Appendix D

Seepage Modelling

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D-1 Introduction

This Appendix outlines the seepage modelling undertaken for specific waste rock stack (WRS) areas for the Macraes Phase 4 Fast Track Approvals project. An overview of the project's location and description is provided in Sections 1 and 2 of the "Macraes Phase 4 FTA – Surface and Groundwater Assessment" report. of which this Technical Memorandum is included as Appendix A. Limitations and assumptions detailed in Section 1 of the "Surface and Groundwater Assessment" are applicable to this Appendix.

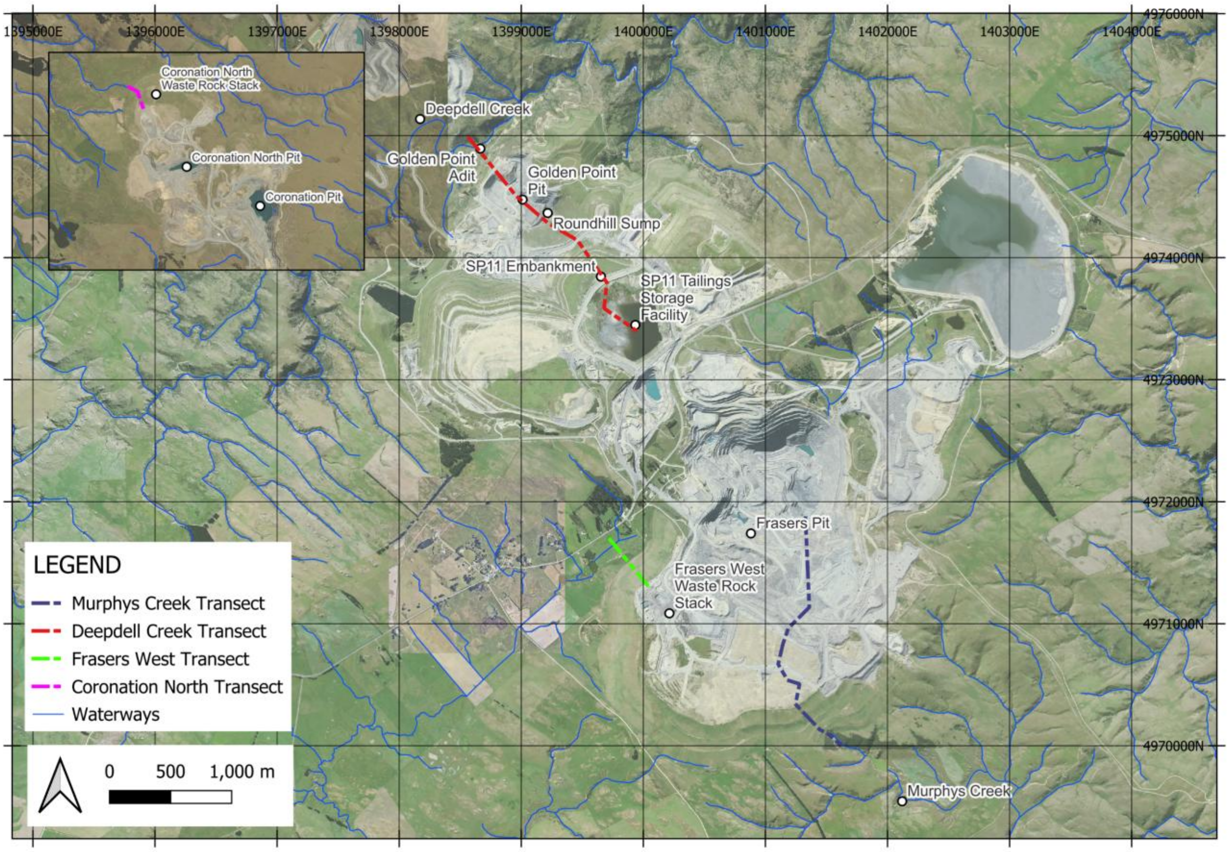


Figure D-1.1 Site plan showing both the Deepdell Creek (red) and Murphys Creek (dark blue) Transects used for 2D-modelling, the creek locations and critical mine infrastructure locations.

D-2 Seepage Modelling – Deepdell Adit

D-2.1 Overview

Historic mine workings associated with the Golden Point Battery are present near Deepdell Creek. A significant proportion of the historic workings have been removed as the Golden Point Underground (GPUG) has progressed. However, some historic workings remain between Deepdell Creek and the Golden Point WRS. Seepage has been observed from one of these historic adits near Deepdell Creek since late 2006. Discharges from the adit were measured from 2007 – 2010 and ranged from up to 6 L/s to nil or negligible flow during winter 2010 (Golder, 2011d). They have interpreted groundwater levels in the Golden Point Pit backfill to below 340 mRL at that time, as that elevation corresponds approximately to the elevation of the lowest of the historical adits. No recent monitoring data are available; however, observations by site staff, indicate that seepage occurs and/or increases when the Roundhill sump level exceeds 347 m RL. Seepage rates have not been measured directly, but during a site visit in March 2024 GHD staff estimated the discharge to be approximately 1-2 L/s.

The Golden Point and Round Hill pit voids are an area of the mine that will receive poor quality mine water seeping from existing and proposed pit backfill material, existing embankments and seepage from the proposed Innes Mills Lake. Current operational practice is to dewater from the Round Hill sump (see Figure D-2.5), to avoid seepage losses to Deepdell Creek via the historic adit. If left unmanaged post closure, mine affected water would seep through the adits to Deepdell Creek and degrade surface water quality.

Seepage modelling has been undertaken along a transect from SP11 tailings storage facility to Deepdell Creek to test potential water management options in this area suitable for closure. The historic workings are shown in an extract from the site model in Figure D-2.1.

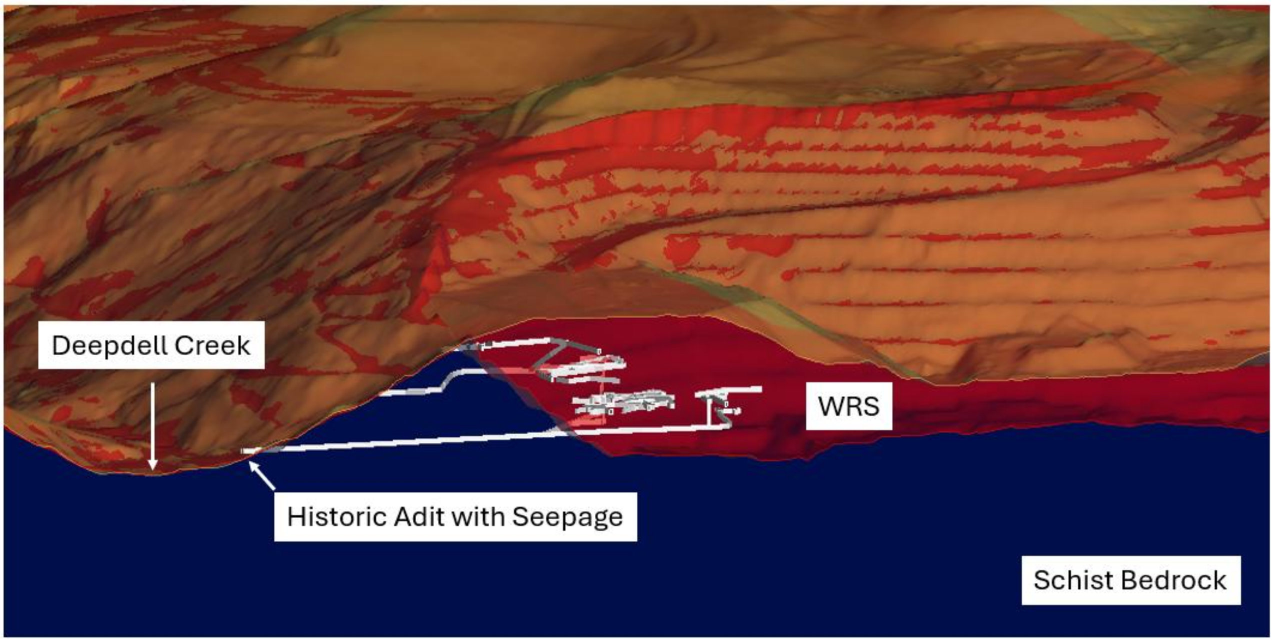


Figure D-2.1 Extract from site leapfrog model showing adit with seepage – historic workings shown in WRS material have been removed during mining

D-2.2 Model Set Up

Groundwater models were developed using Geostudio 2025.1.1 SEEP/W finite element numerical modelling software to represent a transect from SP11 tailings storage facility to Deepdell Creek. The transect includes the SP11 embankment, Roundhill sump, Golden Point WRS, historic mine workings and Deepdell Creek. The transect, approximately 2 km in length, is not a linear cross section, and instead follows the low points through this area, in particular the Roundhill sump and the historic Deepdell adit. The approximate alignment of the transect is shown in red in Figure D-2.2.

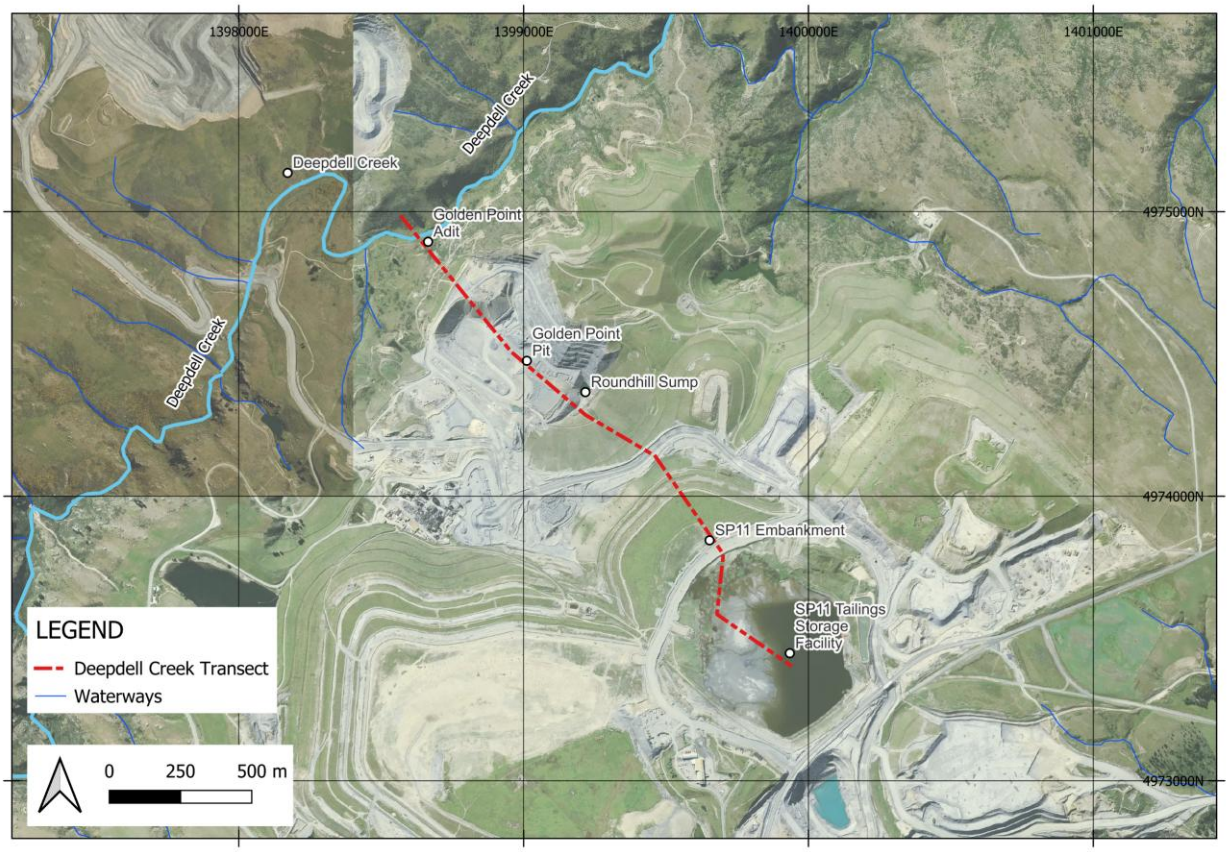


Figure D-2.2 Alignment of transect used in modelling shown in red.

