CHAPTER 12
LAND AND SOIL

BIRD IN HAND GOLD PROJECT
MINING LEASE PROPOSAL

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All maps presented in this chapter are in GDA94 / MGA zone 54 (EPSG: 28354) unless otherwise stated.

12 SOIL AND LAND

Currently the land located within the proposed Mining Lease (ML) supports non-irrigated pastoral beef cattle production, wine processing and vineyards, native vegetation and biodiversity heritage and rural residential properties. The topsoils in the proposed ML consist of predominately acidic clay loams, underlain by silty clays, fine grained clays and siltstones horizons underlain by basement rock of the Tapley Hill formation, sandstones and siltstones.

The Golder Associates (2017) baseline contamination assessment study described the soil within the proposed disturbance area of the Project site as silty clay, sandy clay, gravelly clay and clay. The soil erodibility study (Anderson, 2017) confirmed these findings and added findings of clay loams and the occasional sandy loam.

This section includes soil descriptive data obtained from the Department of Environment and Water (DEW) (formally DEWNR), soils sampled and profiled as part of a site contamination assessment, Terramin soil sampling within and surrounding the proposed ML both utilising a NATA accredited laboratory and calibrated XRF (X-ray fluorescence analyser), as well as a site specific erosion assessment undertaken on top and sub soil. Parsons Brinkhoff had been previously engaged by SA Water in 2006 to undertake a site contamination assessment on the historic Bird in Hand mine area, however, this is not relevant to the disturbance footprint of the proposed Project. It does however provide useful background information and has been included in Appendix L1. All reports referred to in this chapter are listed below in Table 12-1.

TABLE 12-1 | REPORTS COMMISSIONED BY TERRAMIN FOR THE BIHGP

Report	Author	Year	Appendix reference
Site Contamination Assessment	Golder Associates	2017	Appendix L2
Site Contamination Assessment update	Golder Associates	2017	Appendix L3
Soil Erosion Study	Chloe Anderson	2017	Appendix L5

All analysis of Existing Contamination is located in Chapter 14.

12.1 APPLICABLE LEGISLATION AND STANDARDS

The *Environment Protection Act 1993* (together with the Environment Protection Regulations 2009) is the key legislation relevant to soil and land quality at the mine site. The Regulations outline activities that have the potential to result in site contamination. The *Mining Act 1971* (Mining Act) also provides a legislative framework which seeks to ensure that mining operations manage environmental impacts and risks as far as reasonably practicable through the establishment of a Program for Environment Protection and Rehabilitation (PEPR). The PEPR sets out environmental outcomes which are expected to occur as a result of the mining operations and specific criteria to measure the environmental outcomes.

Additional legislation relevant to soil and land quality is as follows:

- *Natural Resource Management Act 2004;*

- *Development Act 1993;* and
- *Explosives Act 1936.*

Further information regarding the requirements and relevance of the legislation is provided in Chapter 4 Statutory Framework. Specifically, the following standards provide a range of criteria relevant to land quality:

- National Environment Protection (Assessment of Site Contamination) Measure 1999;
- Site contamination – acid sulfate soil materials (EPA 2007a);
- Bunding and spill management guideline (EPA 2007b);
- AS 1940-2004: The storage and handling of flammable and combustible liquids;
- AS 1692-2006: Steel tanks for flammable and combustible liquids; and
- AS 2187.2-2006: Explosives: Storage and use – Use of explosives.

The National Environment Protection Council's (1999) National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPM) is established to provide a nationally consistent approach to identifying and managing site contamination. The NEPM refers to three different types of investigation levels: Ecologically-based Investigation Levels (EILs), Health-based Investigation Levels (HILs) and Groundwater Investigation Levels (GILs) which provide criteria (concentrations of contaminants) to guide the assessment of risks to human health and the environment. This approach ensures sound environmental management practices are adopted by all stakeholders when managing site contamination.

The EPA guidelines relating to bunding and spill management provide a framework for the storage and handling of chemicals and hazardous materials. Similarly, the ASS materials guidelines outline measures for the identification of ASS materials and practices for the management of such materials should they be encountered. The measures outlined in each of the guidelines will be incorporated into the design and control measures utilised during construction, operation or closure of the mine site.

The nominated Australian standards each specify specific design criteria that will be incorporated into the design of the mine site to protect the key environmental and stakeholder values relevant to land quality.

12.2 ASSESSMENT METHOD

This section includes data obtained from DEW, as well as soils sampled and profiled as part of a site contamination assessment, Terramin soil sampling within and surrounding the proposed ML both utilising a NATA accredited laboratory and calibrated XRF (X-ray fluorescence analyser), and the site erosion assessment. All data been analysed by suitably qualified professionals.

12.2.1 EROSION ASSESSMENT

A previous study by Golder Associates (2017) found the soil at within the Bird in Hand Gold Project site (the 'Project' or 'BIHGP') was predominantly recorded as silty clay, sandy clay, gravelly clay and clay. Gravelly layers were typically encountered in deeper soil profiles (>1.0 m). The Erosion Assessment methodology identifies the percentages of clay, sand and silt in the soil (Figure 12-1) and calculates the potential for soil erosion potential using the University Soil Loss Equation (Morgan, 2005). The Universal Soil Loss Equation is outlined below:

<u>USLE: The Universal Soil Loss Equation</u> (Morgan, 2005):

- Rainfall Assessment (R) [mm/ha.year]
- Slope Erodibility Factor (K) [tons per ha, per unit R]
- Slope Length. Steepness Factor (LS) [Unitless]
- Cover Management Factor(C) [Unitless]
- Support Practice Factor (P) = 0 (assumed nil to achieve 'natural' A value)

$A\ (ton\ /\ [hectare.\ year] = R.\ K.\ LS.\ C.\ P$

The main objective has been to recommend design and cover management options to result in less than 5 tonnes per hectare per year of soil loss for each of the erosional surfaces. This amount is the current natural rate of erosion identified in the Australia State of the Environment 2016 report (CSIRO, 2011-2016).

The Erosion Assessment for the BIHGP is located in Appendix L5.

