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4.7 Soils and Land Cover

The baseline has been generated using published information relating to the soil and land cover study area (SLC study area) supplemented by field surveys. This information has been used to characterise the land use, pedology, soil quality and quantity that would be influenced by the Project. The published information has been supplemented by:

- Soil mapping of the Project study area, compiled from transect surveys and test pits during 2013 and 2014 (presented in Section 4.7.2, see Appendix 4.7.1 for the field data and interpretative reports);
- An analysis of the soil chemical survey, undertaken by Geoteam (2008-2010), as a part of the geological site investigation programme and from soil samples obtained in 2014 within the main elements of the Project footprint (the data is presented in Section 4.7.6, see Appendix 4.7.2 for the distribution of data points from the SI programme); and
- Land cover and vegetation analysis from satellite image data, dating from 2014 and site walk over studies, see Section 4.7.7.

4.7.1 Soil Classification

A number of published soils reports are available for the RA, which provide sufficient information to establish the baseline dataset for this study. The national soil map identifies the Project to be in an area where brown and black earths (Chernozems) predominate at lower elevations, grading into Mountain Black (Chernozems). Montane Meadows and Montane Meadow Steppe have been classified in the original Russian surveys[1] and confirmed by soil survey (see Appendix 4.7.1). The national distribution of the main soil types in RA is identified on Figure 4.7.1.

[1] Scientific-Research Institute of Pedology and Agro-chemistry (1994) and American University of Armenia (СИСИАНСКИЙ РАИОН, published 1:200,000 soils survey)

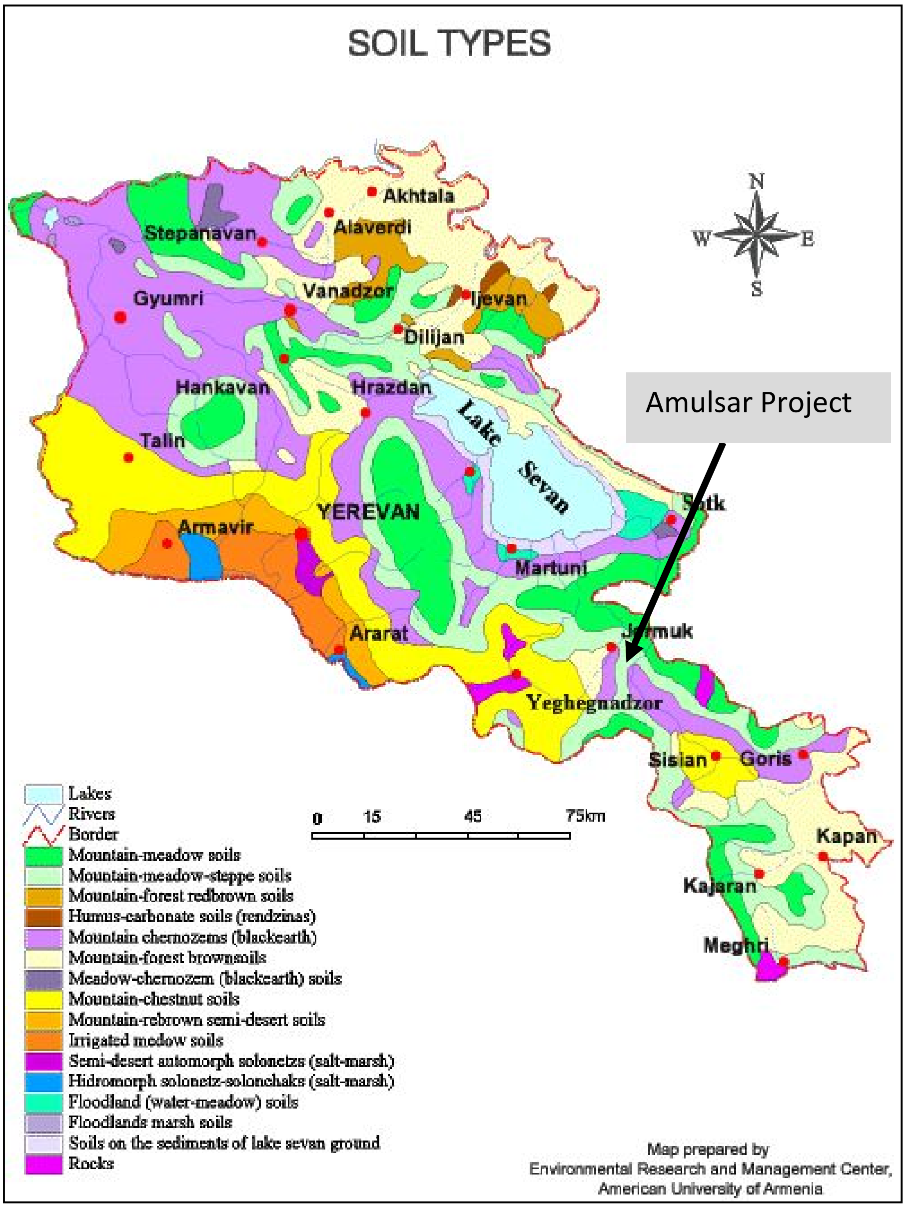

Figure 4.7.1: RA Soil Types and Geographic Distribution

Published soil data is available for the Amulsar region[2] and is shown on Figure 4.7.2, with respect to the Project footprint.

[2] Food and Agriculture Organization of the United Nations (FAO), Country Pasture/Forage Resource Profiles: ARMENIA, (2006)

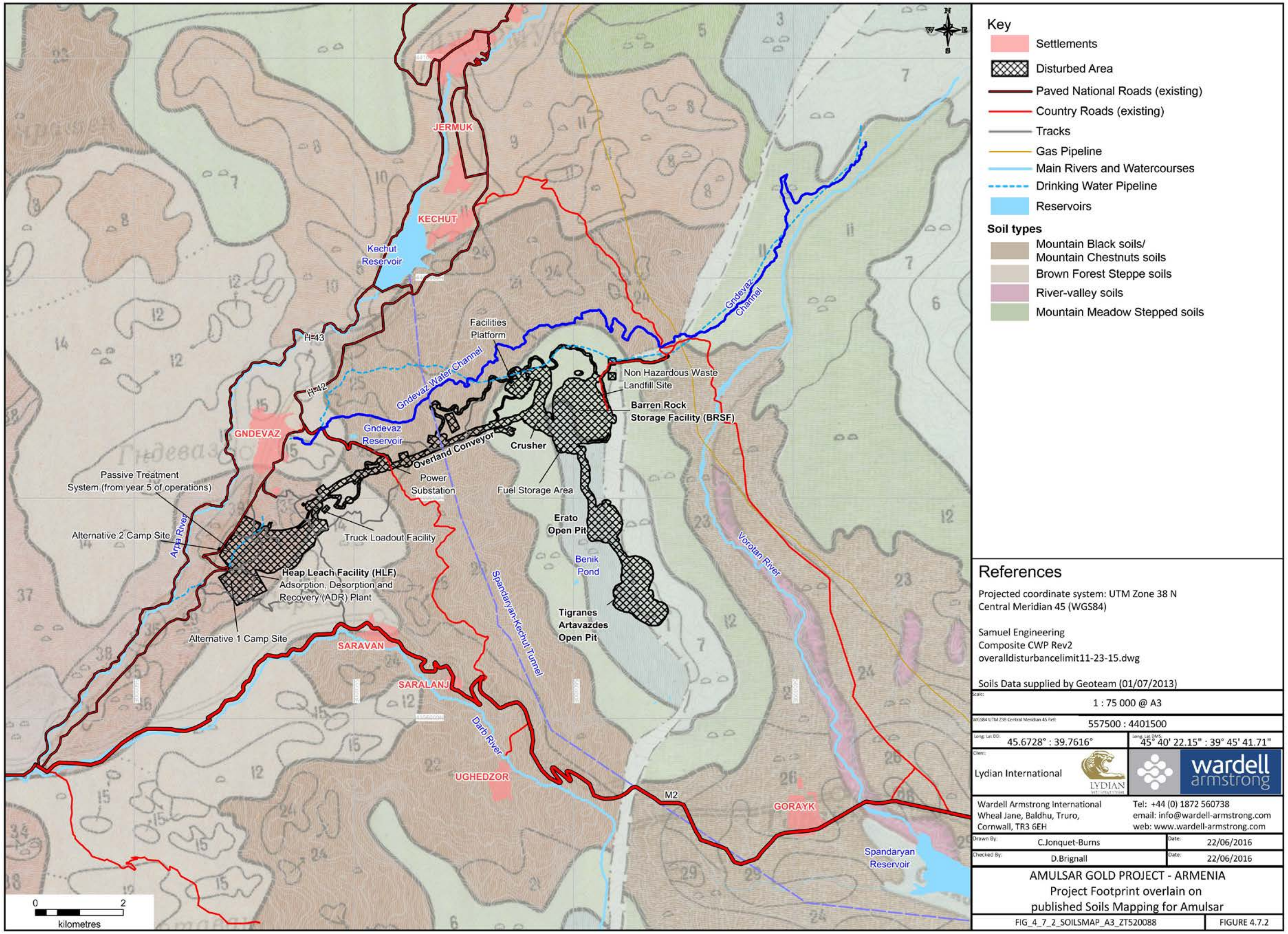

Figure 4.7.2: Project Footprint overlain on published Soils Mapping for Amulsar

Detailed soil profile description

Typical soil profile characteristics of each soil type are as follows, and the description of the landscape type has been cross referenced to the descriptions defined in Section 4.3 and 4.10:

Mountain Meadow soils

Mountain Meadow soils are present on steeper slopes recognised as highland hills and on grazing lands, typically at elevations between 2200 and 4000 m, typically influenced by cold and humid conditions. They typically receive a large excess of moisture resulting in a strong leaching regime which is seen throughout their soil profile. This creates an acidic soil reaction (pH 4.8 to 6.2). They are of a light medium loamy texture, with clay content increasing on shallower slopes and basins. Topsoil profile depths are generally 0.2m, although shallower on steeper slopes, with a generally high organic humus content (17-31%[3]) although this varies depending on the influence of perched groundwater within the subsoil. Topsoil tends to be weakly acidic and generally free-draining to the subsoil that extends to approximately 0.4 m. The open pits and main haul road are located within areas of Mountain Meadow soils; however, due to the altitude and slope constraints in this region these soils tend to be very shallow or absent entirely. Where soil is absent the surface is either bare ground and/or ice/snow. The open pits have a dominant grassland land cover and consequently a larger percentage (Erato 90%; Tigranes-Artavazdes 55%) of Mountain Meadow soils.

