeter interceptor channel will intercept the groundwater as it rises and this will be monitored for quality.

The perimeter interceptor channel will discharge into the existing (Stage 5) east and west perimeter interceptor channel and will be pumped back into the active dam (Stage 5) from where it will be reclaimed to the processing plant.

<u>The interceptor channel would not intercept ground water flow if it were lined.</u>

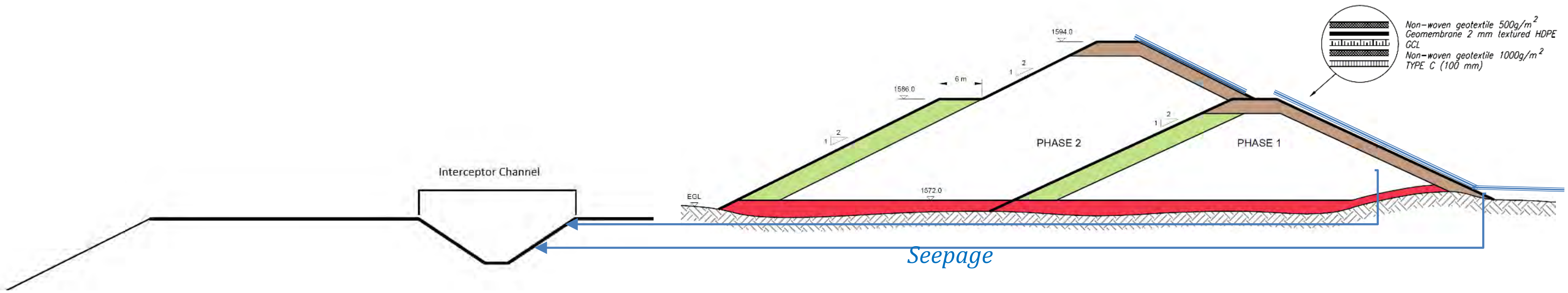

Figure 2 Section embankment walls and perimeter interceptor channel.

Item 5

The need for large quantities of construction material is noted. Table 2.3 of the CRAMP provided with the application indicates a total soil requirement of 672,616m3 and a need to import 170,616m3 for the capping of stages 5 and 6. Table 3.5 of the EIS for the stage 6 extension indicates a total granular rock requirement of 1,738,578m3 some of which will need to be imported as indicated by your text in section 3.2.2.4.

Imported soils and stones will either be quarried by others for the purpose of sale and supply to you, or will be generated as a result of excavations linked to construction projects. Material sourced from the latter will be classified as waste or by-product, depending on the circumstances of the supply contract.

Item 5(a):

In relation to imported material other than that produced by quarries, please state the total quantity of soil and stone, whether classified as waste or by- product, that will be imported for the purpose of capping and construction.

Response

The total quantity of soil and stone, whether classified as waste or by- product, that will be imported for the purpose of capping and construction is **987,528 m^3**

Part 1 Materials Required

Table 1 Materials Required for Closure (m^3)

Description	**(m^3)**	**Total Qty. (m^3)**
Closure Stage 5 Soil	472,950	
Closure Stage 5 Rock	59,000	
Closure Stage 6 Soil	199,666	
Closure Stage 6 Rock	43,560	
(A) Total Closure Soil		**672,616**
(B) Total Closure Rock		**102,560**
Closure Total (A+B) = (C)		**(C) 775,176**

Table 2: Materials Required for Construction (Ref; EIS, Section 3.24, Table 3.5)

Description	Total Qty. (m^3)	
Upstream Wall Construction	234,288	
Downstream Wall Construction	225,550	
Random Fill	1,034,449	
	(D) Total soil/subsoil	**1,494,287**
Road Surfacing	9,958	
Protection Material	60,352	
Drainage	5,000	
Dam Footprint Drainage	208,982	
Coarse Drainage	5,000	
	(E) Total Rock	**289,292**
Construction Total (D +E) = (F)		**(F) 1,783,578**

