Water Corporation

Dawesville 4A/5A Infill Sewer and Pump Stations
Acid Sulfate Soil and Dewatering Management Plan

November 2012

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1. Introduction

1.1 Background

GHD Pty Ltd (GHD) was commissioned by Water Corporation in 2007 to undertake Acid Sulfate Soil (ASS) and groundwater investigations along Estuary Road, in Dawesville, prior to the construction of proposed gravity-fed sewers and pump stations within Dawesville Reticulation Areas 4A and 5A.

The locality of the proposed sewer networks is outlined in Figure 1 and 2.

GHD prepared separate ASS and groundwater investigation reports coupled with ASS management plans for each of the reticulation areas in 2008.

The relevant documents are:

- GHD Report for Dawesville Area 4A, *Acid Sulfate Soil and Groundwater Investigation* (revised August 2011) - document number 13499.
- GHD Report for Dawesville 5A, *Acid Sulfate Soil and Groundwater Investigation* (revised August 2011) – document number 13500.

During the four year delay, design drawings have been altered and construction methodologies in certain areas have also changed. Furthermore, the Department of Environment and Conservation (DEC) has revised their guidelines[1] since the initial investigation reports and management plans were issued by GHD to Water Corporation in 2008. Given the four year delay between the plans being prepared and the likely start date for the construction commencing, Water Corporation requested GHD undertake additional work prior to construction commencing.

GHD completed the following works (as per the recommendations outlined in GHD proposal # 125769 and approved by Water Corporation in September 2012):

- Revised dewatering effluent disposal options and the nominated trigger values assigned by Water Corporation (pending)
- AQTESolv permeability estimations from permeability testing of all wells across both Areas
- Estimations of dewatering rates and total dewatering effluent volumes for the revised sewers, pressure mains and pump stations
- An assessment of the latest baseline groundwater monitoring round results against the relevant guidelines

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[1] *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DEC, 2009) and *Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes* (DEC, 2011)

- Updated guideline references (as the original ASSDMPs reference superseded treatment and management guidelines)
- Flow charts detailing the roles and responsibilities of the principal, consultants and sub-contractors with regards to ASS and dewatering effluent management
- Updated GIS maps with latest sewer designs and proposed construction techniques

The requirement for an Acid Sulfate Soil and Dewatering Management Plan (ASSDMP) was determined based on the findings and recommendations from the ASS and groundwater investigations undertaken by GHD in 2007 for both Reticulation Areas. The need for dewatering has since been confirmed based on the latest groundwater monitoring and sampling events and revision of the sewer invert levels and construction methodologies.

This ASSDMP presents a summary of the findings from the ASS and groundwater investigations conducted within Areas 4A and 5A in 2007, a summary of the additional works completed by GHD in September 2012 to fill in groundwater data gaps and outlines the required management practices to be implemented during and following construction of the sewers in relation to the potential ASS and dewatering areas.

1.2 Proposed Construction Works

The Water Corporation intend to install two pump stations (No. 7 and No. 13), two pressure mains and a number of caissons connected by gravity-fed sewer pipes within Areas 4A and 5A. The sewers will be part of Water Corporation's Infill Sewerage Program whereby established areas using septic tanks for waste water disposal are connected to the sewerage scheme. The reticulated sewer system will enable gravity feeding of sewerage from residential buildings within Areas 4A and 5A to Pump Stations No. 7 and No. 13 respectively. Figure 1 and 2 present aerial overviews of the proposed sewers and pump stations locations in Area 5A and 4A. The majority of the sewers will be installed in the Water Corporation easement on private properties or in road reserves.

The preliminary design drawings for the construction of the sewer network have been revised from the original plans prepared in 2007, and the total length of sewer line and invert depths have changed slightly.

During construction of the caissons, inlets for reticulation sewers that will connect to the caisson and parts of the pressure main will also be constructed, some of which will require minor dewatering. Other reticulation sewers and other work that do not require dewatering would be constructed concurrently with works along the foreshore.

The majority of the gravity-fed sewer along Estuary Rd in both Areas will be constructed using trenchless technologies. This will include sewer between AC8153 in the northern end to AC8054 in the southern end of Area 5A, and sewer between AC7790 in the north to AC7767 in the south of Area 4A.

The shallow (< 1.3 m bgl invert) pressure main in Area 5A beginning from PS No. 7 and heading south to Loton Rd before veering west and south along Ashley Tce will employ open trenching techniques and will involve installing pipes into trenches left open for a period of time. This is also the case for the shallow pressure main in Area 4A. This main will begin at PS No. 13 and traverse north west along Estuary Rd to Hillway Street. These areas present the highest risk of ASS disturbance and must be managed accordingly, particularly because they are likely to require dewatering to allow construction to progress. Due to the close proximity of the works to the Peel Inlet, tidal effect will also affect dewatering and will need to be considered.