The Mountain Meadow soils are influenced by cold, humid, sub-alpine conditions. This limits the topsoil profile formation around the open pits to typically less than 0.15 m depth. It is noted that on the published soil maps of Amulsar Mountain[4], these have been classified locally as a Mining Meadow Turf. The term may relate to the presence of economically valuable minerals in this area, although this is not evident from the published soils maps[4]. The soil survey confirmed that the soil type is that of a Mountain Meadow and that the soil profile is limited in depth, interspersed with rocky outcrops and extensive areas of bare ground (Page 4, Appendix 4.7.1).

[3] Panagos P., Van Liedekerke M., Jones A., Montanarella L. (2012) European Soil Data Centre: response to European policy support and public data requirements Land Use Policy, 29 (2), pp. 329-338.

[4] Ibid. 1, pg4.7.1

Mountain Meadow Steppe soils

Mountain Meadow Steppe soils lie at elevations between 2400 and 2600 m asl (in the Amulsar region), and are characteristically associated with steeper slopes, forested upper gorge, high steppe, plateau grasslands, and foothills. The topsoil profile is generally shallow, and where found on gentle slopes will be on average 0.15 m, overlying a subsoil horizon that varies in depth from very thin to 0.5 m. Soils are black to dark brown, chestnut sandy loam, stony to gravel in places and with a weak structure. Soils are acidic, with little if any limestone content. The transition from subsoil to parent material (C horizon) is vivid with weathered bedrock, and light loamy to stony skeletal soil with little or no structure. Within the Project, the BRSF, crusher, truckshop and administration offices, explosive magazines and the upper part of the conveyor are located within areas that are characterised by Mountain Meadow Steppe soils. The majority of these infrastructure elements are characterised by grassland land cover, and consequently soils will be disturbed in their construction.

To the east of the Project, the field survey encountered Valley Meadow-Steppe soils adjacent to the Vorotan River. These soils will not be affected by the Project; however a description of the profile is given in Appendix 4.7.1.

Mountain Black soils

Mountain Black soils formed on gently sloping and flat valleys of the settled lowlands and are characteristic of the grasslands in the lower farmed and settled foothills of the steppe. They are present at an altitude of 2000 to 2400 m asl. Within the Amulsar region the soil type supports extensive grassland ecosystems, and closer to communities they are also used for a variety of cultivated crops. The soil profile is characterised by a clearly identified A horizon (topsoil), dark in colour from chestnut brown to black, high organic content, medium to heavy loam, stoneless to slightly pebbly, extending to a depth of 0.4 m. There is a noticeable transition to the subsoil that can extend to a depth of 1.1 m, with a slight to medium loamy texture and chestnut with brown shading. This horizon is generally stoneless and overlies a light chestnut coloured heavy loam, which is slightly pebbly and extends to a depth of approximately 1.4 m. The main part of the overland conveyor, access roads and other infrastructure, such as quarries to be developed during the construction phase, are located on this soil type.

Mountain Chestnut soils

Mountain Chestnut soils lie at elevations between 1500 and 1900 m asl and are characteristic of steeper slopes, high steppes and foothills. They have a moderate topsoil organic matter content (2-6%) and are relatively shallow with topsoil depths approximately 0.2 m, although this depth increases into the lowlands. They form under a relatively arid, continental climate which allows the build-up of a humus-rich topsoil horizon, and contributes to the weakly alkaline reaction (pH 7-8). Underlying horizons are greyer in colour, becoming more bleached with depth. Topsoil is of a heavy clay-sandy texture, decreasing in clay content with depth and has a weak profile development. Parts of the HLF and associated roads and access tracks, the ADR plant and offices, water pipeline, part of the conveyor, and the truck load-out facility are all located on this soil type. The HLF facility is located on two different soil types; Mountain Chestnut soils and Brown Forest Steppe soils (see below).

Brown Forest Steppe soils

Brown Forest Steppe soils occur at elevations between 1600 and 1900 m asl and are characteristic of steeper slopes, forested upper slopes, steppes and foothills where there is greater warmth and/or humidity. The topsoil depth is estimated at 0.15 m, overlying a subsoil extending to an average depth of 0.5 m. The relatively high precipitation creates a strong leaching regime, resulting in the translocation of clay vertically through the profile, and the creation of a resulting clay horizon further down the profile. This creates a moderately acidic (pH 4.5-5.9) reaction. Their high topsoil organic matter content (4-8%) is a result of the high organic matter input from the surface vegetation (mainly forest), which also helps to bind the soil's characteristically weak clay-sandy structure together, acting as a preventative measure against erosion. Part of the HLF is located on this soil type.

River-valley soils

Alluvial Brown earths are present in the Vorotan and Apra river basins at an elevation of approximately 2200 m asl. These soils are deeper; the topsoil profile estimated at a depth of 0.25 m, comprising dark chestnut cloddy silty clays. The underlying subsoil is a light chestnut cloddy silty clay, breaking to a fine crumb, and present to a depth of 0.7 m. In river valleys, the soils can be subject to prolonged saturation during spring and autumn. These soil types are widely used for a range of crops and are subject to annual cultivation. These will not be affected by the development of the Project.

Figure 4.7.3 identifies the general arrangement of the Project in relation to the surveyed soil types in the wider study area. This has been used to estimate potential for soil disturbance (see Table 4.7.1).

