



# Kalgoorlie Consolidated Gold Mines (KCGM)

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Soil and Waste Characterisation  
Section 9 – Morrison Flats

April 2010



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# Kalgoorlie Consolidated Gold Mines (KCGM)

## Soil and Waste Characterisation

### Section 9 – Morrison Flats

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## Executive Summary

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Outback Ecology Services (OES) was commissioned by Kalgoorlie Consolidated Gold Mines (KCGM) to conduct a comprehensive soil and waste material characterisation study for the KCGM operations. Stage 1 of the investigation comprised an information review and gap analysis, while Stage 2 incorporated the findings of Stage 1 into a sampling and analysis program to develop a soil and waste materials inventory based on the volumes and characteristics of materials on site.

This report, which comprises Section 9 of the overarching Soil and Waste Characterisation report, presents the investigation into the characteristics of tailings and soil materials within the Morrison Flats area, with the recommendations and conclusions considered jointly with findings from concurrent investigations detailed in Sections 3 to 10 of the overarching Soil and Waste Characterisation report, to develop rehabilitation recommendations for the Morrison Flats area.

Morrison Flats is located in the Hannan's Lake saline lake playa catchment, and is a site of historic tailings storage. It is now dominated by remnant TSFs, as well as areas of water and wind deposited tailings material.

There were three 'typical' soil profiles identified within the Morrison Flats study area. The 'Deep Tailings' profile was associated with remnant tailings storage facilities (TSFs) and had a 100 to 150 cm thick tailings layer overlying an *in situ* calcareous clay soil. The 'Shallow Tailings' profiles were associated with tailings that have accumulated in localised depressions as a 25 to 50 cm thick layer. The 'Surface Tailings' profiles typically had thin tailings layers, between 2 and 10 cm thick, overlying *in situ* soils on vegetated low-relief hills.

The *in situ* soil materials underlying the tailings materials included a 'disturbed' topsoil, gravelly ironstone/clays, mottled and calcareous clays, which are listed in sequence of increasing horizon depth.

### *Soil physical characteristics*

The tailings materials generally had loamy sand or silty loam textures. The thin tailings layer at the Surface Tailings profile was single grained with a loose consistence, while the tailings materials from the Shallow Tailings and Deep Tailings profiles typically had a massive blocky structure (Table ES1). Samples from the thin tailings layer from the Surface Tailings profile were the only tailings materials to exhibit clay dispersion.

Soil strength varied for the tailings materials, however the majority showed potential to hard set (Table ES1). All tailings had relatively slow drainage, which was most pronounced in the finer textured tailings from the Deep Tailings profile. Roots were only observed in the tailings layer of the Surface Tailings profile, where vegetation was observed.

The *in situ* gravelly ironstone and clay soils which were observed in the Surface Tailings profile, had textures of sandy loam and sandy clay loam respectively, while the mottled clay and calcareous soils observed at the bottom of each soil profile were typically classed as a silty loam. The gravelly ironstone/clay horizon was the only *in situ* soil material to exhibit dispersion (Table ES1).

Soil strength varied for *in situ* soils, however they were on average hard setting (Table ES1). Disturbed soil material used in  $K_{sat}$  measurements exhibited slow drainage. Roots were generally only observed at the Surface Tailings profile, where vegetation was present.

#### *Soil chemical characteristics*

All tailings materials and underlying *in situ* soils exhibited alkaline pH values (Table ES2), which were generally comparable to other analogue soil materials in the KCGM study area. Electrical conductivity (EC) values were considered extremely saline for all tailings materials, which was most pronounced in the Shallow and Deep Tailings profile tailings material. Tailings EC values tended to be substantially higher than the EC values of the *in situ* soil materials below at the Shallow and Deep Tailings profiles. None of the tailings material were considered sodic.

Organic carbon, plant-available nitrogen and phosphorus, were all low within the tailings materials, with this the materials considered to have a low nutrient status (Table ES2). These values were generally comparable to those measured for the *in situ* soil materials.

Tailings materials reported levels of arsenic, copper, zinc and mercury which were above their respective Ecological Investigation Level (EIL) values set by the Department of Environment (DoE, 2003). As would be expected, total metal concentrations of the tailings material differed substantially to those of the underlying *in situ* soil materials.

#### *Conclusions and recommendations*

This investigation has highlighted that the tailings layers from the different tailings / soil profiles in the Morrison Flats have several problematic properties in relation to plant growth which include;

- A massive structure and tendency to hard set;
- Extreme salinity; and
- High metal concentrations including elevated levels of arsenic, copper, zinc and mercury which are above their respective EILs.

Little is known about the effect of elevated As, Cu, Zn, Hg on native Western Australian vegetation, however in general, the physical and chemical properties of tailings material suggest that they may provide a relatively hostile environment for plant growth, which is likely to be a contributing factor to the absence of vegetation, particularly within the Shallow Tailings and Deep Tailings profiles.

**Table ES1: Summary of physical properties of tailings / soils within profiles in the Morrison Flats study area. Figures represent average values or most common class for each parameter. Broad ratings of **good**, **intermediate** and **poor**, for each parameter relate to suitability for plant growth and/or overall material stability, relative to the KCGM study area.**

Site Classification	Depth Interval (cm)	Material Description	Soil Texture	Modulus of Rupture (kPa)	Emerson Class
<b>Surface Tailings</b>	0 to 5	Tailings	Loamy sand	Low (27.2)	2 or 4
	10 to 20	Disturbed remnant soil surface	Sandy clay loam	Moderate (39.5)	4
	40 to 50	Gravelly ironstone to clay	Sandy loam to sandy clay	-	2 or 4
	80 to 100	Calcareous Clay	Silty loam	-	6
<b>Shallow Tailings</b>	0 to 5	Tailings	Silty loam	High (91.6)	4
	20 to 30	Tailings	Loamy sand to silty loam	Very high (101.7)	4
	40 to 50	Disturbed soil	Loam sand to sandy clay	-	4
	90 to 110	Calcareous clay	Silty loam	Very high (100.0)	4
<b>Deep Tailings</b>	0 to 5	Tailings	Silty loam	High (86.0)	4
	10 to 20	Tailings	Loamy sand	-	4
	40 to 50	Tailings	Loamy sand to silty loam	High (62.6)	4
	90 to 100	Tailings	Loamy sand to silty loam	Moderate (41.8)	4
	140 to 150	Mottled /Calcareous clay	Silty loam	-	4

**Table ES2: Summary of chemical properties of tailings / soils within profiles in the Morrison Flats study area. Figures represent average values or most common class for each parameter. Broad ratings of good, intermediate and poor, for each parameter relate to suitability for plant growth and/or overall material stability, relative to the KCGM study area.**

Site Classification	Depth Interval	Material Description	pH (H <sub>2</sub> O)	Salinity Class	Organic Carbon (%)	Effective Cation Exchange Capacity (meq/100g)	Exchangeable Sodium Percentage (%)	Nutrient Status
<b>Surface Tailings</b>	0 to 5	Tailings	Moderately alkaline (8.8)	Moderately saline to extremely saline	Low (0.35)	Very High (52.4)	Non sodic (1.8)	Low
	10 to 20	Disturbed remnant soil surface	Moderately alkaline (8.6)	Extremely saline	Low (0.51)	Moderate (19.2)	Sodic (7.3)	Low
	40 to 50	Gravelly ironstone to clay	Moderately alkaline (8.2)	Extremely saline	Low (0.34)	Moderate (19.7)	Highly sodic (33.2)	Low
	80 to 100	Calcareous Clay	Moderately alkaline (8.1)	Extremely saline	Low (0.20)	Low (10.3)	Sodic (6.7)	Low
<b>Shallow Tailings</b>	0 to 5	Tailings	Moderately alkaline (8.5)	Extremely saline	Low (0.44)	High (25.2)	Non sodic (2.7)	Low
	20 to 30	Tailings	Moderately alkaline (8.5)	Extremely saline	Low (0.54)	High (26.8)	Non-sodic (2.5)	Moderate
	40 to 50	Disturbed soil	Moderately alkaline (8.7)	Extremely saline	Low (0.23)	Moderate (17.3)	Non sodic (4.7)	Low
	90 to 110	Calcareous clay	Moderately alkaline (8.8)	Extremely saline	Low (0.21)	Moderate (19.0)	Sodic (6.2)	Low
<b>Deep Tailings</b>	0 to 5	Tailings	Moderately alkaline (8.5)	Extremely saline	Low (0.56)	Very High (67.0)	Non sodic (1.4)	Low
	10 to 20	Tailings	Moderately alkaline (8.5)	Extremely saline	Low (0.45)	Very High (44.7)	Non sodic (0.9)	Low
	40 to 50	Tailings	Moderately alkaline (8.5)	Extremely saline	Low (0.40)	Moderate (23.7)	Non sodic (1.3)	Low
	90 to 100	Tailings	Moderately alkaline (8.5)	Extremely saline	Low (0.51)	-	-	Low
	140 to 150	Mottled to Calcareous clay	Moderately alkaline (8.7)	Very to extremely saline	Low (0.38)	Moderate (23.9)	Non sodic (3.6)	Low

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## 1. INTRODUCTION

### 1.1 Background

Outback Ecology Services was commissioned by Kalgoorlie Consolidated Gold Mines (KCGM) to conduct a comprehensive soil and waste material characterisation study at the KCGM operations. Stage 1 of the investigation comprised an information review and gap analysis, while Stage 2 incorporated the findings of Stage 1 with a sampling and analysis program to develop a soil and waste materials inventory based on of stockpiled and future soil and waste materials on site.

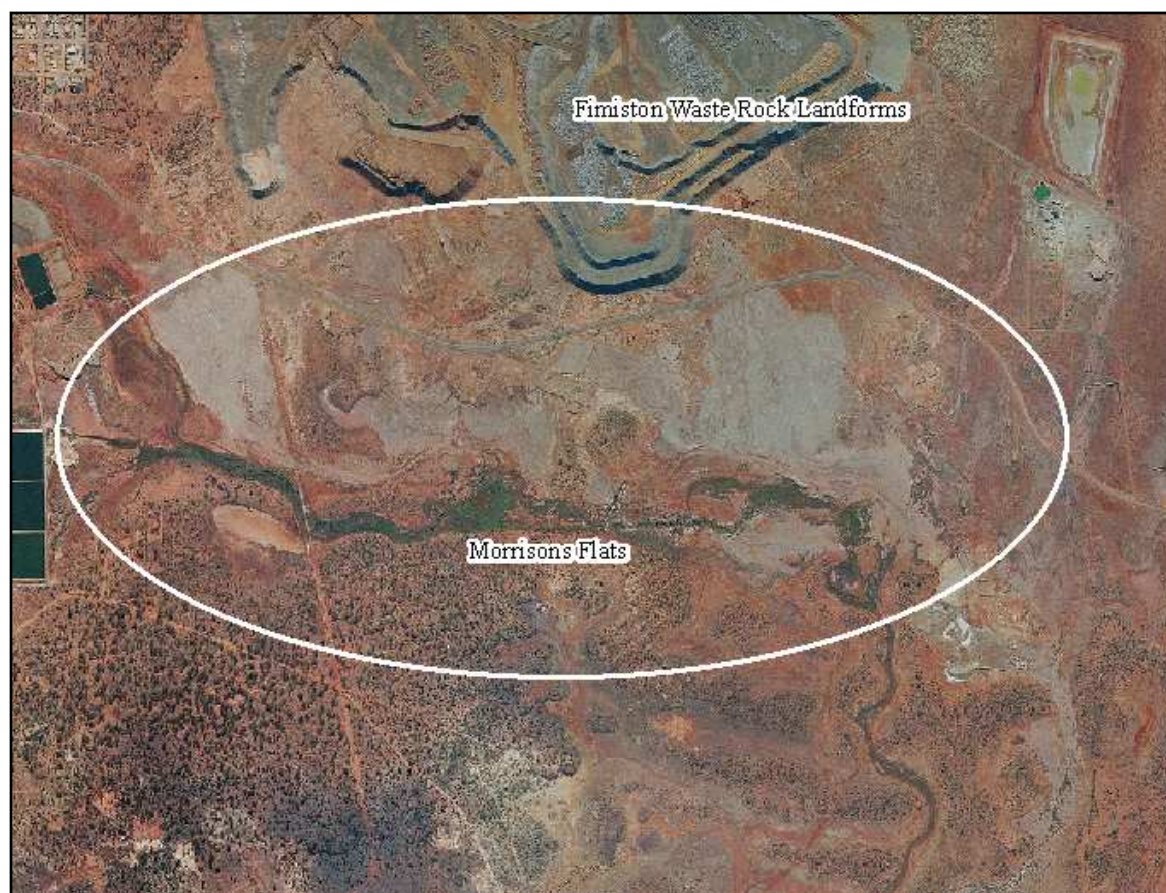
This report, which comprises Section 9 of the overarching KCGM Soil and Waste Characterisation report (Table 1), presents the investigation into the characteristics of tailings and soil materials within the Morrison Flats area.

The Morrison Flats area is situated directly south of the southern landforms of the KCGM operations and encompasses an area of approximately 4 km by 1.5 km (Figure 1). The study area is situated on live tenements M26/95, M26/267, M26/311, M26/377, M26/382, M26/505, M26/518, P26/2048, P26/2201, P26/2537 and P26/2784, and pending tenements M26/550, M26/575, M26/748, M26/800 and P26/3668. The site is situated in the catchment area of the Hannan's Lake saline lake playa, approximately 10 km south of Kalgoorlie.