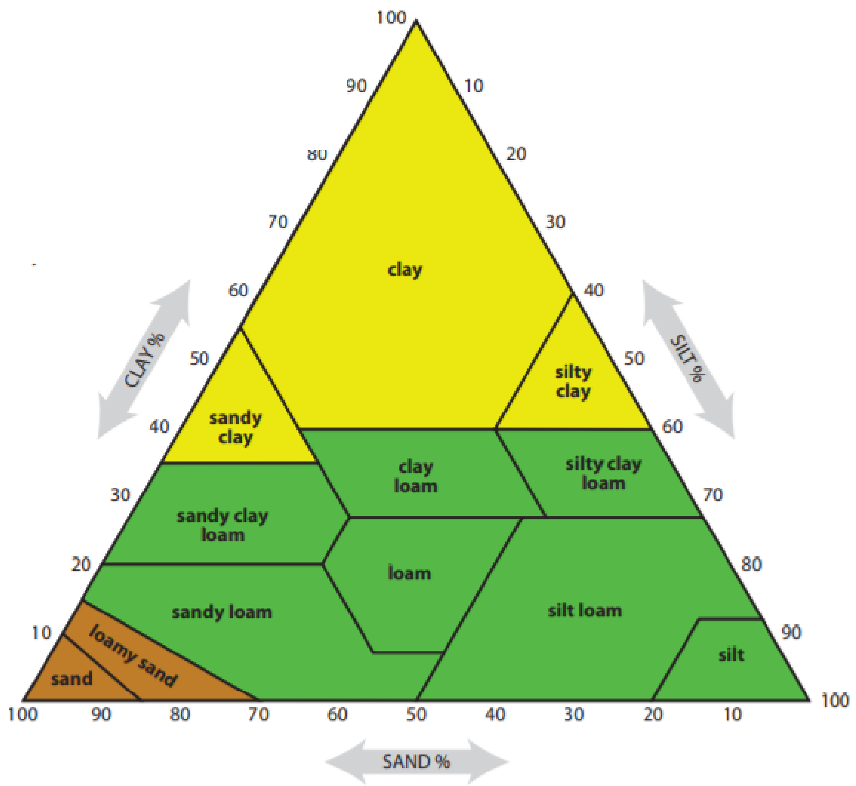

FIGURE 12-1 | SOIL CLASSIFICATION PYRAMID (RENARD ET AL 2011)

12.3 EXISTING ENVIRONMENT

The ML is located in the Adelaide Hills, specifically the Mount Lofty Ranges subregion. Located approximately 400 m above sea level, the topography of the Adelaide Hills generates a wide range of microclimates, however, the region is generally cooler and moister than the plains of Adelaide and the coastal plain.

Soil depth is also variable due to topography, which can range from steep slopes to undulating hills, resulting in shallow stony soils to the top of hills and deep peat-like clays at the bottom of hills.

The majority of the surrounding land is currently used for either livestock grazing pasture, agriculture or horticulture (generally planted vineyards). Extensive irrigation in the catchment is predominantly for horticulture and viticulture while less intensive irrigation is associated with dairy farming and grazing (Adelaide and Mount Lofty Ranges Natural Resources, 2013). Irrigation of orchards, grapevines and pasture increased substantially in the Central Hills region in the preceding 20 years, with the inclusion of apples, strawberries and vineyards in the Inverbrackie Creek sub-catchment. The Western Mount Loft Ranges Water Allocation Plan regulates all groundwater abstraction within the Inverbrackie Creek sub-catchment.

Between the 2000-01 and 2005-06 Agricultural Censuses, the area of agricultural use decreased by 8%, or 2,971 Ha. The Adelaide Hills experienced an increase in agricultural land holdings over this period, with a 22% increase of agricultural establishments (Adelaide Hills Council, 2011). This reflects the changing nature of the Adelaide Hills, with an increasing pattern of agricultural land fragmentation, as a result sub-divisions and urban developments.

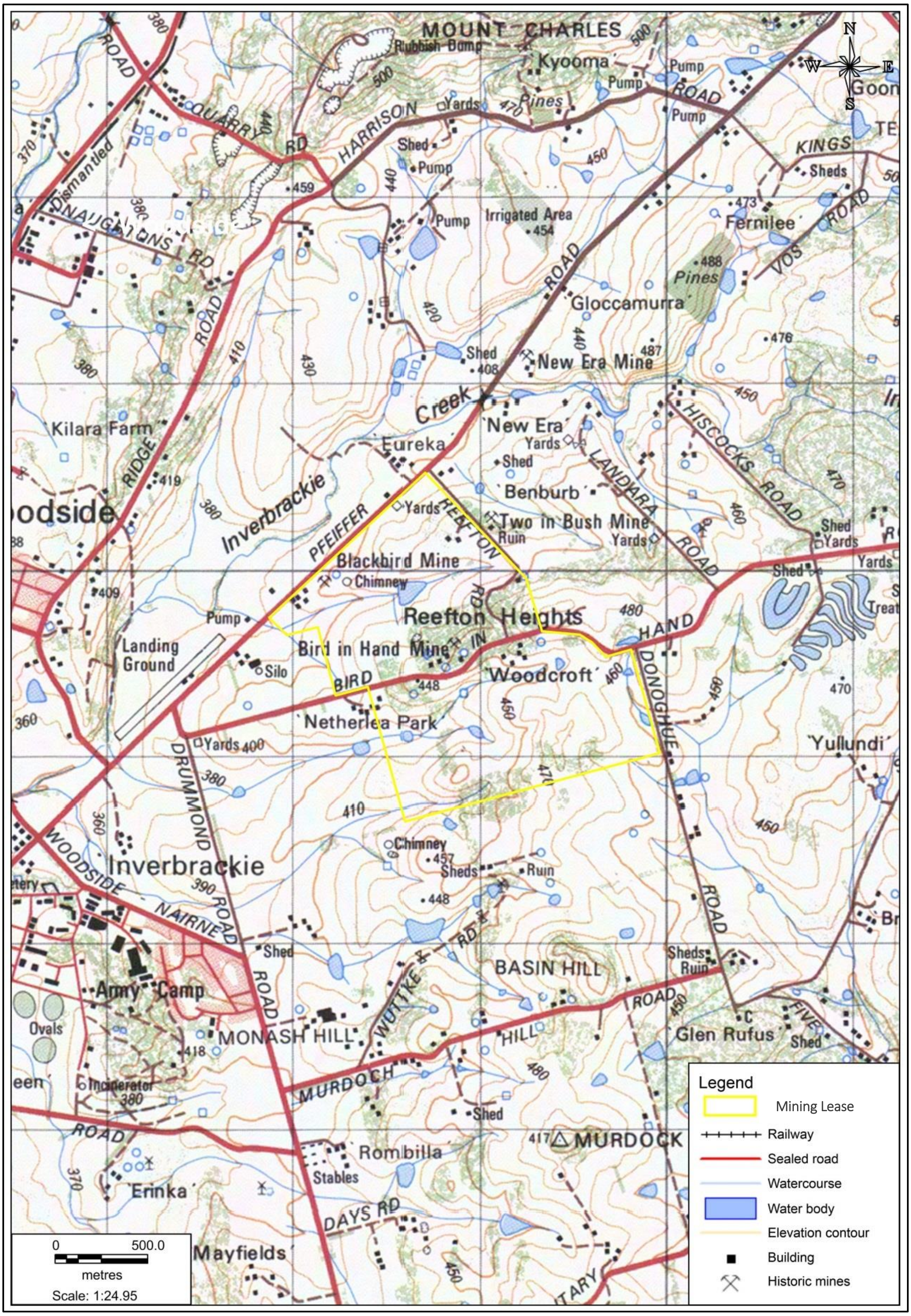

FIGURE 12-2 | ML4113 TOPOGRAPHIC AND LANDSCAPE FEATURES

12.3.1 Soil Classifications

DEW undertook soil sampling in December 1992 within the vicinity of the proposed mining lease (Sample No. CH041 and CH043) and described the soil as "loam to clay loam surface overlying red to reddish brown well-structured friable clay subsoil, grading to weathering fine grained metamorphic rock".