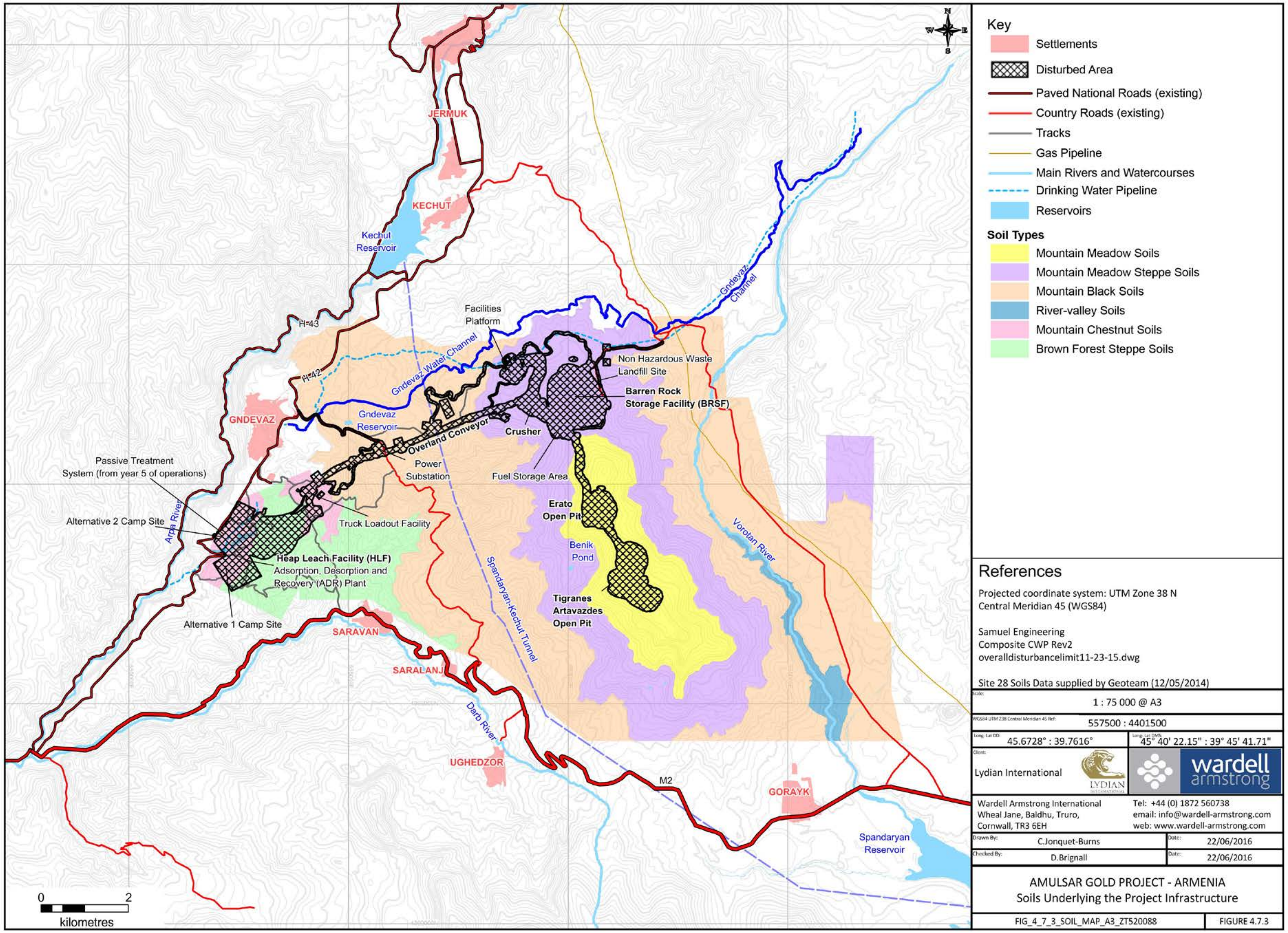

Figure 4.7.3: Amulsar Soil Associations and Project Layout

Table 4.7.1: Primary Soil Associations and Areas Potentially Affected During Development of the Project												
Soil Type	Area of Potential Disturbance (rounded to the nearest 5 ha)											
	Tigranes - Artavazdes Open Pit	Erato Open Pit	BRSF	Construction Camp	HLF, ADR & Ponds	Haul & Access Roads	Primary & Secondary Crusher	Conveyor and load out	Facilities platform	Quarries	Other infrastructure	Total
Brown forest steppe	-	-	-	20	98	2	-	-	-	-	-	120
Mountain black	-	-	162	-	-	43	-	47	-	8	12	272
Mountain chestnut	-	-	-	28	96	2	-	15	-	-	2	141
Mountain meadow	123	47	-	-	-	38	-	13	-	-	2	223
Mountain meadow steppe	-	-	-	-	-	115	15	-	22	5	3	153
Valley river alluvial	-	-	-	-	9	-	-	-	-	-	-	9
Total (ha)	123	47	162	48	203	199	15	77	22	13	17	930

4.7.2 Land Capability Classification

The results of the site investigation together with published soils data can be used to determine an indicative Land Capability Classification, based on the criteria given in Table 4.7.2[5]. Land Capability provides a measure of the capacity of a soil to support a range of economic agricultural activity.

In general, Land Capability Classes I to IV are indicative of suitable soils for growing a range of crops, with increasing limitations with respect to cultivation and crop husbandry. The Class range of V to VIII are more severely limiting through factors such as climate, slope, aspect, and altitude. These may also include factors, such as isolation and lack of infrastructure, which inhibits the economic use of the land for arable agriculture. The use classes are more suited to pasture, woodland or afforestation.

On the basis of the survey data, the soils within the Project area are considered to be predominantly Land Capability Classification V to VII (Limited Arable to Non-Arable), with the exception of the HLF, and surrounding infrastructure (offices, ADR Plant, and water supply pipeline to the Arpa River), which is considered to be Land Capability Classification III.

The land considered to be Land Capability Classification III is used as arable land, particularly orchards (for fruit production, in particular apricots). It is limited to Class III by its soil depth, climate, altitude, and erosion risk. This is generally considered to be high quality agricultural land, and therefore considered to be locally valuable.

The land considered to be Land Capability Classification V to VII has limited agricultural uses as it is limited by slope, climate, altitude, soil depth, and factors such as stone content, that inhibit use for mechanised cultivation which is required for arable agriculture. However, since the grasslands are used by the surrounding communities for grazing and seasonal pasturage (Section 4.16 - Land Use and Tenure), it is clear that Land Capability Classification alone is not sufficient to describe the agricultural/cultural value of land in the Project. In addition, land use has been considered with respect to the national designation of Land Use Capability within the Project (Section 4.3 and 4.16), which identifies the potential of the land in relation to economic use. Land tenure and cadastre has been considered in Sections 4.16.1 and 4.16.2.

[5] Land Capability Classification handbook, 210. Klinbeigal and Montgomery, 1961 (US Govt Print Office).

Table 4.7.2: Land Capability Classification

Land Capability Class		Soil Drainage	Slope %	Depth (m)	Stones % vol	Soil Texture	ECEC Clay	pH Water 1:2.5	K Factor	Erosion Risk	Agricultural Suitability
I	Arable (and irrigable)	Well	<3	>2	<5	Clay loam	>24	6.0 – 7.8	<0.1	None	Arable
II	Arable (and irrigable)	Moderate	<16	>2	<5	Any except sandy	>16	5.3 – 8.5	<0.3	Slight	Arable
III	Arable	Imperfect	<25	>1	<15	Any except sandy	>16	5.3 – 8.5	<0.3	Moderate	Shifting
		Imperfect	<16	>1	<15	Sandy	>12	5.3 – 8.5	<0.3	Moderate	Shifting
IV	Arable	Poor	<25	>0.6	<40	Any except sandy	>12	4.5 – 8.8	<0.5	High	Shifting
		Poor	<16	>0.6	<40	Any except sandy	>12	4.5 – 8.8	<0.5	High	Shifting
V	Limited arable	Very poor	<3	>0.3	<40	Any	4 – 12	4.5 – 8.8	<0.3	Slight	Pasture
VI	Non-arable		<25	>0.3	>40	Any	<4	<4.5		High	Permanent pasture, trees
VII	Non-arable		<40			Sandy				Very high	Permanent pasture and non-agricultural, e.g. forestry
			<60			Any except sandy				Very high	
VIII	Non-arable		>40			Sandy				Very high	Non-agricultural, e.g. forestry
			>60			Any except sandy				Very high	

Notes:
1. LCC assumes good management of mechanised operations. 25% slope is safe limit for mechanised operations. Mechanised operations apply to classes I – VI for arable use and pasture improvements.
2. Soils having >40% stones (volume) are unsuitable for mechanised arable cultivation.
3. Irrigable land should have 2.0m soil depth to allow for any leaching, drainage.
4. Surface irrigation is feasible on slopes <3% and clayey soils.
5. Sprinkler irrigation is feasible on any soil on slopes up to 16%.
6. Erosion risk is a qualitative assessment based on slope, soil texture, ECEC, clay and k value.
7. Sandy soils: Class III at best. Vertisols: Class II at best. Very acid soils (pH<5.3): Class IV at best. Soils with ECEC <4: Class VI at best.
8. Contaminated land (mining, tailings, spoil) is Class VIII.
9. The K factor is a measure of soil erodability and is derived from various physical and chemical parameters in particular the particle size distribution and soil drainage.

Notes continued:

10. Effective Cation Exchange Capacity (ECEC) is a measurement of exchange capacity and is defined as the sum of exchangeable bases and exchangeable hydrogen and exchangeable aluminium.
11. LCC is determined through consideration of the site parameters against criteria identified above with the lowest / worst value determining the overall LCC.
12. Armenian land cadastre categories have been considered in Section 4.16.2
13. Additional areas of disturbance will result from the location of topsoil stockpiles.

Descriptions have been grouped to take account of the main differences between soils within the Project, in particular topography and elevation.

4.7.3 Physical Integrity

The weakly structured Mountain and Mountain Meadow Steppe soils are at risk from sheet and rill erosion, where vegetation cover is reduced, or as a consequence of land slip, resulting in undercutting or exposure of the soil profile on vulnerable steep slopes. In general, where land is maintained with grassland cover, risk of soil erosion can be reduced. Where vegetation cover is removed and the underlying soil profiles are exposed as a consequence of undercutting across steep gradients, there is a risk of incipient and on-going erosion, which requires specific mitigation design.

4.7.4 Sensitivity Criteria

Sensitivity of the soils baseline is established for soil resources based on their agricultural productivity (sensitivity in terms of supporting biodiverse ecosystems is referenced in Section 4.7.5 below). This combines the depth of the soil resource, land capability classification, the economic importance of the agricultural production, and physical integrity of the resource, resulting in a Minor – Very High sensitivity scale (see Table 4.7.3).

Table 4.7.3 Criteria for establishing a sensitivity scale for soils

		AGRICULTURAL PRODUCTIVITY					
		Narrow range of agricultural crops	Versatile – a range of agricultural annual crops	Versatile – a wide range of agricultural crops	Highly versatile – a range of agricultural and horticultural crops		
DEPTH OF RESOURCE	Very Shallow (<0.5 m)	**MINOR**	**MINOR**	**MEDIUM**	**HIGH**	Poor/no structure	STRUCTURAL STABILITY
	Shallow (0.5 – 1 m)	**MINOR**	**MEDIUM**	**HIGH**	**HIGH**	Weak Structure	
	Deep (1 – 1.2 m)	**MEDIUM**	**MEDIUM**	**HIGH**	**VERY HIGH**	Moderate structure	
	Very Deep (>1.2 m)	**MEDIUM**	**HIGH**	**VERY HIGH**	**VERY HIGH**	Well Structured	
		Locally Important	Regionally important	Nationally important	Internationally important (for export)		
		GEOGRAPHICAL IMPORTANCE ECONOMICALLY					

4.7.5 Soils and biodiversity

Section 4.7.4 considers the sensitivity of baseline soils in relation to agricultural productivity, depth of the resource and structural integrity. The sensitivity of the baseline soil resource in relation to supporting biodiverse ecosystems is not considered directly in the assessment of soils and land cover; however, the weakly structured soils, with shallow profiles isolated by crests of bare rock also support the rare and endemic plant species considered in Section 4.10. The soils that have developed in these harsh environmental conditions and that result from a combination of climate, relief, aspect and exposure, have been characterised so that they can be managed separately from the soils that support agriculture and are present at lower elevations.

4.7.6 Soil Chemistry

In the absence of anthropogenic contamination (such as input from agricultural pesticides or factory emissions), metal concentrations in soils are directly related to the chemical composition of the parent material from which the soil is derived, particularly for those soils which are formed from homogeneous or single parent material, or young soils that have been weathered under temperate conditions. In contrast, soils derived from heterogeneous (diverse) parent material, such as glacial tills, soils overlaid by natural parent material, or soils under the influence of anthropogenic activities from various sources, may vary considerably in their metal concentrations.