The Morrison Flats area has been a site of historic tailing deposition / storage which dates back to the 1900s. Due to their relatively high gold content, some of the historic tailings storage facilities (TSFs) have been hydraulically mined and re-processed between 1989 and 1999 to extract the residual gold. Morrison Flats is now dominated by tailings from remnant TSFs which have not been re-processed. Historic construction techniques make the TSFs vulnerable to erosion, which has lead to deposition of water and wind swept tailings in surrounding areas within the Morrison Flats area. The 'soil' profiles in the area therefore tend to consist of a tailings layer of varying thickness, which overlies *in situ* soil material.

**Table 1: Structure of overarching KCGM Soil and Waste Characterisation report**

Report Section	Detail of Each Section
Section 1	Introduction Background Information Review (Stage 1 Report)
Section 2	KCGM Soil and Waste Materials Inventory
Section 3	Golden Pike Cutback Area
Section 4	As-mined Waste Rock
Section 5	Proposed Waste Landform Footprint Areas
Section 6	Existing Topsoil and Oxide Stockpiles
Section 7	Existing Rehabilitation and Rehabilitation Trial Areas
Section 8	Mt Percy
<b>Section 9</b>	<b>Morrison Flats</b>
Section 10	Kaltails
Section 11	Appendices Electronic data base of results

**Figure 1: Location of the Morrison Flats study area provided by KCGM 2010**

Sample sites within the Morrison Flats area were chosen to encompass the range of tailing deposits and vegetation cover that was present in the area. The following attributes of the soil and tailings materials were assessed;

- descriptions of tailings and soil profile morphology, to the maximum depth possible, based on Australian Soil Classification Standards (McDonald *et al.* 1998);
- evaluation of soil and tailings physical parameters (soil structure [Emerson Aggregate Test], particle size distribution, soil texture, hard-setting characteristics [modified Modulus of Rupture test] and water retention characteristics); and
- measurement of soil chemical parameters (soil pH, electrical conductivity, plant-available nutrient concentrations, organic carbon, exchangeable cations and total metals concentration).

The findings of this report are to be used in conjunction with concurrent soil and waste materials studies (Sections 3 to 10 of the overarching Soil and Waste Characterisation report) to facilitate the development of appropriate rehabilitation strategies for the area.

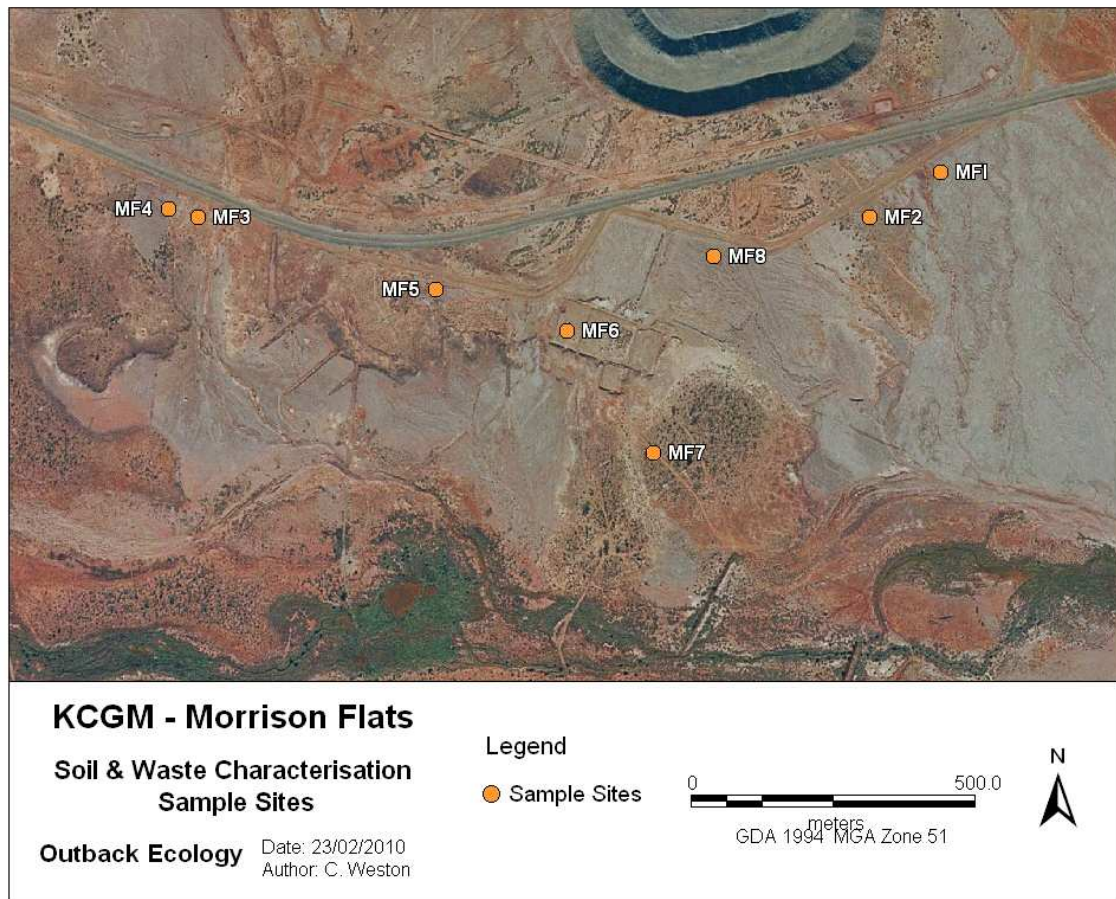
## 2. MATERIALS AND METHODS

### 2.1 Sampling regime

The investigation of surface tailings and *in situ* soil properties was conducted within the Morrison Flats area within areas of tailings deposition. Soil pits were excavated at eight locations (Table 2) (Figure 2), to a maximum depth of 180 cm. The tailings / soil profile was described (soil profile morphology, soil structure, root distribution) based on the Australian Soil and Land Survey Handbook (McDonald *et al.* 1998). Samples were taken from three to five depth intervals within each profile for analyses of chemical and physical parameters.

**Table 2: Sampling sites and locations within the Morrison Flats area**

Site Classification	Site Number	Profile Depth Range (cm)	Material Description	Coordinates (Projection: UTM Zone 51 J, Datum: GDA94)	
				Easting (mE)	Northing (mN)
Surface Tailings	MF 2	0 – 3	Grey tailings	358829	6591029
		3 – 40	Disturbed / <i>in situ</i> layer		
		40 - 100	Calcareous soil		
	MF 3	0 - 10	Loose fine sand	357655	6591027
		10 – 70	Structured clay		
		70 - 110	Calcareous soil		
	MF 7	0 – 2	Tails crust	358288	6591631
		2 - 20	Red earth		
		20 - 60	Gravelly ironstone		
		60 - 110	Hard grey clay		
Shallow Tailings	MF 1	0 – 30	Grey tailings	358953	6591107
		30 – 50	Red tailings		
		50 – 65	Disturbed / <i>in situ</i> layer		
		65 – 100	Clayey soil		
	MF 4	0 – 10	Brown tailings	357602	6591043
		10 - 25	Olive tailings		
		25 - 60	Gritty friable sand		
		60 - 110	Calcareous soil		
Deep Tailings	MF 5	0 – 100	Brown oxide tailings	358071	6590901
		100	Mottled clay/hardcap		
	MF 6	0 - 150	Brown oxide tailings	358299	6590829
	MF 8	0 – 170	Brown oxide tailings	358557	6590960
170 - 180		Calcareous soil			



**Figure 2: Location of sampling sites at Morrison Flats**

## 2.2 Test work and procedures

A range of physical and chemical analyses were conducted on the Morrison Flats materials, as detailed in Table 3.

CSBP Soil and Plant Laboratory conducted chemical and physical analyses, including pH, electrical conductivity, plant-available nutrients (ammonium and nitrate, phosphorus, potassium and sulphur), organic carbon, exchangeable cations and particle size distribution (PSD). Selected samples were sent to ALS Environmental Laboratory for analysis of total concentrations of metals including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), zinc (Zn) and mercury (Hg).

Outback Ecology assessed the Morrison Flats samples for physical properties including gravel content, soil slaking and dispersive properties (Emerson Aggregate Test), soil strength (modified Modulus of Rupture), and saturated hydraulic conductivity ( $K_{sat}$ ).

**Table 3: Soil analyses conducted for characterisation of Morrison Flats soils**

Soil Parameter	Measurement Method	Conducted By	Number of Samples Analysed	Sample Selection Criteria
<b>Chemical properties</b>				
Total Metals (As, Cd, Cr, Cu, Pb, Ni and Zn)	Inductively coupled plasma atomic emission spectroscopy (ICP-AES) method	ALS	35	All samples
Total Metals (Hg)	Cold vapour/ Flow injection mercury system (CV/FIMS method)	ALS	35	All samples
Soil pH	pH measured in 1:5 soil:water and 1:5 Soil:CaCl <sub>2</sub> (Rayment and Higginson, 1992)	CSBP	35	All samples
Electrical conductivity	Measured in 1:5 soil:water (Rayment and Higginson, 1992)	CSBP	35	All samples
Plant-available nitrogen (ammonium and nitrate)	Scarle (1984)	CSBP	35	All samples
Exchangeable cations (Ca <sup>2+</sup> , Mg <sup>2+</sup> , Na <sup>+</sup> and K <sup>+</sup> )	Rayment and Higginson (1992)	CSBP	27	Sub-selection of samples which are representative of materials found within Morrison Flats study area
Plant-available phosphorus and potassium	Colwell (1965); Rayment and Higginson (1992)	CSBP	35	All samples
Plant-available sulphur	Blair <i>et al.</i> , (1991)	CSBP	35	All samples
Organic carbon percentage	Walkley and Black (1934)	CSBP	35	All samples
<b>Physical properties</b>				
Particle size distribution	Pipette method (Day, 1965)	CSBP	27	Sub-selection of samples which are representative of materials found within Morrison Flats study area
Saturated hydraulic conductivity (k <sub>sat</sub> )	Measured on materials packed to their respective field bulk densities, using a constant-head of pressure technique (Hunt and Gilkes, 1992)	Outback Ecology	8	Sub-selection of samples which are representative of materials found within Morrison Flats study area, which correspond with water retention samples
Soil slaking and dispersive properties	Emerson Aggregate Test (McKenzie <i>et al.</i> , 2002)	Outback Ecology	35	All samples
Soil strength	Modified Modulus of Rupture test (Aylmore and Sils, 1982; Harper and Gilkes, 1994)	Outback Ecology	17	Sub-selection of samples which are representative of materials found within Morrison Flats study area

### **3. RESULTS AND DISCUSSION**

#### **3.1 Soil profile descriptions**

A description of the soil profile morphology at each site has been documented, with a summary of the measured physical, chemical and morphological parameters tabulated for each site (Sections 3.1.1 – 3.1.8). Individual soil characteristics are then discussed in further detail (Sections 3.2 – 3.3). The vegetation descriptions given for each site are based on general observations made in the field during the soil survey.

## 3.1.1 Morrison Flats – Shallow Tailings (MF 1)

**Location:** Morrison Flats 1**Profile Description:** Shallow Tailings**Landform:** Flat**Site Coordinates:** 0358953 mE 6591107 mN**Plate 1: Tailings / soil profile at MF 1***Profile Description:*

*0 – 30 cm:* Grey tailings layer with massive blocky structure. Approximately 40% yellow mottles, 100 - 200 mm in size. No coarse fragments observed.

*30 – 50 cm:* Red tailings layer with massive blocky structure. No coarse fragments observed.

*50 – 65 cm:* Layer of massive disturbed soil. No coarse fragments observed.

*65 – 100 cm:* Clayey soil with weak polyhedral aggregates approximately 5-20 mm in size. No coarse fragments observed.

*100 cm +:* Calcareous soil with weak polyhedral aggregates approximately 5-20 mm in size. Approximately 50% white and dark red mottles, approximately 100 mm in size. Approximately 40 % coarse semi-angular fragments, approximately 2-10 mm in size.

*Soil Surface Description:* Thin salty surface crust approximately 2mm thick.

*Vegetation:* No vegetation observed

**Plate 2: Vegetation at MF 1**

**Table 4: Tailings and soil physical characteristics for MF 1**

Depth Interval (cm)	Material Description	Soil Structure	Root Score <sup>1.</sup>	Particle Size Distribution (% of <2mm fraction)				Texture (of <2mm fraction)	Coarse Fragments (%>2mm)	Emerson Test Class <sup>2</sup>	MOR (kPa)
				Coarse sand	Fine sand	Silt	Clay				
0 to 5	Grey tailings	Massive blocky	0	2.3	52	32.7	13	Silty loam	0	4	97.7
10 to 20	Grey tailings	Massive blocky	0	1.1	40.3	46.4	12.1	Silty loam	0	4	101.7
40 to 50	Red tailings	Massive blocky	0	0.3	70.1	24.5	5.1	Loamy sand	0	4	-
50 to 55	Disturbed soil	Massive	0	40.8	32.2	20	7	Loamy sand	0	4	-
70 to 80	Clay	Weak polyhedral aggregates	0	24.1	19.6	24.6	31.7	Silty clay loam	-	4	48.3
120 to 130	Calcareous soil	Weak polyhedral aggregates	0	35.3	13.4	26.6	24.6	Silty loam	-	4	-

1. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for root growth scoring categories.
2. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for Emerson Test class categories.