Total Soil Required (A + D) = (G) 2,166,903 m^3
Total Rock Required (B + E) = (H) 391,852 m^3

Grand total required for Closure and Construction (G +H) = (I) 2,558,755 m^3

Part 2 Materials Available

Table 3 Material available in borrow areas (Ref; BTM Design TMF Table 3)

Material Type	Quantity (m^3)
Rock	486,000
Soil	812,000
Total Available in borrow pits	**(J) 1,298,000**

Material Imported[1] and stockpiled between Apr '16 - Nov '17 = **(K) 273,227 m^3.**

Grand Total available (J + K) = (L) 1, 571,227m^3

Part 3 Shortfall of materials

The total quantity of soil and stone, whether classified as waste or by- product, that will be imported for the purpose of capping and construction is

Total Required (I) - Total Available (L) = Shortfall (M)

(I) 2,558,755 - (L) 1,571,227 = (M) 987,528 m3

[1] Condition 8.12.22 of the Company's existing IE Licence

Item 5(a):

Please state whether authorisation is sought in a revised licence to import construction and demolition waste or materials made from construction and demolition waste. Please specify the quantity of material proposed to be accepted and its proposed uses.

Response

Yes, the Company is seeking authorisation in its revised licence to import construction and demolition waste or materials made from construction and demolition waste.
BTM will continue to source suitable recovered material [2] to meet requirement for construction and closure.

BTM believe that the conditions in its current licence are sufficient to cover the importation of suitable construction and rehabilitation materials:

- Condition 8.12.22 of the Company's existing IE Licence states that "Subject to prior agreement by the Agency the licensee can use recovered material(s) at the TMF".

- Condition 8.13.3 of the Company's existing Industrial emissions Licence states that "Subject to prior agreement by the Agency the licensee can use recovered material(s) for closure and aftercare at the landfill.

[2] Material that has been recovered and/or prepared from waste and is fit for purpose for the operation, maintenance and/or long-term rehabilitation of the TMF.

Appendix to FIR Item 1

- **Evaluation of Alternative Tailings Disposal Methods using Multiple Accounts Analysis (MAA)**

An Evaluation of Alternative Tailings Disposal methods using Multiple Accounts analysis (MAA)

The objective of this process was to evaluate different tailings disposal alternatives and identify and select the most suitable method taking into consideration all aspects of the development life cycle (from construction through operation, closure & rehabilitation).

Multiple Accounts Analysis (MAA) was used as a means of effectively evaluating different alternatives. This process allowed the comparison of the alternatives to allow for selection of the most suitable, or advantageous, method of tailings deposition.

The evaluation was undertaken by a project team which included representatives from;

- ***Golder Associates*** (Consulting Engineers Design Stage)
- Boliden Group Technical Department
- Boliden Tara Mines (BTM) Environmental Department
- BTM Processing Department

The MAA process involved the following steps:

- Step 1: Identifying Alternatives;
- Step 2: Screening of Alternatives;
- Step 3: Characterisation Criteria;
- Step 4: Multiple Accounts Ledger; and
- Step 5: Value-Based Decision process.

An important consideration/factor in the assessment was the distance between the concentrator/processing plant at *Knockumber* and all viable locations. Tailings would have to be pumped a minimum of 3km.

Step 1: Identifying Alternatives

Four alternative tailings disposal methods were selected.

The selection was narrowed to four generic tailings disposal alternatives commonly used in the mining industry. Options including for example 'deep water disposal' were simply not considered as they are not viable in this situation.

The primary difference between the alternatives relates to the solids content of tailings. This is presented in Table 1.

Table 1: Stage 6 Tailings Disposal Alternatives

Alternative Options	Tailings Disposal Plan	Solids content %
Option1	Slurry Deposition	10 to 60
Option 2	Thickened Tailings	60 to 70
Option 3	Surface Paste Tailings	70 to 80
Option 4	Filtered Tailings	80 to 90

The consistency of each alternative method is illustrated in Figure 1.