Dewatering is likely to be required for the open trenching outlined above for both Areas along Estuary Rd based on recent groundwater level monitoring and sewer invert levels (taken from GHD drawings HK35-003-001B and HK42-003-001-01B to HK42-003-005-01B). The trench dewatering is likely to be carried out in short lengths, typically less than 50 m and with relatively shallow drawdown of the groundwater, generally less than 1 m. Dewatering will also be required to abstract groundwater out of the caissons for the deep gravity fed sewer feeding the pump station along Estuary Rd.

No dewatering is anticipated for sewers throughout Areas 4A and 5A to the west of Estuary Rd given the relatively shallow invert depths and steep rise in elevation over anticipated limestone ridges to the west (0-2 mAHD on Estuary Rd foreshore rising up to 10-20 mAHD towards Old Coast Rd).

1.2.1 Area 4A

- The relevant GHD design drawings for this area are: Dawesville 4A & PM Drawings (drawing numbers, HK35-3-1, IP06-2-1)
- A total of approximately 3,150 m of sewer line is to be installed, of which 600 m will be by using trenchless technology.
- The pressure main sewer pipe will be 100 mm in diameter.
- The gravity-fed sewer will be 150 mm in diameter.
- The entire sewerage network will be installed below ground level (bgl). Invert levels range between 1.1 m to 3.4 m bgl with the deeper excavations generally occurring at and south of the PS No. 13.
- Construction across the majority of the Site will be undertaken using open trenching with trenchless technologies being employed to install the sewer along the majority of Estuary Rd and in various private properties.

1.2.2 Area 5A

- The relevant GHD design drawings for this area are: Dawesville 5A & PM Drawings (drawing numbers HK42-3-1, 3-3, & 3-4 & IP07-2-2)
- A total of approximately 9,500 m of sewer line is to be installed of which 1,400 m will be by using trenchless technology.

- The pressure main sewer pipe will be 150 mm in diameter.
- The gravity-fed sewer will be 225 and 150 mm in diameter
- The entire sewerage network will be installed below ground level. Invert levels range between 1.1 m to 6.6 m bgl with the deeper excavations generally occurring at and south of the PS No. 7.
- Construction across the majority of the Site will be undertaken using open trenching with trenchless technologies being employed to install the sewer along the majority of Estuary Rd and in various private properties.

1.1 Dewatering Licenses

The Water Corporation is not required to obtain either a Section 5C or Section 26D licence under the Rights in Water and Irrigation Act (1914) in regards to dewatering. The power given to the Water Corporation by Section 83(2)(b) of the *Water Agencies (Powers) Act 1984* overrides the generic requirements of Sections 5C and 26D of the Rights in Water and Irrigation Act and therefore the Water Corporation is exempt from the requirement to obtain a dewatering licence.

1.2 Objectives of ASSDMP

This ASSDMP addresses key construction activities that may impact on soil, groundwater and surface water systems that will require management by the Water Corporation (Principal) and its designated earthworks/construction contractor, dewatering contractor and environmental consultant. This document outlines strategies and procedural information on management controls for potential key ASS, groundwater and surface water risks resulting from dewatering, recharging and other construction activities, in line with the overarching Construction Environmental Management Plan (CEMP) prepared by GHD (GHD document #125191).

The objectives of this ASSDMP are to:

- provide ASS, dewatering, surface water and groundwater management monitoring measures/strategies/expectations to enable the DC to develop a DMP and the CC to develop a construction schedule prior to construction that ensures all project related activities are conducted in a manner that minimises potential impacts to the local groundwater, surface water systems and ensure that no dewatering effluent enters the Peel Harvey Inlet;
- provide mechanisms (where possible) to evaluate potential groundwater and surface water impacts to ensure such potential impacts are minimised or avoided during the construction phase; and

1.3 Relevant Guidelines

This Acid Sulfate Soil and Dewatering Management Plan (ASSDMP) has been written with reference to the following guidance documents:

- *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DEC, 2009)

- *Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes* (DEC, 2011)
- *Water Corporation Acid Sulfate Soil and Dewatering Management Strategy,* (Parson Brinckerhoff 2007).

2.1 Background on Acid Sulfate Soils

The classification of ASS includes both actual acid sulfate soils (AASS) and potential acid sulfate soils (PASS). AASS are soils that are generating acidity, whereas PASS are soils that have the potential to generate acidity.