**Table 5: Tailings and soil chemical characteristics for MF 1**

Depth Interval (cm)	Soil pH (H <sub>2</sub> O)	EC (dS/m)	Organic Carbon (%)	Plant-available Nutrients (mg/kg)					Exchangeable Cations (meq/100g)				ESP (%)
				NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	P	K	S	Ca	K	Mg	Na	
0 to 5	8.6	15.3	0.59	1	1	7	174	179	18.07	0.04	1.92	0.42	2.1
10 to 20	8.6	13.88	0.59	1	1	3	168	46.4	14.55	0.04	2.37	0.52	3.0
40 to 50	8.6	18.44	0.3	2	1	41	147	16.4	33.06	0.04	2.2	0.76	2.1
50 to 55	8.6	4.73	0.06	<1	1	5	209	5.31	12.05	0.34	2.55	0.47	3.0
70 to 80	8.9	4.65	0.13	<1	4	2	255	766	12.64	0.68	6.79	1.29	6.0
120 to 130	8.8	2.97	0.08	<1	2	< 2	210	517	11.24	0.42	4.33	1.19	6.9

## 3.1.2 Morrison Flats - Surface Tailings (MF 2)

**Location:** Morrison Flats 2**Profile Description:** Surface Tailings**Landform:** Flat**Site Coordinates:** 0358829 mE 6591029 mN**Plate 3: Tailings / soil profile at MF 2***Profile Description:*

*0 – 5 cm:* Grey tailings horizon with massive structure. No coarse fragments observed. Root growth rated as sparse.

*5 – 40 cm:* Disturbed *in situ* soil with weak to moderate polyhedral, approximately 5-40 mm in size. No coarse fragments observed. Root growth rated as sparse.

*40 – 100 cm:* Calcareous mottled horizon with moderate polyhedral, 5 – 40 mm in size. 40-50 % white and dark red mottles between 100 and 200 mm. 20-30 % coarse fragments, predominantly semi-angular, 2-10 mm in size. Root growth rated between nil and sparse.

*Soil Surface Description:* Thin salt surface crust approximately 2 mm thick.

*Vegetation:* Populations of *Maireana* sp. and *Atriplex* sp.

**Plate 4: Vegetation at MF 2**

**Table 6: Tailings and soil physical characteristics for MF 2**

Depth Interval (cm)	Material Description	Soil Structure	Root Score <sup>1</sup>	Particle Size Distribution (% of <2mm fraction)				Texture (of <2mm fraction)	Coarse Fragments (%>2mm)	Emerson Test Class <sup>2</sup>	MOR (kPa)
				Coarse sand	Fine sand	Silt	Clay				
0 to 3	Grey tailings	Massive blocky	0-1	2.3	52	32.7	13	Loamy sand	0	4	26.0
3 to 10	Disturbed soil	Moderate polyhedral	1	1.1	40.3	46.4	12.1	Clay loam	0	4	34.0
10 to 20	Disturbed soil	Moderate polyhedral	1	0.3	70.1	24.5	5.1	Loam	-	4	-
70 to 80	Calcareous soil	Moderate polyhedral	0-1	40.8	32.2	20	7	Silty loam	-	4	-

1. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for root growth scoring categories.
2. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for Emerson Test class categories.

**Table 7: Tailings and soil chemical characteristics for MF 2**

Depth Interval (cm)	Soil pH (H <sub>2</sub> O)	EC (dS/m)	Organic Carbon (%)	Plant-available Nutrients (mg/kg)					Exchangeable Cations (meq/100g)				ESP (%)
				NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	P	K	S	Ca	K	Mg	Na	
0 to 5	8.6	9.71	0.32	<1	10	7	93	3658	91.83	0.04	1.52	0.56	2.1
10 to 20	8.6	5.11	0.41	<1	5	5	343	1280	-	-	-	-	3.0
40 to 50	8.6	5.12	0.23	<1	4	2	242	1109	13.16	0.52	4.78	0.94	2.1
50 to 55	8.6	2.65	0.12	<1	1	2	154	597	11.82	0.32	3.95	0.60	3.0

## 3.1.3 Morrison Flats – Surface Tailings (MF 3)

**Location:** Morrison Flats 3**Profile Description:** Surface Tailings**Landform:** Flat**Site Coordinates:** 0357655 mE 6591027 mN**Plate 5: Soil profile at MF 3***Profile Description:*

*0 – 5 cm:* Single grained soil with very thin tailings layer. Between ‘few’ and ‘many’ roots observed in this depth interval.

*10 – 20 cm:* Well structured clay, moderate polyhedral aggregates approximately 5 - 40 mm in size. Between 5 and 10 % angular coarse fragments 2 – 8 mm in size. Sparse root growth observed in this horizon.

*40 – 50 cm:* Well structured clay, moderate polyhedral aggregates approximately 5 - 40 mm in size. Between 5 and 10 % angular coarse fragments 2 – 8 mm in size. Sparse root growth observed.

*70 – 110 cm:* Calcareous clay with moderate polyhedral aggregates 5 to 100 mm in size. Approximately 50 % white mottles, 50 – 200 mm in size. Observations of plant roots classed between ‘nil’ and ‘sparse’.

*Soil Surface Description:* Thin surface crust approximately 1 cm in thickness. Approximately 30 and 40 % semi-angular and semi-rounded coarse fragments.

*Vegetation:* Predominantly *Maireana* sp. with sparsely scattered populations of *Atriplex* sp.

**Plate 6: Vegetation at MF 3**

**Table 8: Tailings and soil physical characteristics for MF 3**

Depth Interval (cm)	Material Description	Soil Structure	Root Score <sup>1</sup>	Particle Size Distribution (% of <2mm fraction)				Texture (of <2mm fraction)	Coarse Fragments (%>2mm)	Emerson Test Class <sup>2</sup>	MOR (kPa)
				Coarse sand	Fine sand	Silt	Clay				
0 to 5	Loose tailings	Single grained	2-3	40.2	41.2	6.9	11.7	Sandy loam	-	3b	-
10 to 20	Clayey soil	Moderate polyhedral	1	39.5	28	9.9	22.6	Sandy clay loam	-	4	-
40 to 50	Clayey soil	Moderate polyhedral	1	-	-	-	-	Sandy clay loam	-	4	-
90 to 100	Calcareous soil	Moderate polyhedral	0-1	32.7	17	16.1	34.1	Clay loam	-	6	-

1. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for root growth scoring categories.
2. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for Emerson Test class categories.

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**Table 9: Tailings and soil chemical characteristics for MF 3**

Depth Interval (cm)	Soil pH (H <sub>2</sub> O)	EC (dS/m)	Organic Carbon (%)	Plant-available Nutrients (mg/kg)					Exchangeable Cations (meq/100g)				ESP (%)
				NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	P	K	S	Ca	K	Mg	Na	
0 to 5	8.9	2.90	0.4	<1	3	10	166	479	8.47	0.21	1.77	0.33	3.1
10 to 20	8.8	3.69	0.56	<1	1	7	244	967	12.66	0.49	3.96	1.08	5.9
40 to 50	8.4	6.57	0.41	<1	4	<2	261	1620	-	-	-	-	-
90 to 100	7.2	4.89	0.32	1	1	2	145	868	4.80	0.22	3.45	0.76	8.2

## 3.1.4 Morrison Flats – Shallow Tailings (MF 4)

**Location:** Morrison Flats**Profile Description:** Shallow Tailings**Landform:** Flat**Site Coordinates:** 0357601 mE 6591043 mN**Plate 7: Tailings / soil profile at MF 4***Profile Description:*

*0 – 10 cm:* Brown tailings layer with massive structure. No coarse fragments observed.

*10 – 25 cm:* Olive coloured tailings layer with massive structure. No coarse fragments observed.

*25 – 60 cm:* Gritty friable sand with weak polyhedral aggregates approximately 5 – 20 mm in size. Approximately 30 % sub-rounded and sub-angular coarse fragments, 2 - 20 mm in size.

*60 – 110 cm:* Calcareous clay with moderate polyhedral structure. Approximately 50 % sub-angular coarse fragments, 60 – 100 mm in size. Approximately 90 % white mottles 100 - 300 mm in size.

*Soil Surface Description:* Thin surface crust, approximately 1 – 2 mm in thickness.

*Vegetation:* No vegetation present

**Plate 8: Vegetation at MF 4**

**Table 10: Tailings and soil physical characteristics for MF 4**

Depth Interval (cm)	Material Description	Soil Structure	Root Score <sup>1</sup>	Particle Size Distribution (% of <2mm fraction)				Texture (of <2mm fraction)	Coarse Fragments (%>2mm)	Emerson Test Class <sup>2</sup>	MOR (kPa)
				Coarse sand	Fine sand	Silt	Clay				
0 to 5	Brown tailings	Massive	0	16	31	52.3	29.84	Silty loam	-	4	85.6
10 to 20	Olive tailings	Massive	0	-	-	-	-	Loamy sand	-	4	-
30 to 40	Disturbed soil	Weak polyhedral	0	29.2	24.6	17.6	19.18	Sandy clay	-	4	-
90 to 100	Calcareous soil	Weak polyhedral	0	7.5	13.9	67.6	18.37	Silty loam	-	4	151.7

1. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for root growth scoring categories.
2. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for Emerson Test class categories.

**Table 11: Tailings and soil chemical characteristics for MF 4**

Depth Interval (cm)	Soil pH (H <sub>2</sub> O)	EC (dS/m)	Organic Carbon (%)	Plant-available Nutrients (mg/kg)					Exchangeable Cations (meq/100g)				ESP (%)
				NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	P	K	S	Ca	K	Mg	Na	
0 to 5	8.3	39.10	0.29	2	31	5	228	6500	25.92	0.08	2.83	1.01	3.4
10 to 20	8.2	17.52	0.72	<1	19	2	210	4200	-	-	-	-	-
30 to 40	8.8	7.40	0.39	<1	8	4	413	588	10.99	0.75	6.21	1.23	6.4
90 to 100	8.6	9.99	0.41	1	11	2	201	3616	15.43	0.11	1.78	1.05	5.7

## 3.1.5 Morrison Flats – Deep Tailings (MF 5)

**Location:** Morrison Flats  
**Landform:** Mounds and Depressions

**Profile Description:** Deep Tailings  
**Site Coordinates:** 0358071 mE 6590901 mN



**Plate 9: Tailings / soil profile at MF 5**

*Profile Description:*

*0 – 100 cm:* Oxide tailings layer, dark brown in colour and massive in structure. No coarse fragments present.

*100 – 120 cm:* Mottled clay / lateritic soil, strong polyhedral aggregates 10 – 50 mm in size. Approximately 80 – 90 % coarse fragments sub-rounded and sub-angular between 2 and 80 mm in size. Approximately 50 % red mottles, approximately 50 – 100 mm in size.

*Soil Surface Description:* Thin surface crust, Mounds and depressions at approximately 5 metre intervals. No coarse fragments present.

*Vegetation:* No vegetation present.



**Plate 10: Vegetation at MF 5**

**Table 12: Tailings and soil physical characteristics for MF 5**

Depth Interval (cm)	Material Description	Soil Structure	Root Score <sup>1</sup>	Particle Size Distribution (% of <2mm fraction)				Texture (of <2mm fraction)	Coarse Fragments (%>2mm)	Emerson Test Class <sup>2</sup>	MOR (kPa)
				Coarse sand	Fine sand	Silt	Clay				
0 to 5	Oxide tailings	Massive	0	-	-	-	-	Loamy sand	0	4	85.6
10 to 20	Oxide tailings	Massive	0	6.6	65.8	21.9	5.7	Loamy sand	0	4	-
40 to 50	Oxide tailings	Massive	0	2.4	50.8	40.9	5.8	Silty loam	0	2	51.8
100 to 110	Mottled clay/hardcap	Strong polyhedral	0	39.6	28.1	12.7	19.5	-	80	4	-

1. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for root growth scoring categories.
2. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for Emerson Test class categories.

**Table 13: Tailings and soil chemical characteristics for MF 5**

Depth Interval (cm)	Soil pH (H <sub>2</sub> O)	EC (dS/m)	Organic Carbon (%)	Plant-available Nutrients (mg/kg)					Exchangeable Cations (meq/100g)				ESP (%)
				NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	P	K	S	Ca	K	Mg	Na	
0 to 5	8.7	12.86	0.64	1	68	4	267	4978	51.61	0.11	2.72	1.25	2.2
10 to 20	8.5	5.65	0.38	<1	18	<2	128	5182	42.56	0.08	1.63	0.39	0.9
40 to 50	8.6	7.70	0.36	<1	17	2	127	4528	23.13	0.09	1.73	0.30	1.2
100 to 110	8.9	1.64	0.27	<1	3	3	290	689	11.18	0.48	3.23	0.74	4.7

## 3.1.6 Morrison Flats – Deep Tailings (MF 6)

**Location:** Morrison Flats  
**Landform:** Large tailings mound

**Profile Description:** Deep Tailings  
**Site Coordinates:** 0358300 mE 6590829 mN



**Plate 11: Soil profile at MF 6**

**Soil Surface Description:** Thin surface crust, approximately 1 – 2 mm thick, with approximately 2 % leaf litter cover on soil surface. Absence of coarse fragments observed on the surface.

**Vegetation:** Scattered populations of *Maireana sp.* and *Atriplex sp.* throughout site

*Profile Description:*

*0 – 150 cm:* Brown coloured oxide tailings with massive structure. No coarse fragments noted. No roots noted.



**Plate 12: Vegetation at MF 6**

**Table 14: Tailings and soil physical characteristics for MF 6**

Depth Interval (cm)	Material Description	Soil Structure	Root Score <sup>1</sup>	Particle Size Distribution (% of <2mm fraction)				Texture (of <2mm fraction)	Coarse Fragments (%>2mm)	Emerson Test Class <sup>2</sup>	MOR (kPa)
				Coarse sand	Fine sand	Silt	Clay				
0 to 5	Oxide tailings	Massive	0	7	42	43	7.9	Silty loam	0	4	122.3
10 to 20	Oxide tailings	Massive	0	-	-	-	-	Loamy sand	0	4	-
40 to 50	Oxide tailings	Massive	0	9.5	69	17.6	3.9	Loamy sand	0	4	83.3
90 to 100	Oxide tailings	Massive	0	-	-	-	-	Loamy sand	0	4	-

1. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for root growth scoring categories.
2. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for Emerson Test class categories.