In the Project-affected area, superficial soils and rock outcrop samples were collected by Lydian as part of the Project's exploration programme. The soil samples indicate that the superficial materials in the Project area have elevated to very elevated concentrations of a number of metals and metalloids. These are naturally occurring metal/metalloid concentrations in soils and superficial materials which reflect the presence of the ore bodies and the related mineralization in the soil parent material and rock outcrops. Concentrations of various metals were found to be present above Armenian MAC guidelines (see Table 4.7.4). MAC values do not account for naturally occurring elevated baseline metal concentrations present in soils from mineralized areas, such as at Amulsar. Topsoil removed from the area overlying the future open pits and other facilities will be stockpiled for use during closure and reclamation. For these reasons, the Project has developed site-specific soil quality guidelines that reflect the naturally occurring elevated concentrations of various substances in the Project-affected area, for soils that will be stockpiled and used during closure and reclamation (See Chapter 2, Table 2.14).

Environmental Baseline Sampling Programme

A total of 152 soil samples were obtained from the Project site across 2008 – 2010 and 2014 as part of the environmental baseline sampling programme, of which 63 sample locations fall within and adjacent to the proposed Project footprint. These samples were submitted to ALS analytical laboratory in Prague, Czech Republic for chemical analysis. ALS performed a multi-element ICP-MS scan on the soil samples, including analysis for the following elements: As, Ba, B, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Sr, V, W, Zn. Analyses for the following substances were also performed, using various standard methods: ammonia, nitrate, nitrite, carbonates, cyanide, sulphide, chloride, fluorine. Selected samples were analysed for petroleum hydrocarbons; aliphatic and aromatic hydrocarbons were analysed in soil samples collected in 2008 and 2014 (see Appendix 4.7.2).

Mineral Resource Exploration Sampling Programme

A minimum of 2,400 soil and rock chip samples were obtained from the Project site as part of mineral exploration drilling and sampling, which has been on-going since 2006. Although the goals of the mineral exploration programme are different from those of the environmental baseline sampling programme, both programmes document pre-existing soil chemistries and shared sampling sites within the footprint of the open pits. Therefore, the exploration results were examined to see if they provided additional support for adopting site-specific soil standards for reclamation use, that reflect natural mineralization.

The exploration soil and rock chip samples were submitted independently of the environmental baseline samples for chemical analysis for total concentration of metals and metalloids via standard multi-element ICP-MS, including: Au, Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, In, K, La, Li, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, Rh, S, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr.

Analytical Results

Soil samples from both the environmental baseline and the mineral resource exploration programmes showed consistently elevated concentrations of various metals/metalloids across the Project area, generally centred around or adjacent to the ore bodies. For reference, Table 4.7.4 compares the mean values obtained from both sampling programmes against MAC soil values.

Table 4.7.4: Mean Metal Concentrations in Project Area Soils			
Substance(s)	**Soil MAC**	**Environmental Mean**	**Exploration Mean**
Antimony	4.5	12.5	672
Arsenic	2	29.8	31.68
Cobalt	5	19.4	18.7
Copper	3	43.1	60
Manganese	1,500	975.7	896
Nickel	4	44.3	43.7
Nitrates	130	84.4	n/a
Lead	20	33.0	36
Sulphur	160	n/a	848.3

Mean soil concentrations were also compared to the following residential soil screening values:

- United Kingdom General Assessment Criteria (GAC) guidelines; and
- United States Environmental Protection Agency (USEPA) Regional Screening Levels guidelines (risk-based concentrations that are considered by the USEPA to be protective for humans over a lifetime). However, the USEPA values are "regional" and reflect variance in soils/climatic conditions across the US. To adjust for this variance, the Region 9 USEPA preliminary remediation goals (PRGs) have been harmonized with similar risk-based screening levels used by Regions 3 and 6 into a single table on the USEPA database and these USEPA Regional Screening Levels have been adopted in Table 4.7.5.

The mean concentrations for the majority of the metals, metalloids, other inorganics and petroleum hydrocarbons analysed were below all their applicable MAC and screening values. The exceptions were As, Co, Cu, Ni, Pb, Sb, and V; concentrations of these metals exceeded MAC, USEPA, and/or UK GAC/SGV values, as shown in Table 4.7.5.

Table 4.7.5: Soil Metal Concentrations Exceeding MAC and Other Criteria

Substance	Mean Soil Concentration	MAC	USEPA	UK GAC
	mg/kg	mg/kg	mg/kg	mg/kg
As	26.7	2	0.39	32
Co	20.4	5	23	N/A
Cu	42.1	3	3100	2330
Ni	48.6	4	1500	130
Pb	30.8	20	400	450
Sb	10.7	4.5	31	N/A
V	76.6	150	390	75
Note: It should also be clarified that the UK GAC and USEPA RSL's identified in this table relate to residential land use and are therefore conservative given the nature of the development within the Project. Similar standards used for industrial land are also considered not to be applicable due to the requirements of the closure plan that indicates the reclamation, following mining, to be suitable for revegetation to modified grassland habitats.				

Elevated baseline concentrations were found for these metals (As, Co, Cu, Ni, Pb, Sb, and V) in the areas of the Amulsar ore bodies. They are of potential concern to human health and the environment when present in elevated concentrations. The occurrence of these seven metals in the Project-affected area soils is discussed further in this section and the soil/superficial material concentration maps for these elements based on the exploration geochemical data are shown in Appendix 4.7.2.

Environmental soil location drawings are shown in Figure 1, Appendix 4.7.2, which shows the location of soil samples across the sampling period 2008-2014. The following sections and Table 4.7.6 provide information about each of these metals including typical soil concentration ranges worldwide and in the Project-affected area, and a histogram of project sample concentration range frequencies.

Table 4.7.6: Summary of Project Infrastructure in relation to elevated levels of specific elements within the soils.

Element screening values (mg/kg)			Project Infrastructure Component								
			Erato Open Pit	Tigranes-Artavazdes Open Pit	BRSF	HLF, ADR and ponds	Haul and Access Roads	Primary and Secondary crusher	Facilities platform	Conveyor	
As	UK GAC	32		✓							
	USEPA	0.39	✓	✓	✓	✓	✓	✓	✓		
	MAC	2	✓	✓	✓	✓	✓	✓	✓		
Co	UK GAC	-									
	USEPA	23									
	MAC	5	✓	✓	✓	✓	✓	✓	✓		
Cu	UK GAC	2330									
	USEPA	3100									
	MAC	3	✓	✓	✓	✓	✓	✓	✓		
Ni	UK GAC	130									
	USEPA	1500									
	MAC	4	✓	✓	✓	✓	✓	✓	✓		
Pb	UK GAC	450									
	USEPA	400									
	MAC	20	✓	✓							
Sb	UK GAC	-									
	USEPA	31	✓	✓							
	MAC	4.5	✓	✓							
V	UK GAC	75					✓				
	USEPA	390									
	MAC	150									

Arsenic (As)

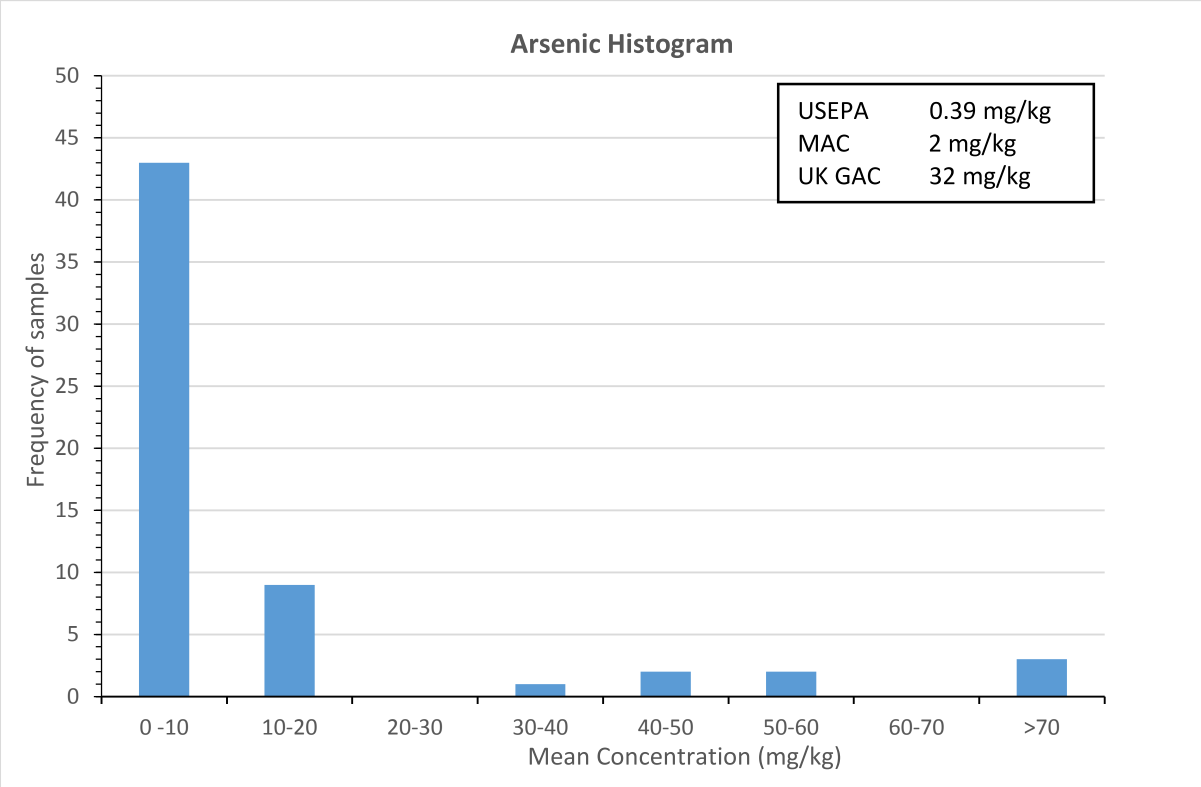

Figure 4.7.4: Frequency of As in Soils of the Project Area

(see Appendix 4.7.2)

Typical naturally occurring As concentrations in topsoil worldwide range from 0.2 to 40mg/kg[6]. Concentrations of As within the soils within the Project-affected area (6.3 – 161 mg/kg) are at the high end of the naturally occurring average range. All of the environmental baseline samples exceeded the MAC (2 mg/kg) and USEPA (0.39 mg/kg) As guideline values with 8 samples (13.3 %) also exceeding the UK GAC (32 mg/kg) value.