ASS are soils containing naturally-occurring, fine-grained metal sulfides typically pyrite (FeS_2), formed under saturated, anoxic/reducing conditions. They generally occur in Quaternary (1.8 Ma – Present) marine or estuarine sediments, predominantly confined to coastal lowlands (elevations generally below 5 mAHD). Within these sediments, the majority of soils that present an environmental risk are generally confined to Holocene aged material (<10 000 years). Where these materials have oxidised, they commonly have a mottled appearance (orange and yellow discolouration) due to the presence of oxidised iron minerals.

Although soils described above represent typical conditions where ASS occurs, the presence of ASS materials is not limited to these soil types. In Western Australia, ASS materials have been identified in other soil types such as leached sands and silts. Accordingly, for areas where no data is available, the extent of ASS materials should be established through field investigations.

2.2 Potential Risks of AASS and PASS

When PASS are disturbed, either by excavation or lowering of the water table below natural seasonal levels, sulfides present are exposed to air, allowing oxidisation and consequently, the formation of sulfuric acid (H_2SO_4). AASS are capable of generating acidity in situ in their natural state; disturbance is not required for acidic discharges to develop.

As a result of the presence of AASS or the oxidation of PASS, surrounding land (soil) and nearby waterways may become acidic (pH<6.5). Under acidic conditions, metals such as aluminium (generally at pH<4.5) and iron, as well as trace heavy metals (including arsenic), become more mobile in the environment and can be taken up by infiltrating waters. As a result, surface and/or groundwater concentrations of these metals may reach concentrations which have the potential to cause acute or chronic toxicity to sensitive terrestrial and aquatic plants and animals.

Acidic conditions generated by ASS can also corrode concrete and steel (pipes, bridge abutments, underground services, and other infrastructure) and can result in the rapid deterioration of asphalt surfaces where they overlie AASS or PASS.

2.3 Management of ASS

Avoiding or minimising disturbance of ASS are the primary methods of management. Where avoiding disturbance is not possible, management techniques available for ASS can include:

- Chemical neutralisation (use of pure fine agricultural lime such as AgLime or a similar neutralising agent);
- Anoxic storage or placement of PASS below the water table and beneath clean non-ASS fill; and

- Hydraulic separation of pyrite from the soil (high maintenance process suitable for coarse grained sediment).

The addition of agricultural lime is the most common amelioration technique applied to acidic soils, where mechanical mixing is completed by plough or excavator to provide adequate homogeneity of the soil/sediment-lime mix.

2.4 Legislative Requirements in Western Australia

The following legislative requirements can apply to works involving ASS:

2.4.1 Western Australian Planning Commission Bulletin 64

The recently amended Planning Bulletin 64/2009 (PB 64/09) aims to provide advice and guidance on matters that should be taken into account in the rezoning, subdivision and development of land containing acid sulfate soils. PB 64/09 requires the identification, assessment and management of soils where:

1. The surface elevation is ≤ 5m AHD, and it is proposed to excavate ≥ 100m^3 of soil;
2. Where the surface elevation is ≥ 5m AHD, and it is proposed to excavate ≥ 100m^3, and the excavation depth is ≥ 2m; or
3. Where any dewatering works are to be undertaken.

2.4.2 Environmental Protection Act 1986

The Environmental Protection Act 1986 (EP Act 1986) provides for an Environmental Protection Authority, for the prevention, control and abatement of pollution and environmental harm, for the conservation, preservation, protection, enhancement and management of the environment and for matters incidental to or connected with the foregoing.

To prevent environmental harm, the EP Act 1986 established under Section 50A, states that, A person who –

(a) *causes serious environmental harm; or*

(b) *allows serious environmental harm to be caused;*

commits an offence.

Accordingly, all parties to a development must show that the environmental risk associated with the development has been assessed and minimised where possible.

3. Site Characterisation

Site characterisation details have been taken from the following sources:

- GHD Report for Dawesville Area 4A, *Acid Sulfate Soil and Groundwater Investigation* (revised August 2011) - document number 13499.
- GHD Report for Dawesville 5A, *Acid Sulfate Soil and Groundwater Investigation* (revised August 2011) – document number 13500.

3.1 Location

Reticulation Areas 4A and 5A in Dawesville are located on the shore of the Peel Harvey Estuary. Area 5A is the larger of the two areas and lies to the northwest of Area 4A. Area 5A is located approximately 1 km to the south of the inner mouth of the Dawesville Channel whilst Area 4A is approximately 3 km south of the Channel.

Area 5A is bounded by Tanjinn Way to the north, Hillway Street and Chapman Road to the south, the Peel Harvey Estuary to the east and Old Coast Road to the west. An aerial overview of the Area 5A is shown in Figure 1.

