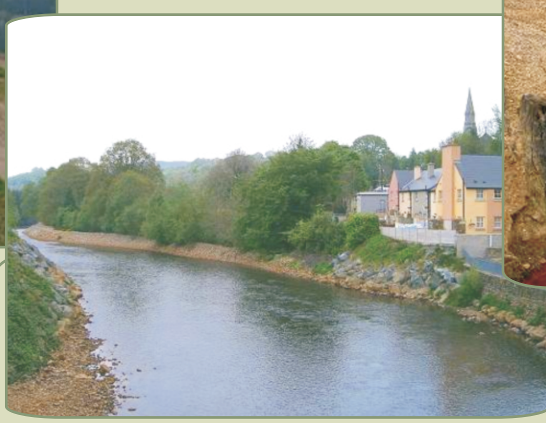
CDM

The Department of Communications, Energy and Natural Resources

Feasibility Study for Management and Remediation of the Avoca Mining Site

Executive Summary

December 2008



Report

Contents

Figures

Tables

Acronyms

µg/l	micrograms per liter
$1x10^{-6}$	one in one million
AMD	acid mine drainage
ARD	acid rock drainage
BERA	Baseline Ecological Risk Assessment
BMI	benthic macroinvertebrates
CDM	Camp Dresser & McKee Inc.
cms	cubic metres per second
COC	contaminants of concern
CSM	Conceptual Site Model
EAs	exposure areas
EMP	electronmicroprobe
ETP	Emergency Tailings Pond
EPA	Environmental Protection Agency (Ireland)
EPC	exposure point concentration
ES	Ecological Solids
EW	Ecological Water
FS	feasibility study
GRAs	general response actions
HDPE	high density polyethylene
GSI	Geological Survey of Ireland
HHRA	Human Health Risk Assessment
HHS	Human Health Solids
HHW	Human Health Water
IEUBK	Integrated Exposure Uptake Biokinetic
kg/day	kilograms per day
km	Kilometers
km^2	square kilometers
l/s	Litres per second
m	Metres
m^2	square metres
m^3	cubic metres
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
mm	Millimeters
mm/yr	millimetres per year
Mt	million tonnes
NA	not applicable, not analyzed, or not available
PET	potential evapotranspiration
PH	Physical Hazards
PRGs	Preliminary remediation goals
RAOs	remedial action objectives
SCEM	site conceptual exposure model
SHA	Seán Harrington Architects

Site	Avoca Mine Site
TDS	total dissolved solids
TSS	total suspended solids
TRV	Toxicity reference values
USEPA	United States Environmental Protection Agency
ZOC	zone of contribution

Executive Summary

1.0 Objectives and Scope of Work

The Avoca River watershed above Arklow, County Wicklow, is situated in a rural, residential, agricultural, afforested, tourist, and, to a lesser extent, industrial area. Mining for copper and pyrite (iron sulfide, FeS_2) occurred in the Avoca district for over 230 years and ceased in 1982. Historic mining, milling, and smelting at the East Avoca and West Avoca mining sites, and tailings disposal at the Shelton Abbey site, have left contaminated waste materials (spoils) on the surface and in the waters; surface waters and waterways have been impacted by high metal concentration acid drainages and discharges; and unsafe conditions exist as a result of abandoned shafts and adits, unstable piles and pit walls, and potential subsidence. In addition, the area contains many historic structures of industrial archaeological, heritage, and cultural importance including engine houses, the Tramway Arch, and the Tigroney Ore Bins. Some of the structures are unsafe and need repair.

In order to address the concerns associated with the historic mining areas and Avoca River watershed, the Minister for Communications, Energy and Natural Resources appointed Camp Dresser & McKee Inc. (CDM) to conduct a feasibility study (FS) for management and remediation of the Avoca Mining Site including the Shelton Abbey tailings facility (the Site). The work was conducted under the direction of the Geological Survey of Ireland. The overall objective of the feasibility study was to prepare a realistic, cost-effective, and achievable integrated management plan for the Site that addresses the many issues at the Site including human and ecological concerns, safety and physical hazards, heritage, future uses, and long-term site management.

The executive summary provides a description of the site, the issues associated with the site such as health and safety concerns, human health risks, and ecological risks. Two site wide alternatives have been selected for the long-term management of the Avoca Mine Site. The process of developing the two site wide alternatives has been a detailed and thorough examination of all technologies combined with an evaluation of their applicability and compatibility to the Avoca site as well as their effectiveness of meeting the remedial objectives. The approach adopted has been comprehensive and is outlined in Figure 1-1; however, for the purposes of the Executive Summary the steps from "Develop Remedial Action Objectives" to "Screening of Alternatives and Selection of Alternatives for Detailed Analysis" are not described. The Executive Summary deals with the issues of the site and the two remediation alternatives selected.

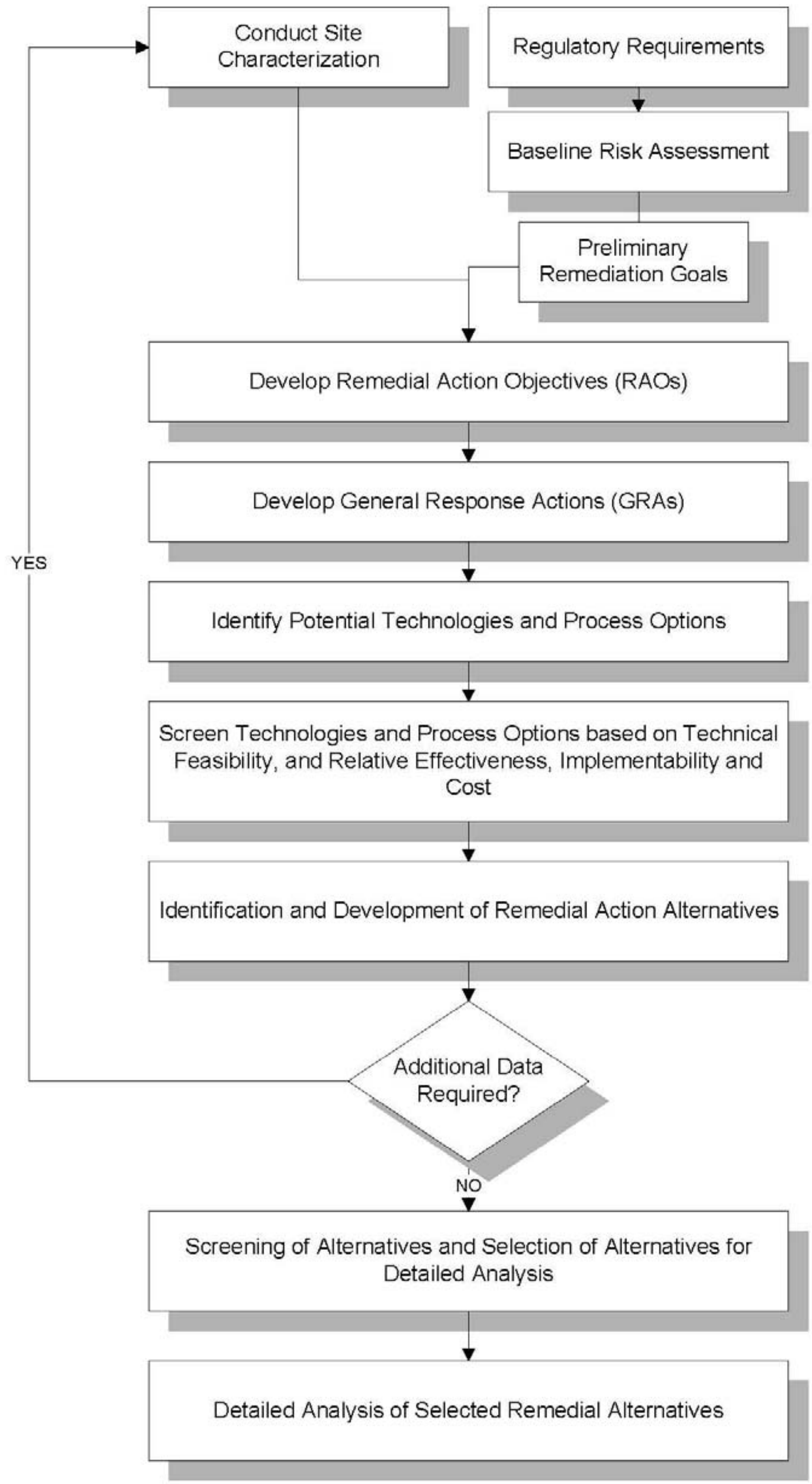


Figure 1-1 General Feasibility Study Approach

The issues at the site include:

Health and Safety Issues

- Many of the shafts and adits and pits are accessible to the public
- The pit highwalls are unstable and could fail
- Some of the spoil piles slopes are unstable and have the potential to fail
- Many of the spoil piles contain elevated levels of metals
- Shelton Abbey tailings facility is in need of maintenance
- Some buildings and mine related structures are in a poor state of repair

Environmental Issues

- Acid mine drainage
- Contaminated river sediments
- Contaminated river water
- Impacted aquatic life
- Contaminated alluvial groundwater
- Acid generating potential within the spoil piles

2.0 Site Description and Information

2.1 Background Information

2.1.1 Location and Topography

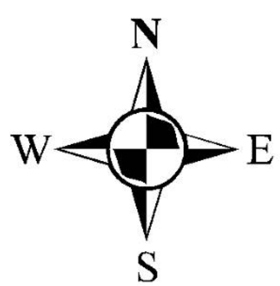
The Avoca mining area is located in a north-south trending, steep-sided valley in the eastern foothills of the Wicklow Mountains some 55 kilometres (km) south of Dublin. The Avoca River is formed by the confluence of the Avonmore and Avonbeg rivers, 1.5 km upstream of the mining area at the Meeting of the Waters and divides the mine sites into East and West Avoca mining areas (see Figure 2-1). It is joined by the Aughrim River at Woodenbridge and various small streams in the vicinity of the mine sites, and flows into the Irish Sea at the town of Arklow, 10km to the southeast of the mining area. The Site includes the East and West Avoca mining areas, the Shelton Abbey Tailings Facility, and the surface waters in the vicinity of these mining and disposal areas. Figures 2-2 and 2-3 provide more detailed maps of the East and West Avoca areas, respectively, and show all features discussed in this document.

The East and West Avoca mine sites cover 0.34 square kilometres (km^2) and 0.29 km^2, respectively, extending from the Avoca River onto the higher ground on either side of the valley to the northeast and southwest. The surface water and groundwater drainage from the Site has been heavily modified and groundwater levels are lower as a result of mining. The East Avoca area mainly drains through the 19th Century Deep Adit and flows into the Avoca River through a short surface channel. There are also a few smaller higher-level discharges that either return underground or flow into small streams. West Avoca is drained by the 19th Century Road Adit beside the main Avoca/Rathdrum Road and flows through a ditch and pipe into the Avoca River.

Fig 2-1 Site Map

Legend

- Mine Features
- Spoils and Mining Areas
- Adits
- Shafts



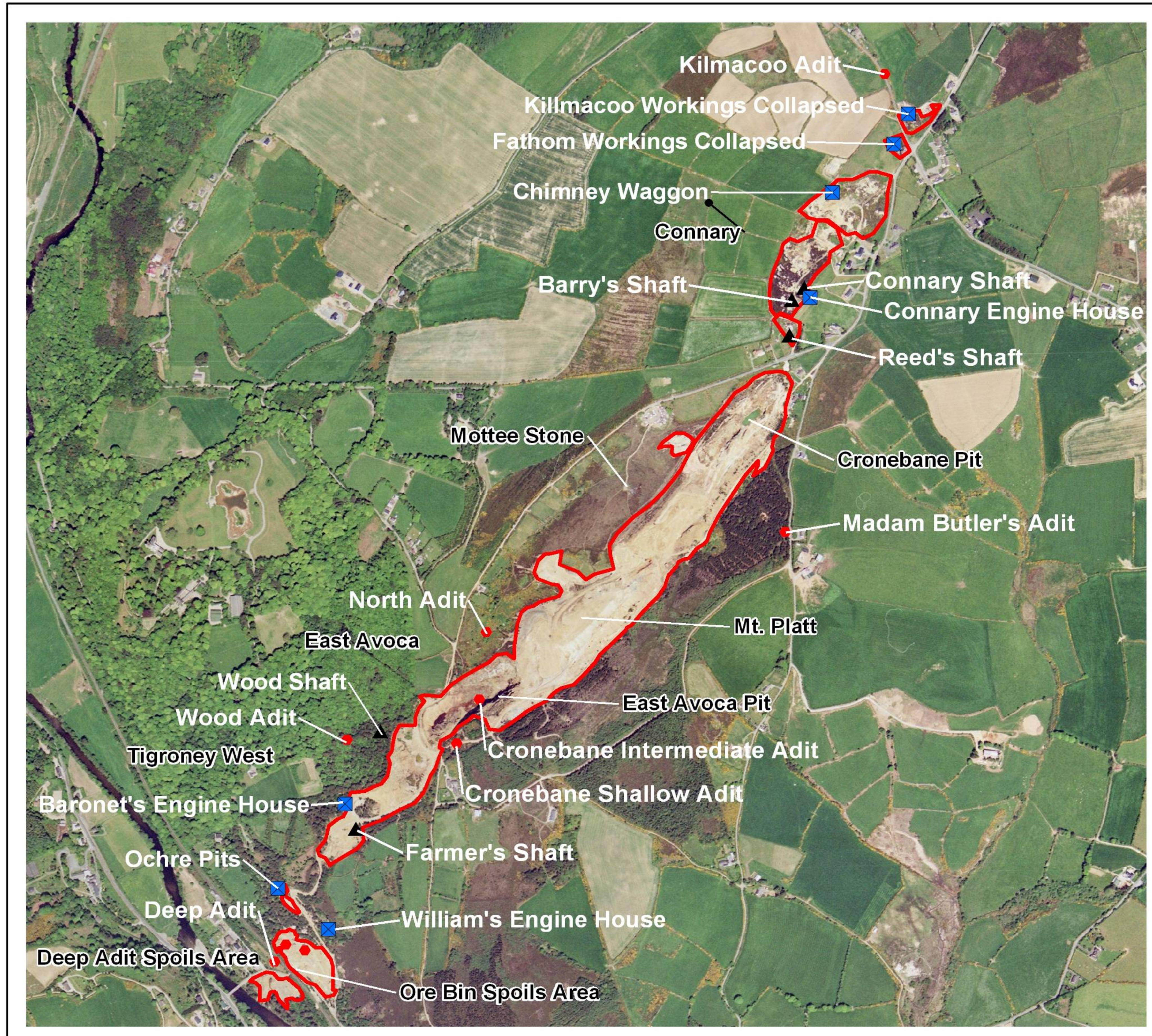
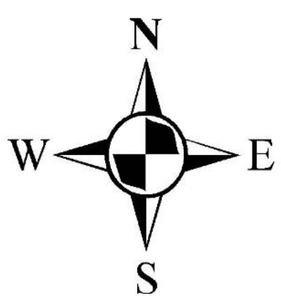


Figure 2-2
Site Features - East Avoca

OSI Licence No - EN 0047 207

Legend

- Spoils and Mining Areas
- Adits
- Shafts
- Mine Features



0 50 100 200 300
Meters

Figure 2-3
Site Features - West Avoca

OSI Licence No - EN 0047 207

Outside the mine sites, the land is a mixture of forestry and pasture with scattered farms and some small groups of houses. The mine sites themselves contain entrances to shafts and adits (mainly sealed), several open-pits, and numerous waste piles with limited vegetation. There are various other mining features such as ochre pits and engine houses, some of which are of heritage interest. The former Pond Lode (Ballymurtagh) open pit was used as a domestic landfill operated by Wicklow County Council between 1989 and 2002. The landfill is now closed and has been rehabilitated. Wicklow County Council continues to monitor the landfill under the terms of an EPA Waste Licence.