D-2.3 Model Inputs and Parameters

Inputs and parameters used in the models, including geometries, boundary conditions, material properties, and initial conditions are presented in Table D-2.1 and Table D-2.2.

Site investigations and previous studies indicate that the intensity of weathering is decreasing with depth. The hydraulic conductivity values applied to the schist in the seepage assessment adopts a similar approach to the 3D groundwater model, with higher hydraulic conductivities values in more weathered schist.

However, the values used in the 2D seepage modelling are approximately one order of magnitude higher than the hydraulic conductivities used in the 3D groundwater model. This difference reflects the treatment of hydraulic conductivity in the 2D model as an effective, plane-averaged parameter, rather than a change in the intrinsic material properties. When the hydraulic conductivity values from the 3D groundwater model were applied directly, the 2D section was unable to transmit the inferred system throughflow, resulting in numerical convergence issues. The adopted values were therefore constrained through calibration to estimated adit flows and are consistent with the range of hydraulic conductivity values previously adopted for the site by others (Golder, 2011c).

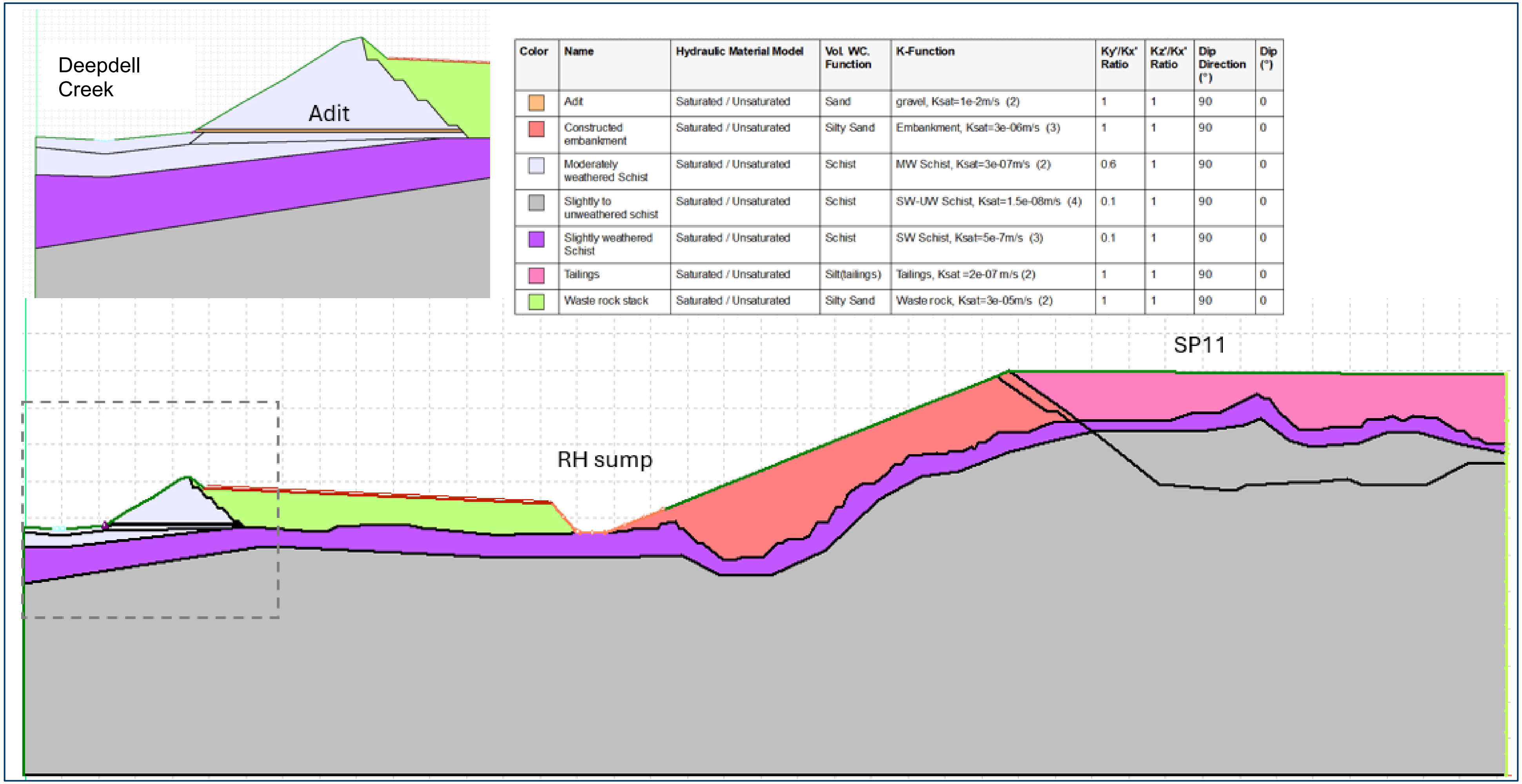
Table D-2.1 Model set up and boundary conditions

Parameter		Adopted properties and values	Comments
Model type		2D - steady state	Steady state to reflect long term changes in groundwater levels and flow rates based on the model parameters for comparison
Mesh		Global mesh - 10 m Lower layers – 20 m	Large mesh size required for scale of cross section
Boundary conditions			
All scenarios	Constant head with potential seepage face – Deepdell Creek	334.5 m RL	Based on invert of stream bed at section location, assumes 0.5 m water depth
	Water Rate (Seepage Face Drainage boundary) – Deepdell adit exit	0 m^3/s	Allows water to discharge to surface
Current scenario	Constant head – SP11 tailings	542 m RL	Assumes tailings are saturated
	Constant head with potential seepage face – Round Hill sump level	347 m RL	Based on site observations of seepage from Deepdell adit when RH sump level at 347 m or higher
	Recharge on WRS surface	70 mm/yr	Higher recharge rate adopted for uncapped WRS, in addition a portion of the WRS is used for discharge of GPUG dewatering to surface
Future scenario	Constant head with potential seepage face – Innes Mills Lake	478 m RL	From project description
	Recharge on WRS surface (long term)	32 mm/yr	Rehabilitated WRS average seepage rate

Table D-2.2 Material properties (calibrated model)

Name	Hydraulic Material model	Vol water content (VWC) function*	Hydraulic Conductivity (K) function (m/s)	Ky/Kx	Comment
Adit	Saturated/Unsaturated	Sand	1×10^{-2}	1	High K value applied to adit – reflecting mix of void spaces with debris
Embankment	Saturated/Unsaturated	Silty sand	3×10^{-6}	1	Constructed embankment, 1 order of magnitude lower than WRS
Moderately weathered Schist	Saturated/Unsaturated	Schist	3×10^{-7}	0.6	Modified from 3D groundwater model
Slightly to unweathered schist	Saturated/Unsaturated	Schist	1.5×10^{-8}	0.1	Modified from 3D groundwater model
Slightly weathered schist	Saturated/Unsaturated	Schist	5×10^{-7}	0.1	Modified from 3D groundwater model
Tailings	Saturated/Unsaturated	Silt (Tailings)	2×10^{-7}	1	Typical value for silt tailings
Waste rock stack	Saturated/Unsaturated	Silty sand	3×10^{-5}	1	Waste rock with silt matrix, best calibration/model stability with the applied recharge
Notes *	The VWC function describes how much water a material holds as a function of soil suction. VWC used are from the SEEPW library				

The 2D model set up to represent the existing conditions is presented in Figure D-2.3.



Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Kz'/Kx' Ratio	Dip Direction (°)	Dip (°)
	Adit	Saturated / Unsaturated	Sand	gravel, Ksat=1e-2m/s (2)	1	1	90	0
	Constructed embankment	Saturated / Unsaturated	Silty Sand	Embankment, Ksat=3e-06m/s (3)	1	1	90	0
	Moderately weathered Schist	Saturated / Unsaturated	Schist	MW Schist, Ksat=3e-07m/s (2)	0.6	1	90	0
	Slightly to unweathered schist	Saturated / Unsaturated	Schist	SW-UW Schist, Ksat=1.5e-08m/s (4)	0.1	1	90	0
	Slightly weathered Schist	Saturated / Unsaturated	Schist	SW Schist, Ksat=5e-7m/s (3)	0.1	1	90	0
	Tailings	Saturated / Unsaturated	Silt(tailings)	Tailings, Ksat =2e-07 m/s (2)	1	1	90	0
	Waste rock stack	Saturated / Unsaturated	Silty Sand	Waste rock, Ksat=3e-05m/s (2)	1	1	90	0

Figure D-2.3 Existing conditions model set up

D-2.4 Steady-state Model Calibration

The model was calibrated by adjusting material properties to simulate the estimated (observed) adit seepage rate of 1-2 L/s when the Round Hill sump level was set to a level of 347 m RL. As the two-dimensional model represents flow per metre width of section, the modelled seepage rate per metre was multiplied up by an assumed length of 200 m to estimate total adit discharge. This length represents the inferred portion of the pit edge drained by the adit and corresponds to approximately half of the pit edge abutting Deepdell Creek. The results are presented in Table D-2.4 for comparison with the future scenario modelling and an excerpt of the current conditions model scenario is shown in Figure D-2.4.

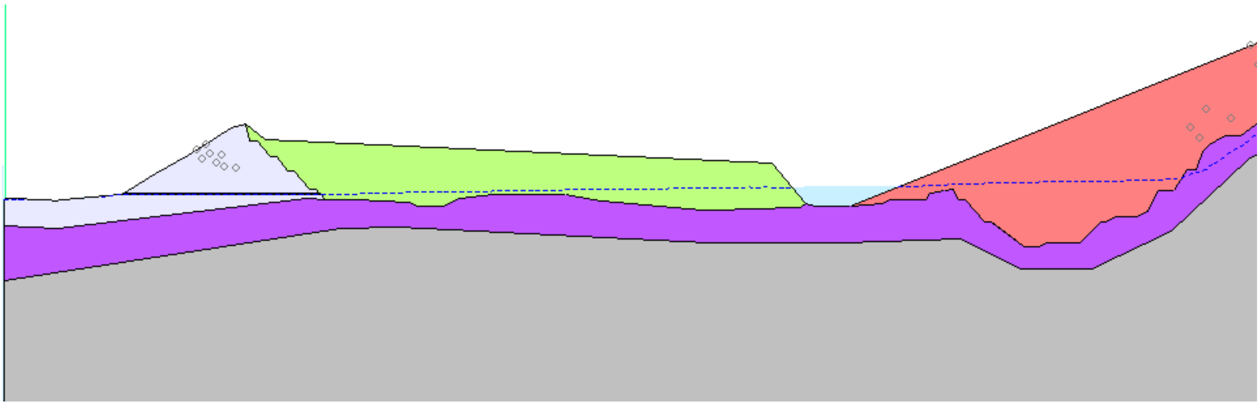


Figure D-2.4 Existing conditions model results

D-2.5 Scenario Modelling

The model was adapted to reflect the proposed changes at mine closure. Key updates for the future scenario are summarised and shown in the schematic (Figure D-2.5):

- Removal of tailings from SP11
- Deepening of Innes Mills Pit to approximately 385-390 m RL
- Filling of Innes Mills Lake to a level of 478 m RL
- Placement of Golden Point backfill to a level of 486 m RL

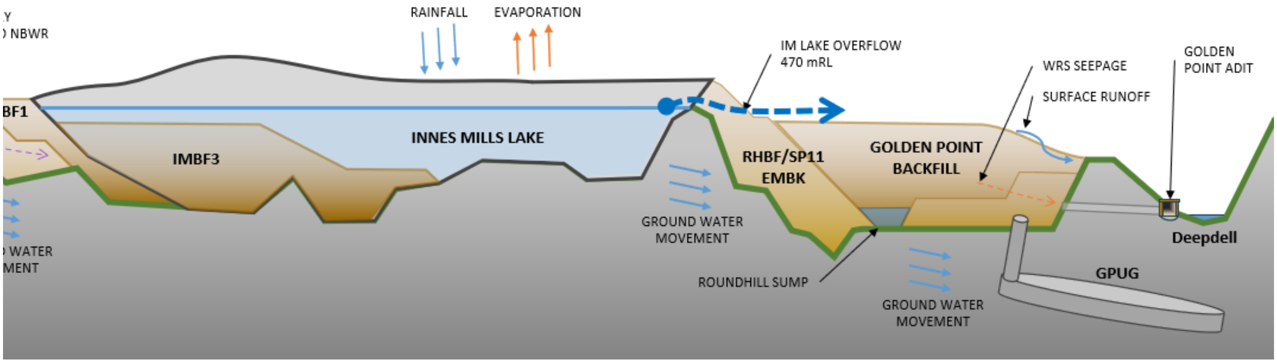


Figure D-2.5 Schematic of future scenario relating to seepage model area

Three scenarios were modelled:

- Future scenario with no mitigation
- Future scenario incorporating a plug at the Deepdell end of the adit (approximately 5 m wide)
- Future scenario with lower permeability liner on the inside of the pit shell (approximately 20 m wide)

Boundary conditions for the future scenario are summarised in Table 1. Material properties are as used for the existing state scenario (Table 2) with the following additional materials (Table D-2.3).