**Table 15: Tailings and soil chemical characteristics for MF 6**

Depth Interval (cm)	Soil pH (H <sub>2</sub> O)	EC (dS/m)	Organic Carbon (%)	Plant-available Nutrients (mg/kg)					Exchangeable Cations (meq/100g)				ESP (%)
				NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	P	K	S	Ca <sup>2</sup>	K	Mg	Na	
0 to 5	8.5	12.16	0.48	1	27	7	352	5325	90.83	0.12	2.56	1.14	1.2
10 to 20	8.6	7.22	0.37	<1	11	3	216	4015	-	-	-	-	-
40 to 50	8.7	8.09	0.31	<1	11	2	200	3923	19.26	0.08	1.66	0.26	1.2
50 to 55	8.7	6.07	0.35	1	12	2	183	3817	-	-	-	-	-

## 3.1.7 Morrison Flats – Surface Tailings (MF 7)

**Location:** Morrison Flats 7**Profile Description:** Surface Tailings**Landform:** Flat**Site Coordinates:** 0358288 mE 6591631 mN**Plate 13: Tailings / soil profile at MF 7****Profile Description:**

**0 – 2 cm:** Platy tailings crust, weak structure, approximately 40 mm in size. No coarse fragments noted. 'Few' to 'many' roots observed in this depth interval.

**2 – 20 cm:** Red earthy horizon with moderate strength, polyhedral aggregates sized between 10 and 40 mm. Approximately 5 – 10 % sub-rounded and sub-angular coarse fragments 2 – 5 mm in size. 'Few' to 'many' roots observed in this depth interval.

**20 – 60 cm:** Gravelly ironstone layer, with approximately 40 % sub-rounded and sub-angular coarse fragments 2 – 30 mm in size. Sparse root growth observed.

**60 – 110 cm:** Hard grey clay, with approximately 10% sub-rounded and sub-angular ironstone coarse fragments sized between 50 and 100 mm. Approximately 30 – 40 % yellow mottles, 100 mm in size. No root growth observed.

**Soil Surface Description:** Thin surface crust and cryptogams present, with less than 5 % litter cover on soil surface. Approximately 5 – 10 % sub-rounded and sub-angular coarse fragments, 2 – 15 mm in size.

**Vegetation:** Mainly *Maireana* sp., with some *Atriplex* sp. and *Eremophila* sp. present.

**Plate 14: Vegetation at MF 7**

**Table 16: Tailings and soil physical characteristics for MF 7**

Depth Interval (cm)	Material Description	Soil Structure	Root Score <sup>1</sup>	Particle Size Distribution (% of <2mm fraction)				Texture (of <2mm fraction)	Coarse Fragments (%>2mm)	Emerson Test Class <sup>2</sup>	MOR (kPa)
				Coarse sand	Fine sand	Silt	Clay				
0 to 5	Tailings crust	Weak platy	2-3	36.7	37.5	16.9	8.9	Loamy sand	-	2	28.5
10 to 20	Red earth	Moderate polyhedral	2-3	34	19.5	17.5	29.1	Sandy clay loam	-	6	45.1
40 to 50	Gravelly ironstone	Single grained	0-1	72.5	12.8	3.9	10.8	Sandy loam	-	6	-
90 to 100	Hard grey clay	Moderate polyhedral	0	11.9	11.1	50.7	26.3	Silty loam	-	6	-

1. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for root growth scoring categories.

2. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for Emerson Test class categories.

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**Table 17: Tailings and soil chemical characteristics for MF 7**

Depth Interval (cm)	Soil pH (H <sub>2</sub> O)	EC (dS/m)	Organic Carbon (%)	Plant-available Nutrients (mg/kg)					Exchangeable Cations (meq/100g)				ESP (%)
				NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	P	K	S	Ca	K	Mg	Na	
0 to 2	8.8	0.30	0.34	<1	1	4	138	72	6.36	0.18	0.98	0.10	-
2 to 20	8.1	2.48	0.55	3	7	2	211	1099	14.20	0.54	3.69	1.76	8.7
20 to 60	8.0	4.05	0.27	1	1	2	222	679	3.91	0.61	8.66	6.55	33.2
60 to 110	8.3	6.06	0.17	1	1	2	72	758	3.22	0.08	1.28	0.41	8.2

## 3.1.8 Morrison Flats – Deep Tailings (MF 8)

**Location:** Morrison Flats 8**Landform:** Flat**Profile Description:** Deep Tailings**Site Coordinates:** 0358557 mE 6590960 mN**Plate 15: Tailings / soil profile at MF 8**

**Soil Surface Description:** Thin surface crust 1 – 2 mm in thickness. No fragments observed.

**Vegetation:** No vegetation present.

*Profile Description*

**0 – 170 cm:** Oxide tailings, brown in colour, with massive structure. No coarse fragments or root growth observed.

**170 – 180 cm:** Calcareous clay, moderate in strength, with polyhedral aggregates 10 – 40 mm in size. Approximately 5 – 10 % sub-rounded and sub-angular coarse fragments, between 2 and 20 mm in size. Approximately 30 % white mottles, 2 to 10 mm in size. No root growth observed.

**Plate 16: Vegetation at MF 8**

**Table 18: Tailings and soil physical characteristics for MF 8**

Depth Interval (cm)	Material Description	Soil Structure	Root Score <sup>1</sup>	Particle Size Distribution (% of <2mm fraction)				Texture (of <2mm fraction)	Coarse Fragments (%>2mm)	Emerson Test Class <sup>2</sup>	MOR (kPa)
				Coarse sand	Fine sand	Silt	Clay				
0 to 5	Oxide tailings	Massive	0	8.5	53.3	31.5	6.8	Silty loam	0	4	50.1
10 to 20	Oxide tailings	Massive	0	-	-	-	-	-	0	4	-
40 to 50	Oxide tailings	Massive	0	3.5	40.5	48.5	7.6	Silty loam	0	4	52.8
90 to 100	Oxide tailings	Massive	0	-	-	-	-	-	0	4	41.8
170 to 180	Calcareous clay	Moderate polyhedral	0	13.5	17.4	64.4	4.8	Silty loam	-	-	-

1. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for root growth scoring categories.
2. See Appendix C in Section 11 of overarching Soil and Waste Characterisation report for Emerson Test class categories.

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**Table 19: Tailings and soil chemical characteristics for MF 8**

Depth Interval (cm)	Soil pH (H <sub>2</sub> O)	EC (dS/m)	Organic Carbon (%)	Plant-available Nutrients (mg/kg)					Exchangeable Cations (meq/100g)				ESP (%)
				NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	P	K	S	Ca	K	Mg	Na	
0 to 5	8.2	12.22	0.55	1	15	2	210	2871	48.54	0.04	1.64	0.39	0.8
10 to 20	8.3	13.42	0.6	3	17	2	228	4211	-	-	-	-	-
40 to 50	8.1	10.92	0.54	3	12	2	193	4134	22.91	0.06	1.38	0.34	1.4
90 to 100	8.3	12.07	0.66	1	10	3	192	3812	-	-	-	-	-
170 to 180	8.5	9.35	0.49	<1	6	4	347	2813	26.96	0.67	3.70	0.80	2.5

## 3.2 Soil physical properties

### 3.2.1 Soil profile morphology

Soil profiles within the Morrison Flats study area were categorised into three profile types based on the thickness of deposited tailings at the surface, namely; Surface Tailings, Shallow Tailings and Deep Tailings.

The Deep Tailings profiles (Sites 5, 6 and 8), located on remnant tailings storage facilities, were typified by tailings layers ranging in thickness from 1.0 m to 1.50 m, overlying the undisturbed calcareous clay soil. The Shallow Tailings profiles (Sites 1 and 4) were located between old TSFs and typically had tailings ranging from 0.25 to 0.50 m in depth over the calcareous clay soil. The Surface Tailings profiles (Sites 2, 3 and 7) were located in vegetated areas within the Morrison Flats study area. These profiles had a thin layer of tailings material deposited on the surface, between 2 and 10 cm thick.

### 3.2.2 Soil texture

Soil texture describes the proportions of sand, silt and clay (the particle size distribution) within a soil. The particle size distribution and resulting textural class of soils is an important factor influencing most physical and many chemical and biological properties. Soil structure, water holding capacity, hydraulic conductivity, soil strength, fertility, erodibility and susceptibility to compaction are some of the factors closely linked to soil texture.

All of the tailings materials within the Morrison Flats area generally had loamy sand or silty loam textures (Table 20), for which a high portion of the <2mm fraction was fine sand (Figure 3). The gravelly ironstone material, when observed at 40 to 50 cm in the Surface Tailings profile, had a sandy loam texture (Table 20), dominated by coarse sand (Figure 3). The mottled clay and calcareous clay soils observed at depth (between 70 cm and 170 cm) at all profile types, typically had a silty loam texture (Table 20), with the particle size distribution dominated by silt sized particles (Figure 3).

### 3.2.3 Soil structure

Soil structure describes the arrangement of solid particles and void space in a soil. It is an important factor influencing the ability of soil to support plant growth, store and transmit water and resist erosional processes. A well-structured soil is one with a range of different sized aggregates, with component particles bound together to give a range of pore sizes facilitating root growth and the transfer of air and water.

Soil structure can be influenced by the particle size distribution, chemical composition and organic matter content of a soil, and is often affected by root growth, vehicle compaction, and with respect to

reconstructed soil profiles, the methods of soil handling and deposition. When a soil material is disturbed, the breakdown of aggregates into primary particles can lead to structural decline (Needham *et al.* 1998). This can result in hard-setting and crusting at the soil surface and a 'massive' soil structure at depth, potentially reducing the ability of seeds to germinate, roots to penetrate the soil matrix and water to infiltrate to the root zone.

With exception of the thin tailings layer at the top of the Surface Tailings profile, all tailings material had a massive structure which could be broken into large block fragments (Table 20). The thin tailings layer at the Surface Tailings Profile was single grained in structure with a loose consistence. The remnant natural soils underlying the tailings materials were generally well structured, with weak to strong polyhedral aggregates (Table 20).

The massive structure of the tailings material in the Morrison Flats study area may act as a physical barrier to root penetration, should these materials be rehabilitated *in situ*, without physical alteration.

#### 3.2.4 Structural stability

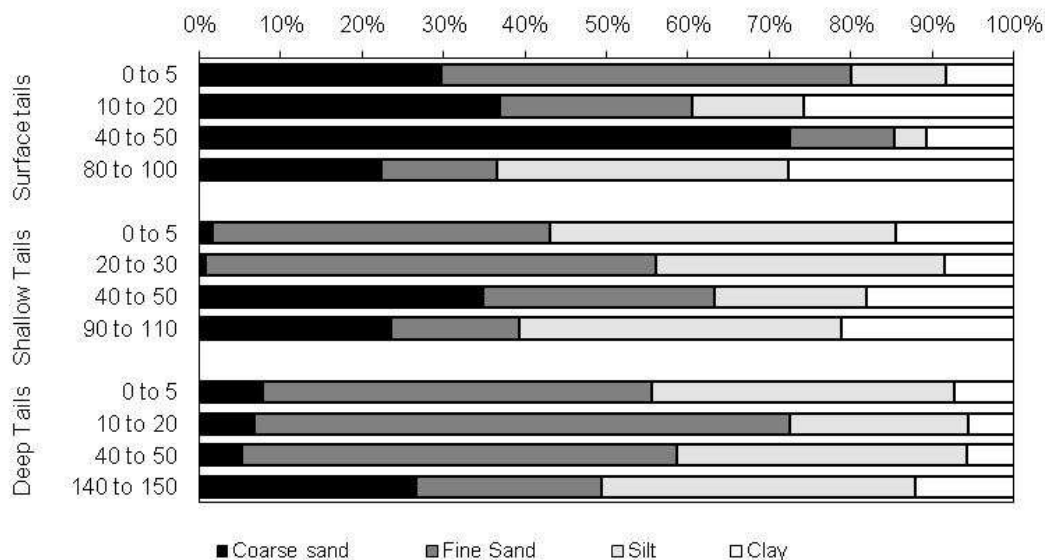
The structural stability of a soil and its susceptibility to structural decline is complex and depends on the net effect of a number of properties, including the amount and type of clay present, organic matter content, soil chemistry and the nature of disturbance. Soil aggregates that slake and disperse indicate a weak soil structure that is easily degraded. These soils should be seen as potentially problematic when used for the reconstruction of soil profiles for rehabilitation, particularly if left exposed at the surface.

The Emerson Aggregate Test identifies the potential slaking and dispersive properties of soil aggregates. The dispersion test identifies the properties of the soil materials under a worst case scenario, where severe stress is applied to the soil material. Generally, samples allocated into Emerson Classes 1 and 2 are those most likely to exhibit dispersive properties and therefore be the most problematic.

Within the Morrison Flats study area, the Surface Tailings profile was the only profile to exhibit materials with Emerson Classes indicating clay dispersion (Table 20). The thin tailings layer at the surface of these profiles, and the gravelly ironstone/clay horizon at depth, both reported Emerson Class 2, indicating a tendency to disperse. The structural instability of the gravelly ironstone/clay horizon is well correlated with a high ESP value, which is known to affect the dispersive properties of a soil, this is discussed further in Section 3.3.5 within this report. All other materials that were studied did not display dispersion and generally tested positive for carbonates (Class 4) (Table 20). The presence of carbonates in soil, indicates that free  $\text{Ca}^{2+}$  in the soil solution, may be at a sufficient concentration to flocculate the clay present, hence improving structural stability. For this reason, these materials are considered relatively stable.