2.1.2 Mining History

Mining has taken place at Avoca since the early 18th Century. The first phase lasted until the mid-19th Century, consisting mainly of small-scale underground extraction of narrow high-grade copper veins yielding up to a few thousand tonnes of ore a year. Pyrite extraction became significant during the 19th Century, when 1.5 million tonnes (Mt) was produced.

Limited exploration and some ochre production occurred in the 1940s and 1950s by the State mining company, Mianraí Teoranta. Since then, there have been two periods of large-scale production. The first, by St. Patrick's Copper Mines, lasted from 1958 to 1962, but was not financially successful and the company went into receivership. The mine was re-opened in 1969 by Avoca Mines Ltd. In addition to continuing underground extraction in West Avoca three open-pits were worked:

- Pond Lode Pit (West Avoca) covering 64,000 square metres (m^2) and up to 50 m deep; 1 Mt of ore was extracted.
- East Avoca Pit covering 20,400 m^2 and with a maximum depth of 40 m; 900,000 tonnes were mined.
- Cronebane Pit (East Avoca) covering 62,000 m^2 and up to 40 m deep; 500,000 tonnes were mined. The pit was 40 percent backfilled.

A total of 8.9 Mt of ore was mined before closure in 1982.

2.1.3 Milling and Tailings Disposal

Ore mined during both the last two periods was treated by conventional flotation producing copper and pyrite concentrates. The resultant tailings (waste materials) were mainly disposed of in a facility located beside the Avoca River at Shelton Abbey 8 km downstream from the mining area. The ultimate volumes of tailings storage was 7,547,000 cubic metres (m^3) covering an area of 30 ha. The main tailings area was remediated by the Receiver to Avoca Mines Ltd. in 1984. The site is now generally unmanaged grassland with trees and scrubs on the berms.

About 200,000 m^3 of tailings were disposed in a 19th Century open-pit in West Avoca (the North Lode open pit). This disposal area is covered with fine spoil and about a third is vegetated. An area on the west bank of the Avoca River just north of the current Wicklow County Council maintenance yard was used as an emergency tailings disposal area and is estimated to contain 129,300 m^3 of tailings. Some tailings (estimated by Wicklow County Council to be 100,000 m^3) were also disposed of in the Pond Lode Pit (Ballymurtagh).

Substantial surface dumps of waste rock (spoil piles) were created during surface mining, particularly in East Avoca. The main pile in East Avoca, known locally as "Mount Platt," contains approximately 700,000 m^3 and five other piles total 280,000 m^3. Thirty one piles, mainly left after the limited beneficiation carried out in the 18th to 19th Centuries, contain about 60,000 m^3 in total low grade ore. These piles cover some 180,000 m^2, of which 70,000 m^2 is accounted for by Mount Platt. Eight spoil piles in West Avoca, mainly from the 19th Century, cover 70,000 m^2 and contain 190,000 m^3, of which 150,000 m^3 is contained in two piles. The larger piles consist dominantly of waste rock from open-cast mining.

2.1.4 Acid Rock Drainage from Avoca

The quality of the water in the Avoca River is not documented prior to the commencement of mining in the 18th Century, but acid waters from the mines reduced its quality. The river continues to be significantly contaminated by acid waters with elevated concentrations of heavy metals, which enter the water from adits draining both East and West Avoca. Acid rock drainage (ARD) generated in waste piles and underground workings contribute to these flows.

From 1994 to 1997, discharges varying from 10 l/s to 72 l/s from East Avoca and 8 l/s to 37 l/s from West Avoca were recorded from two principal drainage adits: the Deep Adit in East Avoca and the Road Adit in West Avoca. The discharges have low pH values and high levels of iron, copper, zinc, and aluminium.

2.1.5 Industrial Archaeology

A considerable legacy of the long period of mining activity remains around Avoca in the form of heritage features and industrial archaeology sites, consideration of which in the overall context of the remediation options developed for the Avoca Mining Area was very important.

The visible important buildings/structures include:

- The Williams Engine House
- The Tigroney Ore Bins
- The Baronet's (or Farmer's) Engine House
- The Chimney to the former Waggon Engine House at Connary
- The Tramway Engine House Chimney at Ballygahan
- The Twin Shafts Engine House
- The Hodgson's Tramway Arch
- The Ballygahan Engine House Chimney
- The Mines Office in West Avoca

The visible mining landscape features include:

- The Open Cast (open pit) Mines at Cronebane, East and West Avoca
- Adits, Shafts, and Underground Mines (many features are not visible)
- Mount Platt

The condition of many of these features was addressed in detail in the *Health & Safety Audit, Avoca Mining Site* prepared by GWP Consultants LLP (GWP 2008). A report by Seán Harrington Architects (SHA) also provided descriptions and photography and evaluated the significance of the various features *(Report on Sites of Industrial Archaeology Importance* 2007). SHA concluded that "There are serious issues regarding pollution, destabilisation, and general health and safety hazards on the Site."

2.2 Health and Safety Concerns from Physical Hazards

A detailed health and safety audit in relation to the physical hazards at the Avoca Mine site was performed by GWP Consultants LLP (GWP 2008). The report documents the conditions and physical hazards of 15 rock faces and pits, 19 spoil piles, six tailings impoundments (lagoons), 28 adits, 44 shafts, and 25 buildings and structures. The following sections summarise the major safety concerns at the Site.

2.2.1 Rock Faces and Pits

Steep, high, unstable rock faces at Cronebane and East Avoca pits are a major physical hazards. The southern faces of Weaver's Lode open pit are also hazardous and the remaining rock faces, although low, are overhanging.

2.2.2 Spoil Piles and Tailings Impoundments

The Shelton Abbey tailings impoundment appears to be stable. However, a rise in internal water table (consequent, for example, to increased infiltration) could lead to failure. The drains on the surface allow infiltrating water into the body of the tailings rather than removing it from the facility. The steepness of the slopes and height of Mt. Platt call for caution regarding its apparent stability. The current condition is temporary and many factors including large precipitation events could alter its current condition resulting in slope failure. Many smaller spoil piles generally show little, if any, signs of major instability.

2.2.3 Adits

There are two partially open adits with easy access from a public road. These are the 850 Adit, accessing the last underground workings at Tigroney (East Avoca) and the nearby Inclined (Branch) Entry to the Deep Adit. In addition, both Wood Adit and North Adit are open, and, although partially flooded, can be entered.

2.2.4 Shafts

Two shafts were found to be open; Air Shaft (at West Avoca) and Farmers (at East Avoca). Since initial inspection, Farmers Shaft has had a steel grate placed over it.

While many shafts are capped, the condition of some of them appears doubtful. The worst is Whelan's shaft (West Avoca) where poor quality materials appear to have been used. At Connary, the Reed's shaft cap has a void developing alongside. At least two other shaft caps, Barry's and Wheatley, appear to be only just wide enough to cover the shaft opening and hence could be vulnerable to similar void formation.

2.2.5 Void Migration

Cavities and depressions have formed in both East and West Avoca due to erosion into underground cavities and progressive collapse of the roofs of underground workings. Other cavities could pose risks of sudden collapse, especially if water levels rise and fall. The large area of backfilled stopes downhill of East Avoca pit is a potential location for such void migration ("weak area"). The Baronets Engine House shaft, located in this area, would be a particular concern.

2.2.6 Structures

Many of the 19th Century engine houses and tramway remains have been conserved by recent works, although some appear to require further attention and all will require ongoing maintenance. Williams Engine House contains a number of dangerous sections. The remains of the 20th Century ore storage bins in Tigroney West are in far worse condition than the 19th Century remains. These bins are located beside a public road.

2.3 Nature and Extent of Contamination

2.3.1 Sources of Water and Solids Contamination

The contamination source for water media is the acid mine drainage (AMD) generated in the abandoned underground mine workings, and the acid rock drainage (ARD) generated from the mines, mine spoils, mill tailings, and exposed rock surfaces. AMD/ARD results from oxidation of reduced minerals such as pyrite and dissolution of metals. The AMD discharges at the surface via the old drainage tunnels or other adits, or seeps into nearby groundwater. The Deep Adit and Road Adit produce substantial metal laden discharges to the Avoca River. Contaminated groundwater also impacts the Avoca River as "diffuse" flow; i.e., water that enters the river via subsoil, soil, aquifer, or bedrock transport. The ARD from spoil heaps and tailings normally percolates into the groundwater but occasionally discharges at the surface. The volume of spoils material in each area of the Site considered for reclamation is provided in Table 2-1. These volumes were based on review of recent aerial photographs (LIDAR Survey, July 24, 2007) and recent site observations.

Table 2-1 Summary of Spoils and Tailings Areas and Volumes

	Area (m^2)	Volume (m^3)
Spoils		
Connary	41,100	47,800
Cronebane/Mount Platt	85,600	659,800
East Avoca/Tigroney West (Not including Deep Adit Site)[1]	51,100	124,800
West Avoca (Not including SP39)[1]	83,600	65,200
Deep Adit Site[1]	3,800	6,300
SP39 (adjacent to Avoca/Rathdrum Road)[1]	14,300	51,800
East/West Avoca Spoils Totals	279,600	955,800
Tailings		
Shelton Abbey Tailings	446,500	7,547,000
Emergency Tailings Pond	34,900	129,300

1 See Figures 2-2 and 2-3 for locations.

The spoils contain significant concentrations of copper (56-11,344 milligrams per kilogram [mg/kg]), zinc (44-7,404 mg/kg), lead (112-41,353 mg/kg), and arsenic (18-3,903 mg/kg). Analyses of seepage from the Mount Platt spoils indicate that the spoils are acid generating resulting in seeps with low pH (typically < 3) and very high concentrations of copper, zinc, iron, and aluminium.

Shelton Abbey is by far the most significant tailings deposit at the Site, with an estimated volume of 7,547,000 m^3. In general, the tailings had lower concentrations of metals than the spoils.

The adits with active discharge for at least a portion of the year include Kilmacoo Adit (seasonal flow), Madam Butler's Adit (no direct discharge), Wood Adit (seasonal flow), Intermediate Adit, Cronebane Shallow Adit, Deep Adit, Road Adit, Ballygahan Adit, and Spa Adit. Table 2-2 provides a summary of the water quality estimated or measured flows for the discharges that have been analysed.

Table 2-2 Summary of Adit Water Quality (mg/l) [1]

Parameter	Intermediate	Cronebane Shallow	Deep	Road	Spa	Ballygahan	Kilmacoo
Average Flow (l/s)	8.5	0.2	16	19	0.02	0.06	0.4
Iron	10.77	22.64	72.34	150.7	15.42	10.8	0.46
Aluminium	71.36	36.7	102.6	20.93	21.73	99.1	4.0
Copper	3.198	8.921	0.845	0.268	8.39	5.24	0.3
Zinc	33.03	85.9	47.62	10.95	14.3	21.68	2.66
Lead	1.352	1.334	1.717	0.308	0.102	0.24	2.18
Sulfate	799	3,215	NM[2]	NM	2,044	2,072	63
pH (su)	4.31	3.92	3.55	4.08	3.5	3.80	4.62

1 CDM Data Report (2008); data for July/August 2007
2 NM = Not measured (only metals analysed; sulphate was measured at the discharge to the Avoca River)

The Intermediate, Deep, and Road Adits had significant metal discharge loads compared to the other adits. Loads of zinc were 24, 68, and 12 kg/day for the Intermediate, Deep, and Road Adits.

2.3.2 Avoca River and Runoff Water Quality

Both direct and diffuse discharges of metals impact the water quality in the Avoca River. The impact is the greatest during low flow conditions in the river. Table 2-3 summarises Avoca River quality for samples collected during the summer of 2007. The June 2007 samples better represent low flow (higher concentration) conditions as River flow in July and August was approximately 1.5 times higher than flows in June. The River has increased concentration of metals throughout the mining area and downgradient of adit discharges when compared to upgradient locations. Water quality improves further downgradient (Avoca Bridge and downgradient of the Aughrim confluence), but elevated concentrations of metals are still present. No increases in metal concentrations were observed between the upgradient and downgradient samples at Shelton Abbey during August 2007.

Table 2-3 Summary of Avoca River Water Quality (dissolved concentrations, µg/l)

Parameter	Avonmore[1] June 14, '07	Avonmore[2] Aug 2, '07	Below Deep Adit[3] June 13, '07	Below Deep Adit[4] July 30, '07	Below Road Adit[3] June 13, '07	Below Road Adit[5] July 31, '07
Iron	<1	72	321	162	75	250
Aluminium	<1	59	17,380	197	4,705	208
Copper	<0.5	4	298	12	69	24
Zinc	16	26	9,167	143	1,159	267
Lead	<0.5	2	239	4	15	7
Sulfate	9,000	5,000	133,000	9,000	105,000	31,000

1 100m above Meeting of the Waters, GSI data
2 Lions Bridge, CDM data
3 Mixing Zone, GSI data
4 T2 mixed composite immediately downgradient of Deep Adit River discharge, CDM data
5 T5 grab (across from abandoned coal yard), CDM data

Samples of runoff (overland flow) from spoil piles during precipitation events were collected by both CDM and the GSI (Geological Survey of Ireland). High metal concentrations (e.g., zinc = 2,800 - 45,200 µg/l) and low pH (2.9 - 3.1) values were observed. The runoff enters directly into the Avoca River.

2.4 Hydrogeological and Geochemical Conceptual Site Model

A hydrogeological and geochemical Conceptual Site Model (CSM) was created using existing site data and the results of site investigations to perform an evaluation of the geochemical and hydrological processes that result in ARD input to the Avoca River.

2.4.1 Hydrological Summary and Conceptual Model

The Avoca River catchment drains eastward from the Wicklow Mountains to Arklow on the coast. It covers an area of approximately 645.6 km^2 and several tributaries empty into the Avoca River in the vicinity of the mine area. The important tributaries include Vale View, Red Road, and Sulphur Brook (Figure 2-1).

There is a significant rainfall gradient from west to east across the catchment, with median annual rainfall of approximately 1,100 mm/yr. Potential evapotranspiration (PET) is estimated at approximately 540 mm/yr (Met Éireann 2007).

The mine site is underlain by dark grey slates and rhyolitic volcanics, overlain by subsoils derived from glacial till and weathering of bedrock. Subsoils are thin (<2 m) or absent on hilltops and thicker (>2 m) along valley floors. The Avoca River valley comprises a thick (10-30 m) sequence of coarse-grained alluvial sediments.

The estimated flow in cubic metres per second (cms) just downstream of the mine site for the period 1993–2005 is shown in Figure 2-4. The wide range of estimated flow conditions implies a rapid response to rainfall that in turn is a function of the physical characteristics of the catchment (high rainfall, steep topography, thin soil cover, low permeability bedrock). The estimated flow for the period ranged from 1.12 to 144.5 cms with a mean of 15.6 cms. The estimated Q95 (flow exceeded 95 percent of the time) was 0.97 cms.