Within the DEW Nature Maps spatial server, soil within the proposed ML is described as Acidic gradational loam on rock, loam over brown or dark clay, acidic loam over clay on rock, or acidic sandy loam over red clay on rock, in either the shallow to moderately deep acidic soils on rock or deep loamy texture contrast soils with brown or dark subsoil soil groups. Soil texture is described as either sandy loam or loam within the proposed ML.

Terramin have undertaken soil sampling within the proposed ML and found that this description is largely representative of the general area both within the proposed ML and proposed operational area.

The soil classification over the ML is a combination of skeletal acidic sandy loam over red clay on rock and skeletal acidic loam over clay on rock. A geotechnical test pit, describing soil analysed during 2016 by Mining One describes the topsoil, to a depth of400mm, as being of low plasticity.

Existing access track conditions to land south of Bird in Hand Road consists of an existing gravelled unformed tracks and existing dirt unformed tracks which are mainly covered with perennial pasture vegetation.

12.3.2 Soil Results: Baseline Contamination Assessment

A baseline contamination assessment was undertaken by Golder Associates in 2016 and 2017 which explored historic potentially contaminating activities on Goldwyn, as well as a targeted intrusive soil investigation in accordance with applicable guidance documentation, including the National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPM). 39 soil cores were targeted across the site, from 0.5 m to 3 m in depth and profiled. Core locations are shown in Figure 12-4. All soil cores were logged and are presented in Appendix H of the Site Contamination Assessment (Appendix L2).

The majority of the Goldwyn site was found to have topsoil consisting of silty/sandy clay morphing into clay after the first 1-2 m, with instances of clayey gravel (inferred as weathered siltstone) through the subsoil layer (Appendix H of the Site Contamination Assessment – Appendix SC1). An example of this is shown below in Figure 12-3.

All soil cores as part of the site contamination assessment returned pH results of between 4.1 to 7.4, indicating neutral to acidic soil conditions no occurrences of acid sulfate soils was recorded. Acid sulfate soils are defined as soils that have somewhere within a 50 cm depth a pH below 3.5 to 4.0 (Food and Agriculture Organization of the United Nations, 1988).

As the proposed project area (Goldwyn) was previously a potato farm, dairy and then beef grazing property, thirteen soil samples were tested for residual organochlorine pesticides (OCP) and organophosphorus pesticides (OPP). Concentrations of OCPs and OPPs in the soil analysed did not exceed the adopted health and/or environmental screening guidelines, outlined in the Site Contamination Assessment – Appendix L2 and L3.

The upper layers of soil were analysed for potassium, nitrogen and phosphorus concentrations in order to classify primary nutrient levels within the proposed project area. Soil testing showed high levels of nitrogen, ranging between 580 and 1980 mg/kg.

More detailed information on site contamination is included in Chapter 14: Existing Site Contamination.

DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION
0.25	E3/01 DS 0.00-0.10 m Rec = 100/100 mm			CI-CH	Silty CLAY medium to high plasticity, dark grey
0.50	EBH03/01 DS 0.00-0.20 m Rec = 200/200 mm				white and grey
1.50	E3/02 DS 0.10-0.30 m Rec = 200/200 mm E3/03 DS 0.30-0.60 m Rec = 300/300 mm EBH03/02 DS 0.30-0.50 m Rec = 200/200 mm EBH03/03 DS 0.50-0.70 m			CH	CLAY high plasticity, red brown and grey
2.00	Rec = 200/200 mm E3/04 DS 0.60-0.90 m Rec = 300/300 mm E3/05				orange brown and grey
2.30	DS 1.50 m EBH03/04 DS 1.50-1.70 m				with some silt
	Rec = 200/200 mm EBH03/05 DS 2.00-2.20 m Rec = 200/200 mm E3/06 DS 2.50 m EBH03/06 DS 2.50-2.70 m Rec = 200/200 mm			CI-CH	Silty CLAY medium to high plasticity, grey green, (Inferred weathered siltstone)
					END OF BOREHOLE @ 3.00 m