Area 4A is bounded by Hillway Terrace to the north, Durham Crescent to the south, the Peel Harvey Estuary to the east and Estuary View Road to the west. An aerial overview of the Area 4A is shown in Figure 2.

3.2 Climate

The average annual rainfall is variable (average since 2001 = 645 mm/yr) of which the wettest months (on average) are June and July with the months between December through to March having very low rainfall, averaging less than 20 mm/month (BOM 2012).

3.3 Land use

Reticulation Areas 4A and 5A in Dawesville are established residential areas on the shore of the Peel Harvey Estuary. The area between the Estuary and Estuary Road is designated as the Dawesville Foreshore Reserve. The Peel Harvey Estuary is part of the Peel-Yalgorup System which is a RAMSAR site and Conservation Category Wetland.

Estuary Road is a sealed road with drainage comprising part-kerbed and part-gravelled swale drains, discharging to the adjacent estuary. Numerous underground services are located along the western side of the road, alongside which the sewer is proposed. The proposed pumping stations will be located on the road and foreshore reserves.

3.4 Topography

Estuary Road lies at an elevation of between 1.0 m and 3.0 m AHD and is set back between 10 m and 50 m from the estuary shoreline. Beyond the road to the west, the land surface generally rises steeply, at around 1V:5H, locally up to 1V:3H, forming the eastern slope of a north-south trending irregular ridge. Site elevation to the west of Estuary Rd in Area 4A generally lies between 10 and 25 mAHD while elevations in Area 5A vary between 4 and 20 mAHD, with the highest elevations closest to Old Coast Rd in the west

3.5 Geological Setting

The Mandurah 1: 50,000 Urban Geology map sheet indicates the sewer line passes through Holocene-aged lagoonal deposits and Pleistocene to Holocene-aged Tamala consolidated limestone and limestone sand present along the shoreline of the Peel Harvey Estuary.

Holocene-aged lagoonal deposits comprise medium to coarse quartz sand and grey brown black humic sandy clays, silts and clayey sands. It is likely that the lagoonal deposits contain Potential Acid Sulfate Soils (PASS) and/or Actual Acid Sulfate Soils (AASS). Beneath the alluvium and mantling the higher ground to the west, above 2 m AHD is Pleistocene-aged Tamala Sand that is associated with leaching and weathering of the underlying Tamala Limestone. The sand is off-white to grey in colour near the surface, and becomes yellow at depth.

The underlying Tamala Limestone is mainly an eolian calcarenite and comprised of shell fragments, quartz grains and some feldspar. The limestone is generally off-white to cream in colour. It is anticipated that limestone (of varying cementation) will be located at shallow but varying depths throughout the reticulation area. Neither the Tamala Sand nor Tamala Limestone is likely to be ASS.

The findings of the geotech and ASS investigations validated the expected geological conditions outlined on the geological maps. Generally the following profiles were encountered in Area 4A and 5A:

3.5.1 Area 4A

- Brown, fine grained sand (imported fill) is present from approximately 0 to 0.5 - 0.8 m below ground level (bgl)
- Variable (pale to dark) grey to dark brown silty sand and sand layers of alluvial origin present from approximately 0.5 m to 3 m bgl. The depth of these layers varies across the site. These layers are moist and become increasingly wet at depth. These are the soil units that contain PASS.
- Variable thickness Tamala limestone below approximately 1 m to 3 m bgl. The depth of the limestone varies across the site. Three boreholes, BH5, PS14A and PS14B, were drilled in close proximity to each other at the pump station site. Of particular note is that whilst BH5 and PS14A met refusal on limestone at depths of 2.5 m and 3.0 m bgl respectively, borehole PS14B nearby did not encounter rock at the completion depth of 5.5 m bgl. Therefore, the

depth to bedrock varies significantly over short distances. It should be noted that all of the boreholes were located closer to the estuary than the proposed sewer alignment so it is likely that limestone may be encountered at a shallower depth along the alignment than in the boreholes, due to the closer proximity to the adjacent hill.

3.5.2 Area 5A

- Variable (pale to dark) grey to dark brown silty sand and sand layers of alluvial origin present from approximately 0.5 m to 3 m bgl, often with roots and a sulfurous odour. The depth of these layers varies across the site. These layers are moist and become increasingly wet at depth. These are the soil units that contain PASS.
- Below the alluvium in BH18 and PS7 (formerly PS13), light brown to light orange fine to coarse Tamala Sand was encountered, tending gravelly with depth.
- Variable thickness Tamala limestone below approximately 1 m to 3 m bgl. The depth of the limestone varies across the site.
- Refusal on Tamala Limestone occurred in boreholes BH8 and BH18, at 2.0 m and 3.0 m depth respectively.