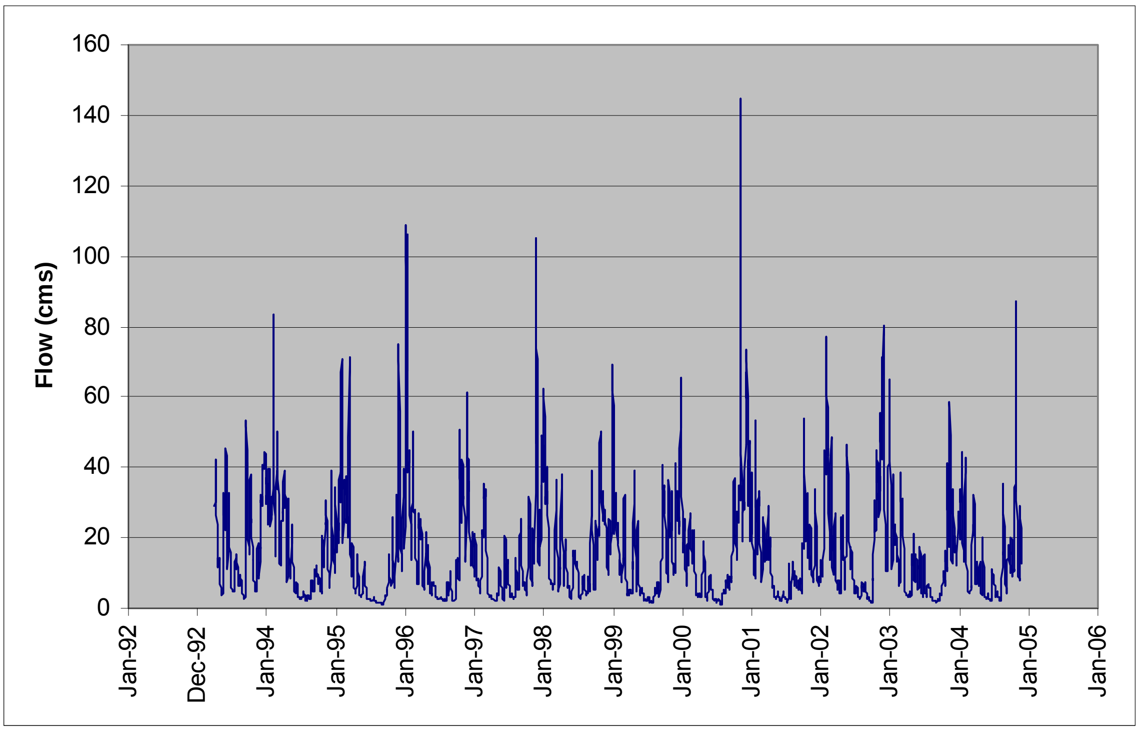


Figure 2-4 Net Estimated Flow of the Avoca River Near the Avoca Mines

In terms of groundwater yield, the GSI classifies the bedrock in the mines area as poorly productive. Water movement in poorly productive bedrock is broken down into three primary pathways:

- Surface runoff (overland flow)
- "Interflow" (flow in subsoils and/or along the fractured top of bedrock)
- "Deep" groundwater (flow in bedrock)

These pathways are shown schematically in Figures 2-5 and 2-6 and discussed in the following sections. Figure 2-6 is a more detailed drawing of the pathways near the Avoca River.

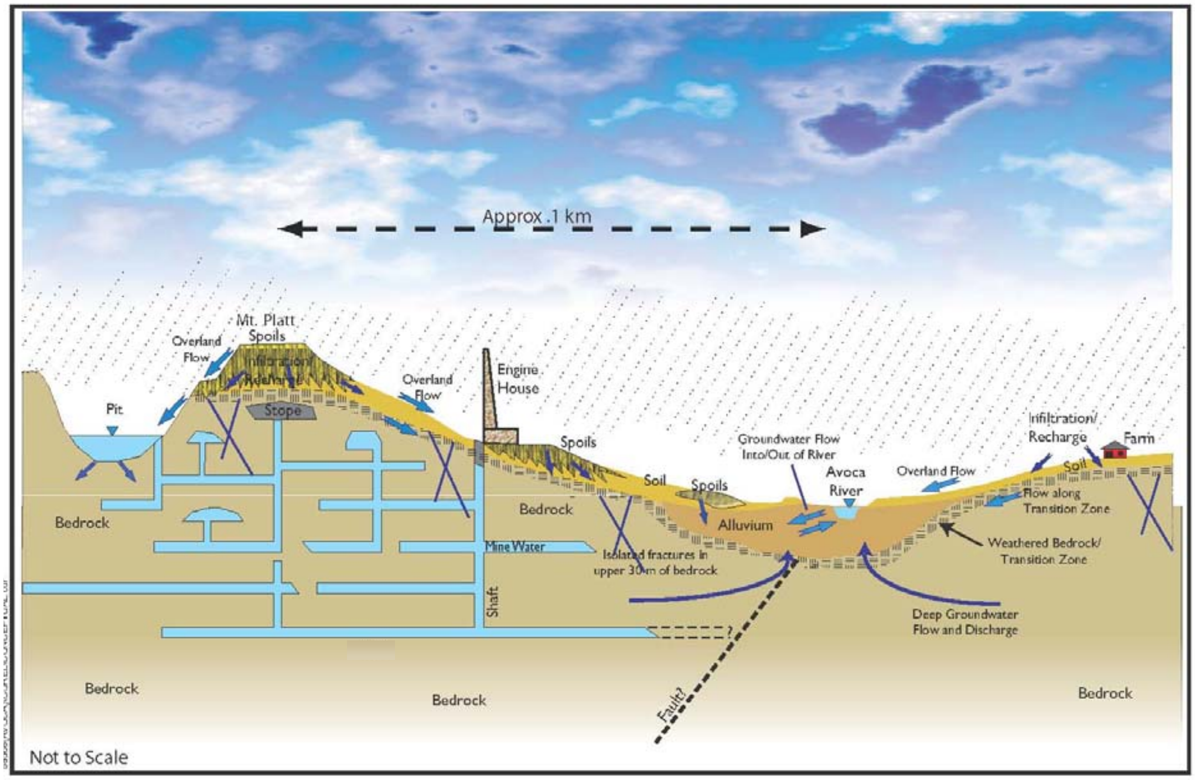


Figure 2-5 Schematic Cross-Section of Flow Components Influencing the Avoca River

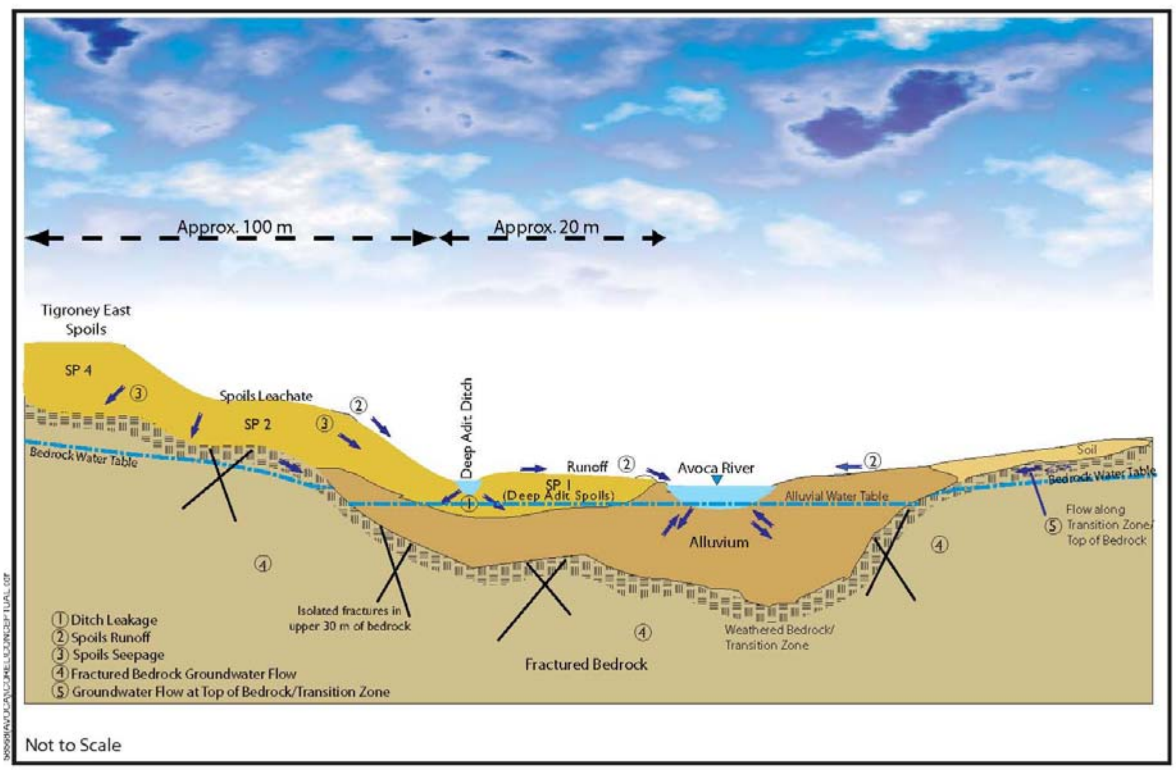


Figure 2-6 Schematic Cross-Section of the East Avoca Area Upgradient of the Deep Adit

Maximum recharge to deep groundwater is limited to less than 100 mm/yr. Due to the low permeability bedrock, groundwater flow systems are short and localised. The majority of the adit discharges result from infiltration and recharge over a limited area, so remediation techniques that decrease infiltration (caps, covers, etc.) will be effective in reducing adit discharge.

Contaminant mass loading to the river may also be contributed by diffuse groundwater flow (flow not discharged to adits), most notably within the alluvial aquifer where groundwater is in direct contact with the spoil areas on both sides of the river. A more minor source of diffuse loading is groundwater that flows through the bedrock outside the capture zone of the underground mine drainage system. Indications are that this diffuse discharge would be expected to range between 1-5 l/s per km of river length. These flows are almost negligible compared to flow rates (and volumes) in the alluvial aquifer.

Shallow alluvial groundwater quality in the Deep Adit spoil wells installed for this study is significantly degraded, notably with very high concentrations of dissolved and total metals – aluminium, cadmium, copper, iron, manganese, nickel, and zinc. On the western side of the river below the Ballymurtagh landfill and the West Avoca open pits, alluvial wells show similar high concentrations of metals, notably in wells placed for this study in the vicinity and upgradient of the Emergency Tailings.

A total of six private wells in the Avoca mines area were sampled once in August 2007. The private wells are typically deeper bedrock wells. With the exception of iron and manganese (which are inferred to be naturally occurring in bedrock), groundwater quality is good, with low metal concentrations below EU Directives/Regulations for drinking and water indicator quality thresholds.

2.4.2 Geochemical Summary and Conceptual Model

ARD is produced mainly by the oxidation of pyrite (FeS_2) within the ore and host rock materials. Pyrite oxidises from exposure to oxygen, producing dissolved sulphate (SO_4^{2-}), ferrous iron (Fe^{2+}), and hydrogen ions (H^+). Other primary sulphide minerals that are present in the deposit, such as chalcopyrite, sphalerite, galena, and arsenopyrite (FeAsS), oxidise to produce dissolved copper, zinc, lead, and arsenic, respectively.

As part of the geochemical evaluations, mass balance calculations were performed using the information concerning flows and contaminant concentrations collected in July and August 2007. The evaluations show that treatment of the Deep and Road Adits alone will not achieve water quality standards for copper in the Avoca River. The diffuse metals must also be captured and treated.

2.5 Human Health Risk Assessment

A Human Health Risk Assessment (HHRA) for the Avoca site was conducted:

- To identify and describe conditions that may result in adverse health effects to people who live, work, or recreate in or near the study area currently or in the future,
- To evaluate potential cancer risks and non-cancer hazards associated with exposure to mine related contaminants, and
- To provide preliminary remediation goals.

Contaminants of concern (COCs) are mine-related constituents that could pose a threat to people that use the Site. COCs were identified for surface soil, spoils, groundwater, surface water, and sediment. Surface soil and spoils COCs are antimony, arsenic, cadmium, cobalt, copper, iron, lead, manganese, thallium, and vanadium. Groundwater COCs for the deep bedrock aquifer (homeowner wells) are aluminium and iron. COCs for shallow alluvial groundwater are aluminium, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, and zinc. COCs for rivers and tributaries include aluminium, iron, lead, and manganese. Contaminants detected in surface water that are potential COCs due to bioconcentration potential in fish include cadmium, copper, lead, manganese, nickel, and zinc.

Exposure pathways are evaluated for both current and potential future land uses (residential, occupational, and recreational). Figure 2-7 shows graphically the various sources, release mechanisms, pathways, exposure routes, and potential receptors.

Potential exposure pathways for exposed populations may include:

- Incidental ingestion of and dermal contact with soil and spoils material
- Inhalation of dust particulates in ambient air
- Incidental ingestion of surface water and river sediment
- Dermal contact with surface water and river sediment
- Ingestion of groundwater (incidental and/or voluntary [domestic groundwater use])
- Dermal contact with groundwater (showering and bathing)
- Ingestion of animal products from animals fed affected feed, or watered with affected surface water or groundwater
- Ingestion of produce from gardens with affected soil and/or watered with affected surface water or groundwater
- Ingestion of contaminated fish

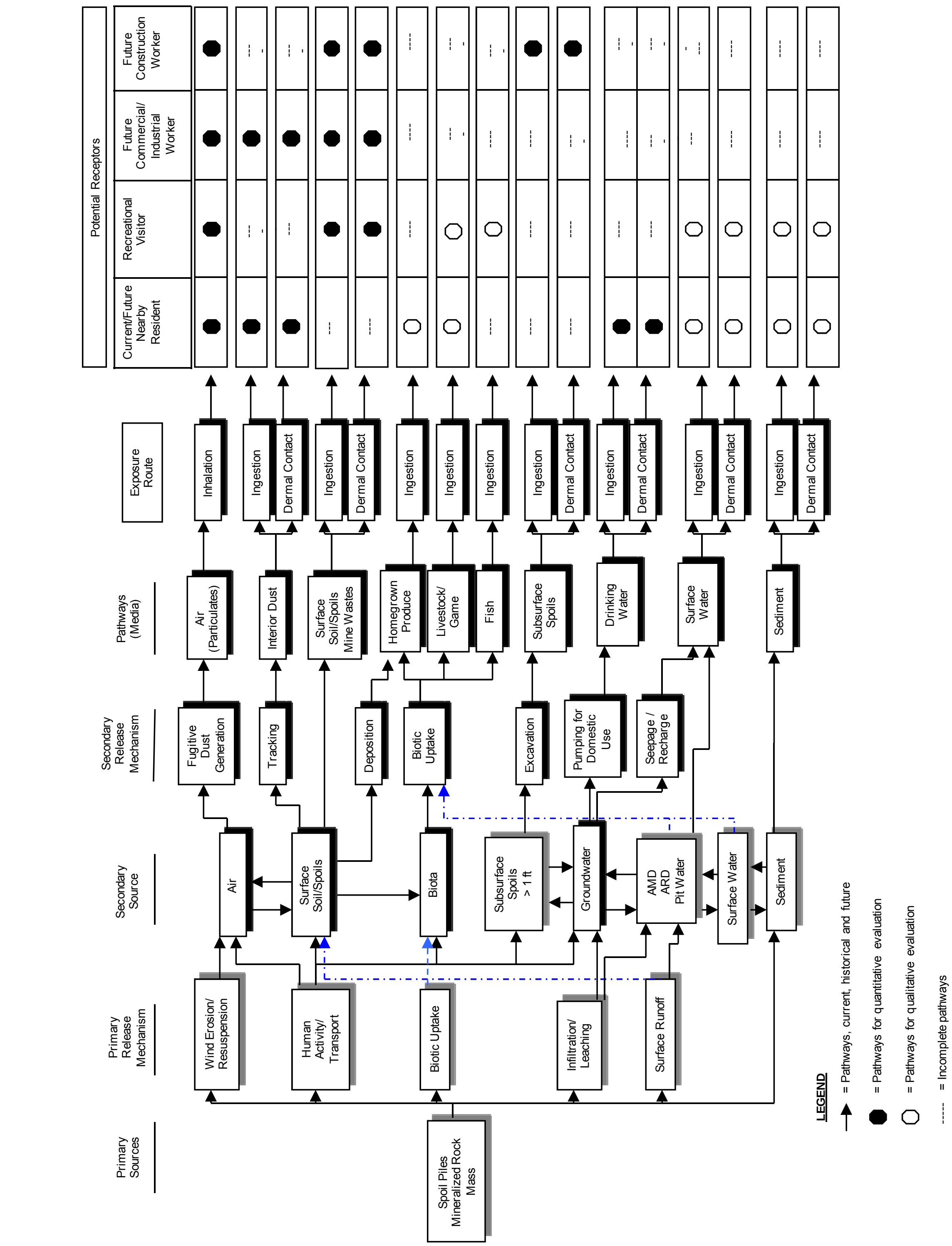


Figure 2-7 Preliminary Site Conceptual Exposure Model - Human Health
Avoca Mine Site

Arsenic is a known carcinogen. Site-specific bioavailability analyses at Avoca have shown that arsenic in spoils at the Site is in a relatively inaccessible form. However, even with low bioavailability, arsenic concentrations are high enough in the spoils to present potential or slightly elevated carcinogenic risk for the following receptors and areas.