FIGURE 12-3 | CORE AND LOG OBTAINED FROM SAMPLE ID EBH03

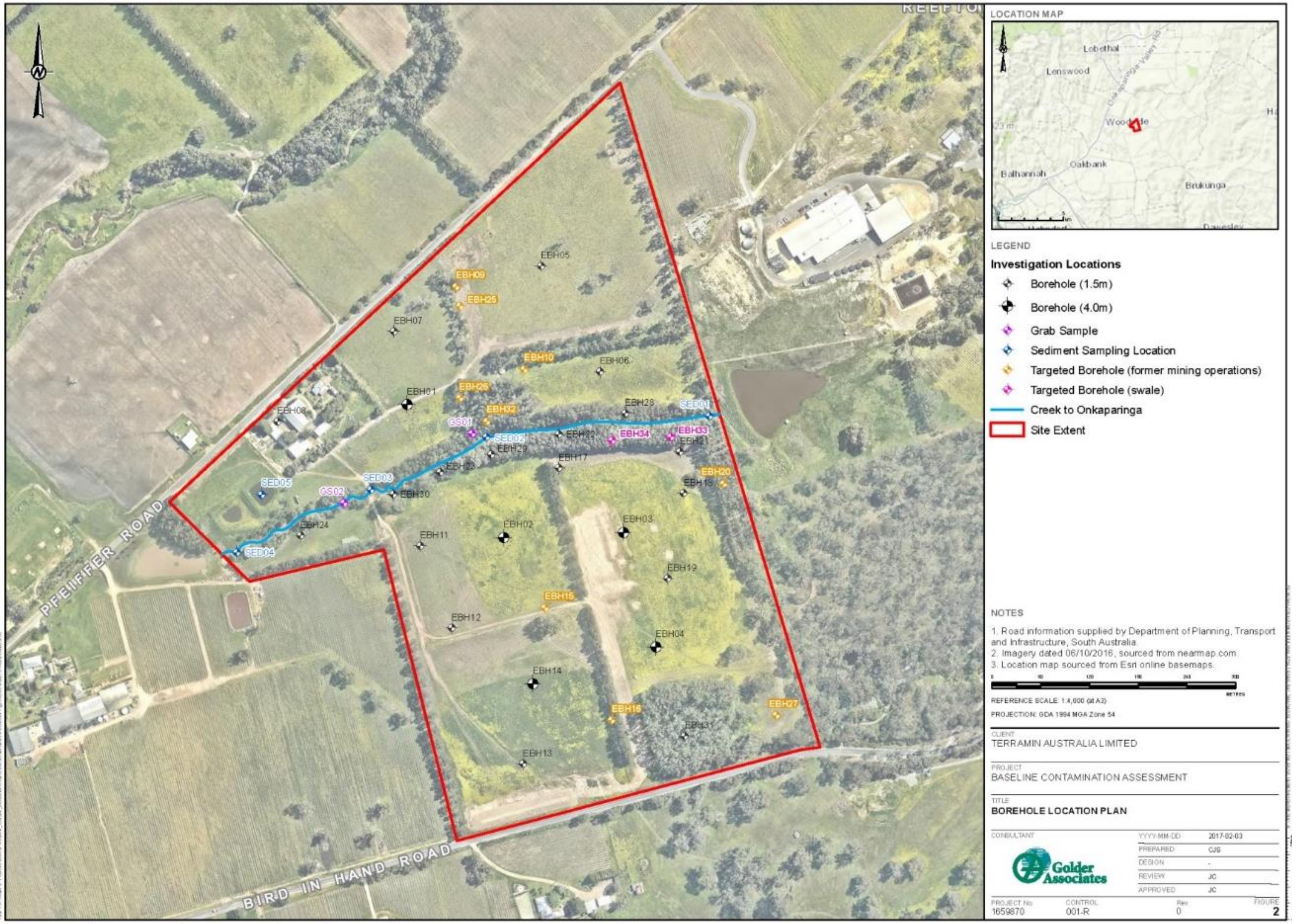

FIGURE 12-4 | PROJECT SITE SAMPLE LOCATIONS UNDERTAKEN BY GOLDER ASSOCIATES

12.3.3 Erosional Potential

The Golder Associates (2017) Baseline Contamination Assessment found the soil within the proposed disturbance area of the Project site was predominantly described as silty clay, sandy clay, gravelly clay and clay, all with the potential to erode (see Table 12-2). This has been compared to the samples taken during erosion assessment research and used to calculate the potential for soil erosion using the University Soil Loss Equation (Morgan 2005), the results of which are located in section 12.6.2.1.

Through the annual State of Environment report for 2016, CSIRO identified 5 tonnes per hectare per year of soil loss is the current natural rate occurring in the region, (CSIRO, 2011-2016). A site specific erosion assessment was undertaken to inform landform design and propose effective management strategies to maintain soil loss to the assessed natural state..

Samples were taken from locations identified in Figure 12-5. The site specific erosion study revealed that the soil is generally classified as clay loam, or sandy clay loam, with instances of silty clay loam, as per the Emerson Class classification system.

The presence of excessive amounts of exchangeable sodium causes soil aggregates to disperse. This is known as deflocculation and occurs in sodic soil. A sodic soil, by definition, contains a high level of sodium relative to the other exchangeable cations (i.e. calcium, magnesium and potassium). A soil is considered "sodic" when the Exchangeable Sodium Percentage (ESP) is 6% or greater. ESP has been calculated for 23 other samples within the proposed ML, and returned values of 0.8 to 8.5% (20 samples less than 6% and 3 samples above 6%).

If soil is sodic (i.e. ESP > 6), clay dispersion declines as the salt concentration of the soil solution increases. Conversely, when soil is sodic and the salt concentration is negligible the soil will disperse easily. This is a common occurrence when rainwater falls upon sodic soil. An expression which is increasingly being used to express the relationship between sodicity and salinity is the Electrochemcial Stability Index (i.e. ESI). Soils with an ESI below 0.05 in the cotton industry are considered dispersive. ESI calculations for the 23 samples within the proposed ML returned values of 0.001 to 0.16 (17 samples above 0.05). This value is not a reliable indicator of dispersity but is often used as a management tool in some agricultural sectors in NSW (mainly cotton farming).

The Erosion Assessment for the BIHGP is located in Appendix L5.

FIGURE 12-5 | EROSION SOIL SAMPLE LOCATIONS

TABLE 12-2 | SOIL CLASSIFICATION BY PARTICLE SIZE

Sample ID	Average % Sand	Average % Silt	Average % Clay	Average % Gravel	Average % Cobbles	Overall Classification
1 A-C	26	48	18	8	<1	Clay Loam
2 A-C	15	41	43	1	<1	Clay Loam
2 D-F	15	43	41	1	<1	Clay Loam
3 A-C	11	25	53	11	<1	Clay Loam
4 A-C	27	48	24	1	<1	Clay Loam
5 A-C	34	36	14	16	<1	Sandy Clay Loam
6 A-C	41	43	14	2	<1	Sandy Clay Loam
7 A-C	30	30	12	28	<1	Sandy Clay Loam
8 A-C	21	20	22	37	<1	Sandy Clay Loam
8D-F	33	28	12	27	<1	Sandy Loam
9 A-C	31	47	14	8	<1	Sandy Clay Loam
9 D-F	15	24	39	22	<1	Sandy Clay Loam
10 A-C	29	43	19	9	<1	Sandy Clay Loam
10 D-F	21	48	18	13	<1	Sandy Clay Loam
11 A-B	12	40	47	1	<1	Sandy Clay Loam
12 A-B	9	15	76	<1	<1	Silty Clay Loam
13 A-B	27	25	45	3	<1	Sandy Clay Loam
14 A-B	41	38	19	2	<1	Sandy Clay Loam
14 C-D	11	20	69	<1	<1	Clay Loam
15 A-B	45	35	18	2	<1	Sandy Clay Loam
15 C-D	24	25	50	1	<1	Silty Clay Loam
16 A-B	10	17	73	<1	<1	Silty Clay Loam
17 A-B	13	15	72	<1	<1	Clay Loam
18 A-B	35	28	28	9	<1	Sandy Clay Loam
18 C-D	11	21	68	<1	<1	Silty Clay Loam
19 A-B	8	18	74	<1	<1	Silty Clay Loam
20 A-B	41	32	25	2	<1	Sandy Clay Loam
20 C-D	21	24	54	1	<1	Clay Loam
21 A-B	35	17	38	10	<1	Clay Loam

12.4 SENSITIVE RECEPTORS

Soil quality in itself becomes the sensitive receptor when discussing potentially impacting events in this chapter. Identified sensitive receptors are detailed in Table 12-3.