**Table 20: Summary of tailings / soil profile morphology, soil structure, texture and structural stability for profiles within the Morrison Flats study area.**

Profile Description	Depth (cm)	Material Description	Soil Structure	Soil Texture (of <2 mm fraction)	Emerson Class			Exchangeable Sodium Percentage (ESP) (%)		Electrical Conductivity (EC) (dS/cm)	
					Range	Mode	Frequency of mode value in tested material	Mean	SE	Mean	SE
<b>Surface Tailings</b>	<b>0 to 5</b>	Tailings	Single grained or massive	Loamy sand	2 to 4	2,3b,4	3 of 3	1.8	1.2	4.31	2.81
	<b>10 to 20</b>	Disturbed soil	Moderate polyhedral aggregates	Sandy clay loam	4 to 6	4	2 of 3	7.37	1.4	3.76	0.76
	<b>40 to 50</b>	Gravelly ironstone to clay	Moderate polyhedral aggregates	Sandy loam to Sandy clay loam	2 to 4	2,4	2 of 2	33.2	-	5.31	1.26
	<b>80 to 100</b>	Calcareous soil	Moderate to strong polyhedral aggregates	Silty loam	4 to 6	6	2 of 3	6.7	1.5	4.53	1.00
<b>Shallow Tailings</b>	<b>0 to 5</b>	Tailings	Massive	Silty loam	4	4	2 of 2	2.71	0.7	27.20	11.90
	<b>20 to 30</b>	Tailings	Massive	Loamy sand to silty loam	4	4	3 of 3	2.5	0.4	16.61	1.39
	<b>40 to 50</b>	Disturbed soil	Coarse textured with weak polyhedral aggregate or massive structure	Loam sand to sandy clay	4	4	2 of 2	4.7	1.7	6.06	1.33
	<b>90 to 110</b>	Calcareous clay	Weak to moderate polyhedral aggregates	Silty loam	4	4	3 of 3	6.2	0.4	5.87	2.11
								-	-	-	-
<b>Deep Tailings</b>	<b>0 to 5</b>	Tailings	Massive	Silty loam	4	4	3 of 3	1.4	0.4	12.41	0.22
	<b>10 to 20</b>	Tailings	Massive	Loamy sand	4	4	3 of 3	0.9	-	8.76	2.37
	<b>40 to 50</b>	Tailings	Massive	Loamy sand to silty loam	2 to 4	4	2 of 3	1.3	0.06	8.90	1.01
	<b>90 to 100</b>	Tailings	Massive	Loamy sand	4	4	2 of 2	-	-	9.07	3.00
	<b>140 to 150</b>	Mottled to calcareous clay	Moderate to strong polyhedral aggregates	Silty loam	4	4	1 of 1	3.6	1.1	5.49	3.86



**Figure 3: Average particle size distribution for tailings / soil profiles within the Morrison Flats study area.**

### 3.2.5 Soil strength

A modified Modulus of Rupture (MOR) test was conducted on selected samples of tailings and *in situ* soils (Figure 4). This test is a measure of soil strength and identifies the tendency of a soil to hard-set as a direct result of soil slaking and dispersion. A modulus of rupture of over 60 kPa has been described as the critical value for distinguishing potentially problematic soils in agricultural scenarios (Cochrane and Aylmore 1997). Restricted root penetration into the soil matrix is a likely consequence of a high modulus of rupture. In reconstructed soil profiles, materials normally deep within the profile that may have a high MOR can often be re-deposited closer to the surface, leading to germination / emergence and root penetration problems.

As this test is conducted on reconstructed soil blocks composed of the < 2 mm soil fraction, it does not take into account the effect of gravel content or soil structure on soil strength, nor any degree of compaction that may be present in the field. It does, however, provide insight into the potential for layers to hard-set and compact with repeated wetting and drying cycles, and the ability of roots to fracture the soil and penetrate crack faces.

The tailings materials tested indicated a variety of soil strength values (Figure 4), with average MOR values typically above the threshold value 60 kPa, indicating a potential to hard set. These values were however, generally similar to the MOR values reported for the *in situ* soil materials (Figure 4).



**Figure 4: Individual and average modulus of rupture (kPa) values grouped into tailings / soil profile type (error bars represent standard error). Vertical red line indicates potential restrictions to plant and root development (Cochrane and Aylmore 1997). Horizontal dashed red line indicates lower boundary of tailings layer.**

### 3.2.6 Hydraulic conductivity

Hydraulic conductivity ( $K_{sat}$ ) refers to the permeability of soil, or the ability of water to infiltrate and drain through the soil matrix, and is dependent on soil properties such as texture and structure (Hunt and Gilkes 1992; Hazelton and Murphy 2007; Moore 1998). Freely draining soils with high  $K_{sat}$  values will generally be less susceptible to surface runoff and erosion. Slow draining soils with low  $K_{sat}$  values, are more likely to experience waterlogging, increased surface runoff and erosion.

Saturated hydraulic conductivity was determined for three representative tailings and soil materials which were collected in the field and repacked to their respective bulk densities. Drainage classes were determined for each core according to their  $K_{sat}$  (Hunt and Gilkes 1992) (Table 21).

*In situ* soil from the Surface Tailings profiles exhibited an average  $K_{sat}$  value of 4.30 mm/hr, considered to be ‘slow’ draining (Table 21). Tailings materials from the Shallow Tailings profiles showed a wide range in  $K_{sat}$ , with values ranging between 0.42 and 11.95 mm/hr, and a ‘moderately slow’ draining average  $K_{sat}$  value of 6.15 mm/hr. Tailings samples from the Deep Tailings profiles (tailings material with a finer texture than the other tailings tested) exhibited the slowest average  $K_{sat}$  value of 0.47 mm/hr which is considered ‘very slow’.

**Table 21: Average saturated hydraulic conductivity ( $K_{sat}$ ) values, soil texture and drainage class for selected tailings and soil samples from the Morrison Flats study area**

Profile Description	Material	Field Texture	Average $K_{sat}$ (mm/hr)	Drainage Class
<b>Surface Tailings</b>	<i>In situ</i> soil	Loamy sand to sandy loam	4.30	Slow
<b>Shallow Tailings</b>	Tailings	Loamy sand to silty loam	6.15	Moderately slow
<b>Deep Tailings</b>	Tailings	Silty loam	0.47	Very slow

### 3.2.7 Root growth

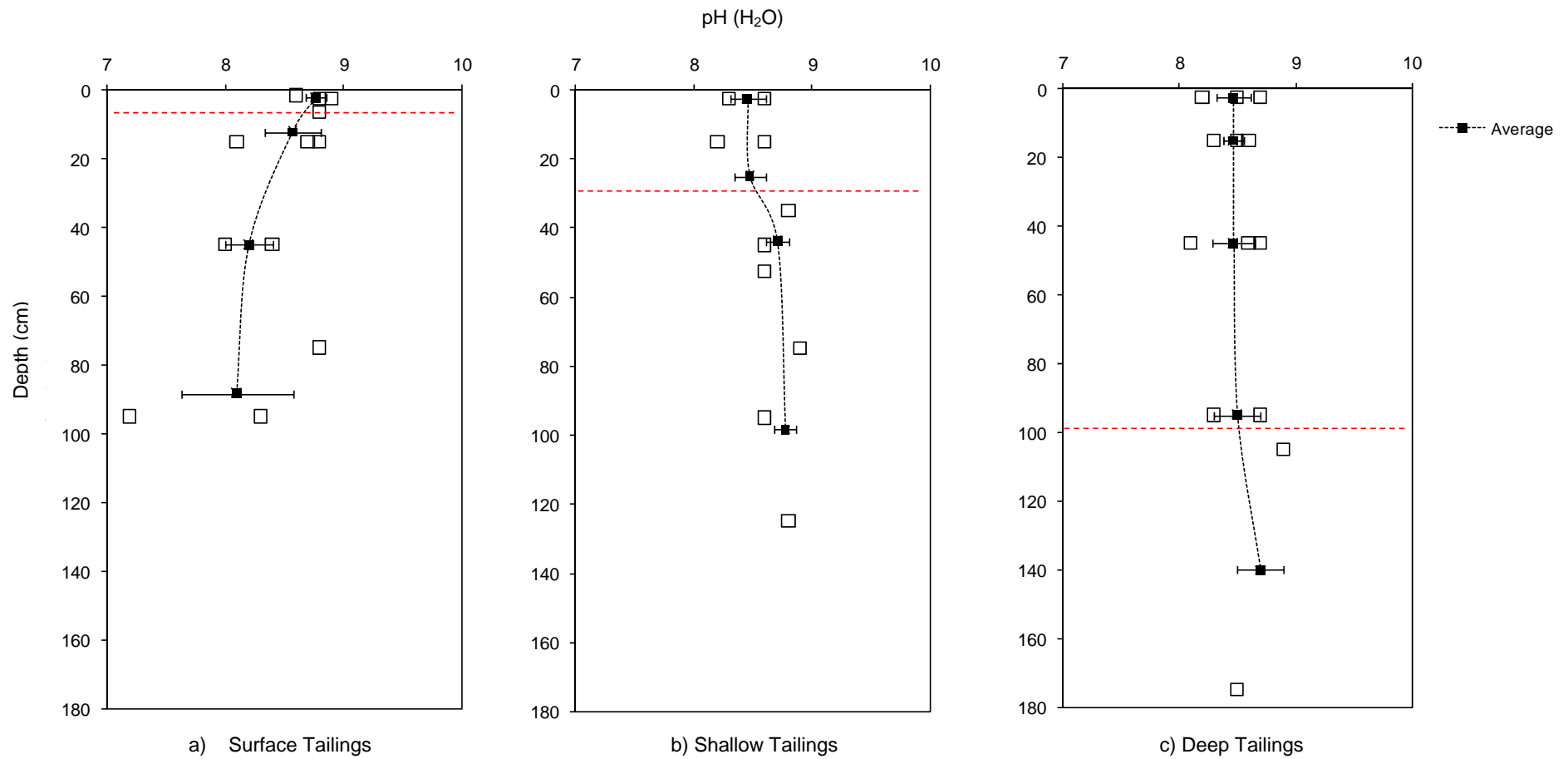
Root growth was generally not observed within the Deep and Shallow Tailings profiles, as vegetation was typically only observed at sites associated with the Surface Tailings profile. As would be expected, root growth within these profiles was generally highest within the 0 to 20 cm depth interval, with root abundance classed from 'few' to 'many' based on Australian Soil and Land Survey classification (McDonald *et al.* 1998). Below approximately 20 cm depth, root abundance declined rapidly from 'few' to 'no roots' within the calcareous clay horizon.

## 3.3 Soil chemical properties

### 3.3.1 Soil pH

The soil pH gives a measure of the soil acidity or alkalinity. The ideal pH range for plant growth of most agricultural species is considered to be between 5.0 and 7.5 (Moore 1998). Outside this range, the plant-availability of some nutrients is affected, while various metal toxicities (e.g. Al and Mn) can become limiting at low pH. For native species, which are known to be tolerant of wider ranges in soil pH, preferred pH ranges are best inferred from the soil in which they are observed to occur. In native soils that were surveyed within the proposed Northern and North-western footprints at the KCGM operations (Section 5 of overarching Soil and Waste Characterisation report) soils were typically considered moderately alkaline.

The pH of all tailings materials sampled was relatively consistent, ranging from pH 8.1 to 8.9 (pH in H<sub>2</sub>O) (Figure 5), with no apparent change with depth. The underlying *in situ* soils showed a greater variability in the pH, ranging from 7.2 to 8.9 (pH in H<sub>2</sub>O) (Figure 5). Again there was no consistent change in soil pH with sample depth within the *in situ* soil materials. In general, all materials sampled were considered moderately alkaline (Van Gool *et al.* 2005) and are therefore comparable to the pH of native surface soils associated with KCGM.