- Recreational visitors at Connary (adults), Ore Bins areas (adults and teens), Deep Adit area (adults), and West Avoca (adults)
- Future commercial/industrial workers at Connary, Mt. Platt/Cronebane, East Avoca/Tigroney West, Ore Bins area, Deep Adit area, West Avoca
- Future construction workers at the Ore Bins area and West Avoca

Carcinogens were not reported above detection limits in homeowner wells. However, if shallow alluvial groundwater near the Site is used as a potable water source in the future, cancer risk could significantly exceed acceptable thresholds. The calculated risk for exposure to arsenic in soils (from pastures) is slightly above acceptable levels. However, because the soils are covered by vegetation, exposure (e.g., ingestion) is not probable and no adverse health effects would be anticipated.

With respect to potential for non-cancer health effects of COC metals (except lead) hazards were acceptable for all receptors exposed to contaminants in spoils except the future commercial/industrial worker and construction worker at the Deep Adit area. The hazard from soils from pastures was only slightly above acceptable levels for the nearby child resident. This exposure will probably not occur due to vegetation cover. In addition because the hazard was due mainly to exposure to metals at concentrations similar to background levels, no additional adverse effects are anticipated from soils in agricultural fields. Possible air concentrations were calculated for the risk assessment based on spoils concentrations and estimates were low and below levels of concern.

Risks from exposure to lead cannot be assessed using standard methods because toxicological criteria for lead are not available. The Integrated Exposure Uptake Biokinetic (IEUBK) model (Version 1.0) is used to evaluate potential risks for nearby residents from lead in surface soils and spoils. Site–specific bioavailability estimates for lead are relatively low for all exposure areas. However, lead levels are of concern for the following:

- Recreational visitors at Connary and the Ore Bins area
- Future commercial/industrial workers at Connary, Ore Bins area, and West Avoca
- Future construction workers at Connary, East Avoca/Tigroney West, Ore Bins area, and West Avoca

2.6 Ecological Risk Assessment

A Baseline Ecological Risk Assessment (BERA) was performed for the Site. The primary purpose was to identify and describe conditions resulting from releases of mining-related contaminants that can result in adverse effects on present or future ecological receptors associated with the Avoca River and adjacent habitats.

The Water Framework Directive requires Ireland to achieve good ecological and chemical water status for its national waters unless less stringent objectives are set and justified. No decision has been reached for the Avoca River. Salmonids are indicators of good water status so efforts are focused on reestablishment of this river as one that supports salmonid survival, growth, and reproduction. Also of concern are the effects of mining-related contaminants on terrestrial receptors (e.g., peregrine falcons, several species of bats, livestock, and vegetation) and on other ecologically important aquatic biota. Benthic macroinvertebrates (BMI) are commonly used as indicators of water quality.

To assist in the BERA, a Site Conceptual Exposure Model (SCEM) is formulated, which describes potential exposure scenarios, including contaminant sources, transport mechanisms, exposure media, exposure routes, and receptors (Figure 2-8). Habitats include aquatic habitats within the mining-affected watershed, riparian habitats along water courses, and terrestrial habitats associated with past mining activities or affected by mine wastes. Ecological receptors are the plants and animals that have potential to be adversely affected. Specific representative receptors or receptor groups are selected for evaluation including aquatic receptors (e.g., fish, amphibians, and insect eating animals), terrestrial receptors (e.g., rabbits, foxes, squirrels), domesticated mammals (e.g., sheep and cattle), and protected species such as bats, peregrine falcon, common lizard, and badger.

From April 3-5, 2007, a screening level BMI survey was conducted within the Avoca River watershed. Diversity and numbers of macroinvertebrates are an indicator of water quality. The presence of intolerant species such as mayflies and caddisflies is an indicator of higher quality waters. The presence of tolerant species such as worms (as well as snails, etc.) is indicative of a lower water quality (indicative of some form of stress). Stations upgradient of the mining area are associated with a large number of organisms. These numbers substantially exceed the totals for all stations downstream of Whitesbridge and upstream of the confluence with the Aughrim River. Overall, the macroinvertebrate survey supports other findings that the Avoca River is impaired and not good status in the vicinity of and downgradient of the Mine area.

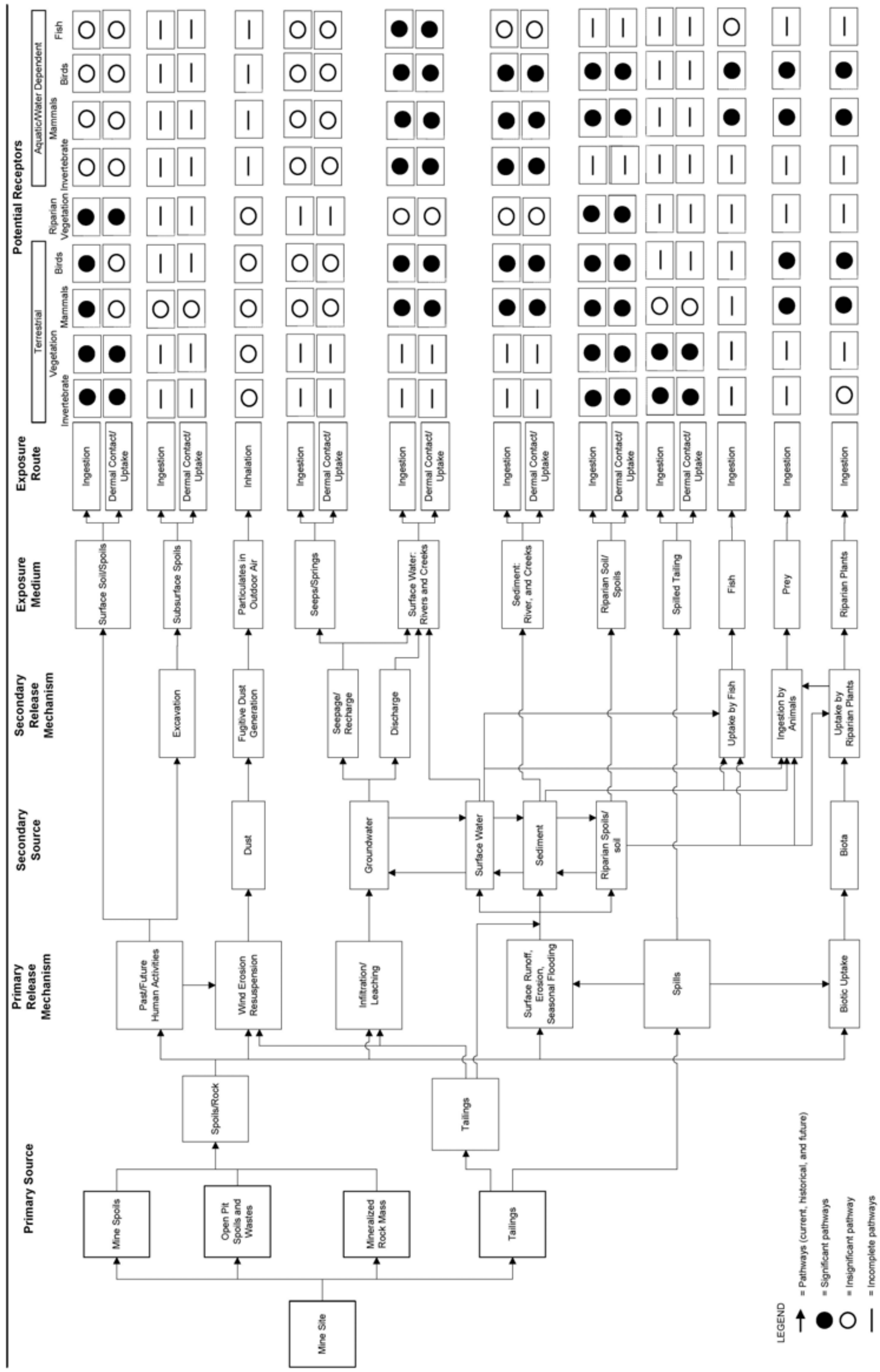


Figure 2-8 Ecological Site Conceptual Exposure Model
Avoca River, Ireland

The ecological contaminants of concern (COCs) include:

- *Surface Water:* ammonia, aluminium, barium, cadmium, cobalt, copper, lead, manganese, mercury, nickel, selenium, silver, uranium, and zinc
- *River Sediment:* arsenic, cadmium, copper, lead, manganese, nickel, and zinc
- *Surface Soil:* arsenic, chromium, copper, lead, manganese, mercury, molybdenum, nickel, silver, thallium, vanadium, and zinc
- *Spoils:* antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, titanium, vanadium, and zinc

Ecological risk is evaluated by comparing exposure concentrations of the COCs (mean values) to toxicity reference values (TRVs). TRVs are based on toxicity data for salmonid fish (for surface water), benthic invertebrates (for sediments) and terrestrial plants and invertebrates (for spoils and soils). Based on these comparisons, concentrations of COCs are unacceptable for the following metals:

Surface Water –For river and tributary high flow sampling, metal levels are acceptable except for copper and zinc. During lower flow, unacceptable levels were observed for aluminium, barium, cadmium, copper, lead, manganese, and zinc.

Sediment– River sediment average concentrations are not acceptable for arsenic, copper, lead, manganese, nickel, and zinc downgradient of the mining areas.

Spoils–Unacceptable levels are present for arsenic, chromium, copper, lead, mercury, silver, thallium, vanadium, and zinc.

Soils –Metals levels in agricultural fields are generally acceptable for molybdenum, nickel, and silver. Hazards may be present for arsenic, copper, chromium, lead, manganese, thallium, vanadium, zinc, and, in a few cases, mercury.

Overall the average concentrations of copper and zinc in the river waters near the mine area exceed salmonid-specific regulatory standards. During low flow conditions, concentrations of aluminium, cadmium, and lead exceed aquatic criteria. The BMI communities in the Avoca River sediments are significantly impaired near and downgradient of the mine area compared to reference areas. Sediment concentration for copper, lead, and zinc exceed reference values.

Concentrations of many metals in spoils exceed reference values for protection of flora and fauna. However, the lack of suitable habitat, limited cover, and the likely scenario of limited foraging in spoils areas suggests that exposures for birds and mammals would be minimal at best. Because metals of concern (mercury) do not accumulate in the aboveground portion of plants, risk to sheep grazing on spoils (Connary) may be minimal. However, grazing of animals on areas of high metal concentrations is not good practice. As a result of low concentrations of metals in soils in agricultural fields and limited exposure to the soils, risks to fauna including grazing cattle and sheep would be insignificant.

Supporting studies were undertaken to provide additional lines of evidence regarding protection of ecological resources. These include a survey and summary of land uses/habitats along the Avoca River and a compilation of information regarding use of the mining-impacted portions of the Avoca River corridor by bats. Fauna recorded or expected at the Site include:

- *Mammals:* badger, fox, hare, brown rat, stoat, mink, rabbit, and red squirrels
- *Birds:* wren, robin, blackbird, rook, jackdaw, woodpigeon, jay, treecreeper, woodcock, blackcap, long-eared owl, buzzard, red kite, and peregrine falcons
- *Fish:* brown trout, salmon, sea trout, eel, brook lamprey, river lamprey, and sea lamprey
- *Bats:* six species

2.7 Summary of Investigations

The investigations and evaluations conducted at the Avoca Site have identified the following concerns:

- Physical Hazard Concerns
  - Stability
  - Safety
- Human Health
  - Residents
  - Recreational Users
  - Commercial and Industrial Workers
  - Construction Workers
- Ecological Concerns
  - Acid/Metal Generation
  - Aquatic life
  - Benthic Macroinvertebrates
  - Flora
  - Terrestrial Animals
  - Protected Species (Fauna)
- Industrial Archaeology Concerns
  - Heritage Structures
  - Mining Landscape Features

Table 2-4 lists these concerns and indicates which of the various site features (spoil piles, adit discharges, etc.) present or contribute to the concerns. The spoil piles present physical hazards and ecological and human health concerns. Many spoil areas (Connary, East Avoca, and West Avoca) are unsafe due to subsidence features and voids. Major piles including Mt. Platt have unstable slopes. In addition, erosion, runoff, infiltration, and seeps from Mt. Platt have low pH values and very high metal concentrations that impact groundwater and surface water. Average metal concentrations in the surface spoils of Mt. Platt affect human health (residents and workers) and ecological health of fauna and flora.

When exposed to rainfall, all spoil piles generate acid conditions and release metals into ground and surface water. The average metal concentrations of spoil piles in all areas affect human and ecological health. The lead concentrations at Connary and the Ore Bins areas are very high and could affect recreational visitors. Arsenic concentrations at Connary, the Ore Bins, Deep Adit, and West Avoca could also affect human health including the recreational visitor. Grazing of animals on spoil piles with high metal concentrations (Connary) is not good practice.

Adit discharges and diffuse groundwater flow affect aquatic life including fish and macroinvertebrates in the Avoca River. Sediment quality (metal concentrations and physical habitat) in the river severely limit macroinvertebrate population. This also affects other aquatic life (fish) due to limited food sources.

Open shafts and adits exist resulting in physical hazards and unsafe conditions. Unstable rock faces and pit highwalls present unsafe conditions as do some unstable historic structures (e.g., Tigroney Ore Bins) which are in accessible areas.

All of these concerns should be addressed to mitigate safety, human health concerns, and ecological concerns, while preserving structures of industrial archeological importance where possible. To the extent possible, actions compatible with the mining landscape and other site features should be evaluated. The local ecology should be preserved or enhanced by any actions (e.g., construction of plugs and seals that allow access to bats).

2.8 Public Participation

The views and concerns of people from the local communities around Avoca and local interest groups are important inputs to the project. There was a high level of interest in the project from local people and from groups who use the area for fishing. Stakeholder engagement took the form of two major public meetings, one before the major fieldwork investigations in July 2007, and another before the completion of the draft Feasibility Study in April 2008. In addition to these meetings, a webpage with information on the project was maintained on the GSI's website for the duration of the project, while a dedicated phone line was established to allow local people to make enquiries.

Table 2-4 Identified Areas of Concern

	ISSUES/CONCERNS													
	Physical Hazards		Industrial Archaeology		Ecology						Human Health			
Site Features	Stability	Safety	Heritage Structures	Mining Landscape Features	Acid/Metal Generation	Aquatic Life	Benthic Macro-invertebrates	Terrestrial Animals	Flora	Protected Species	Residents	Recreational Users	Commercial and Industrial Workers	Construction Workers
Solids														
Spoil Piles	●	●	○	●	●	-	-	●	●	●	●	●	●	●
Tailings	○	○	○	●	●	-	-	●	○	○	○	○	○	○
River Sediments	○	○	-	-	●	●	●	○	○	○	○	●	○	○
Field Soils	○	○	-	-	○	-	-	○	○	○	○	-	-	-
Water														
Adit Discharges	-	-	-	●	●	●	●	●	○	●	●	●	-	○
Seeps	-	-	-	-	●	-	-	-	○	-	○	-	-	-
Springs	-	-	-	-	○	-	-	○	○	○	○	○	○	○
Groundwater-deep (homeowner)	-	-	-	-	○	-	-	-	-	-	○	○	○	○
Groundwater-shallow	-	-	-	-	●	-	-	-	-	-	●	-	-	-
Diffuse Flow	-	-	-	-	●	●	●	-	-	-	-	-	-	-
Surface Water Runoff	-	-	-	-	●	●	●	-	○	-	-	-	-	-
Pit Lakes	-	●	-	●	●	-	-	●	-	●	-	●	-	-
Structures														
Engine houses, etc.	●	●	●	●	-	-	-	-	-	-	-	-	-	-
Ore bins	●	●	●	●	-	-	-	-	-	-	-	-	-	-
Shafts	●	●	●	●	-	-	-	○	-	●	-	-	-	-
Adits	●	●	●	●	-	-	-	○	-	●	-	-	-	-
Open Pits	●	●	○	●	●	-	-	○	-	-	-	-	-	-
Pit Rock Faces/ Highwalls	●	●	○	●	●	-	-	○	-	●	-	-	-	-
Underground Workings	●	●	○	○	●	-	-	-	-	-	-	-	-	-

- = not Applicable

● = Feature contributes to concern

○ = Feature does not contribute to concern

The purpose of the first meeting (July 2007) was to explain the objectives of the project, and to elaborate in particular on the extensive fieldwork planned in the weeks following. The meeting was also used as an opportunity to elicit the views of the local communities. Overall, the key issues raised concerned site safety, the environment, heritage, and cost. A range of views, sometimes conflicting, was expressed and all were recorded and posted on the website.