Figure 1: Consistency of Tailings Disposal Alternatives

Step 2: Screening of Alternatives

A screening assessment of alternatives was undertaken. Screening is the first step in eliminating alternatives that are either flawed or not site suitable.

A basic 'set of criteria' was adopted based on considerable experience of experts in the project team;

- Will there be adequate water storage[1]?
- Will the disposal method suitable for Tara tailings (particle size distribution)[2]?
- Will it provide adequate water treatment?
- Is it suitable in a lined facility?
- Potential environmental impact (air / noise / light / energy use)?
- Is there additional construction requirements?
- Will it result in positive project economics?

The screening assessment is presented in Table 2.

Following the screening stage, Option 4 (the filter cake option) was eliminated from further evaluation, due to a number of reasons but primarily;

- potential mechanical damage to the lining system from either trucks or conveyor system,
- insufficient storage capacity to manage storm events
- having the greatest negative environmental impacts.

The three remaining alternatives were carried through assessment via MAA technique.

Option 1: Conventional slurry disposal
Option 2: Thickened disposal (Thickener plant located at Knockumber processing plant)
Option 3: Paste disposal (Paste plant located at Randalstown).

[1] TSF acts as a repository for solids and as a reservoir for water used in the process
[2] Coarse fraction tailings are used to hydraulically backfill underground stopes. The fines tailings (slimes) are deposited in TSF. When backfilling is not required, total tailings (sand and slimes) are discharged to TSF

Step 3: Characterisation of Alternatives

MAA requires selection of the most important criteria to allow for a relative comparison between alternatives.

In this instance four broad categories of issues were defined, referred to as main ***accounts***[3] ***;***

1. **Technical Account** (focusing on engineering elements)
2. **Environmental Account** (focusing on environmental issues raised during the consultation process)
3. **Socio-Economic Account** (focusing on aesthetics and employment)
4. **Project Economics Account** (focusing of the life of project economics)

In turn, all stakeholder issues, referred to as '***sub-accounts'***[4] , were grouped under one of the main accounts.

Subaccounts are defined as any material impact (benefit or cost) associated with any of the alternatives being evaluated.

Within each sub-account, an 'indicator value' of the issue is defined to give a clear understandable description of the impact.

It should be noted that while some were straightforward and quantitative (such as project economics) others were more difficult to accurately describe / quantify and are qualitative (such as water quality).

Characterisation criteria for each sub-account are presented in Table 3.

[3] Technical, Environmental, Socio-economics and project economics
[4] Any material impact (benefit or cost) associated with any of the alternatives being evaluated

Step 4: Multiple Accounts Ledger

MAA requires a 'multiple accounts ledger' to be developed.

All accounts and subaccounts are listed on the MAA ledger.

When the ledger was completed, numerical evaluations were undertaken.

Step 5: Value-Based Decision Process

A 'value-based' decision process was used involving scoring and weighting analysis.

Since separation of the alternatives may be either very slight or very significant a **Scaled Value (S)** was assigned to each alternative with respect to indicator of each subaccount. A five point scale (1 to 5) was used where the higher value indicated the better option.

Then a **Weighting factor (W)** was applied to all indicators in the ledger to distinguish the relative 'importance' of each account and sub-account.

A weight of '5' indicated a 'high value' of importance; while a '1' value indicated 'low value' or low relative importance.

The weighting factors approved by the project team are presented in Table 4.

MMA Outcome

The cumulative 'score' of one alternative compared to another in any subaccount was obtained by;

> Adding together the products of Scalar Value and Weight of indicator in each subaccount and normalising by dividing by the sum of weights for the indicator of that subaccount.

$$\textbf{Sub-Account Score} = \frac{\sum \ \textit{[Scalar Values X Weights of indicator]}}{\sum \ \textit{Weights of indicator}}$$

The higher the score, the more favorable the alternative in any one category.