Table D-2.3 Materials used in future scenario modelling

Name	Hydraulic Material model	Vol water contend function	Hydraulic Conductivity (K) function (m/s)	Ky/Kx	Comment
Zone A material	Saturated/Unsaturated	Silty sand	1×10^{-7}	1	Lower permeability waste rock material used in embankments
Plug material	Saturated/Unsaturated	Silty clay	1×10^{-8}	1	Low permeability material – concrete or similar

Model set up, including detail of the potential mitigation scenarios modelling are shown in Figure D-2.6 and results are summarised in Table D-2.4 and shown in Figure D-2.7.

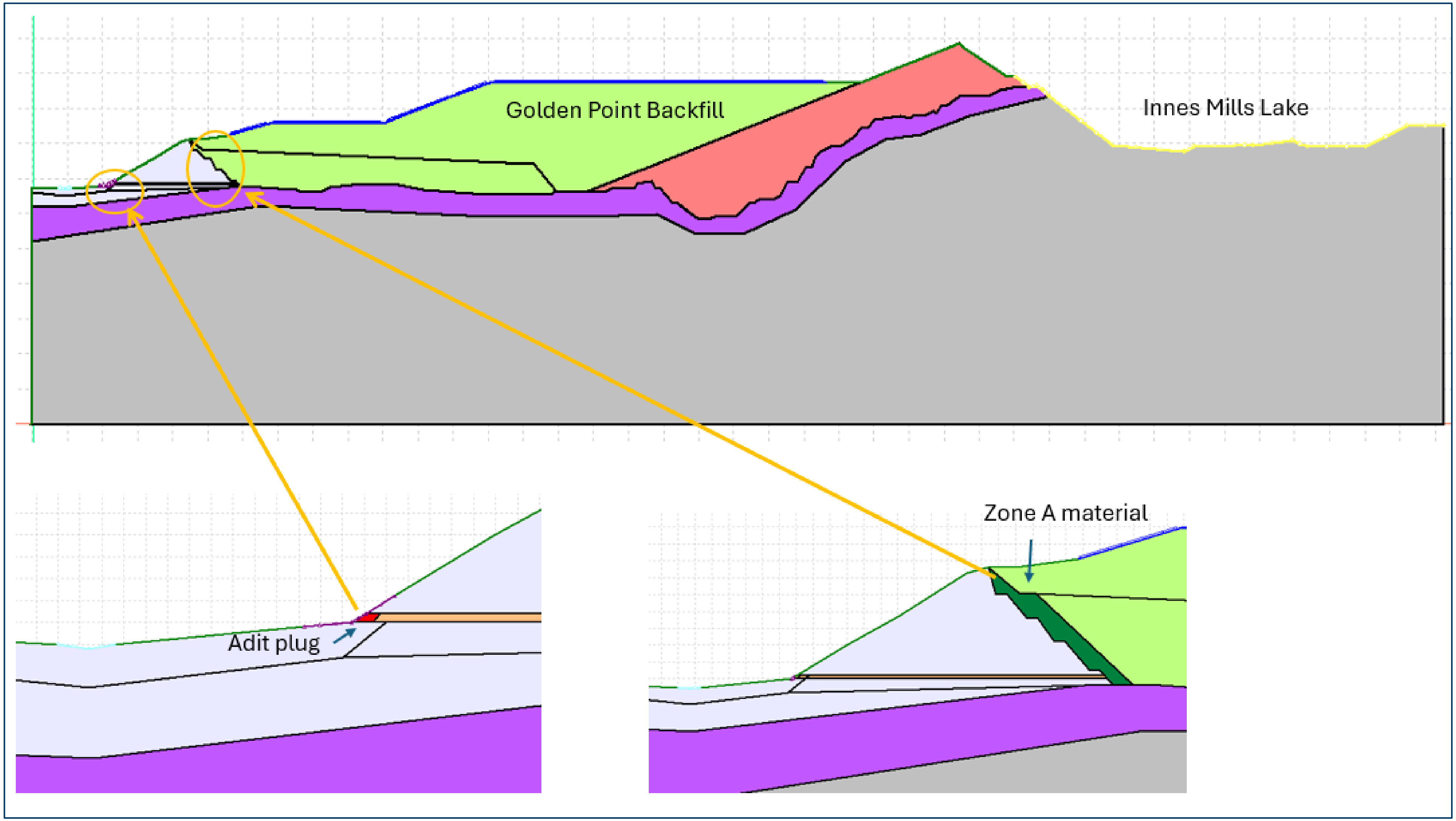


Figure D-2.6 Future scenario model set up – inset showing detail of modelled potential mitigation options

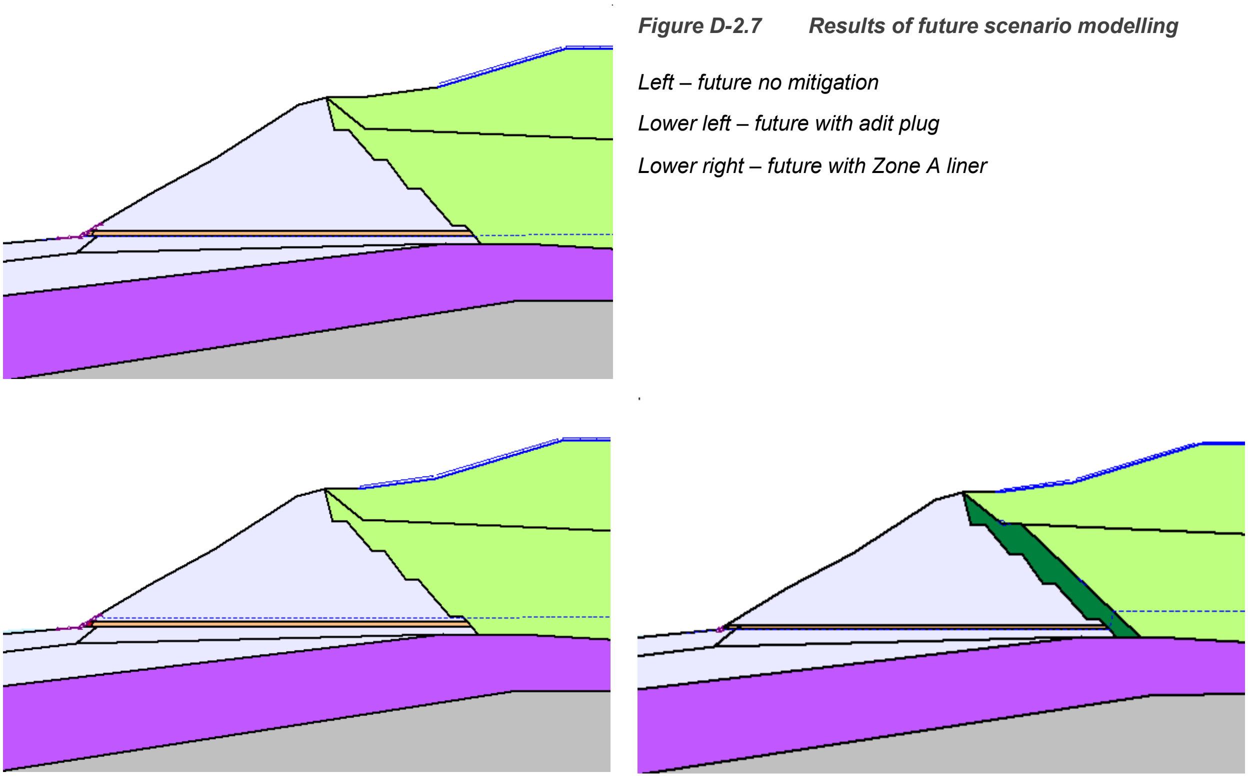


Figure D-2.7 Results of future scenario modelling

Left – future no mitigation

Lower left – future with adit plug

Lower right – future with Zone A liner

Table D-2.4 Model results summary – Deepdell

Scenario	Modelled flow rate from adit (assume 200 m capture zone)	Water level in backfill	Comments
Existing conditions	0.90 L/s	-	N/A controlled by sump level
Future no mitigation	0.45 L/s	340 - 350 m RL	Water level decreases towards DD creek
Future with adit plug	0.40 L/s	345 - 347 m RL	Water level decreases towards DD creek
Future with low permeability zone in pit	0.45 L/s	~350 m RL	Water level drops down as goes through Zone A material

D-2.6 Seepage Modelling Summary

The seepage modelling shows the following:

– Reduction in seepage from the Deepdell adit in the future scenario compared to the existing conditions. This reduction is likely to be the result of a reduction in groundwater head level at the upgradient boundary (from SP11 to Innes Mills lake level) and a reduction in recharge rate applied to the WRS surface.

– Mitigation options such as the adit plug or a low permeability pit liner have minimal impact on adit seepage rates and water level within in the backfill material. In both cases the adit acts as a preferential flow path with groundwater flow directed into the surrounding weathered schist and likely to discharge to surface via fractures.

– The modelling indicates that the majority of the backfill will be unsaturated.

The future scenario modelling undertaken assumed an Innes Mills Lake level of 478 m RL. At lower lake levels, the adit discharge rate and water level in the backfill are expected to be lower.

D-3 Seepage Modelling – Murphys Creek

D-3.1 Overview

Frasers South WRS is located to the south and east of Frasers Pit. Part of the WRS overlies a former channel of Murphys Creek. When this channel was backfilled, it is understood that the method of placement (end tipping) resulted in coarser material being concentrated in low points, such as the Murphys Creek channel. The proposed Frasers Tailing Storage Facility (FTSF will have a tailings level above the invert of the Murphys Creek, therefore there is potential for seepage to preferentially follow the historical channel flow path, as shown in the schematic below (Figure D-3.1).