The second public meeting (April 2008) was held at a point when CDM had almost completed in draft their Feasibility Study of the Avoca Mining Area. Before final decisions were made on the remediation options to be included in the final report, feedback was sought from the local communities. Attendees were shown a presentation on preliminary findings of the study, particularly the results of the extensive fieldwork, and the remediation options being recommended. Generally the response to the presentation was positive, although some attendees felt that individual issues such as heritage were not being given adequate attention in the remediation options. Written comment on the proposals was encouraged and several submissions were received.

2.9 Main Issues on the Site

There are a number of issues of concern related to the Avoca Mine Site. The site consists of three main open pits, over 60 shafts and adits, 25 buildings and structures along with tailings impoundments (including the Shelton Abbey tailings facility) and numerous spoil piles with elevated levels of metals. Many of these features pose health and safety concerns. In addition, the site is contaminating the Avoca River. The main issues at the Site are:

Health and Safety Issues

Many of the shafts, adits, and pits are accessible to the public. Fencing of these features has taken place over the years; however, they are frequently breached allowing public access. These features pose physical safety hazards. Many of the shafts and adits are not properly sealed allowing access to underground workings.

The pit highwalls are unstable and could fail. In the case of the East Avoca Pit, a public road is located within 10 m of the highwall. Any failure of this wall will have consequences for the public road.

Some of the spoil piles such as Mt. Platt have unstable slopes and have the potential to fail. In the Tigroney area, the spoil piles and the ore bins are in poor condition and could fail. These are located within 5 m of a public road.

Many of the spoil piles contain elevated levels of metals. In particular, lead and arsenic are of concern. Trespass onto the site by, for example quad bikers, clay pigeon shooters, or walkers, are exposed to these contaminants. In particular quad biking mobilises dust, which can be inhaled and/or ingested. Lead concentrations in the spoil piles near the ore bins and in the Connary area present unacceptable risks to recreational users. In the Connary area, sheep are allowed graze on some of this material. Arsenic and lead in all other spoil pile areas also present unacceptable risk to humans.

Some buildings and mine related structures are in a poor state of repair or maintenance has been neglected, such as at the Shelton Abbey tailings facility, and represent a collapse hazard thus posing a risk to humans, animals and the environment.

Environmental Issues
The main issue from the Avoca site is AMD. Metal laden, low pH water is entering the Avoca River either as point discharges from adits or as diffuse flow. Some of the tributaries in the area are also contaminated and also add to the contamination of the river. This has an adverse affect on the aquatic habitat and the biodiversity of the river.

Over many years, some of the sediments in the river have become ferricreted and these contribute to the ongoing contamination of the river.

All the spoil piles have a high acid generating potential which contribute to the degradation and contamination of both groundwater and surface water. There is little or no vegetation growth on these spoil piles leaving the contaminated material accessible to animals and people.

3.0 Site-Wide Combined Alternatives

Two site-wide combined alternatives were developed to address physical hazards and both solid and water contamination for all locations at the Avoca Site. Each combined alternative comprises process options evaluated for each individual site location. Both combined alternatives are designed to protect human health and the environment while addressing the physical hazard health and safety concerns outlined in the Site remedial action objectives. Heritage and long-term site management are also considered.

Each specific area of the Site (e.g., Cronebane, Connary, etc.) and each media (solid and water) were evaluated individually to select the most effective remedial action for the area. These actions were combined into site-wide Combined Alternative 1. Some areas or media had secondary remedial actions that were similar but not as effective as the actions in Alternative 1. These remedial actions were selected for Combined Alternative 2, which cost less than Combined Alternative 1. The two alternatives were selected to provide decision makers with a range of options and costs for each area of the site. The selected process options and the main differences in the two alternatives are summarised in Tables 3-1 (solids) and 3-2 (water). The selected process options and rationale for selection are provided in the next sections.

Table 3-1 Solids Process Options

	Alternative 1		Alternative 2	
Area	**Spoils Relocate**	**Cover**	**Spoils Relocate**	**Cover**
Connary Spoils	No	Lime/soil/vegetation	No	Soil/vegetation
Mt. Platt Spoils	Yes	Lime/soil/vegetation	80%	Soil/vegetation
Cronebane Pit	—	HDPE/soil/vegetation	—	Soil/vegetation
East Avoca Pit	—	HDPE/soil/vegetation	—	Soil/vegetation
East Avoca (unstable area)	Yes	HDPE/soil/vegetation	Yes	Soil/vegetation
Tigroney West/Ore Bins Spoils	Yes	Replace with clean soil/vegetation	No	Soil/vegetation
Deep Adit Spoils	Yes	Replace with clean soil/vegetation	Yes	Replace with clean soil/vegetation
SP39 Spoils	No	Lime/soil/vegetation	No	Soil/vegetation
West Avoca Spoils	Yes	Lime/soil/vegetation	Yes (only large piles)	Soil/vegetation
Weaver's Lode Pit	—	HDPE/soil/vegetation	—	Soil/vegetation
River Sediments	Yes	Onsite Disposal	Yes	Onsite Disposal
Emergency Tailings	No	—	No	—
Shelton Abbey Tailings	No	Enhanced drainage/ some cover/vegetation	No	Enhanced drainage/ some cover/vegetation

Table 3-2 Water Process Options

	Alternative 1	Alternative 2
East/West Avoca Acid Mine and Rock Discharges	Active water treatment plus pilot passive facility	Active water treatment
East/West Avoca Groundwater Diffuse Flow	Soil bentonite wall plus extraction wells	Soil bentonite wall plus extraction wells
Shelton Abbey Groundwater Diffuse Flow	Soil bentonite wall, extraction wells, active water treatment	No action with monitoring

3.1 Combined Alternative 1

Of the two combined alternatives, Combined Alternative 1 presents a more effective, permanent, and sustainable combination of remedial options for each site location when compared to Combined Alternative 2. Plan views of Combined Alternative 1 are illustrated graphically in Figures 3-1 through 3-5. Tables on the figures also summarise the selected options.

3.1.1 Solids

The remedial technologies and process options applied to each site and the advantages are summarised below.

East and West Avoca Spoil Piles and Open Pits (Figure 3-1 and 3-2)

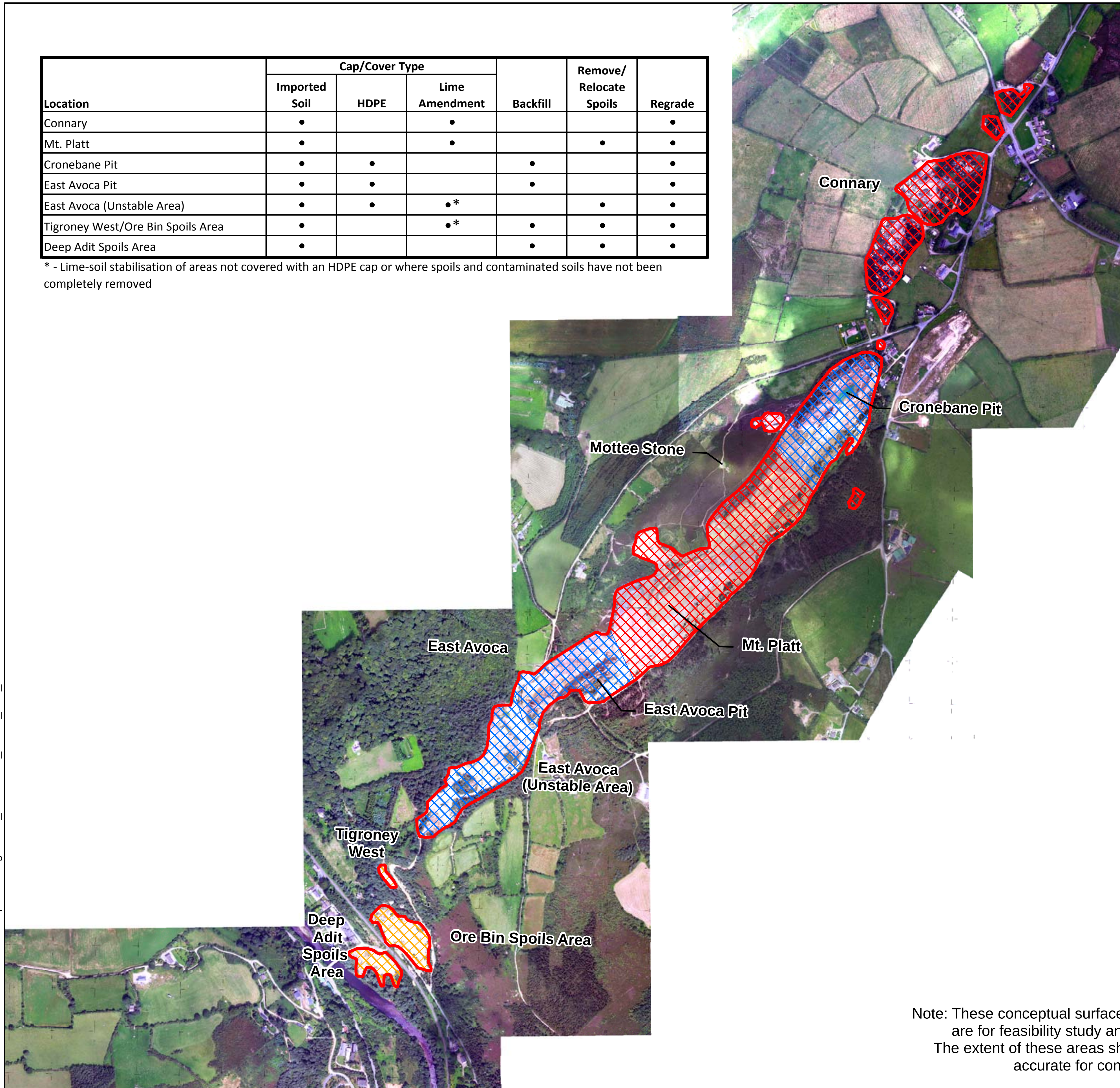
The work to be carried out on the Avoca Mine Site is given below; the sites will be described from the northeast to the southwest.

The Connary spoil heaps/areas will be regraded, stabilised, and covered using a lime/soil/vegetation cover.

The Mt. Platt spoils will be relocated to the Cronebane Pit, capped using HDPE, soil and vegetated. The area under Mt. Platt will then be regarded, treated with lime amendment, covered with soil, and vegetated.

Location	Cap/Cover Type: Imported Soil	HDPE	Lime Amendment	Backfill	Remove/ Relocate Spoils	Regrade
Connary	•		•			•
Mt. Platt	•		•		•	•
Cronebane Pit	•	•		•		•
East Avoca Pit	•	•		•		•
East Avoca (Unstable Area)	•	•	•*		•	•
Tigroney West/Ore Bin Spoils Area	•		•*	•	•	•
Deep Adit Spoils Area	•			•	•	•

* - Lime-soil stabilisation of areas not covered with an HDPE cap or where spoils and contaminated soils have not been completely removed



Legend

- Imported Soil Cover
- HDPE Cap, Imported Soil Cover
- Add Lime Amendment, Imported Soil Cover
- Reclamation Areas

* - All reclaimed areas will include indigenous revegetation, surface water management, and institutional controls.

N W E S

Meters

0 50 100 200 300 400 500

1 centimeter = 100 meters

Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

CDM

FIGURE 3-1

Combined Alternative 1 - Solids

Connary, Cronebane/Mt. Platt and East Avoca/Tigroney West

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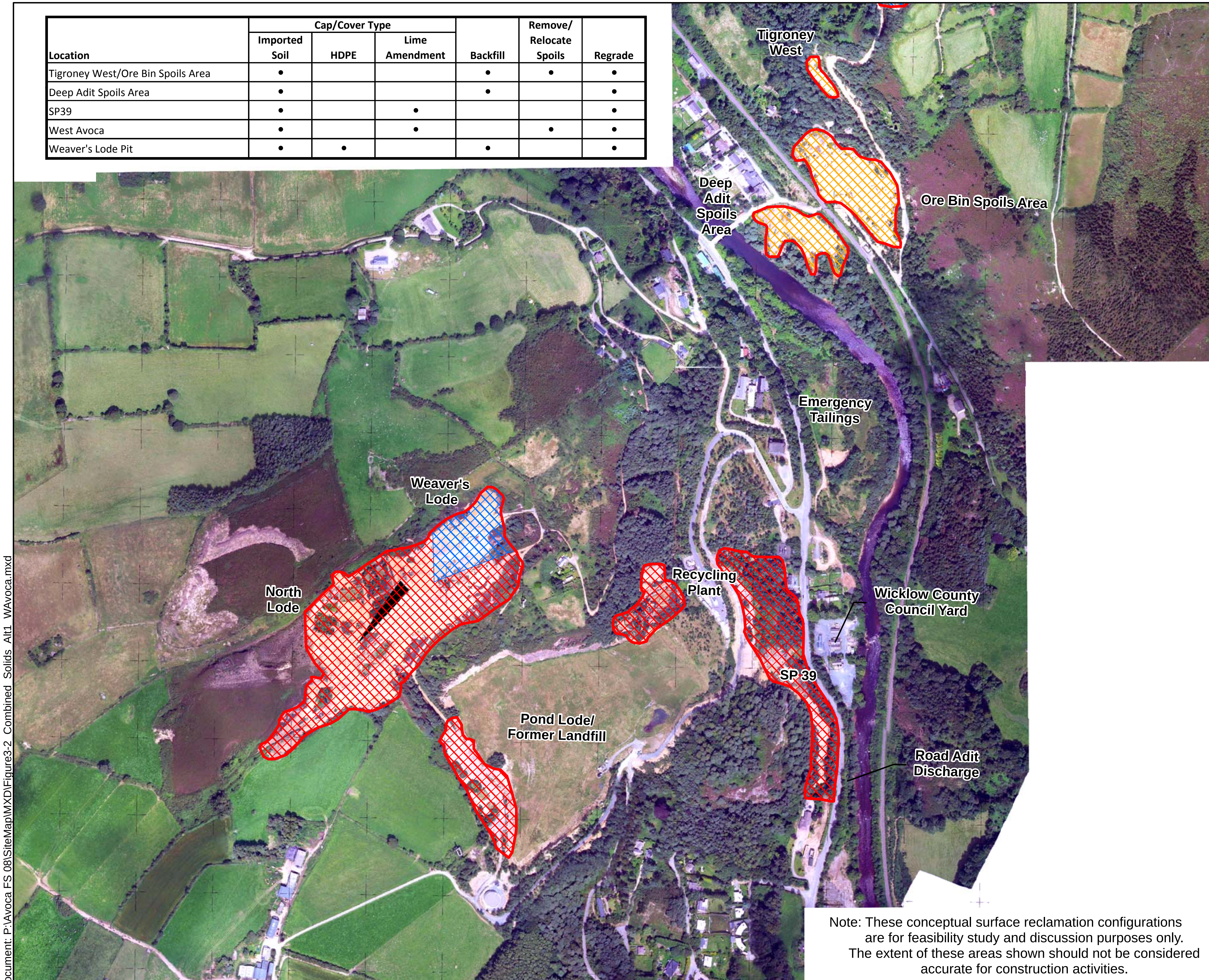
Location	Cap/Cover Type			Backfill	Remove/ Relocate Spoils	Regrade
	Imported Soil	HDPE	Lime Amendment			
Tigroney West/Ore Bin Spoils Area	•			•	•	•
Deep Adit Spoils Area	•			•		•
SP39	•		•			•
West Avoca	•		•		•	•
Weaver's Lode Pit	•	•		•		•



Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

Legend

- Imported Soil Cover
- HDPE Cap, Imported Soil Cover
- Add Lime Amendment, Imported Soil Cover
- Reclamation Areas

* - All reclaimed areas will include indigenous revegetation, surface water management, and institutional controls.