The process of adding together the sub-account scores to obtain the account scores for the four accounts and the overall MAA score follows the same procedure of weighting and normalisation. The numerical evaluation is presented in Tables 5 and 6.

A summary of the Overall MAA Score is:

- Option 1 : Slurry tailings disposal 3.85
- Option 2 : Thickened tailings disposal 3.22
- Option 3 : Paste tailings disposal 2.30

Summary and Conclusion

Four tailings disposal alternatives were identified for the Stage 6 TSF development. MAA was used as a means to effectively evaluate different alternatives.

Three alternatives were carried through assessment process:

Option 1 : Slurry tailings disposal

Option 2 : Thickened tailings disposal

Option 3 : Paste tailings disposal

Numerical evaluations were undertaken and the alternative with the highest overall score indicating the most favorable method.

It was concluded that Option 1, slurry deposition, was the most suitable, or advantageous, method for tailings deposition.

Table 2: Screening Assessment

Pre-Screening Criteria	Option 1 (Slurry)	Option 2 (Thickened)	Option 3 (Paste)	Option 4 (Filtered)
Will it provide for water Storage[5]	Yes	Yes	Yes but paste will be discharged under water	No – separate water storage required
Is disposal method suitable for Tara Tailings	Yes – Slimes and total tailings readily sent to TSF	No – Slimes and total tailings will behave differently in the thickener	No – Slimes and total tailings will behave differently in the paste plant	No – Slimes and total tailings will behave differently in the filter plant
Will it provide for water treatment	Yes – greater volume of water increases settlement time therefore less metal concentration	Yes but with less water volume = higher concentration	Yes but with less water volume = higher concentration	Yes but much lower water volume = higher metal concentration
Suitable for discharge in lined facility	Yes, liner readily protected	Yes, liner readily protected	Yes, liner readily protected	No - liner difficult to protect from conveyor system / trucks
Environmental impacts	No additional noise or additional lighting required. Tailings in saturated conditions – not prone to dusting	Additional electrical energy required for thickener. Noise and light generated from plant running 24 hours. Tailings prone to dusting	Additional electrical energy required for paste plant. Noise and plant generated for plant running 24 hours. Tailings prone to dusting	Additional electrical energy required for filter plant. Noise generated form plant running 24 hours. Tailings prone to dusting
Additional Construction Requirements	No	Yes (dewatering of tailings by thickener)	Yes (dewatering of tailings by deep cone thickener)	Yes (dewatering of tailings by mechanical or vacuum press)
Positive Project Economics	Yes	Yes	No	No
Should alternative be excluded from further Assessment	No	No	No	Yes

[5] The TSF also acts as a water reservoir

Table 3: Characterisations criteria for each account of the alternatives

Characterisation Criteria	Indicator Value	Option1 (Slurry)	Option 2 (Thickened)	Option 3 (Paste)
Technical				
Physical characteristics of tailings	Tailings pumped to TSF are both slimes and total tailings separately	Deposited as slurry	Deposited as thickened tailings	Deposited as paste tailings
Supporting infrastructure design	Dewatering of tailings by thickeners	No requirements	Thickener Plant at the Processing site. Pumping to TSF at increased pressure - new pipeline and pumps required. Thickener plant will need to be designed for both slime and total tailings	Paste plant at the TSF. Increased pumping pressure - additional pipelines and positive displacement pumps required. Paste plant will need to be designed for both slime and total tailings
Tailings delivery and deposition system design	Delivery and deposition design	Current disposal method	New delivery pipe line on the crest required	New delivery pipe line on the crest required
Beach slope angle	Impact on storage capacity and closure design	Flatter beaches obtained from slurry which maximises storage capacity	Beach slope angle is generally higher compared to slurry deposition resulting in a potential loss of storage due to steeper slope.	Beach slope angle is generally higher for Paste tailings compared to thickened deposition resulting in a potential loss of storage due to steeper slope.
Water management system design	TSF acts as water reservoir – storage required	No additional requirements	No additional requirements	No additional requirements but paste could end up being placed under water
Closure design	Plan to cap with soil and vegetate.	Requires longer time for surface tailings to desiccate	Requires shorter time for surface tailings to desiccate	Requires shortest time for surface tailings to desiccate
Precedent	Proven method	Method adopted for past 40	Unknown in Tara context -	Unknown in Tara context -