Sensitive receptors which are related to soil quality, however, primarily regarding another aspects, such as surface water, or ecological values, have been discussed in the relevant chapters listed below.

- Public safety, Chapter 7;
- Groundwater, Chapter 10;
- Surface water, Chapter 11;
- Air quality, Chapter 15;
- Vegetation and weeds, Chapter 19; and
- Agricultural impacts, Chapter 22.

TABLE 12-3 | IDENTIFIED SENSITIVE RECEPTORS

Sensitive Receptor	Summary	Impact ID
Soil quality	Soil quality which has the potential to impact other land uses	PIE_12_01 PIE_12_02 PIE_12_03 PIE_12_05 PIE_12_06 PIE_12_08
Post-mining land use	Post-closure land use which could be impacted by poor soil quality and quantity	PIE_12_04 PIE_12_07

12.5 POTENTIALLY IMPACTING EVENTS

Soil quality is primarily affected through both natural and manufactured contaminants, or by unnatural physical processes such as compaction of soil loss through excessive erosion. Contaminants could include potentially acid forming material on surface, as well as hazardous materials including hydrocarbons. The primary pathway is surface water run-off resulting in the mobilisation (infiltration/suspension) of spilled contaminants.

Potentially impacting events are detailed in Table 12-4.

TABLE 12-4 | IDENTIFIED POTENTIALLY IMPACTING EVENTS

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	PIE ID
Inappropriate handling of waste materials including the disposal of hazardous materials, sewerage and/or wastewater, contaminating soil and/or water resources	Construction, Operation, Closure	Onsite storage and handling of hazardous materials, sewerage and wastewater	Mobilisation (infiltration/suspension) of spilled contaminants	Soil quality (with indirect impacts on groundwater quality)	No	PIE_12_01
Movement/disturbance of contaminated material onsite has the potential to impact onsite soils (including PAF and ASS)	Construction, Operation, Closure	Contaminated material	Movement and placing of materials	Soil quality	Uncertain	PIE_12_02
Flooding or release of contaminated surface water from operational area impacts on soil quality	Construction, Operation, Closure, Post-closure	Hazardous materials stored on site	High impact rainfall events	Soil quality	No	PIE_12_03

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	PIE ID
Mining activities (establishment of roads, foundations and hardstand areas) have the potential to compact soils reducing productivity and/or vegetation growth	Post-closure	Establishment of roads, foundations and hardstand areas	Soil compaction	Post mining land use	Yes	PIE_12_04
Movement of contaminated material offsite has the potential to impact offsite soils (including PAF and ASS)	Construction, Operation, Closure	Contaminated material	Movement and placing of materials	Soil quality	No	PIE_12_05
Sedimentation of surface water via erosion of bunds results in impact to soil quality	Operation, Closure	Erosion of bunds	Surface water flows	Soil quality	Yes	PIE_12_06
Inappropriate handling of waste materials including the disposal of hazardous materials, sewerage and/or wastewater, impacting soil quality post closure	Post-closure	Onsite storage and handling of hazardous materials, sewerage and wastewater	Mobilisation (infiltration/suspension) of spilled contaminants	Post mining land use	Yes	PIE_12_07
AMD or NMD in surface water runoff has the potential to contaminate soils and impact on soil quality	Post-closure	AMD or NMD material in post-closure surface landforms	Surface water flows	Soil quality	No SPR however outcome proposed for community confidence.	PIE_12_08
Exploration works result in remobilisation of potential contaminants in the drainage line within the ML (south of Bird in Hand Road) impacting soil quality	Exploration	Overland flow erosion of exposed surfaces	Surface water flows	Soil quality	No	PIE_12_09

12.6 CONTROL MEASURES TO PROTECT TOPSOIL AND SUBSOIL

All control measures regarding erosion have been replicated in Chapter 11: Surface Water.

All control strategies in order to prevent or limit the potential for surface water contamination outlined in Chapter 11 are relevant for this chapter.

12.6.1 Design Measures

The site is divided up into specific catchments, with specific areas which have run off directed to the water treatment plant via a network of sumps and pumps. Areas which report to the water treatment plan include run off from the Integrated Mullock Landform (IML), workshop and cement batching plant. This negates the risk of runoff from identified potentially acid forming (PAF) mullock and/or hydrocarbons and/or cement from the workshop and cement batching plant entering into the surface water drainage and ultimately Inverbrackie Creek.

Collection sumps have been integrated into the stormwater management site design to reduce the risk of hydrocarbons and sedimentation exiting site, as well as the construction of a surface water retention dam (detention basin) to allow sediments to drop out naturally before entering the surface drainage system which reports to Inverbrackie Creek.

These areas will be known as operational and non-operational zones.

The IML has been designed to be encapsulated within landscape amenity bunding (retaining walls on the inside), and a drainage system which reports to the water storage dam prior to undertaking water treatment. This ensures all sedimentation from the IML is captured within the water treatment system, preventing it from entering stormwater runoff and into the riparian areas. This is outlined in the Stormwater Management Plan in Appendix I3. Additionally, the shape of the IML has been configured with broad radius curves (50 m) to minimise the impact of erosion caused by water runoff.

Primary design methods incorporated into the landscape design include testing soil characteristics and utilising erosion modelling during the design process of the landscape amenity bunds to determine appropriate slope characteristics, as well as cover management strategies. Design options include reducing slope angles, hyperbolic bund slopes and contour lines on bund slopes.

Slopes of the landscape amenity bunds located on the inside of the operational area are designed to be of a steeper gradient, to allow maximum use of the available area and reduce the overall footprint of the site. As a result, they carry a higher likelihood of water erosion. A synthetic erosion control blanket that has a flexible membrane that works to protect the soil surface from erosion and can be altered to support the growth of vegetation or prevent it through the use of a hydrophobic polymer will be used to prevent erosion in these cases.

All chemical and hydrocarbon storage will be in accordance with:

- AS 1940-2004: The storage and handling of flammable and combustible liquids;
- AS 1692-2006: Steel tanks for flammable and combustible liquids;
- Relevant South Australian legislation; and
- Best practice guidelines.

The wheelwash and washdown area will bunded, with wash-water recycled within the washdown area.

Although the need for new formed tracks for exploration is not currently planned there may be a need for short lengths of formed track to be constructed were unformed tracks degrade through a combination of wear and rain events. Formed tracks may also be required for access to drill pads on steep hills. Access roads and earthworks for all exploration will be managed and rehabilitated in consultation with the relevant landholders and the Exploration Management Plan (Appendix B7).