N W E S

Meters

0 50 100 200 300

1 centimeter = 50 meters

CDM

FIGURE 3-2

Combined Alternative 1 - Solids

West Avoca

Document: P:\Avoca FS 08\SiteMap\MXD\Figure3-2 Combined Solids Alt1 WAvoca.mxd

The East Avoca and Tigroney spoil piles will be relocated to the East Avoca Pit. These areas will then be regraded. A HDPE cap will be utilized over the East Avoca Pit area and East Avoca; however, in the Tigroney area, a lime amendment will be used over contaminated spoil material, and where all the contaminated spoil is removed, imported soil will be used and vegetated. The ore bins will be reclaimed and relocated in the general area for safe viewing.

The West Avoca spoils areas, except for the area adjacent to the Avoca/Rathdrum Road (SP39), will be relocated to the vicinity of the Weaver's Lode Pit. The area will be regraded to stable slopes including SP39. A HDPE cap will be used over the Weaver's Lode Pit area while lime amendment will be used in all other areas in West Avoca.

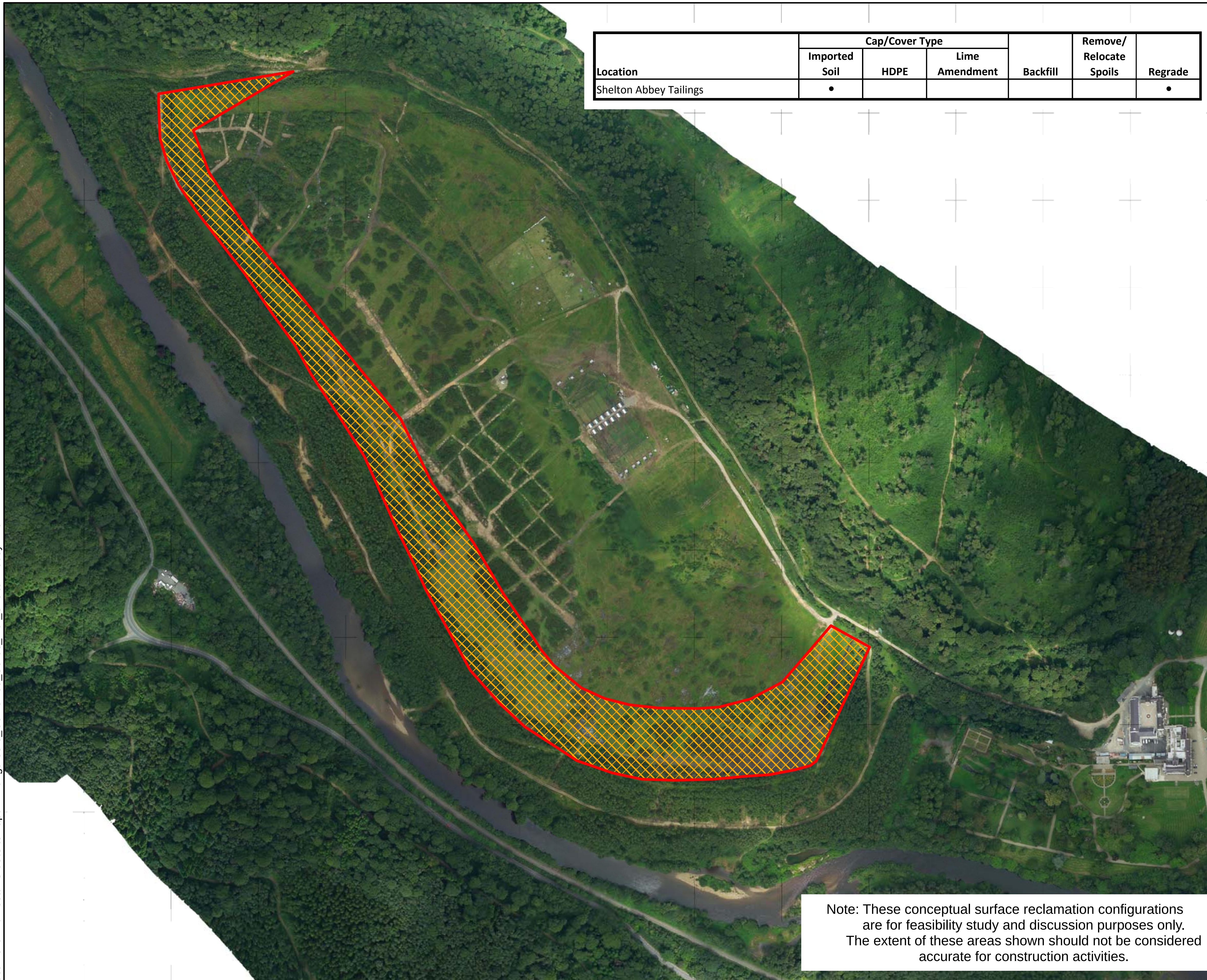
In all cases, surface water management systems will be put in place in accordance with good practice.

The above programme has the effect of:

- Stabilisation of the spoil piles
- Reducing the hazard of high rock faces, rock slides and pit ponds by partial infilling of pits
- Uncovering physical hazards and allowing their mitigation
- Eliminating/reducing the human health risk
- Infiltration reduction, minimising contaminated water entering groundwater and surface water
- Providing greater opportunity for ecological diversity and increased opportunities for site use

Avoca River Sediments
Avoca River sediments and ferricrete deposits in the vicinity of the Deep and Road Adit discharges will be removed, relocated in an onsite repository, and stabilised. This will reduce continued release of metals into the water and improve both macroinvertebrate habitat and Avoca River water quality.

Shelton Abbey Tailings (Figure 3-3)
The Shelton Abbey Tailings site will be improved by importing clean earth to fill in low areas, and for construction of a wide, mild-sloping buttress against the inside of the main embankment; constructing and stability cross-drainage and perimeter drainage ditches; and planting the disturbed and bare areas with indigenous vegetation. Proper surface water management will reduce ponding and infiltration reducing contamination to the groundwater and Avoca River. It will also provide long-term effectiveness and sustainability of the Site, which has degraded and will continue to do so unless upgraded and maintained.



Location	Cap/Cover Type			Backfill	Remove/ Relocate Spoils	Regrade
	Imported Soil	HDPE	Lime Amendment			
Shelton Abbey Tailings	•					•

Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

Legend

- Imported Soil Cover
- Reclamation Areas

* - All reclaimed areas will include revegetation, surface water management, and institutional controls.

N
W E
S

Meters
0 50 100 150 200
1 centimeter equals 50 meters

CDM

FIGURE 3-3

Combined Alternative 1 - Solids

Shelton Abbey

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3.1.2 Water

East/West Avoca Water (Figure 3-4)

The selected remedial technologies and process options for East/West Avoca water are:

- Construct and operate an active water treatment-lime precipitation plant in the vicinity of the Deep Adit spoils area to treat all acid mine water discharges and extracted groundwater. The plant will provide the most important improvement to river water quality.
- Implement source /discharge control measures for acid mine water discharges, including shaft sealing and plugging, excavation and backfilling, control bulkheads, and shallow, leaky bulkheads.
- Implement groundwater containment and extraction through use of soil bentonite walls and extraction wells in the vicinity of the Deep Adit spoil areas on the east side of the river and the Emergency Tailings Pond on the west side of the river.
- Construct and operate an experimental, pilot scale, passive treatment system located at the reclaimed East Avoca area, downgradient from the East Avoca Pit.

Shelton Abbey Water (Figure 3-5)

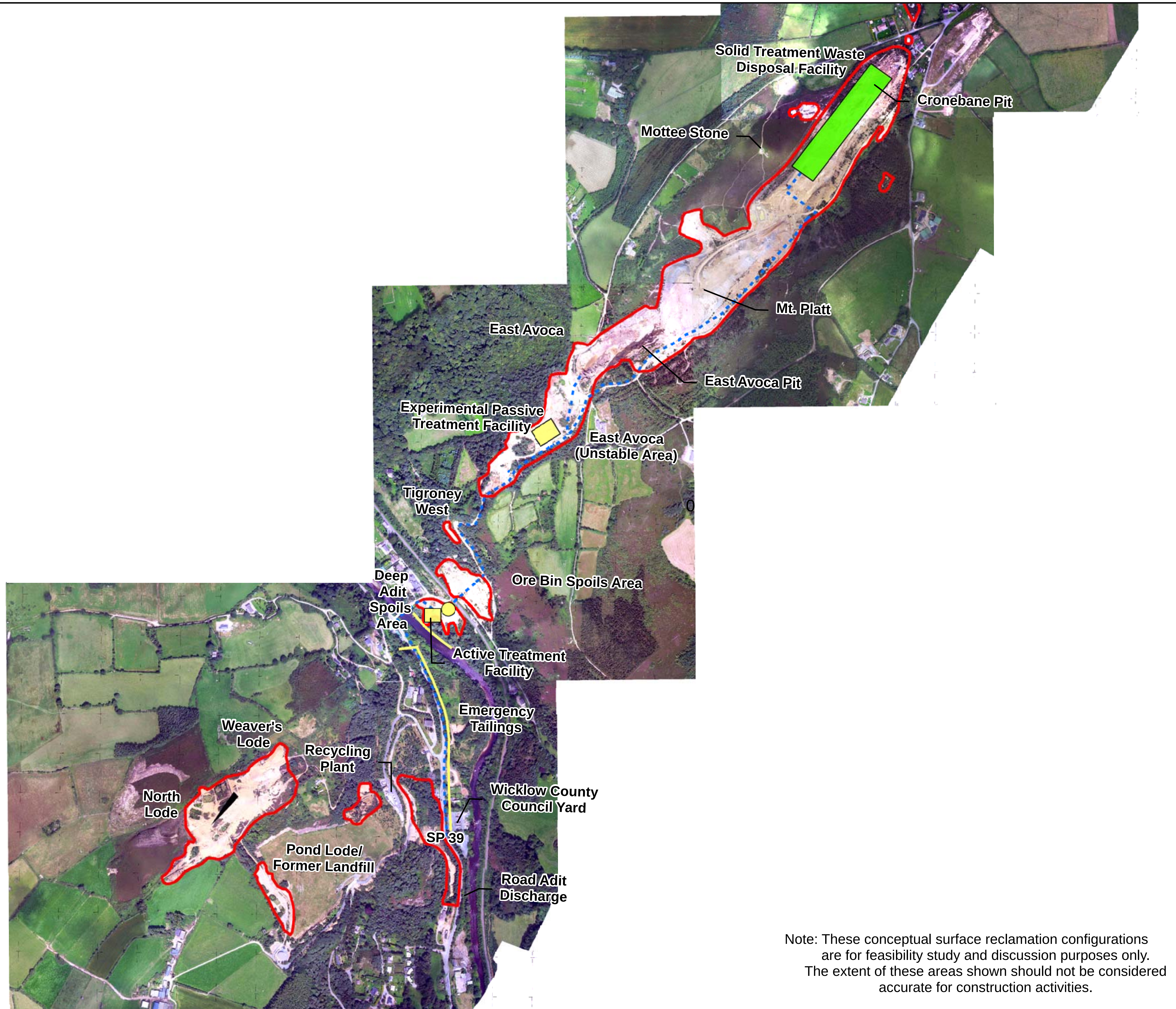
The selected remedial technologies and process options for Shelton Abbey water are:

- Implement groundwater extraction by constructing a soil-bentonite wall and installing and operating extraction wells at the base of the main embankment, along the lower perimeter road.
- Construct and operate an active water treatment-lime precipitation facility located either along the lower perimeter road or on the surface of the Shelton Abbey Tailings site.
- Monitor treatment plant discharges.
- Construct and operate an onsite solid treatment waste disposal facility on the surface of the Shelton Abbey Tailings site.

3.1.3 Institutional Controls, All Locations

The institutional controls include the following:

- Implement access controls/restrictions such as gates, barriers, and fencing at and around access points, work areas, and facilities.
- Utilise legal restrictions and covenants, including signage and legal documents/agreements where appropriate.
- Construct a berm and fence between the reclaimed Mt. Platt area and the East Avoca Pit.



Legend

- Tank
- Soil-Bentonite Barrier and Pump-Back System
- Pipe
- Reclamation Areas

* - Implement appropriate institutional controls, such as fencing and gates around reclaimed areas, and deed restrictions.

N W E S

Meters

0 50 100 200 300 400 500

1 centimeter = 100 meters

CDM

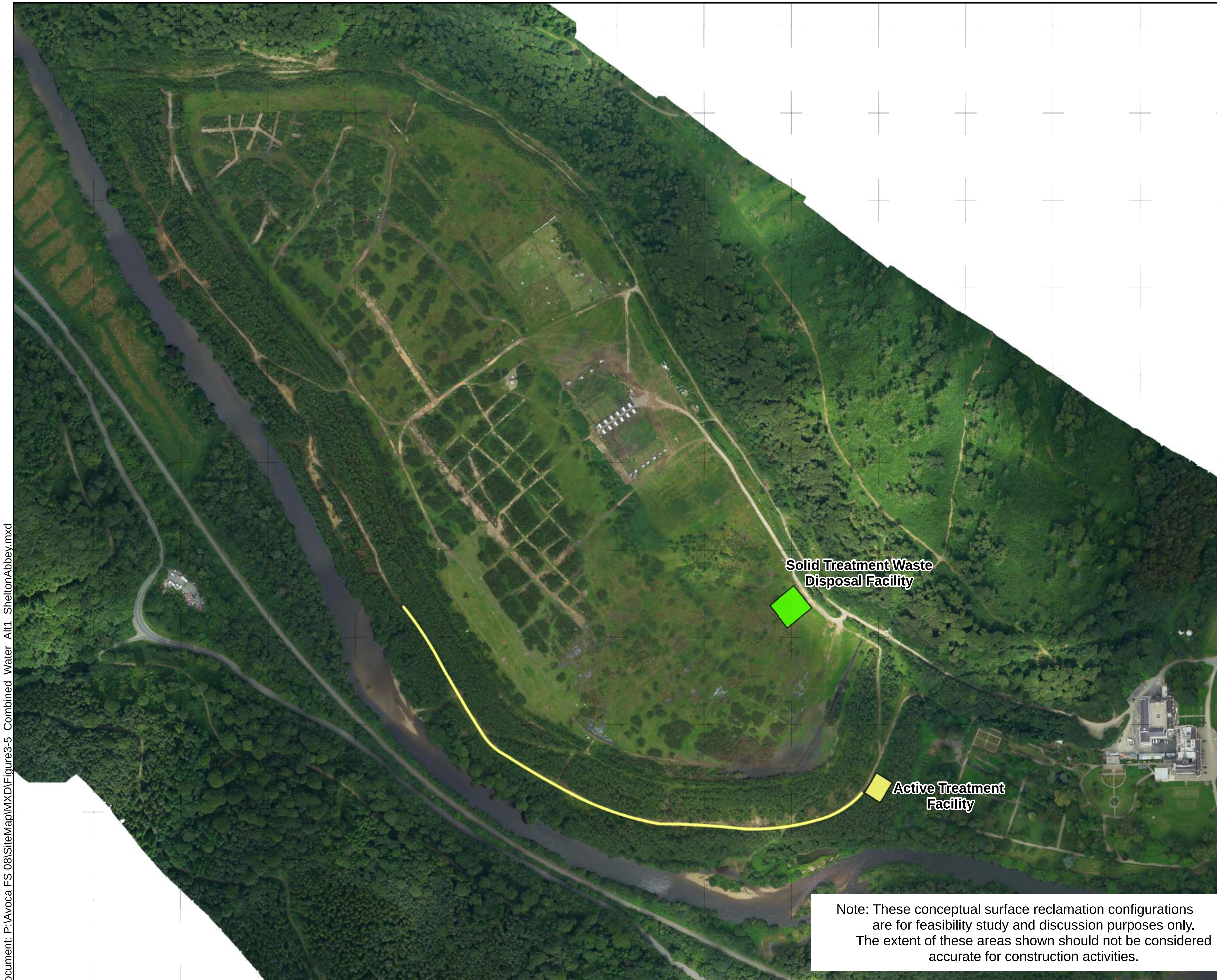
FIGURE 3-4

Combined Alternative 1 - Water

East/West Avoca

Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

Document: P:\Avoca FS 08\SiteMap\MXD\Figure3-4_Combined_Water_Alt1.mxd



Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

Legend

- Soil-Bentonite Barrier and Pump-Back System

* - Implement appropriate institutional controls, such as access control (fencing, gates) and legal restrictions.