Characterisation Criteria	Indicator Value	Option1 (Slurry)	Option 2 (Thickened)	Option 3 (Paste)
		years	will depend on ability of thickener to manage two tailings streams	will depend on ability of paste plant to manage two tailings streams
Technical risks	Failure of operation	Simplest to operate and least technical risk	Relatively simple to operate and additional risk managed at plant site	Maintaining paste consistency is main risk and contingencies required for any variation in solids content.
		Environmental		
Geochemical characterisation of tailings	Acid generating potential of tailings	No impact - tailings not acid generating	No impact	No impact
Atmospheric issues	Dust Blow	Tailings maintained in saturated condition	Prone to dusting in dry weather - extensive sprinkler system required	Prone to dusting in dry weather - extensive sprinkler system required
Overall affected land footprint of impoundment	Difference in footprint size	Has maximum footprint area	Potentially less footprint area	Potentially least footprint area
Water Treatment	TSF is integral part of existing water management system	Greatest volume of water to be treated (high volume, low concentration)	Less volume of water to be treated (medium volume, medium concentration)	Least volume of water to be treated (low volume, high concentration)
Environmental risks	Impact of failure	Potentially greater volume of water on Stage 6 and therefore the consequences of failure are higher	Potentially less volume of water on Stage 6 and therefore the consequences of failure are lower	Potentially less volume of water on Stage 6 and therefore the consequences of failure are lower
Energy Usage	Energy requirements	High energy usage associated with pumping slurry.	Higher energy requirement to manufacture and construct thickener, replace	Higher energy requirement to manufacture and construct paste plant,

Characterisation Criteria	Indicator Value	Option1 (Slurry)	Option 2 (Thickened)	Option 3 (Paste)
			pipeline and existing pumps. Potentially less energy to pump thickened tailings due to less water in the circuit	replace pipeline and existing pumps. Potentially more energy to pump paste tailing with positive displacement pumps.
Noise Pollution	During operation	None	None (If thickener plant is located on the main processing plant)	Noise source from paste plant (24hour operation) located at TSF site
Light Pollution	During operation	None	None (If thickener plant is located on the main processing plant)	Lighting required at paste plant during periods of darkness could be a nuisance to neighbours
Wildlife and habitat	Positive Ecological benefit - Value of land, water, aquatic, bird or terrestrial species,	Greatest ecological value – larger area of open water providing a habitat for large number of birds including migrating whooper swan and golden plover	Potentially less area of open water = potentially less habitat = less bird numbers	Potentially least area of open water = potentially less habitat = less bird numbers
		Social		
Archaeology	Risk of unidentified sites	No impact	No impact	No impact
Perception	Familiarity	Same as current facility	Some unknowns	Some unknowns
Aesthetics	Visual Impact of development – site location same for each alternative	As current operation	As current operation Provided thickener is located at the plant site	Potential 3 story high paste plant at TSF which will be fully lit during times of darkness
Employment	Short and long-term opportunities	No change in labour levels during operation	Short term increase in employment opportunities	Short term increase in employment opportunities