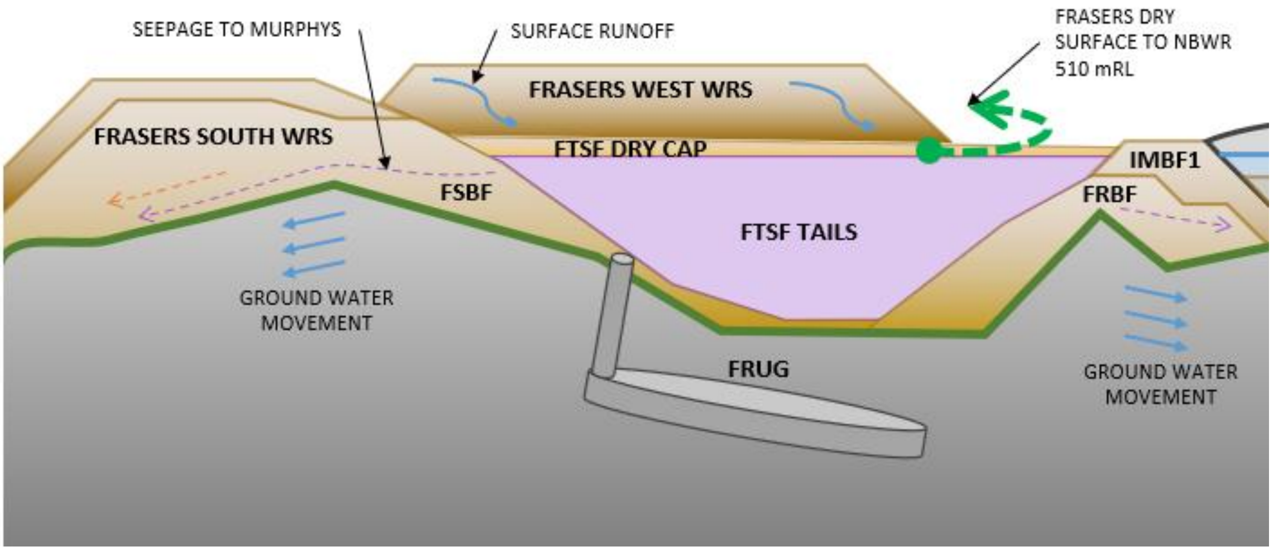


Figure D-3.1 Schematic of FTSF and seepage to Murphys Creek silt pond

D-3.2 Model set up

Groundwater models were developed using Geostudio 2025.1.1 SEEP/W finite element numerical modelling software to represent a transect from FTSF to Murphys Creek. The transect, extending approximately 3 km, follows the former Murphys Creek channel as shown in

Figure D-3.2, and not a linear cross section, as this represents the low point beneath the waste rock stack to provide a relative conservative estimate seepage from the FTSF through the base of the waste rock stack. The conceptual SEEP/W transect is shown in Figure D-3.3. The intent of modelling is to estimate the seepage through this path only. Seepage through the WRS from rainfall recharge is estimated and discussed separately within the site water balance model (Appendix E) and hasn’t been included here.

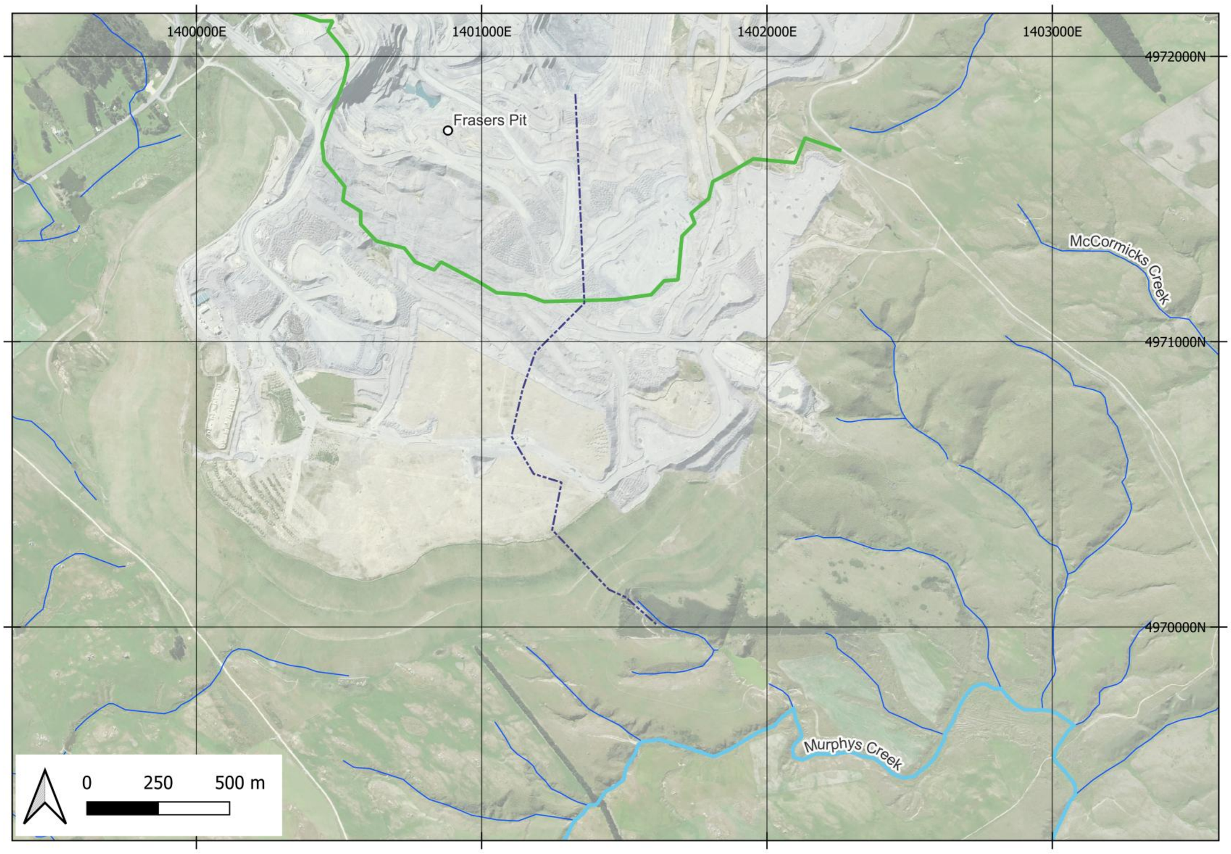


Figure D-3.2 Model section alignment (dark blue), green line represents edge of Frasers Pit

D-3.3 Model Inputs and Parameters

Inputs and parameters used in the models, including geometries, boundary conditions, material properties, and initial conditions are presented in Table D-3.1.

Material properties were adopted from the Deepdell Adit model (Section D-2) and are summarised in Table D-3.2. A higher hydraulic conductivity was applied to the coarser waste rock material shown in light blue colour in Figure D-3.3. This material is inferred to be deposited by end-tipping into the lower part of the former Murphys Creek valley.

The in-situ schist overflow level along the transect is approximately 486.5 m RL. The models do not include any perimeter drains and/or underdrainage that may be installed within the Frasers TSF.

Table D-3.1 Model set up and boundary conditions – Murphys Creek

Parameter	Adopted properties and values	Comments
Model type	2D - steady state	Steady state to reflect long term changes in groundwater levels and flow rates based on the model parameters for comparison
Mesh	Global mesh - 20 m Layers around drain – 10 m	Large mesh size required for scale of cross section
Boundary conditions		
Drainage – Murphys Creek	0 m^3/s	Allows water to discharge to surface
Constant Head – Tailings saturation	520 m RL 510 m RL 500 m RL 495 m RL	Water level within tailings – four scenarios

Table D-3.2 Material properties – Murphys Creek

Name	Hydraulic Material model	Vol water contend function	Hydraulic Conductivity (K) function (m/s)	Ky/Kx	Comment
Slightly to unweathered schist	Saturated/Unsaturated	Schist	1.5×10^{-8}	0.1	Modified from 3D groundwater model
Slightly weathered schist	Saturated/Unsaturated	Schist	5×10^{-7}	0.1	Modified from 3D groundwater model
Tailings	Saturated/Unsaturated	Silt (Tailings)	2×10^{-7}	1	Typical value for silt tailings
Waste rock stack	Saturated/Unsaturated	Silty sand	3×10^{-5}	1	Waste rock with silt matrix, best calibration/model stability with the applied recharge (from Deepdell model).
Waste rock stack (coarse)	Saturated/Unsaturated	Silty sand	5×10^{-5}	1	Representing coarser material end tipped into channel

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Kz'/Kx' Ratio	Dip Direction (°)	Dip (°)
	Slightly to unweathered schist	Saturated / Unsaturated	Schist	SW-UW Schist, Ksat=1.5e-08m/s (4)	0.1	1	90	0
	Slightly weathered Schist	Saturated / Unsaturated	Schist	SW Schist, Ksat=5e-07m/s (3)	0.1	1	90	0
	Tailings	Saturated / Unsaturated	Sandy Silt (Coarse Tailings)	Silt(tailings), Ksat=2e-07m/s (2)	1	1	90	0
	Waste rock stack	Saturated / Unsaturated	Silty Sand	Waste rock, Ksat=3e-05m/s (2)	1	1	90	0
	Waste rock stack coarse	Saturated / Unsaturated	Silty Sand	Waste rock coarse, Ksat=5e-05m/s (3)	1	1	90	0

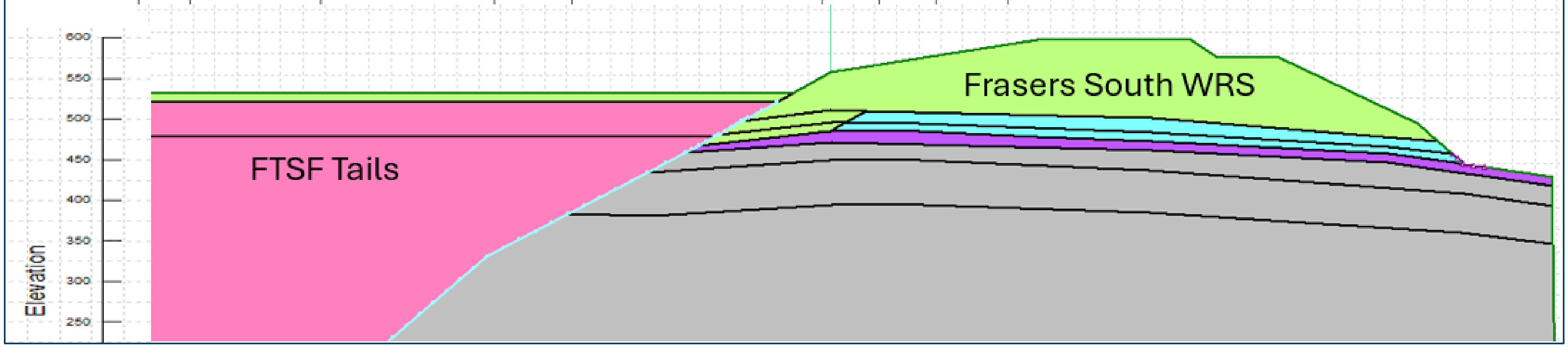


Figure D-3.3 Murphys Creek seepage model

D-3.4 Scenario Modelling and Results

The modelling assumes fully saturated tailings to 520 m RL at the end of tailings disposal. Over time it is expected that the saturation level will drop as the tailings drain to ground, therefore three additional scenarios have been modelled to simulate tailing saturation levels of 510, 500 and 495 m RL.

Tailings seepage via the Murphys channel flow-path is expected to be negligible below ~490 m RL as the water level drops below the channel invert.

As noted in Section D-3.2, rainfall recharge and drainage through the WRS has been excluded from this assessment as this component is included in site wide water balance model (Appendix E). Likewise, seepage through the Frasers pit wall into the schist bedrock has not been assessed as this component is included in the 3D groundwater model for Macraes central area (Appendix C). The results of the modelling are summarised in Table D-3.3. The model flow rate, per metre, has been scaled by 100 m, representing the approximate width of the channel valley. The seepage rates decrease with assumed decreasing tailings saturation level from a high of 3.3 L/sec (at an assumed tailings saturation level of 520 m RL at the end of tailings deposition) to 0.4 L/sec (at an assumed tailings saturation level of 495 m RL. Model exerts depicting the modelled phreatic surface for the 520 m RL and 495 m RL scenarios are shown in Figure D-3.4.