As is found in elevated concentrations at all Project infrastructure locations (Table 4.7.6). It was found to be particularly elevated at the Tigranes-Artavazdes open pit location, where it exceeded all 3 screening values, often with a concentration more than double that of the value for the highest screening value (UK GAC 32 mg/kg). Similar trends are seen in the other Project infrastructure components in which the majority of soil samples showed elevated concentrations double that of the MAC screening value (2 mg/kg) (see Table 4.7.6). In general,

[6] Walsh, L.M, M.E. Sumner, and D.R. Keeney, 1977, Occurrence and distribution of arsenic in soils and plants: Environmental Health Perspectives, 19:67-71.

elevated concentrations of As in soils are derived from either anthropogenic sources (e.g. the use of As-bearing pesticides, mineral smelting activities, or coal-fired power plant emissions[5]) or from the weathering of As-bearing parent rock. The latter situation is considered to be the case with the elevated soil As concentrations at Amulsar (see Table 4.7.6).

Average As concentration increases as Project infrastructure components increase in elevation (see Table 4.7.6). This trend can be attributed to the decreasing soil depth with elevation, as factors such as the climate and slope gradient become major limitations to soil formation and structure. Consequently the soil becomes thinner and is more highly influenced by the As-bearing weathered parent rock, allowing As to become more highly concentrated in the soil.

Cobalt (Co)

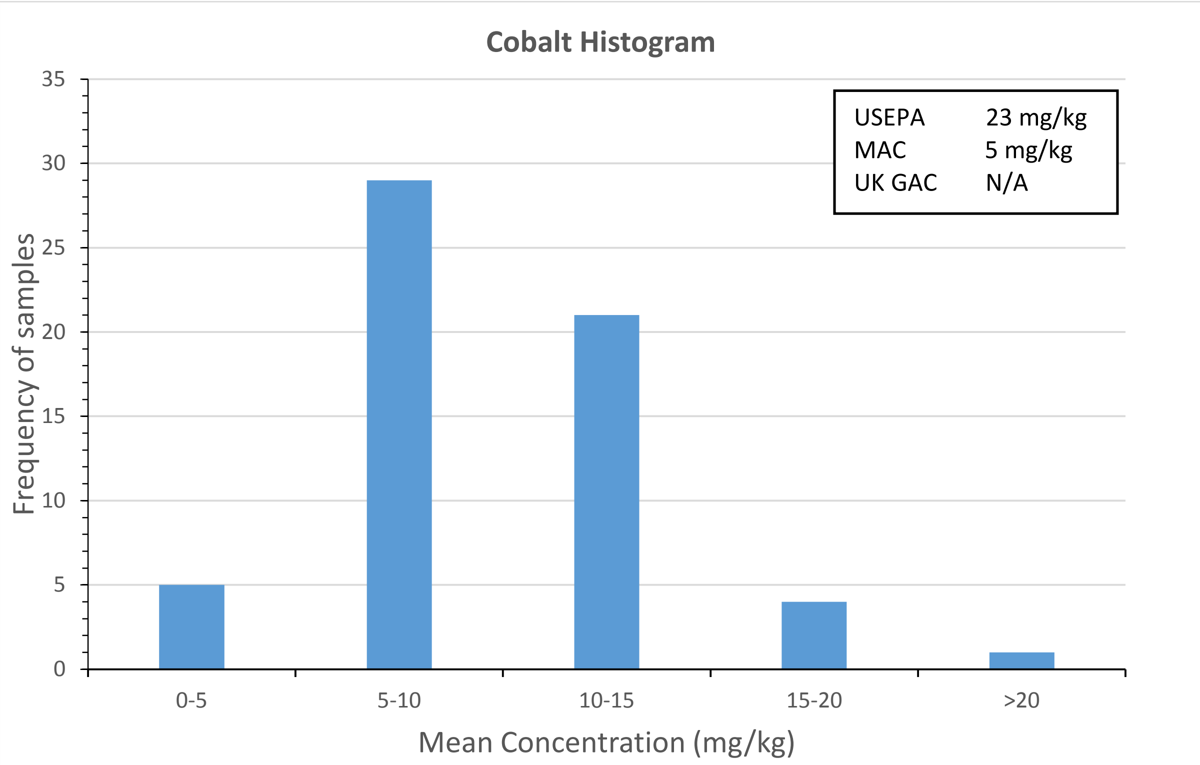

Figure 4.7.5: Frequency of Co in Soils of the Project Area

Cobalt is a relatively rare element in the earth's crust (with an average crustal concentration of 0.0023%) and is usually found in association with other metals such as Cu, Ni, Mn, and As.

In soils it occurs in the divalent Co form[7] with approximately 1 mg/kg to 200 mg/kg and higher with ferromagnesium deposits[8]. Co concentrations ranged from 2.25 to 22.0 mg/kg in Project area soil samples.

Co is found in elevated concentrations at all Project infrastructure component locations (Table 4.7.6) showing widespread existence. 55 environmental baseline samples exceeded the MAC (5 mg/kg) Co guideline value (92%) but none were found to exceed the Co USEPA (23mg/kg) guideline value. Minor Co mineralization from underlying rock is considered to be the main source of soil Co concentrations. Mineralization is likely to be accelerated at the maintenance and storage site, open pits and crushing areas due to their high elevations causing harsher climatic conditions and a stronger relief. Consequently the arid continental climate causes accelerated mineralisation of the Co in the parent rock, which becomes more concentrated in the thinner soils.

Copper (Cu)

In soils, naturally occurring mineralised copper is present as a divalent cation and is bound on inorganic exchange sites within the soil and is thus not readily available for uptake by plants. Concentrations of Cu in soils are typically in the range of 5 to 50 mg/kg worldwide[9]. Soil concentrations of Cu within the baseline study area (14.5 to 79.0 mg/kg) tended to be at the higher end of the natural average range. All of the environmental baseline soil samples exceeded the MAC (3 mg/kg) but the Cu USEPA (3,100 mg/kg) and UK GAC (2,330 mg/kg) guidelines were not exceeded by any sample (Table 4.7.6). Minor copper mineralization is present at Amulsar (see Section 4.6) and it is considered likely that elevated concentrations in soils reflect underlying Cu mineralization in the soil parent material.

[7] Ecological Screening Levels (ECO-SSL), Cobalt and Nickel, USEPA, http://www.epa.gov/ecotox/ecossl/
[8] Mitchell, R. L, Trace Metals in Soil, in Fe Bear, Chemistry of the Soil, 1964
[9] McLaren and Crawford, Studies on Soil Copper, Journal of Soil Science, Vol 24, 2973

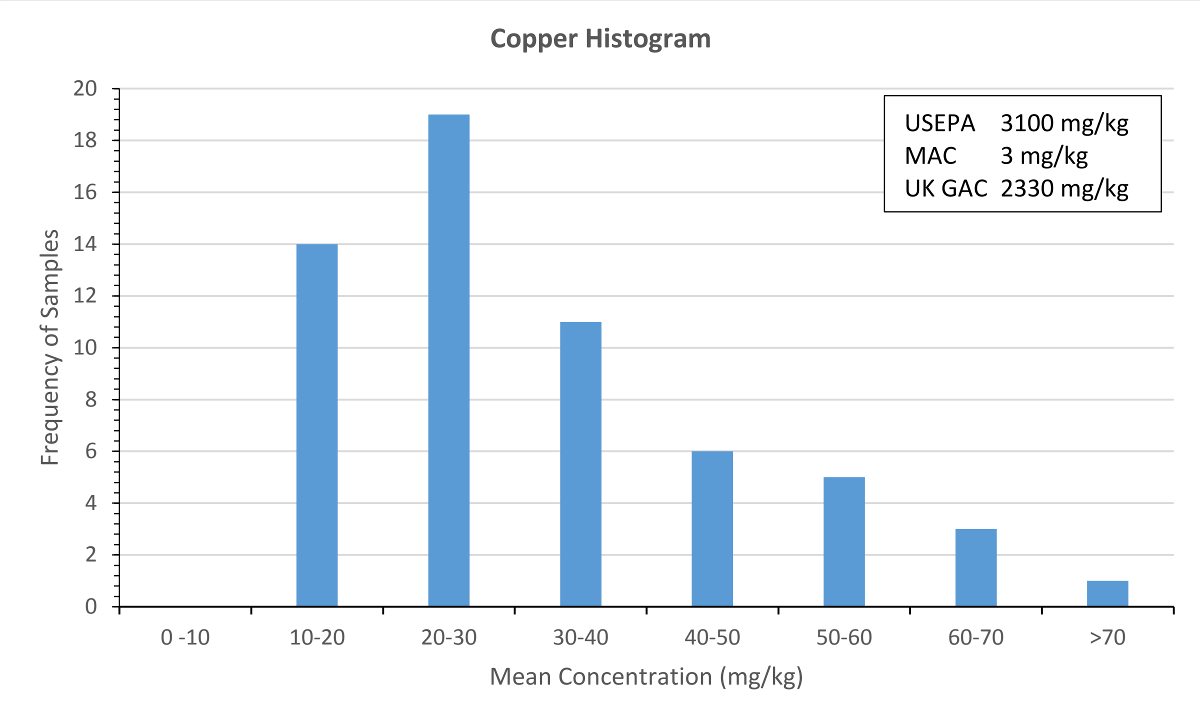

Figure 4.7.6: Frequency of Cu in Soils of the Project Area

(see Appendix 4.7.2)

Nickel (Ni)

Nickel can be found in all environmental media: air, soil, sediment, and water and anthropogenic nickel can be released to the environment through the extraction, processing and use of Ni compounds; concentrations of less than 100mg/kg are typical of soils[10]. Ni concentrations in Project area soils ranged from 5.9 – 57.0 mg/kg (see Table 4.7.6). All of the environmental baseline soil samples exceeded the MAC (4 mg/kg) Ni guideline value but none of the soil samples exceeded the USEPA (1,500 mg/kg) and UK GAC (130 mg/kg) Ni guideline values. Consequently, all Project infrastructure components were found to be located on soils which exceed the MAC guidelines (Table 4.7.6), reflecting the naturally elevated background levels of Ni in the parent rocks.