Characterisation Criteria	Indicator Value	Option1 (Slurry)	Option 2 (Thickened)	Option 3 (Paste)
			in manufacturing and installing thickener, pipes and pumps. No change in labour level during operation	in manufacturing and installing paste plant, pipes and pumps. Minimum of 2 increase in labour level during operation
Project Economics				
Capital Expenditure	Material and construction costs	Least expensive	Less expensive	Most expensive
Operational Expenditure	Consumables, energy and labour costs	Least expensive	Less expensive	Most expensive
Closure Cost	Material and construction costs	Most expensive	Less expensive	Least expensive

Table 4: Weightings of indicators in Accounts and Sub-Accounts

Account	Weight	Sub Account	Score
Technical Issues	4	Physical characteristics of the tailings	5
		Supporting infrastructure design	3
		Tailings delivery and deposition system design	3
		Beach slope angle	3
		Water management system design	5
		Closure design	3
		Precedent	5
		Technical risk	5
Environmental Issues	5	Atmospheric issues	5
		Overall affected land footprint size of impoundment	3
		Water Treatment	5
		Environmental risk	5
		Energy Usage	3
		Noise	5
		Light	3
		Wildlife and habitat	3
Socio-Economics Issues	3	Perception	4
		Aesthetics	5
		Employment	3
Project Economic	3	Capital Cost	5
		Operating Cost	3
		Closure Cost	5

Table 5 Numerical Evaluation

Account	Sub-Account	Weight	Slurry	Thickened	Paste	Slurry	Thickened	Paste
			Ranking			Score		
Technical Issues	Physical characteristics of tailings	**5**	5	4	3	25	20	15
	Supporting infrastructure design	**3**	5	3	1	15	9	3
	Tailings delivery & deposition design	**3**	5	3	1	15	9	3
	Beach slope angle	**3**	5	4	3	15	12	12
	Water management system design	**5**	5	4	1	25	20	5
	Closure design	**5**	1	4	5	5	20	25
	Precedent	**5**	5	3	1	25	15	5
	Technical risk	**5**	5	3	1	25	15	5
Sub-Account Totals		**32**				**148**	**104**	**81**
Sub-Account Score						**4.63**	**3.50**	**1.80**
Environmental Issues	Atmospheric issues	**5**	5	3	1	25	15	5
	Overall affected land footprint	**3**	1	3	4	3	9	12
	Water Treatment	**5**	1	3	5	5	15	25
	Environmental risk	**5**	1	3	5	5	15	25
	Energy Usage	**3**	5	3	1	15	9	3
	Noise	**5**	5	4	1	25	20	5
	Light	**3**	5	4	1	25	20	5
	Wildlife and habitat	**3**	5	3	1	15	9	3
Sub-Account Totals		**32**				**108**	**104**	**81**
Sub-Account Score						**3.38**	**3.25**	**2.53**

Account	Sub-Account	Weight	Slurry	Thickened	Paste	Slurry	Thickened	Paste
			Ranking			Score		
Socio-Economic Issues	Perception	**4**	5	3	1	20	12	4
	Aesthetics	**5**	5	3	1	25	15	5
	Employment	**3**	1	3	5	3	9	15
Sub-Account Totals		**12**				**48**	**36**	**24**
Sub-Account Score						**4.00**	**3.00**	**2.00**
Project Economics Issues	Capital Cost	**5**	5	3	1	25	15	5
	Operating Cost	**3**	5	3	1	15	9	3
	Closure Cost	**5**	1	3	5	5	15	25
Sub-Account Totals		**13**				**45**	**39**	**36**
Sub-Account Score						**3.46**	**3.00**	**2.77**

Table 6 Numerical Evaluation

Account	Weight	Slurry	Thickened	Paste	Slurry	Thickened	Paste
		Sub Account Score			Score		
Technical Account	4	4.63	3.50	1.80	19	14	8
Environmental Account	5	3.38	3.25	2.53	17	16	13
Socio-Economic Account	3	4.00	3.00	2.00	12	9	6
Project Economics Account	3	3.46	3.00	2.77	10	9	8
Account Total	15				58	48	34
Overall MAA Score					**3.85**	**3.22**	**2.30**