Table D-3.3 Seepage results summary - Murphys

Tailings saturation level	Seepage rate via Murphys Creek flow path
520 m RL	3.3 L/s
510 m RL	1.9 L/s
500 m RL	0.8 L/s
495 m RL	0.4 L/s

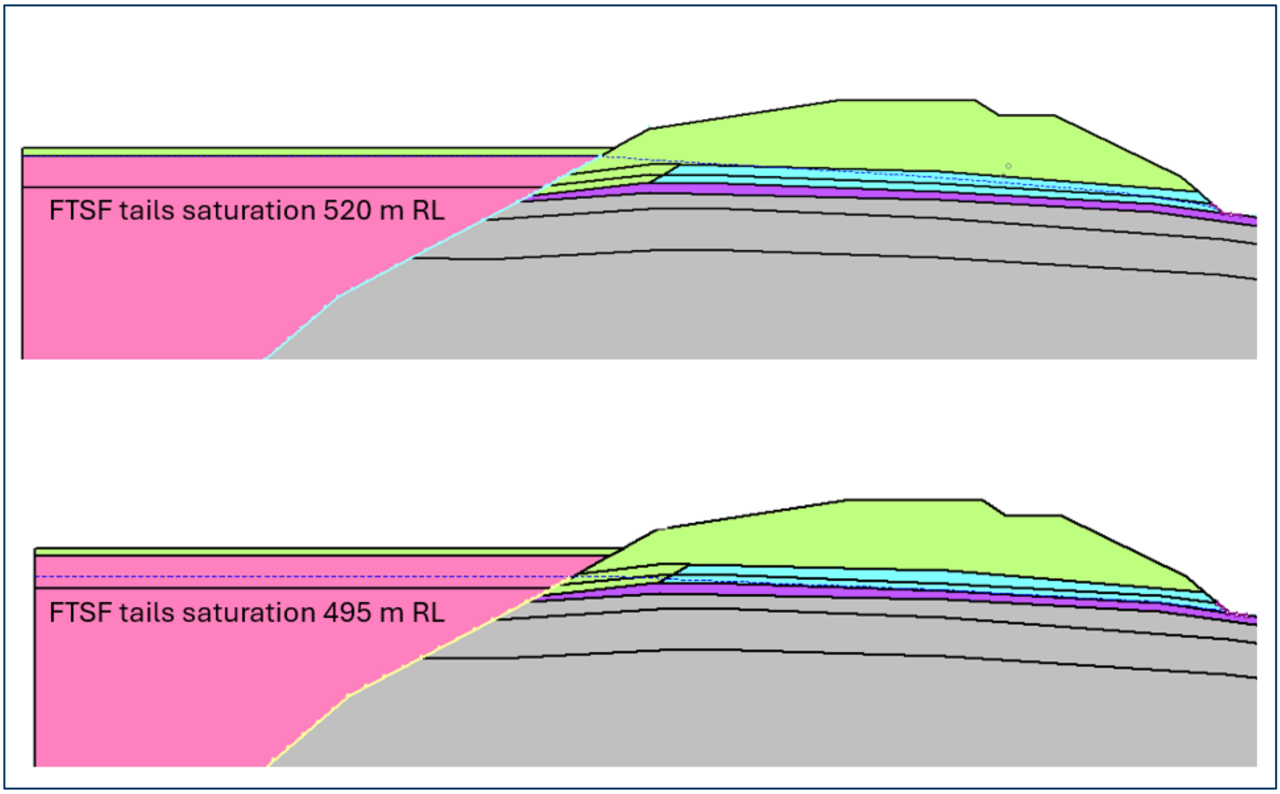


Figure D-3.4 Model exert – tails saturation at 520 and 495 m RL

D-4 Seepage Capture Drains Modelling

D-4.1 Overview

Seepage capture drains (SCD) are proposed to be installed at the toe of some WRS to capture seepage generated from percolation through the WRS. The SCD will comprise a series of trenches connecting to collection sumps, intercepting WRS seepage before it enters surface water. Collected seepage will be pumped from the sumps to a water treatment facility or for use onsite within the mine water management system. The concept design for the SCD is included in “Macraes Phase 4 FTA Project. Engineered Seepage Capture Drain – Concept Design Report, GHD (2026a), with an exert shown in Figure D-4.1 and a typical cross section detail shown in Figure D-4.2 . The drains will comprise:

– Slotted drainage pipe connecting to a sump
– Trench filled with drainage aggregate (gravel)
– Low permeability cap/plug at the top of the trench to prevent surface water ingress

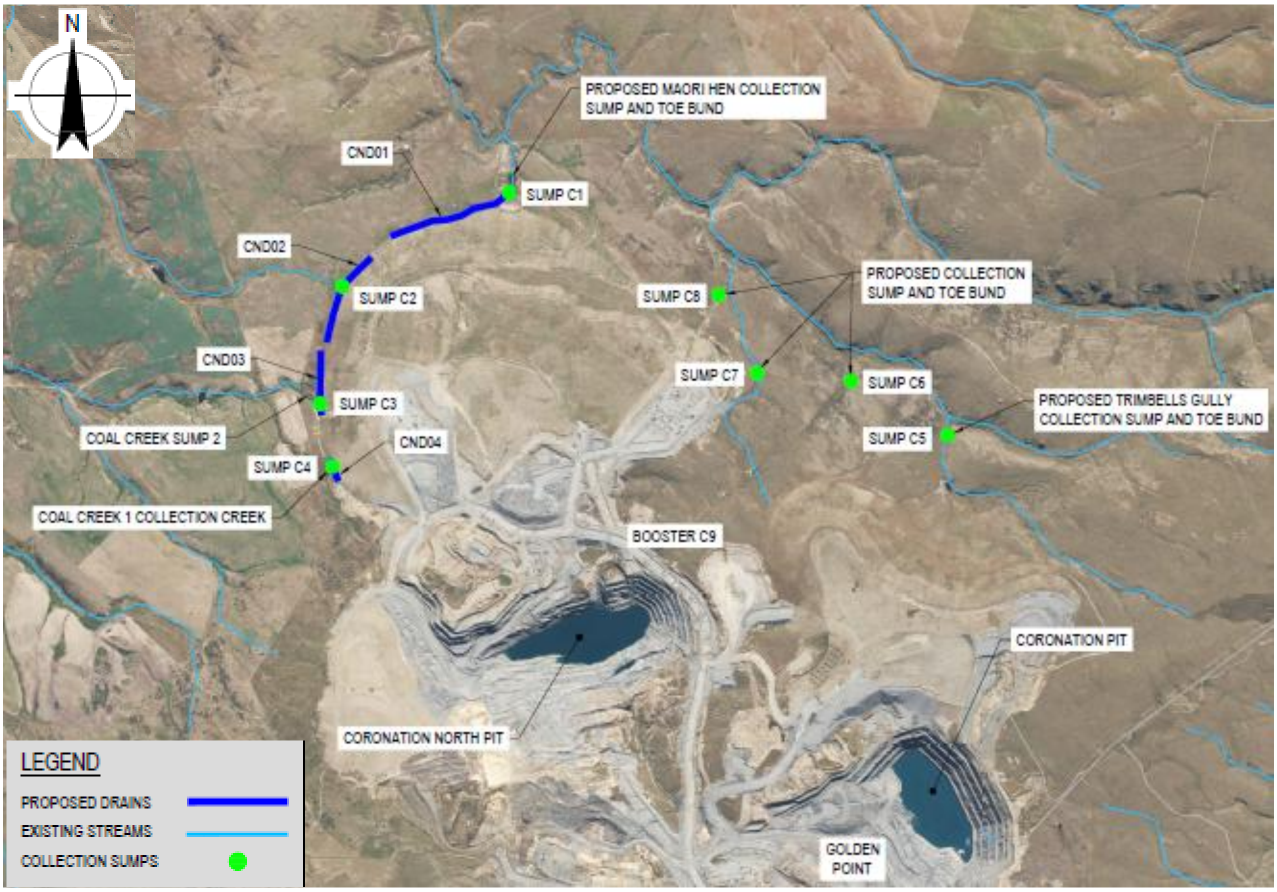


Figure D-4.1 Coronation North WRS SCD location plan (not to scale), (GHD, 2026a)

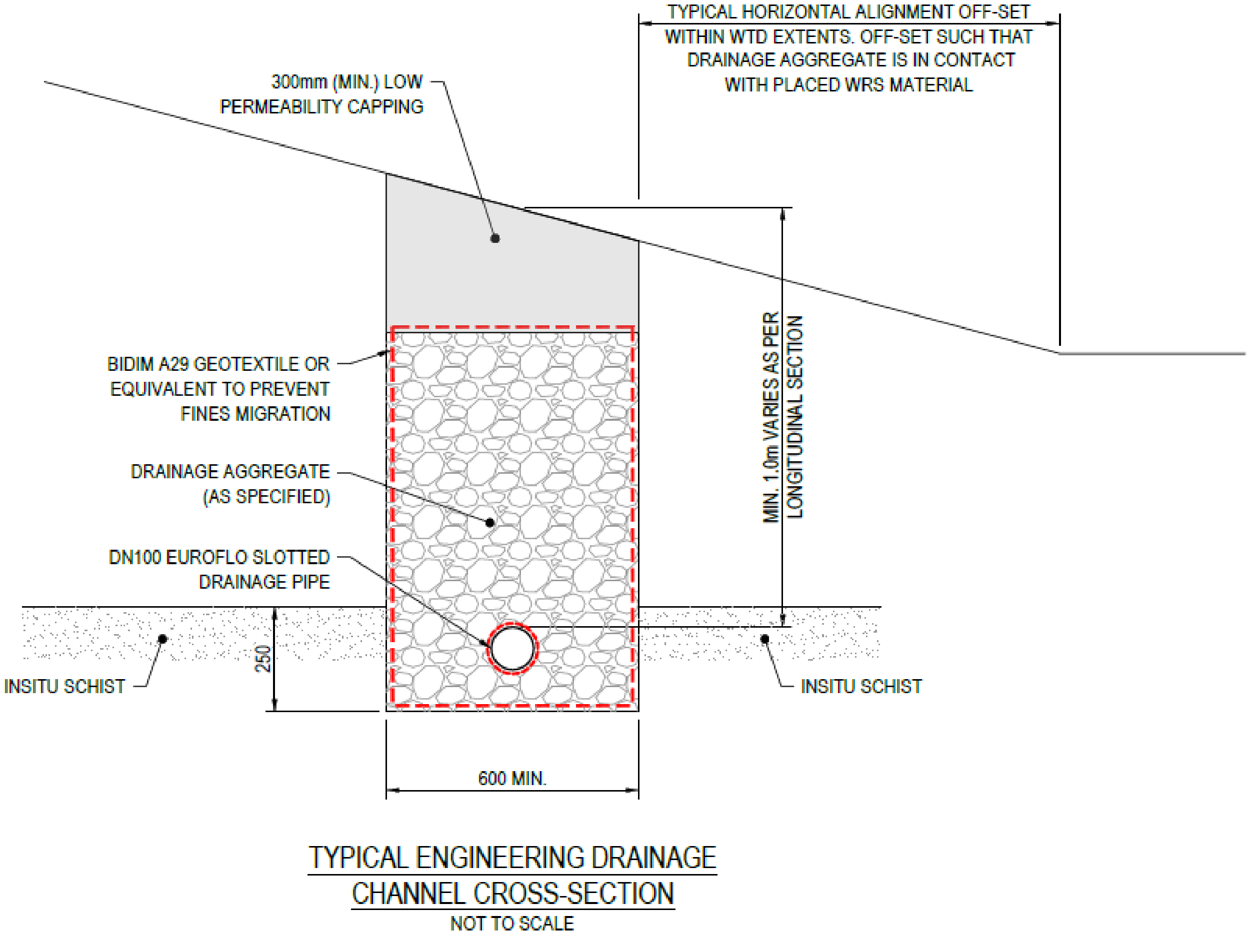


Figure D-4.2 Typical cross section detail of a seepage capture drain (GHD, 2026a)