[10] Mengel, K, Kirkby, EA, Principles of Plant Nutrition, 1978

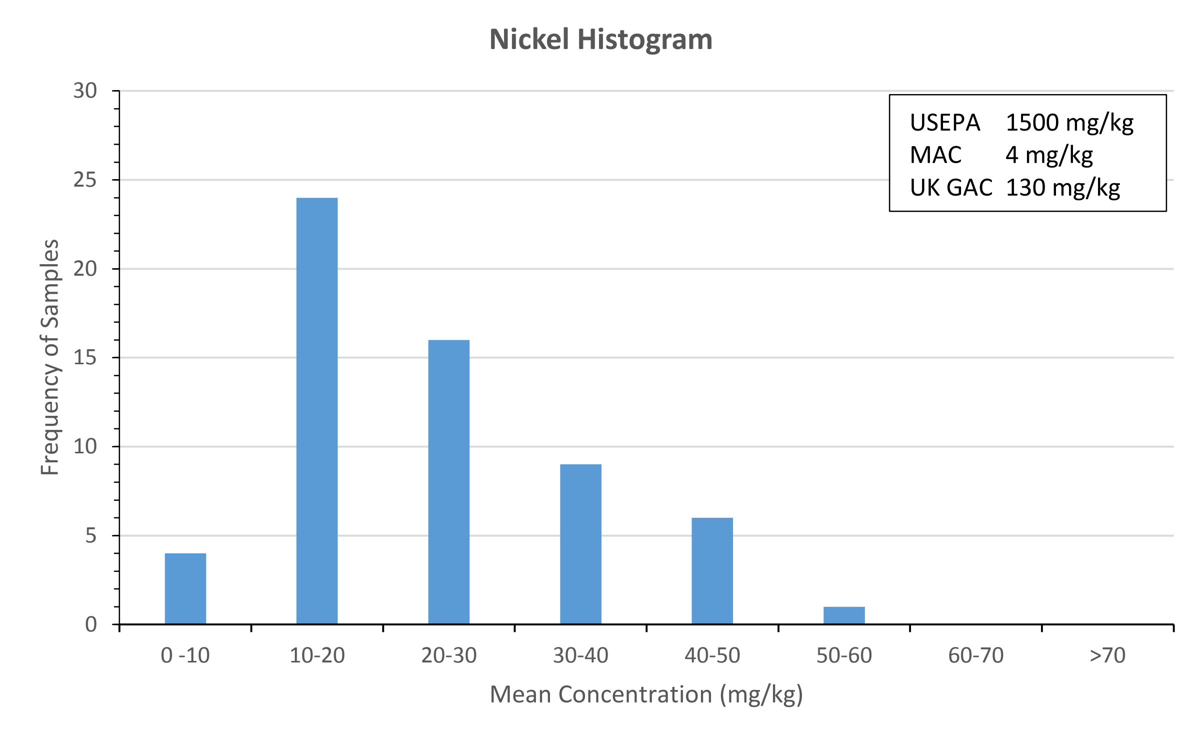

Figure 4.7.7: Frequency of Ni in Soils of the Project Area

(see Appendix 4.7.2)

Lead (Pb)

In the absence of Pb mineral deposits, naturally occurring levels are in the range of 2 to 200 mg/kg[9] in soils worldwide. The distribution of Pb in the biosphere is such that anthropogenic-sourced Pb in soil is common and widespread especially in urban areas, in part from the use of leaded gasoline. Soil Pb concentrations within the environmental baseline study area ranged from 7.1 to 288.0 mg/kg, slightly exceeding the natural average range. Eighteen samples (30%) from the Project footprint area exceeded the MAC (20 mg/kg) Pb guideline value but no baseline samples exceeded the USEPA (400 mg/kg) and UK GAC (450 mg/kg) Pb guideline values (Table 4.7.6). Minor Pb mineralization is present in the Project area, and is considered to be the main source of elevated background soil Pb concentrations.

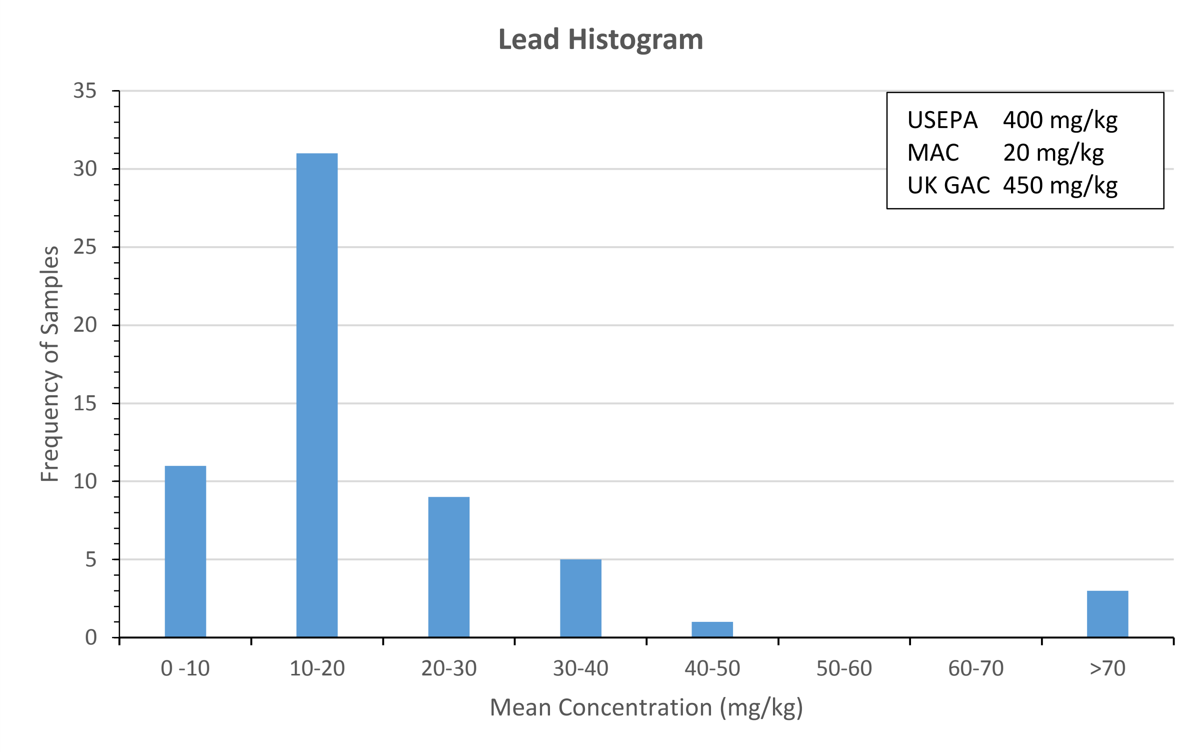

Figure 4.7.8: Frequency of Pb in Soils of the Project Area

(see Appendix 4.7.2)

Antimony (Sb)

Naturally occurring concentrations of Sb in topsoil are generally in the range of 0.3 to 8.6mg/kg worldwide[11]. In Project-affected area soils (Table 4.7.6), Sb concentrations ranged from 0.2 to 137.0 mg/kg, within and significantly exceeding the average global range of soil Sb concentrations. Eleven environmental baseline samples (18 %) exceeded the MAC (4.5 mg/kg) Sb guideline value; 5 samples (8.3 %) also exceeded the USEPA (31 mg/kg) Sb guideline value; there is no UK GAC guideline value for Sb (Table 4.7.6). These elevated concentrations are considered to be the result of soil development from mineralized parent rock with elevated Sb concentrations.

Particularly elevated Sb concentrations were found within the Erato and Tigranes-Artavazdes open pits, and at the BRSF (Table 4.7.6). These are the three highest infrastructure components located on the top of Mount Amulsar. Consequently, the harsher climatic conditions, exposed parent rock, and stronger relief causes accelerated mineralisation of the

[11] Tschan, M., B.H. Robinson, and R. Schulin: 2009, Antimony in the soil-plant system – a review: Environmental Chemistry, 6:106-115.

parent rocks in these locations, which accumulates and produces a higher concentration within the thinner soils present in these areas.