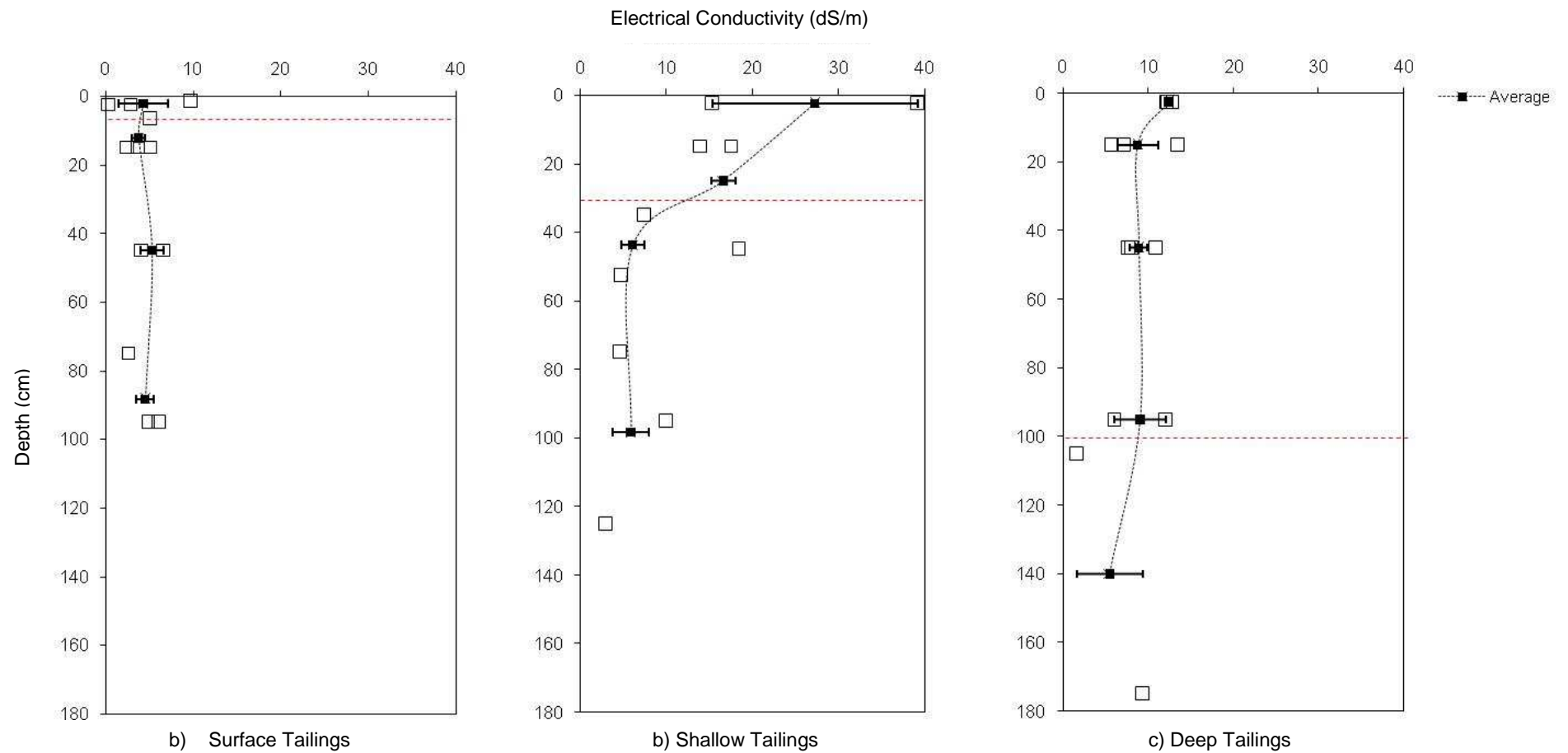
**Figure 5: Individual and average pH ( $H_2O$ ) of materials grouped into a) Surface Tailings b) Shallow Tailings and c) Deep Tailings profiles. Dashed red line represents average depth tailings layer and error bars represent standard error.**

### 3.3.2 Electrical conductivity

Electrical conductivity (EC) is a measurement of the soluble salts in soils or water. Soil salinity results from natural processes of landscape evolution, hydrological processes and rainfall (Hunt and Gilkes 1992).

Soil salinity was consistently high in all materials sampled, with EC ranging from 0.3 to 9.72 dS/m (Figure 6) and associated salinity ratings of 'moderate' to 'extremely saline' (Table 22) according to the standard USDA and CSIRO categories. There was substantial variation in salinity values recorded, however with the exception of the Surface Profile, the tailings materials tended to have more extreme salinity values than the underlying *in situ* soil materials (Figure 6).

The EC values measured in the Morrison Flats study area were significantly higher than that of native soils studied within the broader KCGM project area (SWC 2007; Section 5 of overarching Soil and Waste Characterisation report). However it would be expected that materials within this area would have naturally high concentrations of salt due to their position within the landscape and proximity to Hannan's salt lake (Kalgoorlie Consolidated Gold Mines, 2004).



**Figure 6: Individual and average EC values of tailings and soil materials, grouped into a) Surface Tailings b) Shallow Tailings and c) Deep Tailings profiles. Dashed red line represents average depth of tailings layer and error bars represent standard error.**

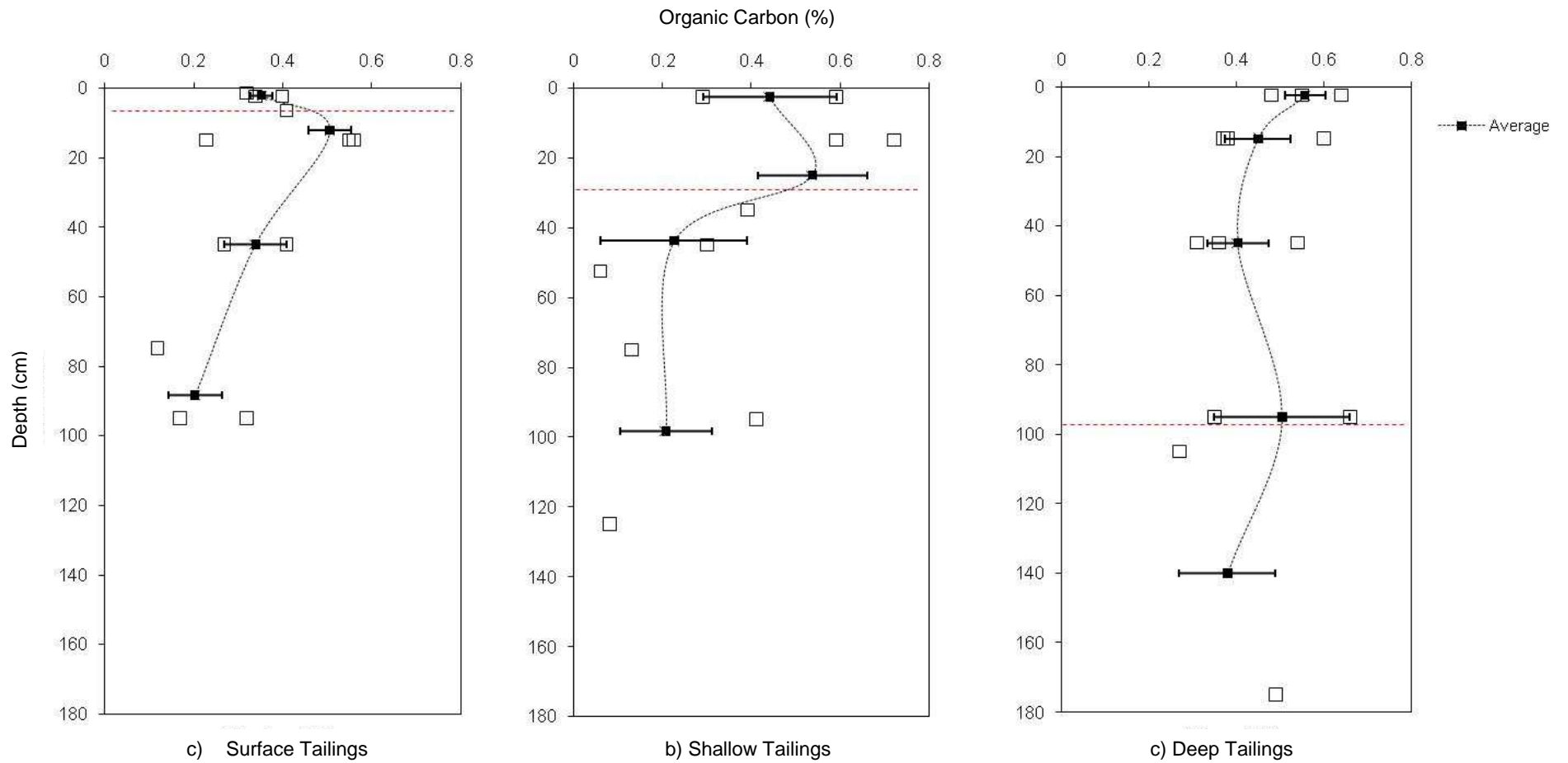
**Table 22: Summary of soil texture, electrical conductivity (EC) and salinity class ratings for tailings and soil materials in the Surface Tailings, Shallow Tailings and Deep Tailings profiles within the Morrison Flats study area.**

Profile Description	Site	Depth (cm)	Description	Field Texture	EC (dS/cm)	Salinity Class
Surface Tailings	MF2	0-3	Tailings	Loamy sand	9.71	Extremely saline
		3-10	Disturbed <i>in situ</i> soil	Clay loam	5.10	Extremely saline
		10-20	Disturbed <i>in situ</i> soil	Loam	5.12	Extremely saline
		70-80	Calcareous clay	Silty loam	2.65	Extremely saline
	MF3	0-5	Tailings	Sandy loam	2.90	Extremely saline
		10-20	Disturbed <i>in situ</i> soil	Sandy clay loam	3.68	Extremely saline
		40-50	Clayey soil	Sandy clay loam	6.57	Extremely saline
		90-100	Calcareous clay	Clay loam	4.89	Extremely saline
	MF7	0-5	Tailings	Loamy sand	0.30	Moderately saline
		10-20	Disturbed soil	Sandy clay loam	2.47	Extremely saline
		40-50	Gravelly ironstone	Sandy loam	4.04	Extremely saline
		90-100	Calcareous clay	Silty loam	6.05	Extremely saline
Shallow Tailings	MF 1	0-5	Tailings	Silty loam	15.30	Extremely saline
		10-20	Tailings	Silty loam	13.8	Extremely saline
		40-50	Tailings	Loamy sand	18.4	Extremely saline
		50-55	Tailings / <i>in-situ</i> soil interface	Loamy sand	4.73	Extremely saline
		70-80	Calcareous clay	Silty clay loam	4.65	Extremely saline
		120-130	Calcareous clay	Silty loam	2.97	Extremely saline
	MF4	0-5	Tailings	Silty loam	39.10	Extremely saline
		10-20	Tailings	Silty loam	17.52	Extremely saline
		30-40	Tailings / <i>in-situ</i> soil interface	Sandy clay	7.40	Extremely saline
		90-100	Calcareous clay	Silty loam	9.98	Extremely saline
Deep Tailings	MF5	0-5	Tailings		12.86	Extremely saline
		10-20	Tailings	Loamy sand	5.65	Extremely saline
		40-50	Tailings	Silty loam	7.70	Extremely saline
		100-110	Calcareous clay	-	1.63	Extremely saline
	MF6	0-5	Tailings	Silty loam	12.16	Extremely saline
		10-20	Tailings	Silty loam	7.22	Extremely saline
		40-50	Tailings	Loamy sand	8.08	Extremely saline
		90-100	Tailings	Loamy sand	6.07	Extremely saline
	MF8	0-5	Tailings	Silty loam	12.22	Extremely saline
		10-20	Tailings	Silty loam	13.42	Extremely saline
		40-50	Tailings	Silty loam	10.92	Extremely saline
		90-100	Tailings	Silty loam	12.07	Extremely saline
		170-180	Calcareous clay	Silty loam	9.35	Extremely saline

### 3.3.3 Soil organic matter

The organic matter content of soil is an important factor influencing many physical, chemical and biological soil characteristics. Directly derived from plants and animals, its functions in soil include supporting the micro and macro fauna and flora populations in the soil, increasing the water retention capacity, buffering pH and improving soil structure. The organic matter content of the soils within the study area was determined as a measure of the soil organic carbon percentage.

There was a range of soil organic carbon (SOC) values reported for materials within the Morrison Flats study area, however all exhibited low soil organic carbon values (< 1 %) (Purdie 1998) (Figure 7), which is relatively common for arid soils found in Western Australia. Below the tailings layers within each profile there appeared to be a general decline in SOC with increasing depth of the soil materials. The low organic carbon values are relatively similar to those of analogue surface soils within the greater KCGM project area (SWC 2007; Section 5 of overarching Soil and Waste Characterisation report).



**Figure 7: Individual and average soil organic carbon values for tailings and soil materials, grouped into a) Surface Tailings b) Shallow Tailings and c) Deep Tailings profiles. Dashed red line represents average depth tailings layer and error bars represent standard error.**

### 3.3.4 Exchangeable cations

Exchangeable cations, held on clay surfaces and within organic matter, are an important source of soil fertility and can influence the physical properties of soil. Generally, if cations such as  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{K}^+$  are dominant on the clay exchange surfaces, the soil will typically display increased physical structure and stability, leading to increased aeration, drainage and root growth (Moore, 1998). The effective cation exchange capacity (eCEC) is an estimate of the cation exchange capacity (which is measured by chemical analysis) and is calculated by summing the individual exchangeable cation concentrations.

There was a large degree of variation in the eCEC of the tailings and soil materials analysed at Morrison Flats (Table 23), reflecting the range of materials present. The tailings materials generally had the highest values, and there appeared to a decrease in eCEC with increasing profile depth into the *in situ* soil materials. Tailings material from the surface 0 to 5 cm sampling interval tended to have high (25 to 40 meq/100g) to very high (> 40 meq/100g) eCEC according Hazelton and Murphy (2007). The remaining materials typically had cation exchange capacities considered to be moderate.