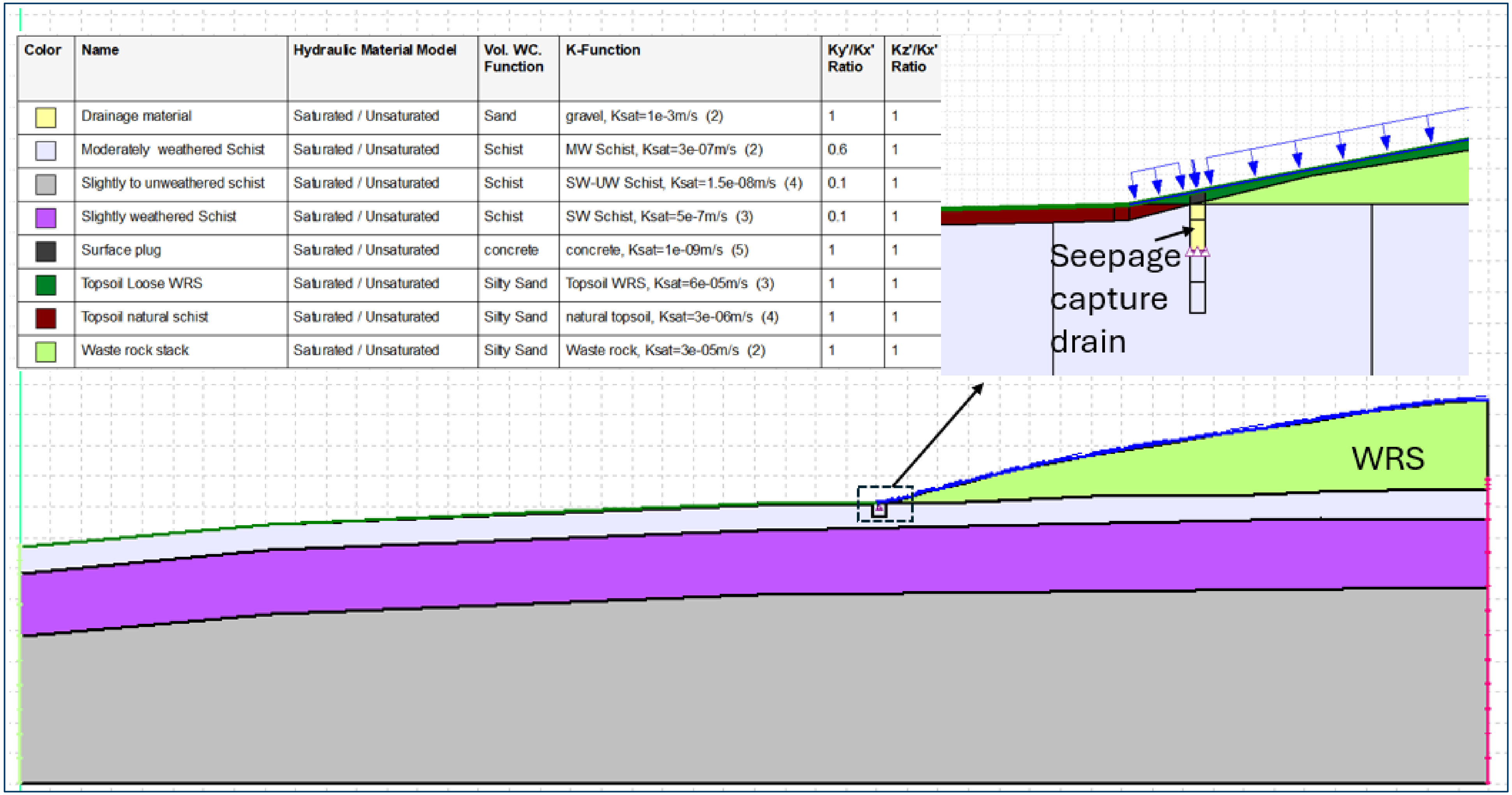
Groundwater modelling (2D cross sections) was undertaken to simulate the proposed SCD concept design and to test various design scenarios. Modelling was undertaken at two representative locations:

– Coronation North WRS – representing a WRS on a hilly area where surface flow and seepage flows to incised channels.
– Frasers West WRS – representing an area with moderate natural relief, adjacent to wetlands and surface water features.

D-4.2 Model Set Up

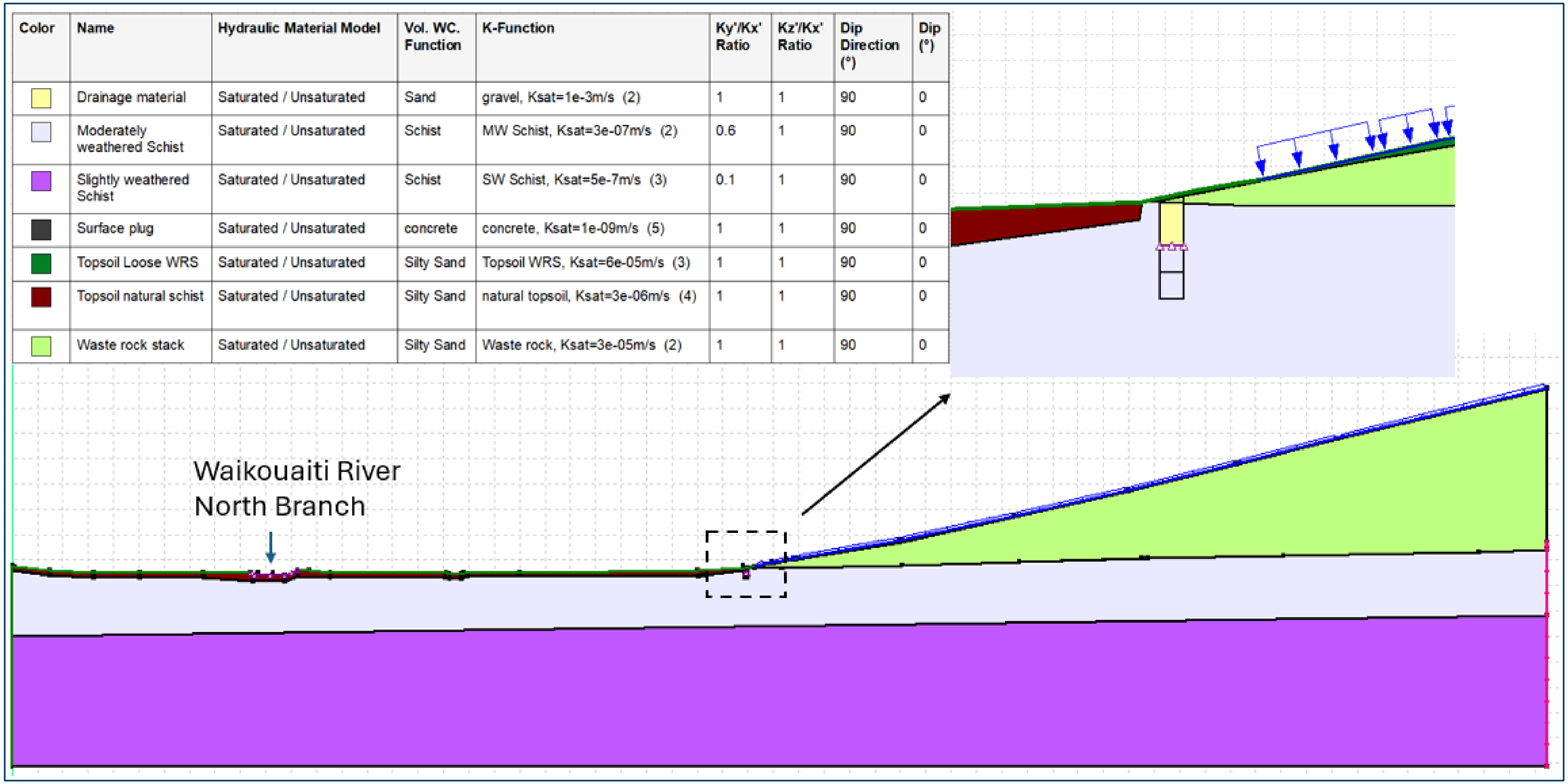
Groundwater models were developed using Geostudio 2025.1.1 SEEP/W finite element numerical modelling software to represent a transect from the Coronation North WRS westwards down towards a tributary of Coal Creek (Figure D-4.3). This section has been used as a representative section for the majority of WRS on site.

Additional models were created to represent a transect from Frasers West WRS to the base. The key difference in the Frasers West models compared to the Coronation North section, is that the transect intersects a tributary of the North Branch of the Waikouaiti River and is near an area of historical mine workings (Macraes Dredge Ponds), with surface water channels and wetlands present at the western edge of the transect.



Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Kz'/Kx' Ratio
	Drainage material	Saturated / Unsaturated	Sand	gravel, Ksat=1e-3m/s (2)	1	1
	Moderately weathered Schist	Saturated / Unsaturated	Schist	MW Schist, Ksat=3e-07m/s (2)	0.6	1
	Slightly to unweathered schist	Saturated / Unsaturated	Schist	SW-UW Schist, Ksat=1.5e-08m/s (4)	0.1	1
	Slightly weathered Schist	Saturated / Unsaturated	Schist	SW Schist, Ksat=5e-7m/s (3)	0.1	1
	Surface plug	Saturated / Unsaturated	concrete	concrete, Ksat=1e-09m/s (5)	1	1
	Topsoil Loose WRS	Saturated / Unsaturated	Silty Sand	Topsoil WRS, Ksat=6e-05m/s (3)	1	1
	Topsoil natural schist	Saturated / Unsaturated	Silty Sand	natural topsoil, Ksat=3e-06m/s (4)	1	1
	Waste rock stack	Saturated / Unsaturated	Silty Sand	Waste rock, Ksat=3e-05m/s (2)	1	1

Figure D-4.3 SCD model set up (Coronation North WRS)



Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Kz'/Kx' Ratio	Dip Direction (°)	Dip (°)
	Drainage material	Saturated / Unsaturated	Sand	gravel, Ksat=1e-3m/s (2)	1	1	90	0
	Moderately weathered Schist	Saturated / Unsaturated	Schist	MW Schist, Ksat=3e-07m/s (2)	0.6	1	90	0
	Slightly weathered Schist	Saturated / Unsaturated	Schist	SW Schist, Ksat=5e-7m/s (3)	0.1	1	90	0
	Surface plug	Saturated / Unsaturated	concrete	concrete, Ksat=1e-09m/s (5)	1	1	90	0
	Topsoil Loose WRS	Saturated / Unsaturated	Silty Sand	Topsoil WRS, Ksat=6e-05m/s (3)	1	1	90	0
	Topsoil natural schist	Saturated / Unsaturated	Silty Sand	natural topsoil, Ksat=3e-06m/s (4)	1	1	90	0
	Waste rock stack	Saturated / Unsaturated	Silty Sand	Waste rock, Ksat=3e-05m/s (2)	1	1	90	0

Figure D-4.4 SCD model set up (Frasers West WRS)

D-4.3 Model Inputs and Parameters

Inputs and parameters used in the models in Table D-4.1 and Table D-4.2.

Material properties were adopted from the Deepdell Adit model (Section D-2) and are summarised in Table D-4.3. The models include additional materials representing the natural topsoil on the schist bedrock and a topsoil layer on top of the WRS. Prior to WRS placement, the topsoil layers are scraped off, therefore the schist topsoil is only present in undisturbed areas.