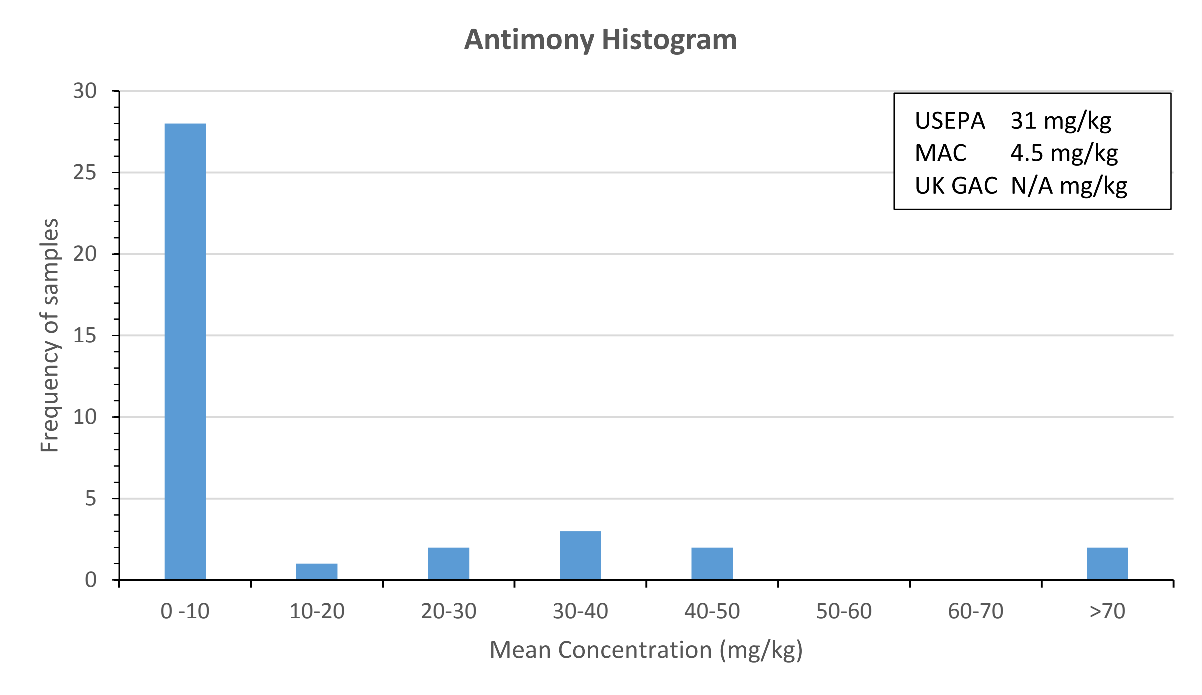

Figure 4.7.9: Frequency of Sb in Soils of the Project Area

(see Appendix 4.7.2)

Vanadium (V)

Naturally occurring concentrations of Vanadium in topsoil are generally within the range of 3 to 310 mg/kg worldwide[12] with some concentrations up to 400 mg/kg in areas found to be polluted by anthropogenic Vanadium sources, such as Uranium mining and steel smelting. In Project-affected area soils (Table 4.7.6), V concentrations ranged from 1.1 to 114 mg/kg, within the average global range of soil V concentrations. Fourteen samples (23.3 %) exceeded the UK GAC guideline value for V (75 mg/kg), but no baseline samples exceeded the MAC (150 mg/kg) and USEPA (390 mg/kg) V guidelines (Table 4.7.6). These elevated concentrations are considered to be the result of soil development in areas where there is a higher than average crustal weathering of basement rocks.

[12] Waters, M.D. Toxicology of vanadium. In: Goyer, R.A. & Mehlman, M.A., ed. Advances in modern toxicology. Vol. 2. Toxicology of trace elements. New York, Wiley, 1977, pp.147-189.

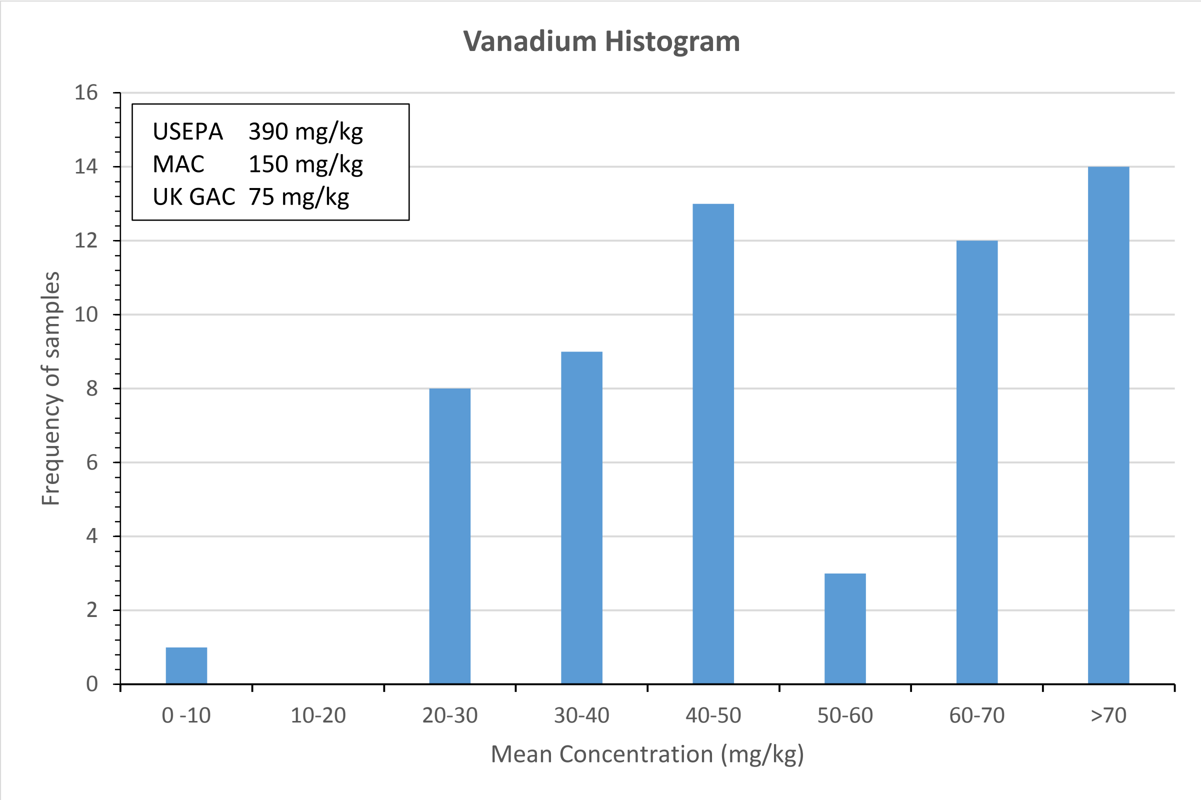

Figure 4.7.10: Frequency of V in Soils of the Project Area

(see Appendix 4.7.2)

Summary

Table 4-6 (also see Appendix 4.7.2) identifies where soil with elevated levels of metals, metalloids and other inorganics is located within the Project-affected area. This is intended to inform the working methodology for the Project with regards to soil stripping and storage. This identifies that soil with elevated concentrations of the above elements is found at all major Project infrastructure components, but in all cases they can be attributed to natural sources, rather than anthropogenic sources such as smelting industries. The primary source of these elements within the soil is attributed to the weathering of the parent rock. Studies[13] have found that all of the above elements are considered to be 'pathfinder elements', often occurring in association with each other and with gold mineralisation. This is due to the conditions necessary for gold formation where hydrothermal waters, heated by tectonic activity, deposit gold in solution into fissures within rocks. These hydrothermal waters often

[13] Leia Michele Toovey, 2011, *Indicator Minerals, Pathfinder Minerals and Gold Exploration.* Gold Investing News. R.E.Lett, W. Jackaman and A.Yeow, 1998*, Detailed geochemical exploration techniques for base and precious metals in the Kootenay Terrane*, British Colombia Geological Survey Geological Fieldwork.

also carry other elements in solution such as As, Co, Cu, Ni, Pb, Sb and V, or can cause reactions with elements already present within the rock. Weathering of these rocks allows these elements to accumulate into the surrounding media, in this case the soil, which increases their relative concentrations. Consequently, although these soils have elevated concentrations of these elements, the origin of their source is through the natural weathering processes of the parent rock. The parent rock exhibits background levels of these elements that is naturally high.

4.7.7 Land Cover

Land cover in the wider area that contains the Project was determined using a Normalized Difference Vegetation Index (NDVI) analysis on satellite imagery and field data of the Project area. NDVI analysis utilizes various bandwidths of visible and near-infrared spectral imaging data to calculate an NDVI value between 1.0 and -1.0 representing different types of land cover determined by their reflectance value. Actively growing healthy vegetation produces higher values, with increasingly lower values indicating sparse vegetation cover, barren land, water, ice/snow cover, and cloud cover. The following satellite data was utilized:

- 0.5m resolution WorldView-2 acquired 20/10/2010 and 28/11/2010 – 4 band data (Blue, Green, Red and Near Infra-Red); and
- 50m grid spacing Digital Elevation Model (DEM) produced from the supplied contour dataset.