**Table 23: Summary of exchangeable cations and effective cation exchange capacity (eCEC) for profiles within the Morrison Flats study area.**

Profile Descriptions	Sample Depth (cm)	Material Description	Ca (mg/kg)		K (mg/kg)		Mg (mg/kg)		Na (mg/kg)		eCEC (mg/kg)	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Surface Tailings	0 to 5	Tailings	35.55	28.14	0.14	0.05	1.42	0.23	0.45	0.12	52.37	41.59
	10 to 20	Disturbed soil	13.43	0.77	0.52	0.03	3.83	0.13	1.42	0.34	19.19	1.00
	40 to 50	Gravelly ironstone to clay	3.91	-	0.61	-	8.66	-	6.55	-	19.73	-
	80 to 100	Calcareous clay	6.61	2.64	0.21	0.07	2.89	0.82	0.59	0.10	10.30	3.42
Shallow Tailings	0 to 5	Tailings	22.00	3.93	0.06	0.02	2.38	0.46	0.72	0.30	25.15	4.69
	20 to 30	Tailings	23.81	9.26	0.04	0.00	2.29	0.09	0.64	0.12	26.77	9.29
	40 to 50	Disturbed soil	11.52	0.53	0.55	0.21	4.38	1.83	0.85	0.38	17.30	1.88
	90 to 110	Calcareous clay	13.10	1.23	0.40	0.16	4.30	1.45	1.18	0.07	18.98	1.26
Deep Tailings	0 to 5	Tailings	63.66	13.61	0.09	0.03	2.31	0.34	0.93	0.27	66.98	13.91
	10 to 20	Tailings	42.56	-	0.08	-	1.63	-	0.39	-	44.66	-
	40 to 50	Tailings	21.77	1.25	0.08	0.01	1.59	0.11	0.30	0.02	23.73	1.25
	90 to 100	Tailings	-	-	-	-	-	-	-	-	-	-
	140 to 150	Mottled to calcareous clay	19.07	7.89	0.58	0.10	3.47	0.24	0.77	0.03	23.88	8.25

### 3.3.5 Exchangeable sodium percentage

The exchangeable sodium percentage (ESP) describes the sodium fraction of the exchangeable cations held on soil surfaces. If sodium cations ( $\text{Na}^+$ ) are dominant on exchange surfaces (determined by calculating the ESP), and exceed more than 6 % of the total exchangeable cations, then the soil is considered to be *sodic*, which can lead to poor physical properties in clay rich soils, particularly clay dispersion, hard-setting and increased erodibility. If the ESP exceeds more than 15 %, then the soil is considered to be *highly sodic* (Moore 1998). For soil with high ESP values, high electrical conductivity can reduce the dispersive effects of high sodicity.

All tailings samples within the Morrison Flats study area were considered non-sodic (Table 24). The *in situ* soil horizons reported a range of ESP values, with the gravelly ironstone/clay material from the Surface Tailings profile exhibiting the highest ESP value of 33.2 %, which is classified as highly sodic. Some samples of the calcareous clay material were also sodic, with values ranging between 2.5 and 8.2 %. The disturbed *in situ* soil material from the Surface Tailings profiles also showed potential for structural instability, where an average ESP value of 7.3 % was reported.

High EC values are known to reduce the dispersive influence of exchangeable sodium in sodic and highly sodic soils, therefore the high EC values of the *in situ* soil materials (disturbed soil, gravelly ironstone/clay and calcareous clay) (Table 24), may reduce the amount of dispersion in these soils. This may explain why dispersion was not observed for the majority of these materials, during the Emerson Test (see Section 3.2.4 of this report).

**Table 24: Summary of average exchangeable sodium percentage (ESP), electrical conductivity (EC) and clay content for profiles at the Morrison Flats study area.**

Profile Description	Sample Depth (cm)	Material Description	ESP (%)		EC (dS/m)		Clay Content (%)	
			Mean	SE	Mean	SE	Mean	SE
Surface Tailings	0 to 5	Tailings	1.8	1.2	4.3	2.8	8.3	2.1
	10 to 20	Disturbed <i>in situ</i> soil	7.3	1.4	3.8	0.8	25.9	3.3
	40 to 50	Gravelly ironstone to clay	33.2	-	5.3	1.3	10.8	-
	80 to 100	Calcareous clay	6.7	1.5	4.5	1.0	27.8	3.3
Shallow Tailings	0 to 5	Tailings	2.7	0.7	27.2	11.9	14.5	1.5
	20 to 30	Tailings	2.5	0.4	16.6	1.4	8.6	3.5
	40 to 50	Disturbed soil	4.7	1.7	6.1	1.3	18.1	11.1
	90 to 110	Calcareous clay	6.2	0.4	5.9	2.1	21.3	7.2
Deep Tailings	0 to 5	Tailings	1.4	0.4	12.4	0.2	7.4	0.6
	10 to 20	Tailings	0.9	-	8.8	2.4	5.7	-
	40 to 50	Tailings	1.3	0.1	8.9	1.0	5.8	1.1
	90 to 100	Tailings	-	-	9.1	3.0	-	-
	140 to 150	Mottled to calcareous clay	3.6	1.1	5.5	3.9	12.2	7.4

Note: Yellow highlight indicates sodic values (>6 % ESP) and red highlight indicates highly sodic values (>15 % ESP)

### 3.3.6 Soil macro-nutrients

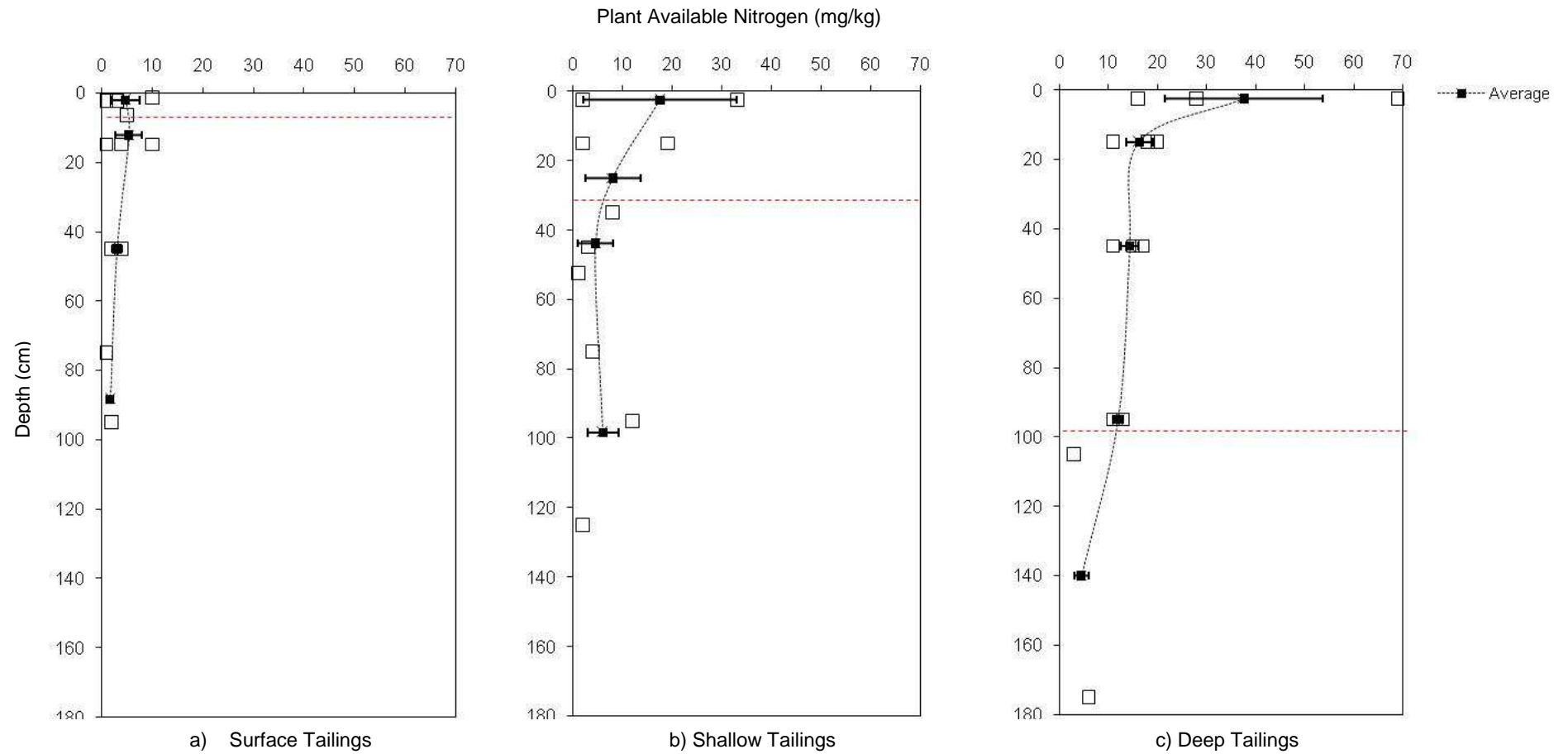
The most important macro-nutrients for plant growth are nitrogen (N), phosphorus (P), potassium (K), and sulphur (S). These nutrients are largely derived from the soil mineral component and organic matter. While the definition of adequate levels of these nutrients are well known for agricultural plant species, relatively little information is available for the nutrient requirements of native species.

There was a high degree of variation in plant-available nitrogen between the different soils / profiles in the Morrison Flats study area, particularly in the 0 to 5 cm depth interval (Figure 8). In the Surface Tailings profile, plant available nitrogen ranged between 1 and 10 mg/kg, was highest in the tailings layer and decreased with depth. In the Shallow Tailings profiles plant-available nitrogen ranged between 1 and 33 mg/kg, was highest and most variable in the tailings layer, and also decreased with depth. The tailings layer in the Deep Tailings profile reported the highest individual plant-available nitrogen value of 69 mg/kg. In all *in situ* soil materials analysed, the average plant available nitrogen values were considered low (< 8 mg/kg). These values for the *in situ* soils are within the range expected for native soils within the KCGM project area (SWC 2007; OES 2010 - Section 5 of overarching Soil and Waste Characterisation report)

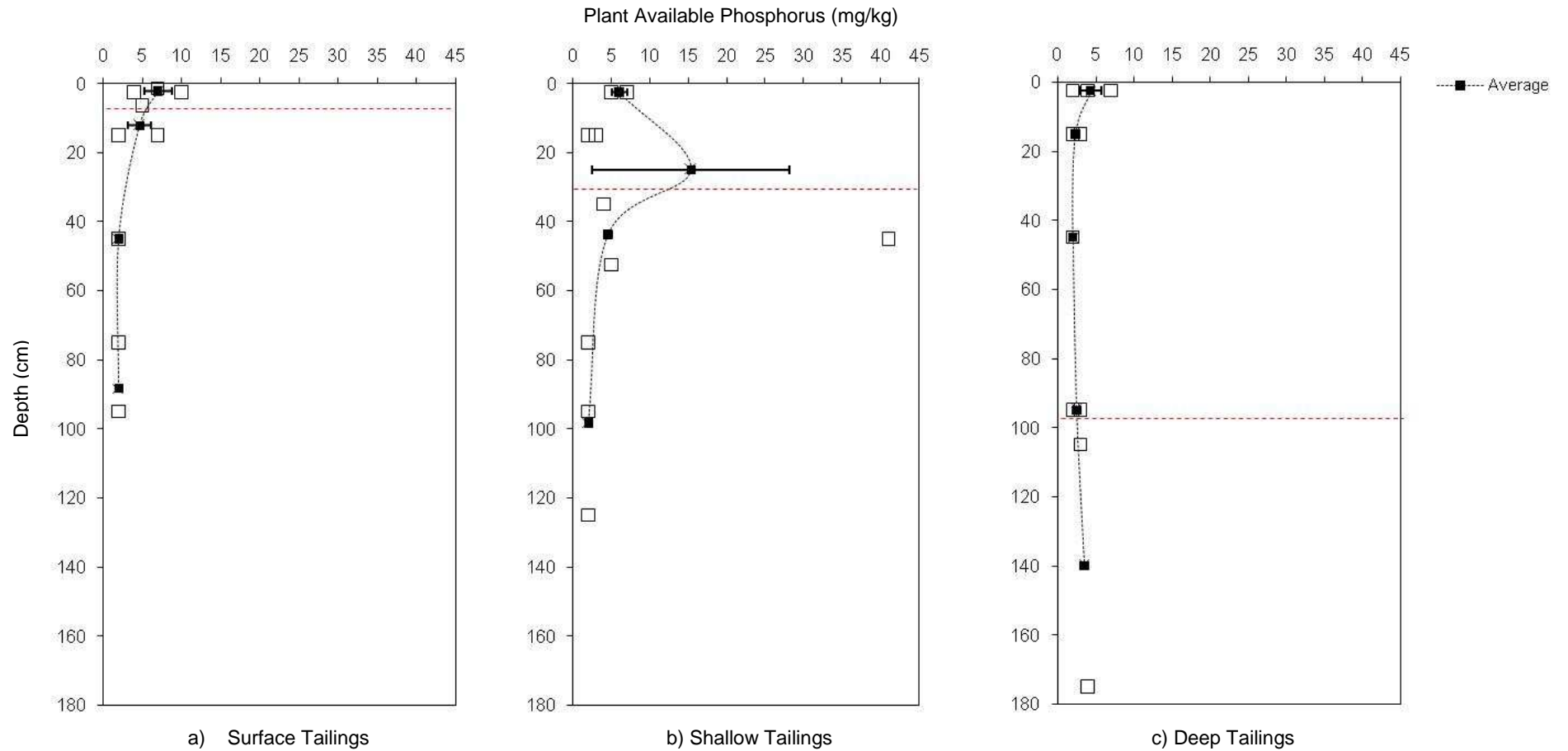
Plant-available phosphorus tended to be highest within the 0 to 5 cm depth interval of the tailings layer, across all profile types, however all materials reported low values of phosphorus (<12 mg/kg) (Figure 9), which are comparable to the concentrations measured for native soils within the KCGM project area (SWC 2007; OES 2010 - Section 5 of overarching Soil and Waste Characterisation report).

Plant-available potassium in the profiles examined varied significantly within each of the profiles (Figure 10), however the concentrations were, on average, relatively consistent with depth, and between the different profiles measured. Again, these values are comparable to values measure for the native soils within the KCGM project area (SWC 2007; OES 2010 - Section 5 of overarching Soil and Waste Characterisation report).