Table D-4.1 Model set up and boundary conditions – Coronation North WRS

Parameter	Adopted properties and values	Comments
Model type	2D - steady state	Steady state to reflect long term changes in groundwater levels and flow rates based on the model parameters for comparison
Mesh	Mesh size 1 or 2 m Drain – 0.5 m Lower schist layer -10 m	Smaller mesh size for drain and upper layers (where rainfall recharge infiltrates)
Boundary conditions		
Drainage (seepage face) – SCD	0 m^3/s	Simulates removal of groundwater through drainage and pumping
Rainfall recharge	32 mm/yr	Average long term recharge rate (rehabilitated WRS)
Constant head - upgradient groundwater	547 m RL	Groundwater level in WRS (from Coronation North Recovery 3D GW model)
Constant head – downgradient groundwater	490 m RL	Estimated based on topography (groundwater level 3 m below ground level at end of cross section)

Table D-4.2 Model set up and boundary conditions – Frasers West WRS

Parameter	Adopted properties and values	Comments
Model type	2D - steady state	Steady state to reflect long term changes in groundwater levels and flow rates based on the model parameters for comparison
Mesh	Mesh size 1 m Drain – 0.5 m Lower schist layer -10 m	Smaller mesh size for drain and upper layers (where rainfall recharge infiltrates)
Boundary conditions		
Drainage –(seepage face) SCD	0 m^3/s	Simulates removal of groundwater through drainage and pumping
Rainfall recharge	32 mm/yr	Average long term recharge rate (rehabilitated WRS)
Constant head - upgradient groundwater	505 m RL	Groundwater level in WRS – 1 m above base of WRS at upgradient boundary
Stream boundary (potential seepage face)	0 m^3/s	Waikouaiti River North Branch – ephemeral/intermittent in this location, allows for groundwater seepage into stream

Table D-4.3 Material properties – Coronation North WRS and Frasers North WRS models

Name	Hydraulic Material model	Vol water contend function	Hydraulic Conductivity (K) function	Ky/Kx	Comment
Slightly to unweathered schist	Saturated/ Unsaturated	Schist	1.5×10^{-8}	0.1	Modified from 3D groundwater model
Slightly weathered schist	Saturated/ Unsaturated	Schist	5×10^{-7}	0.1	Modified from 3D groundwater model
Topsoil (undisturbed schist)	Saturated/ Unsaturated	Silty sand	3×10^{-6}	1	Weathered schist colluvium, silt with some sand and rock fragments.
Waste rock stack	Saturated/ Unsaturated	Silty sand	3×10^{-5}	1	Waste rock with silt matrix, best calibration/model stability with the applied recharge (from Deepdell model)
Topsoil WRS	Saturated/ Unsaturated	Silty sand	6×10^{-5}	1	Representing looser material at top of WRS, approximately 0.5 m thick
Drainage material	Saturated/ Unsaturated	Sand	1×10^{-3}	1	Gravel placed in seepage capture drain
Surface plug/cap	Saturated/ Unsaturated	Concrete	1×10^{-9}	1	Low permeability plug or cap preventing surface water ingress
Liner	Saturated/ Unsaturated	Concrete	1×10^{-9}	1	Low permeability synthetic liner or similar to reduce groundwater flow from downgradient side of SCD

D-4.4 Scenario Modelling and Results – Coronation North WRS

Several scenarios were modelled to test the layout and depth of the SCD. Table D-4.4 summarises the model scenarios. Four different depths were tested for each scenario, the depth shown in Table D-4.4 represents the depth below ground level, including a ~0.4 m thick low permeability plug at the surface and a thickness of WRS material (for scenario 1 only) before intersecting the schist bedrock.

Table D-4.4 SCD Coronation North WRS – model scenarios

Number	Scenario	Depth of drain (from ground surface)
1	SCD installed within WRS footprint	- 1 m - 2 m - 3 m - 4 m
2	SCD installed at toe of WRS	- 2 m - 4 m

The modelling indicates that the positioning of the seepage capture drain with the WRS footprint is important to reduce the risk of seepage breakout. The model simulated seepage breakout from the WRS when the drain is positioned at the toe of the WRS (Figure D-4.5). In contrast, all scenarios with a seepage capture drain installed within the WRS footprint (i.e. waste rock is excavated and backfilled above the drain), did not result in seepage breakout (Figure D-4.6).

The modelled flow rate to the drain was low for all Scenario 1 models, in the order of 6×10^{-7} m^3/s per meter of drain. However, the 2D model represents a simplified section and does not capture the complexity and variability of the original schist surface, localised flow paths, or the three-dimensional geometry of the WRS. Therefore, the SCD network has been incorporated in the 3D groundwater models, with the results presented in Appendix B of this report.

While there was no significant difference between flow rates at the different drain depths, a deeper drain resulted in a lower groundwater level at the base of the WRS, with the 1 m drain scenario having a groundwater level nearer the ground surface. On that basis, it is recommended that SCD are either installed at least 1.5 m below ground level (and excavated into the underlying schist) or install further back into the WRS footprint.

The flow paths function of SEEP/W was used to track the path a drop of water falling on the WRS as rainfall through the WRS and into groundwater. The majority of flow paths terminated in the SCD indicating that drain is effective at intercepting seepage from the WRS. However, the model did show some flow paths entering the underlying groundwater system within the schist bedrock. These effects are modelled in the site 3D groundwater models (Appendix B).

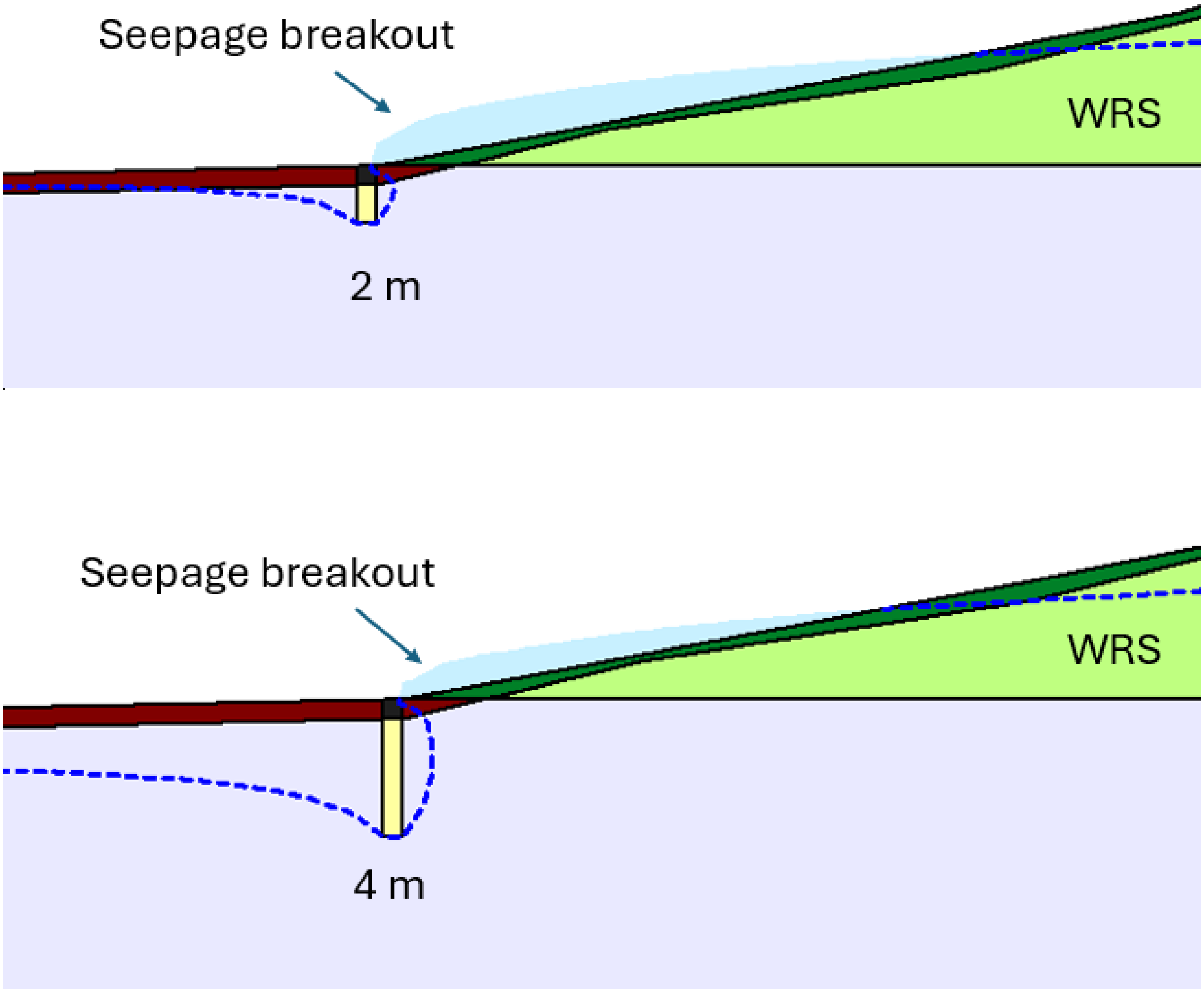


Figure D-4.5 Model results - SCD at toe of WRS (outside footprint of WRS)

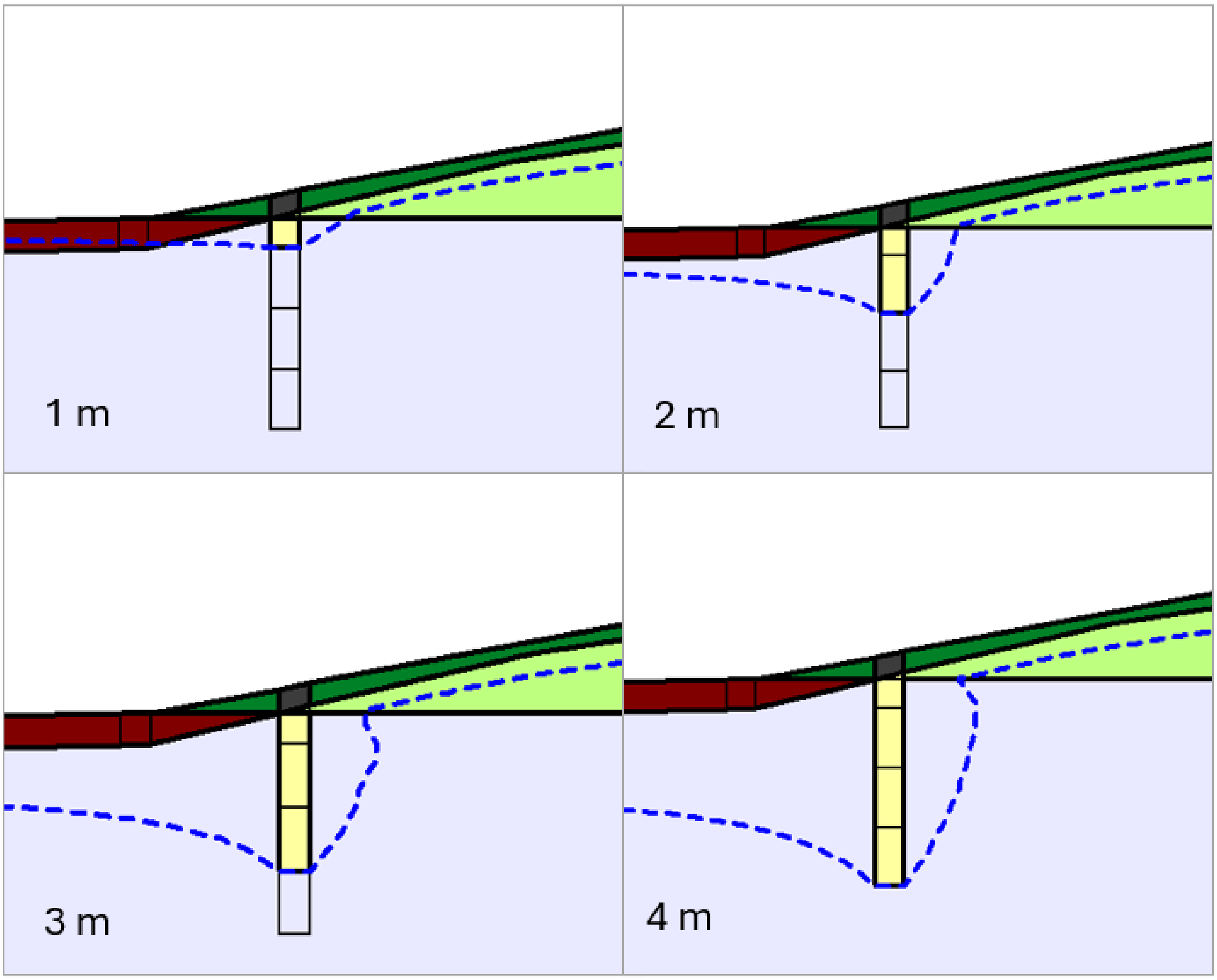


Figure D-4.6 ***Model results -seepage capture drain within WRS footprint***

D-4.5 Scenario Modelling and Results – Frasers West WRS

Several scenarios were developed to model the effects of the SCD on groundwater levels and flows near Frasers West WRS. Table D-4.5 summarises the model scenarios. The Frasers West WRS modelling did not include simulations with the SCD outside of the WRS footprint as this has been shown as ineffective in the Coronation North WRS scenarios (Section 4.4). As mentioned above the 2D model represents a simplified section and does not capture the complexity and variability of the original schist surface, localised flow paths, or the three-dimensional geometry of the WRS. Therefore, the SCD network has been incorporated in the 3D groundwater models, with the results presented in Appendix B of this report.