Meters

0 50 100 150 200

1 centimeter equals 50 meters

CDM

FIGURE 3-5

Combined Alternative 1 - Water

Shelton Abbey

Document: P:\Avoca FS 08\SiteMap\MXD\Figure3-5_Combined_Water_Alt1_SheltonAbbey.mxd

3.2 Combined Alternative 2

Combined Alternative 2 typically presents less effective, but less costly, combinations of remedial technologies and process options for each site location. Institutional Controls are the same for both alternatives. Plan views of Combined Alternative 2 are illustrated graphically in Figures 3-6 through 3-9.

3.2.1 Solids

The differences between Alternative 2 and Alternative 1 for solid media are provided in Table 3-1 and shown on the tables in Figures 3-6 to 3-8. Major differences are summarised below.

For Connary, Alternative 2 uses a soil cover without the addition of lime. Only 80 percent of Mt. Platt is relocated to the Cronebane Pit in Alternative 2. This achieves a stable and maintainable land form free of physical hazards. The relocated material is covered with soil but without the HDPE liner.

The unstable area of the East Avoca spoil piles and the Deep Adit spoils will be relocated to the East Avoca pit. A soil cover will be used without an HDPE liner. The Tigroney West spoil piles will be regraded in place and covered with soil without lime addition or an HDPE liner. Only the larger spoil piles at West Avoca will be relocated to Weaver's Lode Pit.

Remedial actions for the river sediments, Shelton Abbey tailings, and the Emergency Tailings are the same as Alternative 1.

3.2.2 Water

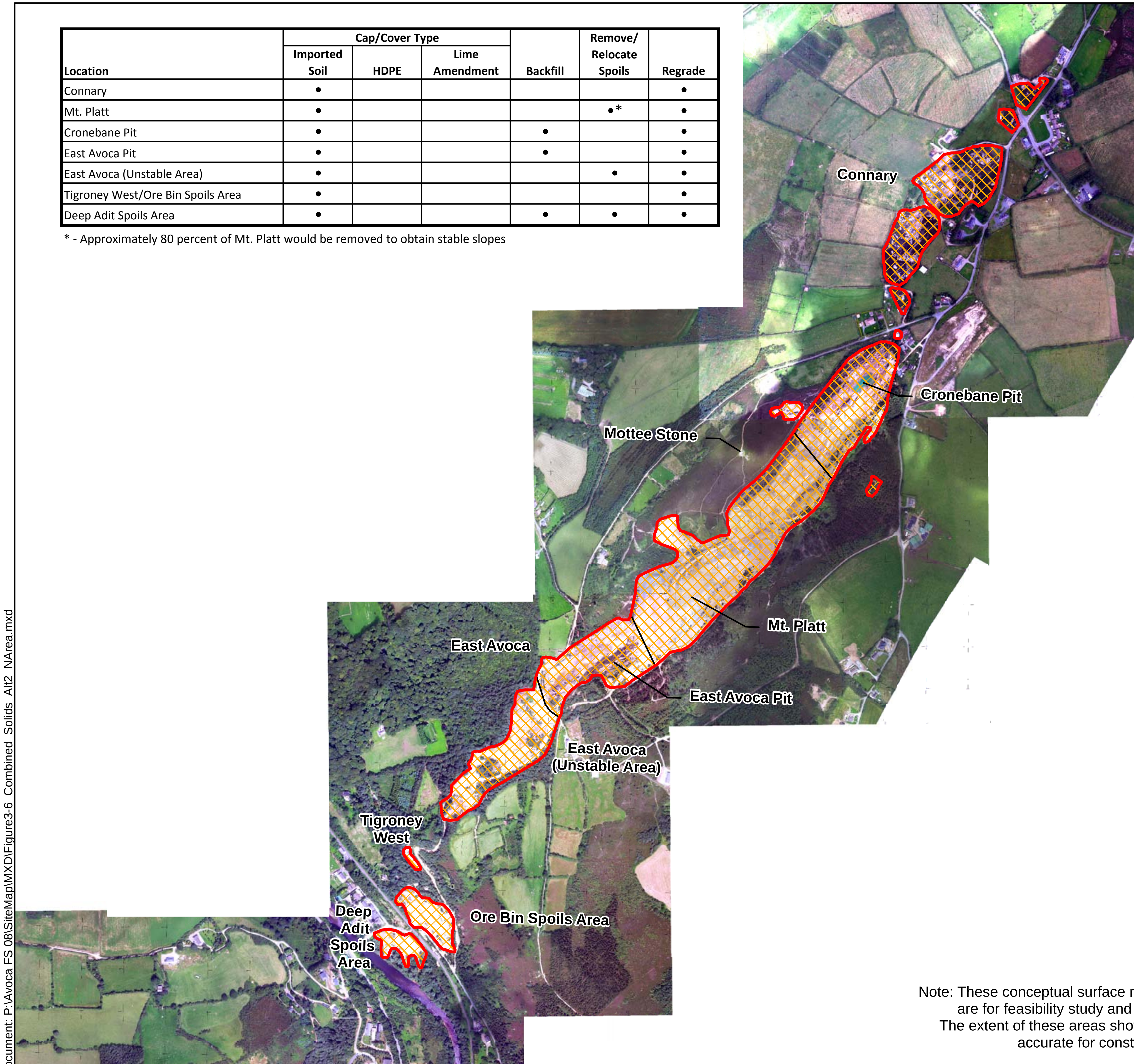
The differences between Alternative 2 and Alternative 1 for water are provided in Table 3-2 and shown in Figure 3-9. For East/West Avoca, the Alternatives are the same except the pilot plant passive treatment facility will not be constructed. Monitoring only is proposed at Shelton Abbey instead of groundwater collection and treatment.

3.3 Monitoring

A comprehensive monitoring programme will be implemented covering routine water quality and flow monitoring, operational monitoring of treatment facilities, geotechnical monitoring, and routine inspections of remediated features. This should take place before, during, and following the completion of the remediation programme.

Location	Cap/Cover Type: Imported Soil	Cap/Cover Type: HDPE	Cap/Cover Type: Lime Amendment	Backfill	Remove/ Relocate Spoils	Regrade
Connary	•					•
Mt. Platt	•				•*	•
Cronebane Pit	•			•		•
East Avoca Pit	•			•		•
East Avoca (Unstable Area)	•				•	•
Tigroney West/Ore Bin Spoils Area	•					•
Deep Adit Spoils Area	•			•	•	•

* - Approximately 80 percent of Mt. Platt would be removed to obtain stable slopes



Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

Legend

- Imported Soil Cover
- Reclamation Areas

* - All reclaimed areas will include indigenous revegetation, surface water management, and institutional controls.

N
W E
S

Meters
0 50 100 200 300 400 500

1 centimeter = 100 meters

CDM

FIGURE 3-6

Combined Alternative 2 - Solids

Connary, Cronebane/Mt. Platt
and East Avoca/Tigroney West

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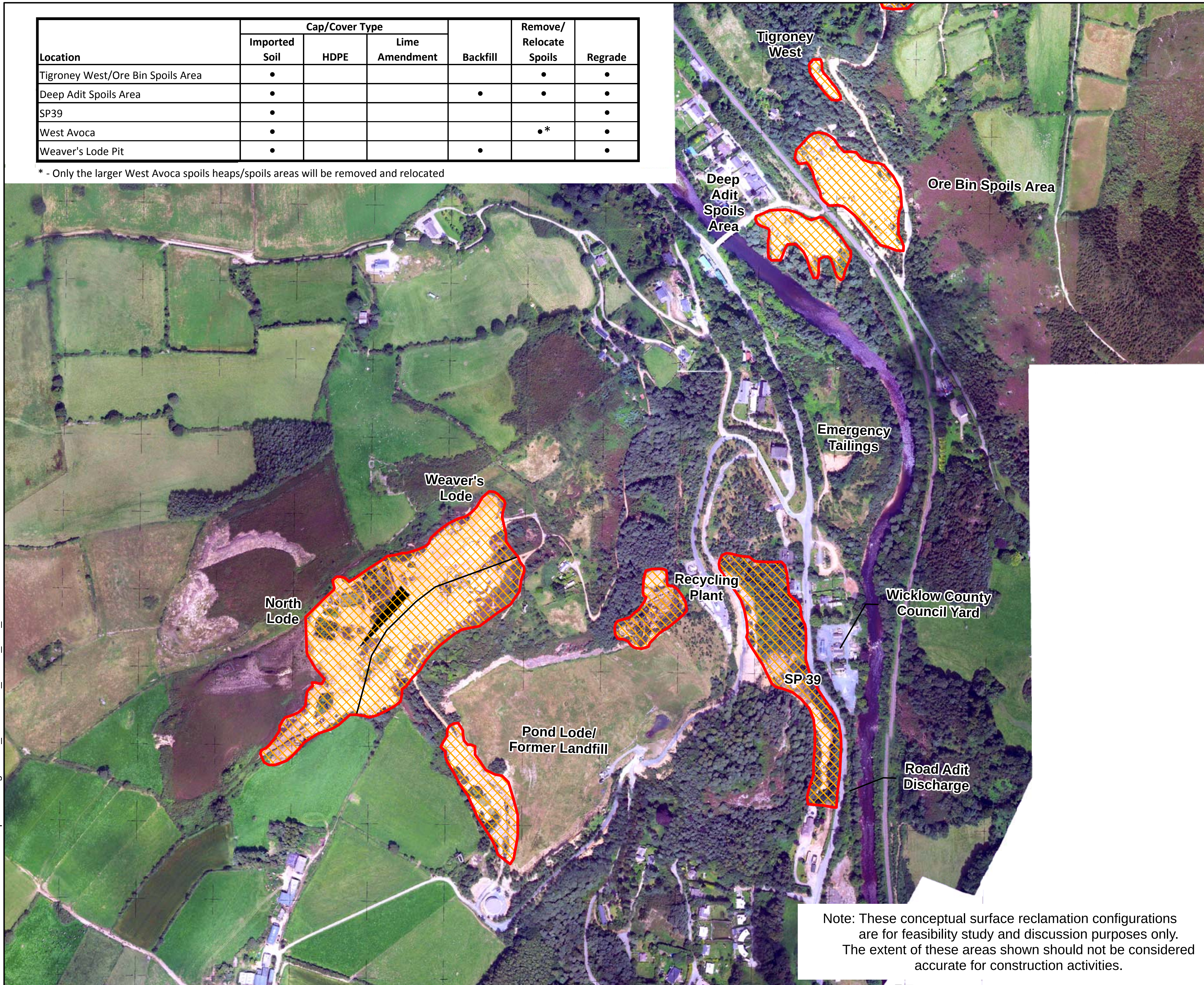
Location	Cap/Cover Type			Backfill	Remove/ Relocate Spoils	Regrade
	Imported Soil	HDPE	Lime Amendment			
Tigroney West/Ore Bin Spoils Area	•				•	•
Deep Adit Spoils Area	•			•	•	•
SP39	•					•
West Avoca	•				•*	•
Weaver's Lode Pit	•			•		•

* - Only the larger West Avoca spoils heaps/spoils areas will be removed and relocated

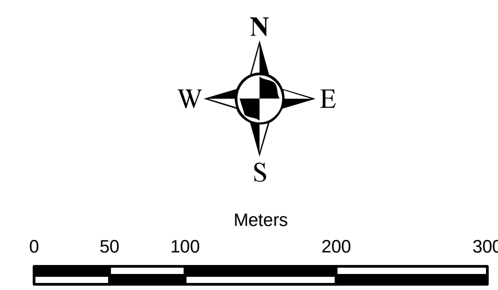


Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

Legend

- Imported Soil Cover
- Reclamation Areas

* - All reclaimed areas will include indigenous revegetation, surface water management, and institutional controls.



1 centimeter = 50 meters

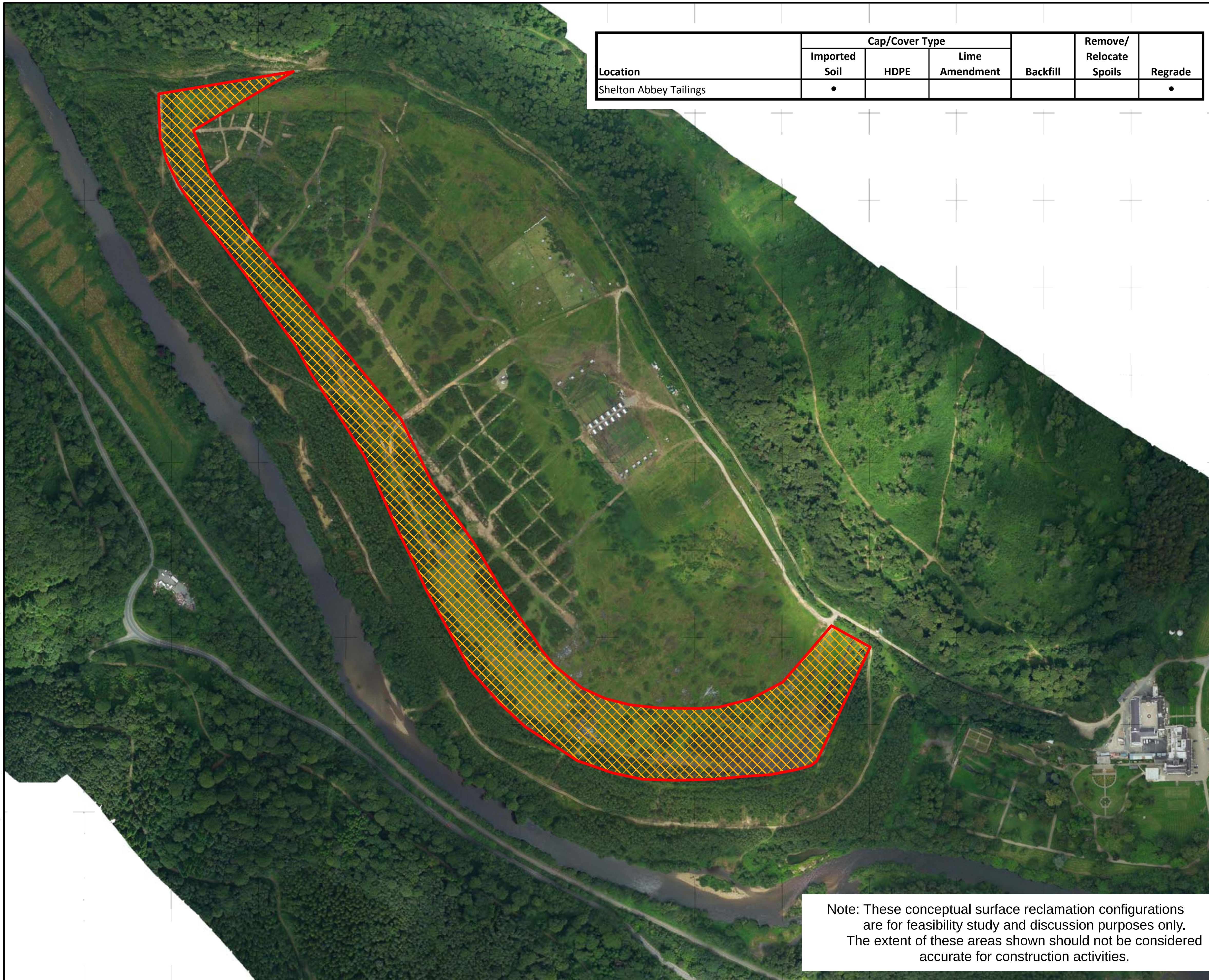
CDM

FIGURE 3-7

Combined Alternative 2 - Solids

West Avoca

Document: P:\Avoca FS 08\SiteMap\MXD\Figure3-7_Combined_Solids_Alt2_WAvoca.mxd



Location	Cap/Cover Type			Backfill	Remove/ Relocate Spoils	Regrade
	Imported Soil	HDPE	Lime Amendment			
Shelton Abbey Tailings	•					•

Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

Legend

- Imported Soil Cover
- Reclamation Areas

* - All reclaimed areas will include revegetation, surface water management, and institutional controls.