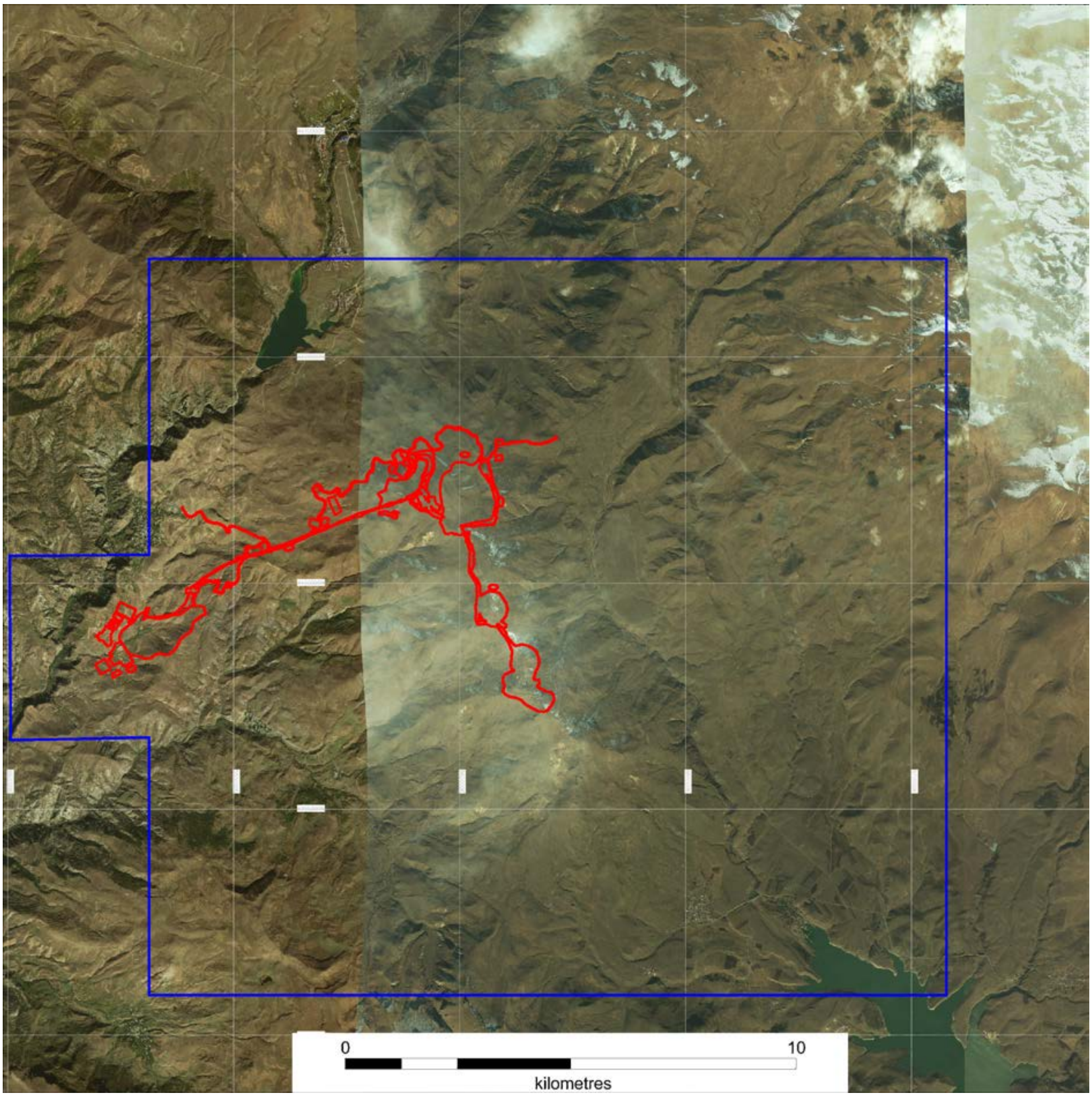

Figure 4.7.11: Area of interpretation for Land Cover data

Land Cover within the Analysis area

The study area for satellite imagery is delineated by the blue line comprising the Project-affected area and surrounding lands (see Figure 4.7.11). Also within the blue line boundary, but not visible at this scale are the settlements of Gorayk (to the southeast), Gndevaz (to the northwest), Saravan (to the southwest) and Kechut and Jermuk (to the north).

The landcover by vegetation for the satellite analysis area is summarized in Table 4.7.7. It is noted that agriculture is defined by the presence of clear field boundaries or recent ploughing and may therefore result in the coverage of agriculture being underestimated and grassland overestimated in some locations.

Table 4.7.7: Land Cover within the Satellite Analysis Area					
Land Cover		**Wider analysis area ha**	**Wider analysis area %**	**Project disturbed area (ha)**	**Project disturbed area (%)**
Agricultural Lands	Recent evidence of agricultural activity	2793	9%	185	20%
Grassland	Low level vegetation	20,377	68%	610	65%
Scrubland	Intermediate level vegetation, commonly 'woody' shrubs	567	2%	15	2%
Bare ground	Exposed rock and soil, including road surfaces	4785	16%	95	10%
Settlement	Individual building extents	-	0%	-	-
Ice and snow	Ice/snow obscuring land cover	1440	5%	25	3%
Cloud/Shadow	Land cover obscured by shadow	33	0%	<0.1	-
Total analysis area (Figure 4.7.11)		**29,995**		**922**	

The analysis demonstrates that land cover across the wider area around the Project is predominately grassland/pastures (68%), compared to 65% within the Project disturbed area. The agricultural land represents 20% of the Project disturbed area and is generally located within the HLF, access roads, sections of conveyor and within laydown areas for construction. Bare ground, scree and rocky outcrops are increasingly present at higher elevations, such as on the ridgeline of Amulsar Mountain, and is equivalent to 16% of the wider analysis area, compared to 10% of the Project disturbed area.

Individual infrastructure components

The surface cover for each of the infrastructure components is detailed in Table 4.7.8 (Project footprint) and Table 4.7.9 (Project disturbed area), demonstrating that all infrastructure components are located within areas of grassland with an increased diversity of agricultural land management at a lower elevations, for example within the footprint of the HLF.

Where grassland is present at lower elevations, such as at the HLF, BRSF, conveyor, maintenance workshop and haul / access roads, the more fertile Mountain Black, Brown Forest Steppe and Mountain Chestnut soils, have resulted in areas of both seasonal summer pasture and, where both slope and aspect are favourable, the grass crop is conserved as hay for winter feed.

Where agricultural land is present at lower elevations, specifically around the HLF, there is increased agricultural land use, together with apricot orchards and hay fields.

Bare ground is increasingly evident at higher elevations correlating with steeper slopes and harsher climate, characterised by Mountain Meadow and Mountain Meadow Steppe soils, which generally have a weak structure, combined with the shallow depth.

Table 4.7.8: Project footprint (rounded to the nearest 1 ha)

Vegetation cover or characteristic	Infrastructure component										
	Tigranes-Artavazdes	Erato	BRSF	HLF, ADR & ponds	Haul / Access roads	Primary / Secondary Crusher	Conveyor and load out to HLF	Facilities platform	Quarries	Construction camp	Other infrastructure and ponds
Agricultural Lands	-	-	8	58	9	-	2	-	2	6	4
Grassland	62	36	102	91	48	14	13	18	7	-	18
Scrubland	-	-	-	10	-	-	4	-	-	-	-
Bare ground	25	2	25	7	22	-	-	-		-	-
Settlement	-	-	-	-	-	-	-	-	-	-	-
Water bodies	-	-	-	-	-	-	-	-	-	-	-
Ice and snow	9	3	4	-	-	-	-	-	-	-	-
Cloud/Shadow	-	-	-	-	-	-	-	-	-	-	-
Total (ha)	96	41	139	166	79	14	19	18	9	6	22

Table 4.7.9: Potential Zone of Disturbance (rounded to the nearest 1 ha) - Project Disturbed Area											
Vegetation cover or characteristic	**Infrastructure component**										
	Tigranes-Artavazdes	**Erato**	**BRSF**	**HLF, ADR & ponds**	**Haul / Access roads**	**Primary / Secondary Crusher**	**Conveyor and load out to HLF**	**Facilities platform**	**Quarries**	**Other infrastructure and ponds**	**Construction camp**
Agricultural Lands	-	-	8	85	9	-	27		5	4	48
Grassland	71	42	120	101	168	15	46	12	8	26	-
Scrubland	-	-	-	10	-	-	4	-	-	-	-
Bare ground	33	2	30	7	22	-	-	-	-	-	-
Settlement	-	-	-	-	-	-	-	-	-	-	-
Water bodies	-	-	-	-	-	-	-	-	-	-	-
Ice and snow	19	3	4	-	-	-	-	-	-	-	-
Cloud/Shadow	-	-	-	-	-	-	-	-	-	-	-
Total (ha)	123	47	162	203	200	15	77	12	13	30	48

4.7.8 Summary

This chapter has identified five soil types within the Project footprint; Mountain Meadow, Mountain Meadow Steppe, Mountain Chestnut, Mountain Black and Brown Forest Steppe. All soils within the Project footprint were identified to have naturally high background concentrations of As, Co, Cu, Ni, Pb, Sb, and V attributed to mineralisation of the parent material.

Mountain Chestnut and Brown Forest Steppe soils occur at lower elevations around the HLF, access and haul roads, and correlate with areas of agricultural land use and rotational grassland which is utilised for hay and pasture. Consequently, these soils have high agricultural productivity value, are considered to be sensitive, and therefore require mitigation to minimise both loss and potential for degradation off site.

Mountain Black soils are found across the majority of the Project area; however, only the conveyor, haul roads and access roads are located on these soils. These support rotational grassland for hay and grassland use and are of medium sensitivity due to their capability to support agriculture. Consequently, these too require mitigation measures to ensure they are properly handled and stored as they can be used post-closure.

Mountain Meadow and Mountain Meadow Steppe soils are found at the highest elevations. The BRSF, open pits, haul and access roads, conveyor, crushers, maintenance areas, and construction camp are all located on these soils. These soils are thin, poorly structured and weak, and therefore do not support agricultural land. The land use on these soils is grassland, bare ground and ice/snow; however, they do support critical habitats as considered in Section 4.10. Consequently, although these soils are identified as being of minor sensitivity in relation to agricultural production, they require appropriate consideration with respect to their support for critical habitats.