The design measures which relate to land and soil are detailed in Table 12-5.

TABLE 12-5 | DESIGN MEASURES: SOIL

Design Measures	Impact ID
Landscape amenity bund slope design and cover management informed by erosion modelling	PIE_12_06
Drainage system designed around wheelwash and washdown area	PIE_12_07
Chemical and hydrocarbon storage in accordance with Australian standards and applicable legislation and best practice methods	PIE_12_01
Bunding around storage areas of chemicals and hydrocarbons (AS standards)	PIE_12_01
Hydro-mulching of exposed soils as soon as practical	PIE_12_06
Retaining walls utilised where required on steeper slopes	PIE_12_06
Contour lines to be included during construction on the sides of bunds	PIE_12_06
Synthetic erosion control blanket on steeper landscape amenity bunding where required	PIE_12_06
Sealing of internal access roads for external vehicles (excluding fire access roads and road between underground and IML)	
If any PAF material encountered, directed to designated storage within IML structure (PAF management plan)	PIE_12_05 PIE_12_08
Runoff from IML directed to sump and pumped to water treatment plant (surface water management plan)	PIE_12_05 PIE_12_08
Runoff from workshop areas directed to sump and pumped to water treatment plant (surface water management plan)	PIE_12_07
Primary and secondary Gross Pollutant Traps (GPT) within stormwater management design	PIE_12_07
Water Sensitive Urban Design (WSUD) swales incorporated near existing drainage lines to further reduce potential for sedimentation leaving site	PIE_12_07
Stormwater dam to allow analytes to be removed before entering the surface drainage system	PIE_12_07
Stormwater dam overflow to be directed to WSUD swale system	PIE_12_07
Water storage dam to be designed to accepted AS standards	PIE_12_08 PIE_12_03
Sewerage system to be designed to AS standards	PIE_12_01
Covered/shedded areas to capture rainfall and overflow to be direct WSUD swale areas	PIE_12_04
Water treatment plant bunded	PIE_12_01

12.6.2 MANAGEMENT STRATEGIES

Management strategies regarding pre-existing site contamination have been included in Chapter 14: Existing Site Contamination. A site contamination management plan is included in Appendix L4.

In order to minimise and mitigate impacts to surface water during construction, operation and closure activities, control and management strategies would be incorporated into the PEPR and implemented for relevant project phases. Key control and management strategies are outlined below in Table 4.

Management strategies to ensure vegetation success will be based on standard land management practices (weed, fire, soil erosion, etc.) as out lined in the Biodiversity Management Plan (Appendix R6).

The Landscape Function Analysis (LFA) technique will be used to monitor erosion and other ecosystem health parameters on bunds and revegetated areas. EFA will assist with identifying areas requiring improvement and provides an analytical measure of condition.

Vehicle access will be restricted from operating on bunds to prevent erosion impacts as part of the traffic management plan.

The proposed waste management plan provides that all chemical and hydrocarbon spills are remediated to meet EPA guidelines within 48 hours of the spill, or a longer time agreed by the Director of Mines.

Spill kits will be located both on surface and underground.

Records will be kept of volumes of putrescible waste taken off-site to demonstrate disposal of all potentially polluting waste taken to an approved EPA site and in accordance with the Waste Management Plan.

A Waste Management Plan would be included as part of the PEPR to ensure waste is managed, resulting in minimal impact to the environment through a hierarchical approach (Figure 12-6).

FIGURE 12-6 | HIERARCHY OF CONTROL TO MINIMISE WASTE PRODUCTION AND IMPACT ON THE ENVIRONMENT (ZERO WASTE SA, 2012)

Provision of a report once prior to entering closure monitoring phase by a suitably qualified site contamination consultant verifies that a site contamination assessment and if required remediation in accordance with the NEPM and relevant EPA guidelines has occurred, ensuring there is no unacceptable risk to human health or the environment as a result of the contamination when compared with relevant baseline concentrations and relevant NEPM investigation levels.

All hardstand areas which are to be returned to vegetation for the post-closure land use will be deep ripped, and either direct seeded or planted with tubestock, as per the final Closure Plan which will be included in the PEPR.

12.6.2.1 EROSIONAL POTENTIAL (REPLICATED FROM CHAPTER 11: SURFACE WATER)

Water erosion potential of the topsoil through the proposed ML has been classified by DEW as moderately high, with the majority of the proposed operational area classified as Moderate. The entirety of the proposed ML is classified as a low potential for wind erosion.

More recent erosional testwork undertaken of soils within the proposed operational area (Figure 12-8) demonstrate that erosion of the proposed operational area can be maintained at the accepted background rates of less than 5 tonnes per hectare, both during operations and post closure.

The management and control strategies proposed demonstrate that long term erosion control is achievable.

Utilising the Universal Soil Loss Equation has demonstrated that erosion control and management strategies are required. This is due to the soil types, the various slope lengths and angles of the proposed landscape amenity bunds within the operational area. Different strategies were tested, but the erosion assessment report firstly recommends that all the proposed landscape amenity bunds initial be treated by Hydromulching in conjunction with planting and seeding dense shrub and native grass cover. For the Southern Bund Extension, Hillside Screening Bund and for Central Bunds 2 and 4, the cover from dense shrub and native grasses is sufficient erosion control, but for the remainder of the landscape amenity bunds, there is a need for additional mulch placement for the life of the mine. Further control actions, highlighted in the P factor, is required through retaining walls and contour intervals along the slope lengths. For Central Bunds two and four, there is proposed retaining walls on both sides of the slopes preventing potential erosion. Furthermore, for all the landscape amenity bunds, excluding the Northern Topsoil Bund, the Car Park and Central Bund one, there is a need for contour intervals at approximately every 3m with a slope of 2-5° to be added along the slope lengths. These management and control strategies have resulted in less than the 5 ton/hectare.year natural erosional potential for the BIH location for each of the proposed landscape amenity bunds.

Finally, the erosion assessment report has recommended a number of management and control strategies to allow the proposed landscape amenity bunds to achieve sustainable natural erosional levels post closure of the mine. For the Northern Topsoil Bund, the Southern Bund Extension and the Hillside Screening bund, the proposed management strategies are sufficient to remain as native vegetation cover. For the Eastern Screening Bund, the bund should be cut down to a height of 1.5 metre, with interval contours and to be covered in dense shrub vegetation. The remainder of the landscape amenity bunds are proposed to stay in place, covered in vegetation under the post mining land uses. As part of the management strategy, it is proposed that a soil erosion Trigger Action Response plan (TARP) be in place and that after the proposed landscape amenity bunds have been constructed, each bunds performance be monitored and regularly reviewed. A topsoil management plan would also be developed and submitted with the PEPR to ensure the integrity of stockpiled topsoils for use during rehabilitation, as well as the development of both erosion and air quality (dust) management plans.