N
W E
S

Meters
0 50 100 150 200
1 centimeter equals 50 meters

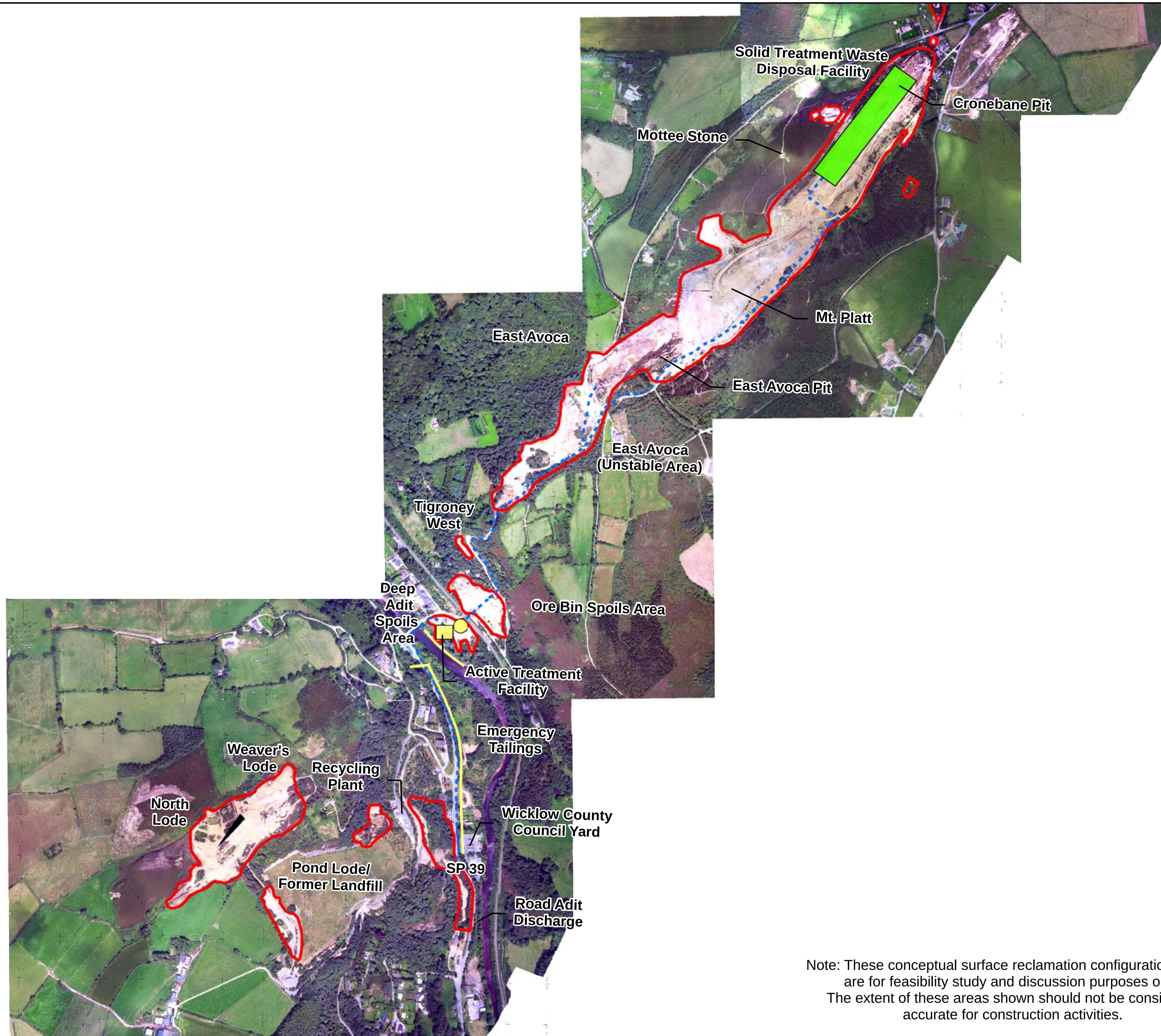
CDM

FIGURE 3-8

Combined Alternative 2 - Solids

Shelton Abbey

Document: P:\Avoca FS 08\SiteMap\MXD\Figure3-8_Combined_Solids_Alt2_SheltonAbbey.mxd



Note: These conceptual surface reclamation configurations are for feasibility study and discussion purposes only. The extent of these areas shown should not be considered accurate for construction activities.

Legend

- Tank
- Soil-Bentonite Barrier and Pump-Back System
- Pipe
- Reclamation Areas

* - Implement appropriate institutional controls, such as fencing and gates around reclaimed areas, and deed restrictions.

N
W E
S

Meters

0 50 100 200 300 400 500

1 centimeter = 100 meters

FIGURE 3-9

Combined Alternative 2 - Water

East/West Avoca

Document: P:\Avoca FS 08\SiteMap\MXD\Figure3-9_Combined_Water_Alt2.mxd

3.4 Construction Schedule Scenarios

An estimated lead time of two to three years would be necessary before initiation of mine site remediation construction to allow for completion of major engineering investigations and design issuance of the construction bid documentation, preparation of planning applications, including environmental impact statement (EIS) and the assembly of other necessary permissions. Scenarios for the scheduling of construction can assist in the overall project planning.

3.4.1 Construction Schedule Scenarios for Combined Alternative 1

The work would be in three phases. The physical institutional controls and barriers to public safety hazards at the East and West Avoca sites would be installed immediately. Work phases are estimated to be on the order of one to two years each. Total construction time can be as short as three years for an optimum schedule, or as long as six or more years for a balanced cost and funding schedule.

Optimum Schedule

Work items that begin in one phase may be completed in the following phase. For example, the construction of the active water treatment plant would begin relatively late in Phase 1, allowing for long lead-time deliveries and site preparations, and conclude in Phase 2. It is estimated that the work would begin as soon as the major construction contracts are awarded.

Phase 1

- Install and maintain physical institutional controls, signage, and other temporary or permanent barriers to the sites' physical hazards in order to safeguard the public.
- Order long lead-time equipment and materials. Mobilise.
- Remediate the Deep Adit spoils site.
- Construct the active water treatment plant.
- Remediate the Cronebane/Mt. Platt area.
- Construct the solid treatment waste disposal facility.
- Construct the control bulkheads in the Deep Adit and Road Adit, and the pipe connections to the active water treatment plant.
- Install the permanent water-related monitoring units.

Phase 2

- Install the soil bentonite walls and groundwater extraction system; construct the shaft plugging, shallow bulkheads, and the pipe/channel connections to the active water treatment plant; and implement any additional water institutional controls.

- Remediate the East Avoca/Tigroney West Area (not including the Deep Adit spoils site).

- Remediate the West Avoca area.

Phase 3

- Remediate the Connary Area.

- Construct the experimental passive treatment system and related components in the East Avoca area.

- Remove/contain Avoca River sediments.

- Remediate Shelton Abbey tailings.

- Construct Shelton Abbey groundwater extraction and treatment/disposal system.

- Install the permanent geotechnical monitoring units.

- Accept the work, site clean-up, and demobilisation.

Balanced Cost and Funding Schedule

An optional schedule for Combined Alternative 1 that better balances the cost per phase can be accomplished by moving the construction of the active water treatment plant to Phase 2, and remediation of the West Avoca area to Phase 3. The schedule for the phasing would be commensurate with the funding and may be up to 2 years for each phase.

3.4.2 Construction Schedule Scenarios for Combined Alternative 2

Because Combined Alternative 2 does not include HDPE caps or lime-soil stabilisation; experimental passive treatment system; or groundwater extraction, treatment, or solids disposal at the Shelton Abbey Tailings site, the time for project build-out would be somewhat shorter. The schedule scenarios are the same as for Combined Alternative 1; however, the costs are lower.

3.4.3 Alternative Construction Schedules

Many different construction scenarios are possible and depend upon the priorities, procurement methods, and bids received from construction contractors. As discussed in Section 3.3, various types of monitoring will be conducted including water quality and geotechnical monitoring. Results of the monitoring program may reveal some immediate priorities or changed priorities that may affect the schedule. For example, monitoring may indicate that stabilisation of the East Avoca Pit highwall (southwest area near the road) needs to be addressed as soon as possible. The schedule scenarios could be changed so that the East Avoca pit is backfilled during Phase 1.

4.0 Estimated Remedial Costs

Based on the Combined Alternatives, preliminary designs and quantity estimates were made for the remedial technologies and process options for each specific area of the Avoca Site. Unit costs for labour, equipment, and material were used to develop capital costs, annual operation and maintenance costs, and total present value costs. The cost estimates for Combined Alternatives 1 and 2 are presented in Table 4-1.

Table 4-1 Combined Alternative Cost Estimates

	Euros (€)	
	Combined Alternative 1	**Combined Alternative 2**
Total Capital and Indirect Cost	58,500,000	46,125,000
Annual Operating Cost	1,206,000	1,010,000
Total Present Value (20 years)	74,890,000	59,851,000

All costs are exclusive of VAT and present value costs assumed an operating life of 20 years and a discount rate of 4 percent (Department of Finance, May 2007). The costs presented are in real terms and do not take into account inflation. It should be noted that these costs are for an EPCM (Engineering Procurement and Construction Management) type of construction contract and will require significant input by the client in managing the project. This latter cost has not been estimated.

The sum of the multiplication of unit costs and quantities results in the direct cost or Total Capital Cost. The Total Capital Cost is a bare construction cost that does not account for many items that are real project costs. These costs include mobilization/ demobilization; contractor's preliminaries, overhead and profit; general conditions; scope and bid contingency; engineering design; and construction management. Overall, the adjustments result in an increase of approximately 109 percent of the bare capital costs. The costs provided do not include costs for such items as environmental impact statements (EISs), planning and assessment documents, permissions, and Integrated Pollution Prevention Control (IPPC) licenses.

Overall the anticipated accuracy of the costs in this document is estimated to be ±25 percent. Costs provided are an opinion of probable capital and operation/ maintenance costs only. CDM has no control over the cost of labour, materials, equipment, or services furnished, schedules, contractor's methods of determining prices, competitive bidding, market conditions, or negotiating terms. CDM does not guarantee that this cost opinion will not vary from actual costs, or contractor's bids.

The schedule of work is set out to address the immediate health and safety issues as a priority. Work includes installation of physical barriers to known mine openings (i.e., open shafts/adits) and other physical hazards (e.g., unstable highwalls and structures) and remediation of the ore bins. Remediation would be carried out as a priority for these items; however, the design would be compatible with the long-term, overall site management plans. Depending on the availability of funds, schedules are set out in three phases allowing the flexibility of the work to be carried out over various time periods from three to six years or more (see Section 3.4). The total capital and indirect costs of each of the phases range from €12 to 27 million for an optimum (minimal time period) schedule and from €18 to 21 million for balanced cost schedule (longer time period). The cost to address the immediate health and safety issues is approximately €3 million.

5.0 Comparative Analysis of Combined Alternatives

The two combined site-wide alternatives presented in Section 3 are comparatively evaluated in this Section using effectiveness, implementability, relative cost, and site compatibility criteria with a focus on the entire site, rather than a media specific evaluation. This comparative analysis evaluation, performed on each geographic remediation area, is technically driven and assumes appropriate remaining requirements can be completed (e.g., EIS, planning documents, and necessary permits). Each comparative criterion is defined below.

Effectiveness is the ability of the remedial alternative to achieve remedial action objectives including protection of human health and the environment and addressing health and safety concerns due to physical hazards. In addition, effectiveness in this step of the feasibility study process also includes the long-term permanence, reliability, and continued ability to achieve remediation goals of the completed action. Long-term permanence, reliability, and effectiveness are also considered the same as sustainability. The combined alternative with the maximum probability of achieving remediation goals (e.g., water quality standards in the Avoca River, protecting human health, etc.) over the long term, and addressing physical hazards would be rated high for this criterion.

Implementability used in this step of the feasibility study process relates to both the technical and administrative feasibility of constructing, operating, and maintaining the site-wide combined alternatives given the physical constraints of the site. The availability of needed materials and services is also considered. Technical feasibility considerations include the technical difficulties or steps anticipated in construction of the remedy, the impact of construction on the local community, and ease of operations and maintenance of any part of the completed remedy. Administrative feasibility relates to the ability to complete planning processes; procure treatment if required, storage, and disposal services (onsite or offsite); and procure the needed land, equipment, and expertise. For the alternatives comparison, the assumption is that the planning and permitting process can be completed.

The relative costs were derived for each combined alternative and compared.

Site compatibility is an evaluation of how each alternative fits into or complements current land use, the existing heritage and cultural features, landscape, and public access. Site compatibility also evaluates overall long-term site management and potential future uses.

Table 5-1 provides a side by side comparison of the overall effectiveness, implementability, relative cost, and site compatibility of the two combined alternatives. While both combined alternatives address physical hazards and protect human health and the environment, Combined Alternative 1 is more effective at reducing acid mine water production through use of an HDPE cap/soil cover and lime amendment in spoils. Combined Alternative 1 is more effective, reliable, and sustainable over long time periods than Combined Alternative 2. Combined Alternative 2, with less relocation of spoils material, shorter construction durations due to ease of soil/vegetation covers, and less transportation of materials within the site during construction is easier to implement than Combined Alternative 1. The relative cost for Combined Alternative 1 is higher than that of Combined Alternative 2.

6.0 References

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Table 5-1 Comparative Analysis of Combined Alternatives

Site-Wide Combined Alternatives	Effectiveness	Implementability	Relative Cost	Site Compatibility
Alternative 1 – Relocation of Mt. Platt, East Avoca, Tigroney West, and West Avoca spoils, regrading of Connary spoils and SP39. Containment of relocated solids material through HDPE cap overlain with soil/ indigenous vegetation. Alternative includes treatment of both East/West Avoca Water and the Shelton Abbey Tailings Water.	●	◕	€€€	●
Alternative 2 – Relocation of 80 percent of Mt. Platt; relocation of East Avoca and West Avoca spoils; regrading of Connary, Tigroney West spoils and SP39. Containment of relocated solids material through lime amendment tilled into spoils surface overlain with soil/indigenous vegetation. Alternative includes treatment of only East/West Avoca water.	◕	●	€€	●

● Complies with the criterion

◕ Complies less with the criterion

€ Relative cost, the greater number of € symbols, the greater the cost