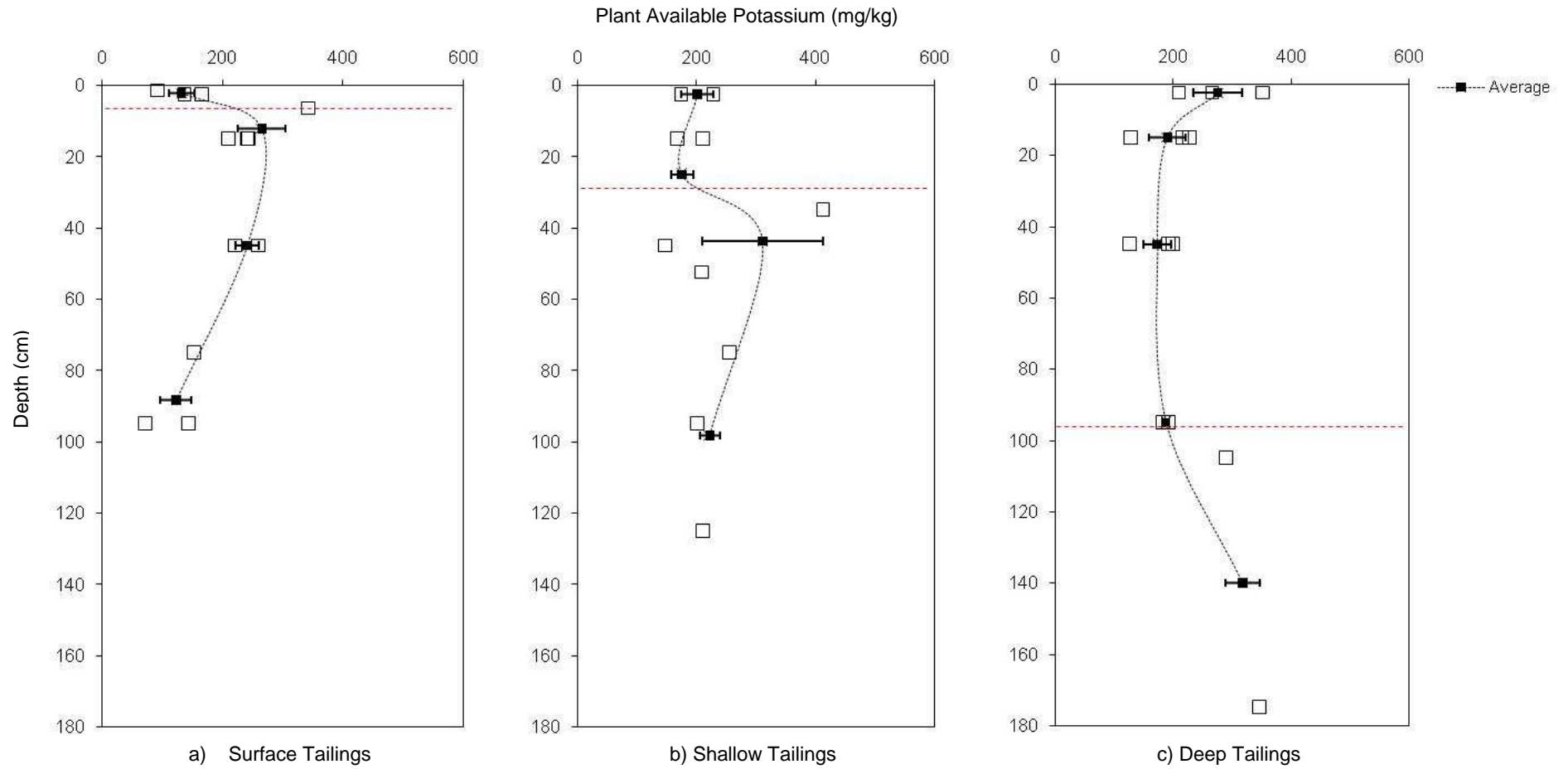
There was a wide range in plant-available sulphur values for all materials analysed across the different profiles, with the highest values reported within the tailings layers (Figure 11). *In situ* soil materials generally had available sulphur values that were comparable to values measure for the native soils within the KCGM project area (SWC 2007; OES 2010 - Section 5 of overarching Soil and Waste Characterisation report).



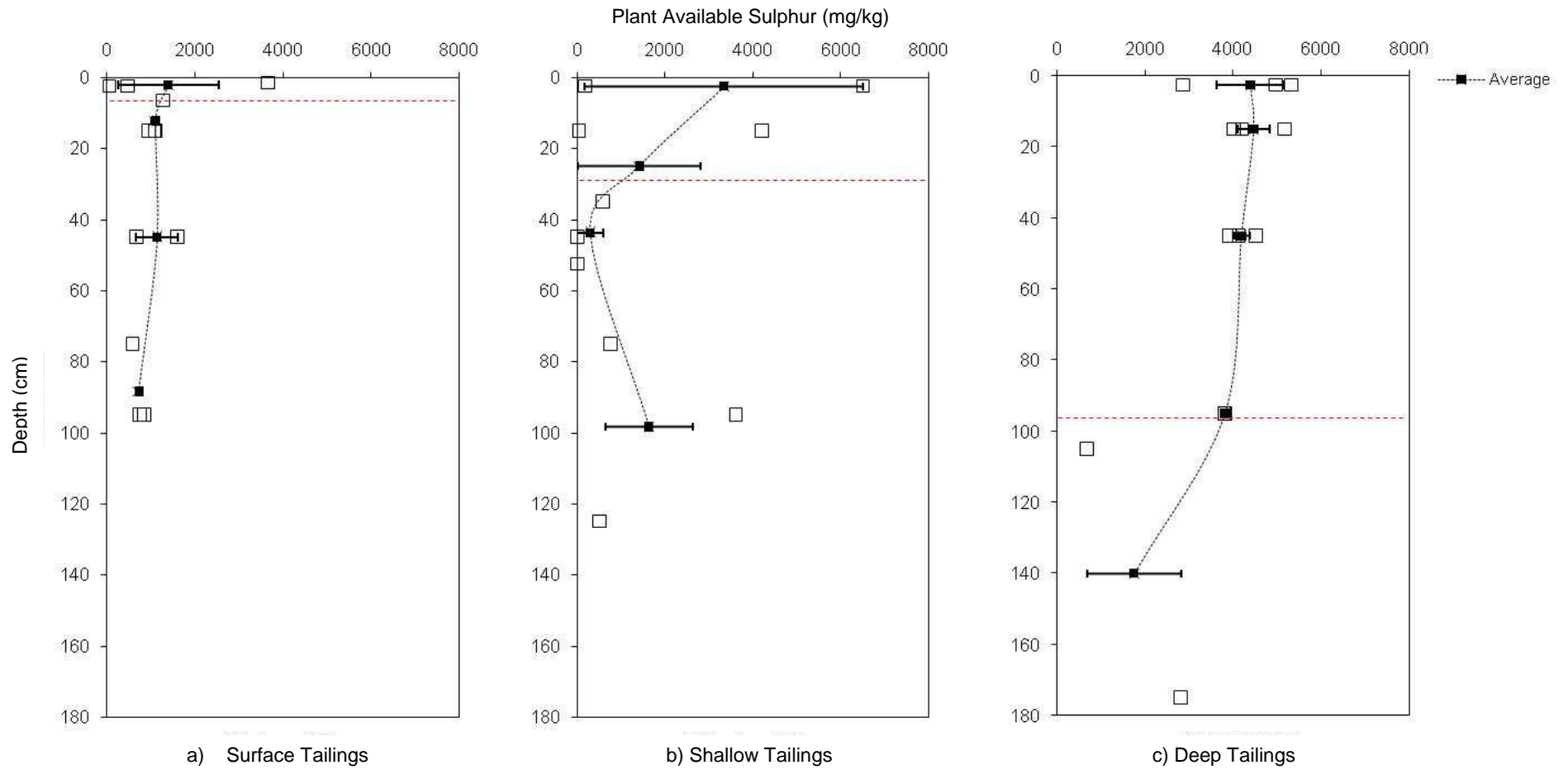
**Figure 8: Individual and average plant available Nitrogen ( $\text{NO}_3^- + \text{NH}_4^+$ ) values of materials, grouped into a) Surface Tailings b) Shallow Tailings and c) Deep Tailings profiles. Dashed red line represents average depth of tailings layer and error bars represent standard error.**



**Figure 9: Individual and average plant available phosphorus values of materials, grouped into a) Surface Tailings b) Shallow Tailings and c) Deep Tailings profiles. Dashed red line represents average depth of tailings layer and error bars represent standard error.**



**Figure 10: Individual and average plant available potassium values of materials, grouped into a) Surface Tailings b) Shallow Tailings and c) Deep Tailings profiles. Dashed red line represents average depth of tailings layer and error bars represent standard error.**



**Figure 11: Individual and average plant available sulphur values of materials, grouped into a) Surface Tailings b) Shallow Tailings and c) Deep Tailings profiles. Dashed red line represents average depth of tailings layer and error bars represent standard error.**

### 3.3.7 Total metal concentrations

Measurements of total metal concentrations of surface samples indicated that variable levels of As, Cd, Cr, Cu, Pb, Ni, Zn and Hg were present within all profiles, particularly when comparing the tailings materials to the *in situ* soil materials (Table 25). All results were compared with 'Ecological Investigation Levels' (EILs) for soils (Department of Environment, 2003). The EILs are intended as a guide only, as higher EIL values may be acceptable for some metal concentrations, such as As, Cr, Cu, Ni, Pb and Zn, in areas where soils naturally have high background concentrations of these substances (Department of Environment, 2003).

The tailings materials regularly reported As, Cu, Zn and Hg values above its EIL values (Table 25). The *in situ* soil materials below the tailings were typically lower in As, Cu, Zn and Hg concentration, but exhibited levels of Cr above its EIL (Table 25).

Arsenic is naturally found at high concentrations in mineralised deposits such as gold, and for this reason, As concentrations can be found at concentrations between 280 and 15,000 mg/kg in gold tailings materials (Naidu *et al.* 2006) depending on the type of ore. The high mercury levels in the tailings layers may be due to a natural high abundance, as well as historic ore processing techniques in which mercury was used for separation and recovery of coarse gold (Posgold Kaltails 1995).

The effect of high levels of As, Cu, Zn and Hg are poorly understood for vegetation that is native to Western Australia. Furthermore, copper and zinc values measured within the tailings material are comparable to some of the native soils within the proposed Northern footprint area where healthy native vegetation was observed (Section 5 of the overarching Soil and Waste Characterisation report) and therefore may not inhibit plant growth.

**Table 25: Individual total metal values (mg/kg) for selected tailings and soil samples from the Morrison Flats study area, including limits of reporting (LOR) and Ecological Investigation Levels (EILs).**

Profile Description	Site	Depth (cm)	Description	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Surface Tailings	MF 2	0-3	Tailings	111	<1	44	47	19	24	117	<0.1
		3-10	Disturbed soil	14	<1	136	38	9	46	62	<0.1
		10-20	Disturbed soil	10	<1	135	27	6	39	49	<0.1
		70-80	Calcareous clay	9	<1	92	24	<5	30	41	<0.1
	MF 3	0-5	Tailings	30	<1	138	34	16	36	74	0.1
		10-20	Disturbed soil	6	<1	138	29	6	35	36	0.1
		40-50	Clay	9	<1	146	32	9	42	18	<0.1
		90-100	Calcareous clay	6	<1	100	12	<5	7	<5	<0.1
	MF 7	0-5	Tailings	37	<1	148	36	15	31	75	0.3
		10-20	Disturbed soil	<5	<1	134	37	9	44	19	<0.1
		40-50	Gravelly ironstone	12	<1	122	54	7	77	14	<0.1
		90-100	Calcareous clay	<5	<1	29	11	<5	8	<5	<0.1
Shallow Tailings	MF 1	0-5	Tailings	124	<1	7	43	<5	14	82	0.3
		10-20	Tailings	122	<1	7	54	<5	15	139	0.2
		40-50	Tailings	935	<1	6	292	24	52	396	1.2
		50-55	Tailings/ <i>in-situ</i> soil interface	39	<1	132	54	10	34	74	<0.1
		70-80	Calcareous clay	10	<1	132	24	6	37	36	<0.1
		120-130	Calcareous clay	8	<1	100	17	<5	24	42	<0.1
	MF 4	0-5	Tailings	220	<1	12	76	61	23	240	3
		10-20	Tailings	180	<1	13	63	43	23	209	<0.1
		30-40	Tailings/ <i>in-situ</i> soil interface	12	<1	146	40	8	47	59	0.4
		90-100	Calcareous clay	<5	<1	22	5	<5	5	<5	<0.1

Profile Description	Site	Depth (cm)	Description	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Mercury
				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	
Deep Tailings	MF 5	0-5	Tailings	168	1	27	64	25	23	165	4
		10-20	Tailings	201	1	28	76	31	26	184	7.3
		40-50	Tailings	250	1	12	97	40	24	250	7.3
		100-110	Calcareous clay	8	1	8	31	7	49	38	0.2
	MF 6	0-5	Tailings	121	1	18	63	41	30	208	1
		10-20	Tailings	130	1	10	66	49	30	247	2.6
		40-50	Tailings	123	1	11	71	50	32	253	3.7
		90-100	Tailings	124	1	10	67	38	29	232	2.4
	MF 8	0-5	Tailings	8	1	12	80	32	26	180	8.1
		10-20	Tailings	261	1	8	88	41	24	258	8.8
		40-50	Tailings	262	1	8	95	46	27	273	12.1
		90-100	Tailings	269	1	8	130	49	25	315	5.9
		170-180	Calcareous clay	26	1	107	64	6	43	53	0.2
<b>LOR</b>				<b>5</b>	<b>1</b>	<b>2</b>	<b>5</b>	<b>5</b>	<b>2</b>	<b>5</b>	<b>0.1</b>
<b>EIL</b>				<b>20</b>	<b>3</b>	<b>50</b>	<b>60</b>	<b>300</b>	<b>60</b>	<b>200</b>	<b>1</b>

Note: Values above the Ecological Investigation Levels (EIL) (DoE, 2003) are highlighted yellow

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