Table D-4.5 SCD Frasers West WRS – model scenarios

Number	Name	Depth of drain (from ground surface)	Description
1	Current Conditions	No drain	Existing conditions
2	Base case	– 2 m – 3 m – 4 m	Base case scenario, material properties and boundary conditions as outlined in Section 4.2
3	High K Topsoil	– 2 m – 3 m – 4 m	Increase hydraulic conductivity of valley topsoil by one order of magnitude to 3×10^{-5} m/s
4	High water table in WRS	– 2 m – 3 m – 4 m	Increase constant head boundary representing groundwater level in WRS by 0.5 m.
5	SCD liner	– 2 m – 3 m – 4 m	Model installation of a low permeability liner on the valley side of the SCD
6	SCD liner with high K topsoil	– 2 m – 3 m – 4 m	As for Scenario 5, but with a valley topsoil hydraulic conductivity of 3×10^{-5} m/s (increased by one order of magnitude)

The current conditions (without SCD) model simulates seepage from the toe of WRS. In the steady state model, this is shown as ponded water, but in reality the seepage is diffuse, resulting in boggy/wetland areas at the toe of the WRS (Figure D-4.7) with the water draining away via surface water channels.

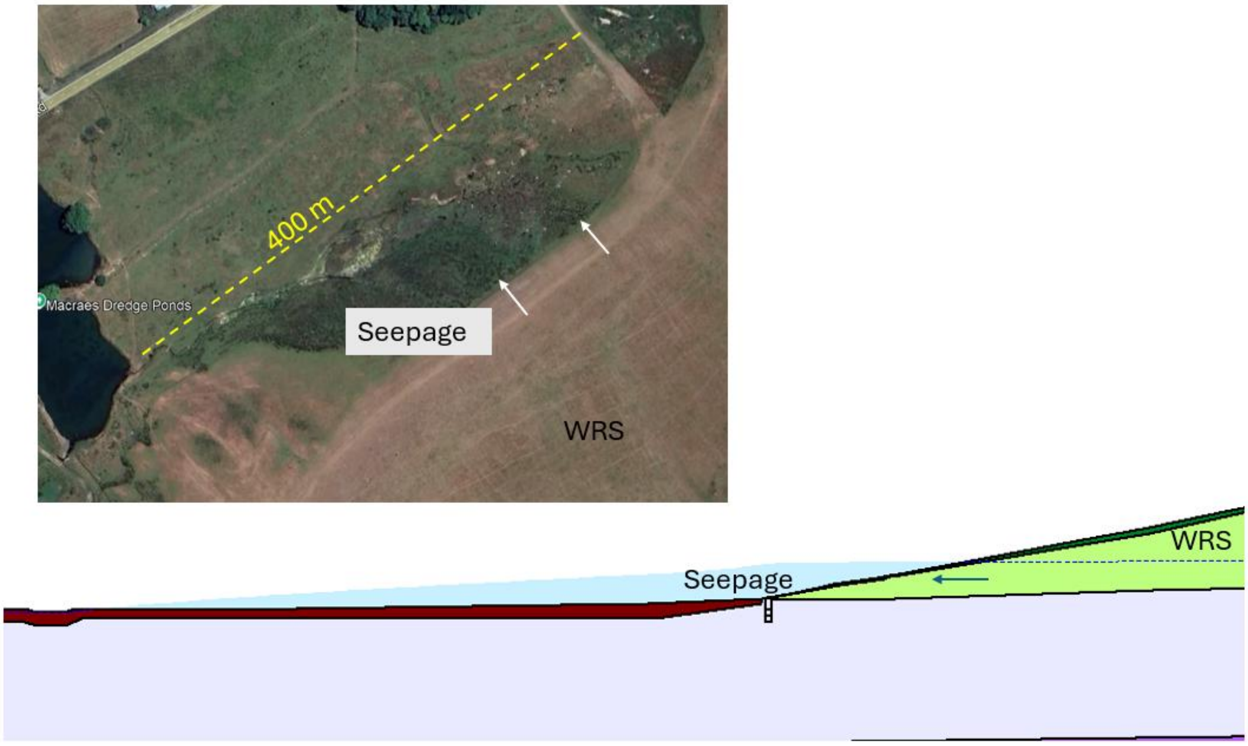


Figure D-4.7 Current conditions – Frasers west WRS

The results of the SCD modelling are summarised in Table D-4.6 Summary results – SCD modelling at Frasers West WRS. The values presented in Table D-4.6 represent the modelled drainage rates for a 1 m thick cross section. Table D-4.6 includes estimates for groundwater discharge to a channel representing the approximate location of the North Branch of the Waikouaiti River. These results are provided for comparative purposes only to assess the relative effect of different drain depths, potential design features (i.e. use of liner) and variability in soil permeability.

While the modelling indicates that the proposed SCD are effective in intercepting seepage from the WRS, some of the WRS seepage is likely to flow through groundwater to the North Branch Waikouaiti River channel and/or via deeper groundwater flow paths. Most of the model scenarios simulate ponding of water at surface, while the depth of ponding is less than the current conditions scenario (Figure D-4.7), it does suggest minor seepage at the WRS toe. In some scenarios, the ponding was limited to surface depressions or former channels. Model exerts for the base case scenario are shown in Figure D-4.8.

Table D-4.6 Summary results – SCD modelling at Frasers West WRS

Scenario	SCD depth (m bgl)	Surface ponding shown by model	SCD rate per m (m3/s)	Modelled GW discharge to stream per m (m^3/s)
2. Base case	2	Yes	1.7×10^{-6}	4.8×10^{-7}
	3	Yes	1.75×10^{-6}	4.4×10^{-7}
	4	Yes	1.8×10^{-6}	3.9×10^{-7}
3. High K top soil	2	Former channel only	1.4×10^{-6}	8.0×10^{-7}
	3	No	1.5×10^{-6}	6.7×10^{-7}
	4	No	1.65×10^{-6}	5.6×10^{-7}
4. High water table in WRS	2	Yes	2.4×10^{-6}	5.2×10^{-7}
	3	Yes	2.5×10^{-6}	4.8×10^{-7}
	4	Yes	2.55×10^{-6}	4.3×10^{-7}
5. SCD with liner	2	Yes	1.7×10^{-6}	4.9×10^{-7}
	3	Yes	1.5×10^{-6}	4.5×10^{-7}
	4	Yes	1.8×10^{-6}	4.0×10^{-7}
6. SCD with liner with high K topsoil	2	Former channel only	1.4×10^{-6}	8.1×10^{-7}
	3	Former channel only	1.3×10^{-6}	7.0×10^{-7}
	4	No	1.6×10^{-6}	5.9×10^{-7}

The depth and hydraulic properties of topsoil within the valley is not known. For this modelling assessment, the topsoil layer was assumed to be ~1.5 - 2 m thick. For the base case scenario a hydraulic conductivity of 3×10^{-6} m/s was assumed, representing a gravelly silt topsoil. If the topsoil is sandier, the hydraulic conductivity is likely to be higher. Scenarios 4 and 6 include a topsoil layer with a hydraulic conductivity of 3×10^{-5} m/s. However, this may still be an underestimate if there is sandy gravel present within the valley alluvium.

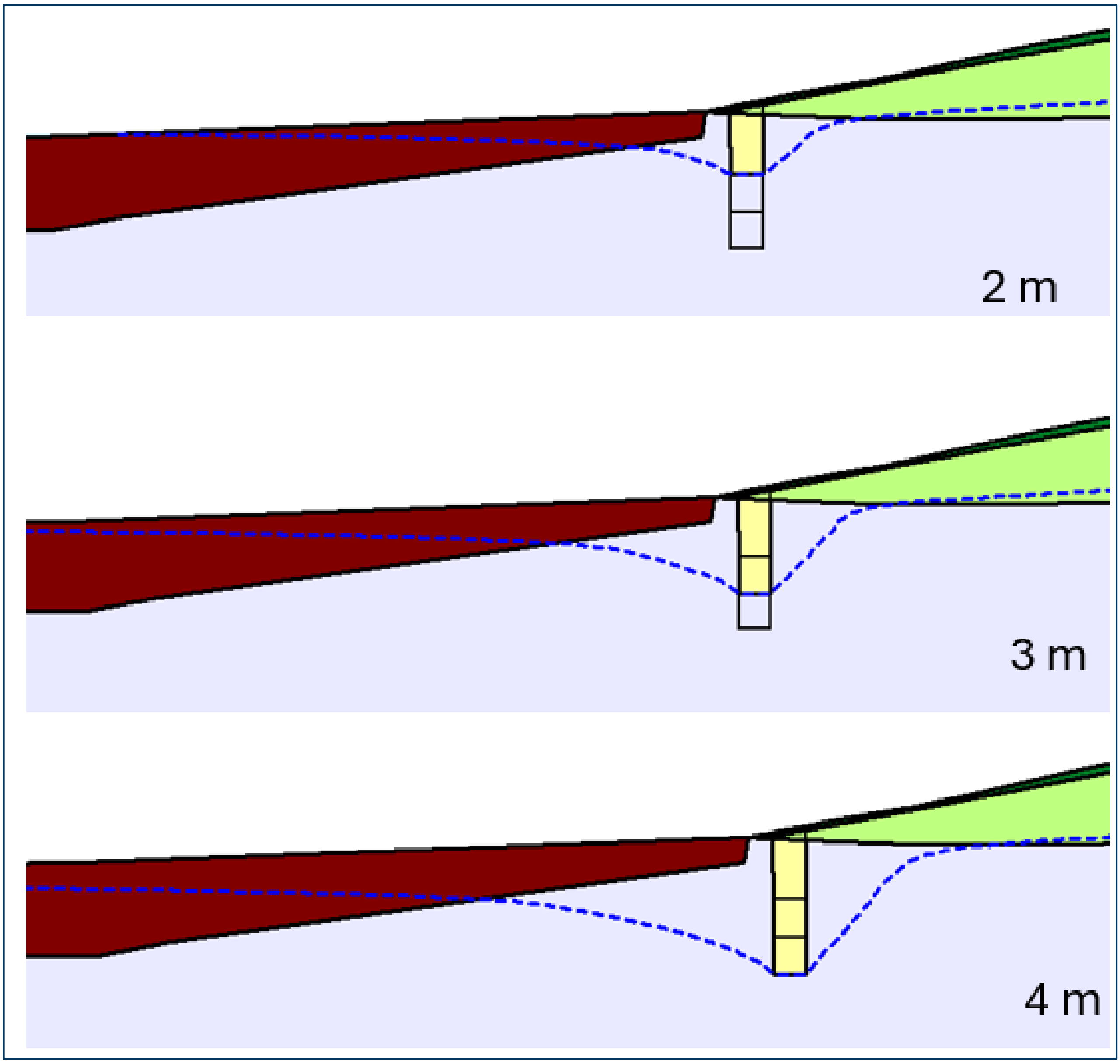


Figure D-4.8 SCD modelling – base case scenarios

In summary the modelling indicates:

- The difference in flow rate between the 2, 3 and 4 m SCD is small as the main inflow is via the connection to the WRS at the top of the drain. However, the modelling indicates that the groundwater drawdown is greater with a deeper SCD. The modelled extent and depth of surface ponding is less with a deeper SCD due to the lower groundwater level.
- The models include a upgradient constant head boundary representing a WRS saturated thickness of 1 m (i.e. groundwater level is 1 m above the top of the schist). If the groundwater level is higher (Scenario 4) flow rates are expected to be higher than modelled in the base case scenario.
- Scenarios 5 and 6 included a low permeability liner on the downgradient side of the SCD. The presence of a liner had little effect on flow rates and groundwater levels, as a result of the already low hydraulic conductivity of the surrounding schist. It is understood that topsoil is removed prior to placement of the WRS. However, if the SCD was installed (or partially installed) within more permeable topsoil or alluvium, a liner may be required to reduce groundwater ingress from the valley alluvium into the SCD.