The Erosion Assessment for the BIHGP is located in Appendix L5.

Importantly, the soil management plan including the unexpected finds protocol prepared by Golder Associates (appendix L4) will apply for all exploration works. Although there is currently no soil test results indicating contamination sources, the soil management zone has been expanded to include all historic workings located on the southern side of Bird in Hand Road – shown in Figure 12-7.

FIGURE 12-7 | EXPLORATION SUBJECT TO SOIL MANAGEMENT ZONE SOUTH OF BIRD IN HAND ROAD

TABLE 12-6 | MANAGEMENT STRATEGIES: LAND AND SOIL

Management Strategies	Impact ID
Waste Management Plan (as part of Biodiversity Management Plan) • Spill kits • Remediation of spills requirement • Reporting and auditing requirements • Closure site contamination review	PIE_12_01 PIE_12_07
PAF Management Plan to be implemented which outlines storage requirements for identified PAF material from mining operations and includes no PAF material to be left on surface at close of operations.	PIE_12_05 PIE_12_08
Identified PAF material documented and prioritised for backfill	PIE_12_05 PIE_12_08
Surface Water Monitoring Plan to be developed with reference to baseline surface water quality data, the EPA Water Quality Policy 2015 (SA) and ANZECC water quality guidelines (as referred to in the EPA Water Quality Policy 2015 (SA)).	PIE_12_01 PIE_12_02 PIE_12_03 PIE_12_04 PIE_12_05 PIE_12_06 PIE_12_07 PIE_12_08
For appropriate storage and handling of hydrocarbons and chemicals, the following measures will be implemented: • Develop and implement chemical and fuel storage, handling and emergency response procedures in accordance with AS 1940-2004. • Develop and implement a regular inspection programme to audit and monitor fuel and chemical storage areas to ensure integrity, housekeeping and correct use. • Maintain appropriate spill kit/clean up material, as required by the developed procedures.	PIE_12_01 PIE_12_07
Construction activities will incorporate sediment and erosion management practices outlined in an Erosion and Sediment Control Plan, which align with standard industry practice to manage sediment from construction sites, such as WSUD swales, contour lines, hay baling, temporary sediment traps, dust generation management and bunding of stockpiles.	PIE_12_06
The IML will be covered using hydro-mulching or a biodegradable binding product to manage water and wind erosion if required.	PIE_12_08
Water Storage Dam Management Plan which includes monitoring of water storage dam embankments through survey prisms and water level trigger levels.	PIE_12_03
Routine maintenance and inspection of pipework and associated infrastructure on surface to reduce likelihood of blockage and leaks.	PIE_12_01
Erosion Trigger Action Response Plan (TARP)	PIE_12_06
Topsoil Management Plan	PIE_12_06

FIGURE 12-8 | EROSION SAMPLING LOCATIONS

12.7 IMPACT ASSESSMENT

The primary risks to soil quality are impacts resulting from hydrocarbon spills, sedimentation/erosion of landforms, and disturbance of any potentially existing contamination locations.

Chemicals and hydrocarbons will be kept within designated storage areas bunded to prevent the accidental mobilisation of contaminants affecting soil quality. Final design of the bunding of the any hazardous materials storage area(s) will be designed to retain or redirect away from the area, surface water flows during a 1 in 100 year flood event. A storm event exceeding the capacity of the storage area could result in the contamination of surface water flows by contaminants, subsequently affecting soil quality.

A flood event exceeding the capacity of the storage area is considered **unlikely** (i.e. during the 8 year project lifespan) during construction and operation of the proposed mine, and as the storage area reports to contained water storage dams or the treatment plant located onsite, the consequence of the flood event can be contained and therefore is considered **minor**.

Utilising all of the storage and bunding requirements, as well as proposed remediation of all spills to NEPM standards and reporting all chemical and hydrocarbon spills reduces the expected impact to soil quality to **negligible**.

Spill kits will be located both on surface and underground.

Records will be kept of volumes of putrescible waste taken off-site to demonstrate disposal of all potentially polluting waste taken to an approved EPA site and in accordance with the Waste Management Plan.

Provision of a report once prior to entering closure monitoring phase by a suitably qualified site contamination consultant verifies that a site contamination assessment and if required remediation in accordance with the NEPM and relevant EPA guidelines has occurred, ensuring there is no unacceptable risk to human health or the environment as a result of the contamination when compared with relevant baseline concentrations and relevant NEPM investigation levels, reduces the potential for soil impacts affecting post closure land use to **negligible**.

As such, the overall risk of contamination of soil quality is considered to be **low**.

There is a concern that metalliferous drainage may exist from former tails and mine waste areas from the historic Ridge mine. This includes a private landholder stock dam located directly downstream from the historic Ridge chimney and downstream from Terramin exploration sites. Terramin do not own or control the land, and do not expect to access the dam area for exploration.

However it is noted that water quality obtained from the dam from 2014-2016 indicates no traces of mercury, cyanide, and within average ranges of metals as all other dams and surface water in the region – as seen in

Table 12-7. The dam had sediments cleaned out during 2015 by the landholder and this waste was located to the south of the dam. The dam is currently used for stock. Stock access the dam and there are a number of shallow depressions within the floor of the dam, presumably from stock pugging whilst seeking water. Stock access has resulted in a low pH during 2018 due to low water levels and animal waste. The dam is located in the riparian zone and fills each year, overflows generally each winter and is equipped with a flow diversion for when the dam is full. This diversion flows each year and has been observed operating the last 4 years and presumably has done so since the property was used for agricultural uses. There is no additional credible risk to the soil quality from Terramin's exploration activities from these historic areas.

TABLE 12-7 | RESULTS OBTAINED FROM FORMER RIDGE DAM AND REGIONAL STATISTICS TO DATE (2018)

Date Sampled	pH	EC uS/cm	TDS mg/L	As Tot mg/L	Cd Tot mg/L	Cu Tot mg/L	Fe Tot mg/L	Mn Tot mg/L	Pb Tot mg/L	Zn Tot mg/L	Hg Diss mg/L	Hg Tot mg/L	Cn Tot mg/L
24-Mar-14	7.04	167	89	0.01	<0.0001	0.009	7.1	0.236	0.053	0.006	<0.0001	<0.0001	<0.004
30-Jun-14	7	156	291	0.004	0.0001	0.016	8.53	0.059	0.049	0.016	<0.0001	0.0002	<0.004
14-Jul-14				<0.001	<0.0001	0.007	1.36	0.021	0.005	0.015	<0.0001	<0.0001	
26-Nov-14	9.34	272	421	0.017	0.0003	0.021	13.2	0.276	0.093	0.05			
07-Sep-16	7.19	160	154	0.003	0.0001	0.006	1.91	0.043	0.011	0.005			
26-Apr-18	3.07	1310	769	0.033		0.027	18.4	0.805	0.153	0.041	<0.0001	<0.0001	
Regional surface water ranges (excl. former Ridge dam)	5.5-9.8	62-3930	99-3280	0.001-0.89	0.0001-0.0066	0.001-0.17	0.07-649	0.003-59.9	0.001-0.898	0.005-0.509	<0.0001	0.0012	<0.004
Sample count regionally (excl. former Ridge dam)	358	366	353	277	258	297	285	285	297	297	70	53	12

12.7.1 SEDIMENTATION/EROSION

Water erosion provides the highest risk rating of potential impacts to surface water quality, specifically though construction.

Through the use of temporary strategies including erosion management practices which align with standard industry practice to manage sediment from construction sites, such as hay baling, temporary sediment traps, dust generation management and bunding of stockpiles, as well as the design of the landscape amenity bunding and the use of, contour banking, hydro-mulching, and synthetic erosion control blankets, the risks associated with sedimentation have been reduced to as low as reasonably practical. Still, the erosion management system relies upon successful implementation, maintenance and checking of a human controlled system. For this reason, a credible worst case scenario which results in increased sedimentation in the surface water exiting Goldwyn is **possible** through construction, however, due to the pre-existing understanding of the Inverbrackie Creek and turbidity it frequently experiences pre-mining, the impact of such an event is considered **minor**, as the ecological value of the Creek is considered poor, and the impact would be a relatively short timeframe (that is, over hours), the overall impact is considered **low**. Once the site is constructed, control measures installed and vegetation established, no impact is expected.

Landscape amenity bunds will all have contour banking and hydro-mulching applied which will reduce potential for wind and water erosion until vegetation germinates, further stabilising the soil. The landscape amenity bunds will then be planted with native vegetation tubestock containing species which are endemic to the region. Between the surface treatments, spraying of grasses and tubestock planting, Terramin expect a self-sustaining system to establish which stabilises the soil and prevents surface water sedimentation from occurring from the landscape amenity bunds.

Surface drainage (overland flow paths and swales) will be protected by erosion control measures, where required (to be determined by assessing soil particle size distribution, slope and other variable parameters). Erosion control measures typically consist of providing a surface treatment to slow water velocity, or resist scouring velocities and structures within the channel to reduce flow velocities.

Given the relatively high rainfall in the area, site vegetation cover within the drainage channels will establish naturally once planted with sedges. However other treatment measures will be required to minimise channel flow velocities, where high grades are experienced. In these areas rock rip rap utilising local materials won from the site during the construction phase will be installed at critical locations within the channels.

Rock rip rap will be placed:

- at pipe outlet points,
- at the culvert road crossing of the existing creek,
- at the upstream end of the surface water retention dam (detention basin), and
- within swales where flow velocities are estimated to be greater than 2 m/s.

12.8 DRAFT OUTCOME(S) AND MEASUREMENT CRITERIA

In accordance with the methodology presented in Chapter 6, an outcome has been developed for surface water impact events with a confirmed link between a source, pathway and receptor (S-P-R linkage), see Table 12-8.

All outcomes are supported by draft measurement criteria which will be used to assess compliance against the draft outcomes during the relevant phases (construction, operation and closure), and where relevant draft leading indicator criteria. These measurement criteria and leading indicators are indicative only and will be developed further through the PEPR.

All Outcomes for the entire project are presented in Appendix D1.

TABLE 12-8 | DRAFT OUTCOMES AND MEASUREMENT CRITERIA

Draft Outcome	Draft Measurable Criteria	Draft Leading Indicator Criteria
No adverse impacts to soil quality or quantity within the mining lease caused by mining activities that could compromise the post mining land use No adverse impacts to soil quality or quantity on surrounding land caused by mining activities	Annual review of soil movement records, including topsoil available / stockpiled for closure, shows no measurable decline in soil quality or quantity	A materials balance of topsoil available / stockpiled for closure demonstrates requirements are met or identifies a deficiency.
	Annual mine records demonstrate all areas of PAF and ASS encountered were appropriately contained and/or treated	None proposed
	All chemical and hydrocarbon spills are remediated to meet EPA guidelines within 48 hours of the spill, or a longer time agreed by the Chief Inspector of Mines.	All topsoil stockpiles located on the proposed ML will be annually sampled as per AS4482.1-2005 standards. Any results higher than topsoil baseline samples will be investigated and appropriate actions taken.
	Records will be kept of volumes of putrescible waste taken offsite to demonstrate disposal of all potentially polluting waste has been taken to an approved EPA site and in accordance with the Waste Management Plan	None proposed
	During rainfall events which generate runoff, three samples will be taken to measure turbidity at the car park, south-western drainage line, central drainage line and at the overflow point of the surface water retention dam as per sampling method AS/NZS 5667.1:1998 standards. A paired t-test will demonstrate that turbidity at the car park, south-western drainage line and at the overflow point of the surface water retention dam is not significantly greater (p-value ≤ t-test value) from the mean of the samples taken at Inverbrackie Creek upstream of the ML at that point in time.	After high rainfall events which generate runoff, records of visual inspections of silt traps, the surface water retention dam, and surface drainage systems demonstrates that silt volumes are no more than 50% of trap capacity and there is no breach in walls.
	Provision of a report once prior to entering closure monitoring phase by a suitably qualified site contamination consultant verifies that a site contamination assessment and if required remediation in accordance with the NEPM and relevant EPA legislation/guidelines has occurred, ensuring there is no unacceptable risk to human health or the environment as a result of the contamination when compared with relevant baseline concentrations and relevant NEPM investigation levels.	None proposed

All land on the mining lease affected by mining and associated activities is rehabilitated to achieve the agreed post mining land use.	Independent audit at mine completion demonstrates all reasonable actions have been taken to achieve post mining land use, where this use has been agreed with stakeholders. Independent audit at mine completion confirms all land in the mining lease is suitable for the agreed post mining land uses.	None proposed

12.9 FINDINGS AND CONCLUSIONS

In summary, Terramin have designed stormwater management, water erosion management, chemical storage and spill response procedures to reduce or eliminate potential pathways to the environment, particularly in terms of land and soil quantity and quality. The stormwater management system is of the appropriate size and design to manage the expected rainfall and potential surface water impacts at the Project site, while protecting the identified sensitive receptors. Primary engineering control reduce or eliminate the potential for impacts to land and soil quality and quantity, and have reduced all potential impacts to as low as reasonably practical.