3.6 Hydrogeology

Groundwater is present within 1m bgl in the shallow sandy material present across Areas 4A and 5A, GHD conducted baseline monitoring on all nine existing wells during October 2012. Results from these monitoring events indicate that dewatering will be required onsite during earthworks (based on current invert levels and groundwater levels). Likely locations and effluent volumes for each sewer are discussed further in Section and 6. 2 and 6.3.

A summary of recent groundwater levels is presented in Table 2.

Table 1 Summary of Groundwater Levels across Areas 4A and 5A

Area	Well ID	Surface Level ^ (m AHD)	Groundwater Standing Water Level (m bgl)	Groundwater Standing Water Level (m AHD)
5A	BH21	0.6	0.86	-0.26
5A	PS7S*	0.85	0.65	0.2
5A	PS7D*	0.85	0.65	0.2
5A	BH16*	0.8	0.49	0.31
5A	BH13*	0.53	0.49	0.04
5A	BH9A	1.25	0.98	0.27
4A	PS13S*	0.98	0.46	0.52
4A	PS13D	0.98	0.41	0.57
4A	BH1	0.8	0.6	0.2

^ Surface heights interpolated from 0.5 m contour information provided by Water Corporation.

* These bores were unable to be found during the site visit in September 2012 and were assumed to be destroyed since the initial investigation in 2007. They were redrilled on 9th and 10th October 2012. With the exception of BH21 which was monitored on 7th September 2012, the dip levels are taken from 15th and 16th October 2012.

Groundwater levels are anticipated to change due to seasonal variations and tidal flows from the Peel Inlet. As a result, the requirement for dewatering across both Areas during construction is likely to change depending on the timing of construction is undertaken. Dewatering may be minimised and/or not required in some areas if construction is undertaken at the end of "summer" (i.e. close to April).

It is assumed that there are a number of groundwater bores in Areas 4A and 5A that are used by residents for irrigation purposes. The bores that are likely to be affected (if any), will be the bores closest to the Foreshore where dewatering is planned for both Areas. Residents should be notified of the site works and these bores should be inspected pre and post construction to ensure they are functional before the construction and dewatering works begin and after all works have ceased.

3.6.1 Groundwater Quality Field Parameter Readings

Baseline groundwater monitoring was undertaken in October 2012 with all wells being monitored in the field using a water quality meter and flow cell. Readings were taken to ensure stabilisation of water quality parameters whilst purging and before sampling so that representative groundwater samples could be obtained.

Table 2 presents the water quality parameters (measured in the field) for each of the existing and recently redrilled groundwater wells.

Table 2 Groundwater quality field parameters for each well across both Areas

Area	Well ID	Date	Vol Purged (L)	pH	EC (µS/cm)	Temp (°C)	DO (%Sat)	DO (ppm|mg/L)	ORP (mV)
5A	BH21	07/09/2012	20	7.05	703	19.2	14.8	1.42	-123.4
5A	PS7S	15/10/2012	60	7.09	5116	19.3	4.7	0.43	-208.6
5A	PS7D	15/10/2012	2	7.32	12708	21.4	40.2	3.42	-18.7
5A	BH16	16/10/2012	30	7.21	6463	19.5	0.6	0.05	-156.8
5A	BH13	16/10/2012	30	7.06	7715	20.1	0.5	0.04	-114.8
5A	BH9A	16/10/2012	40	7.15	2558	19.4	20.8	1.9	-91.2
4A	PS13S	15/10/2012	40	7.23	2273	19.6	16.8	1.55	-169.7
4A	PS13D	15/10/2012	2	7.17	22158	20.2	19.8	1.64	-40.0
4A	BH1	15/10/2012	30	6.87	5390	19.6	10.7	0.97	-162.8

The field monitoring results indicate that the groundwater across Areas 4A and 5A along Estuary Rd is generally neutral pH, reducing, low in dissolved oxygen and (with the exception of BH21) brackish to saline in terms of salinity. The initial investigation undertaken by GHD (2007) highlighted the fact that groundwater results indicated the presence of a fresh groundwater and estuarine saltwater interface occurring within the surficial aquifer.

As part of the baseline groundwater sampling in October 2012, GHD recovered groundwater quality readings of pH, EC and oxidation-reduction potential (ORP) at 1 m bgl depth intervals for six of the wells across the Site. This was achieved by slowly lowering a water quality meter down groundwater wells and allowing readings to stabilise. The aim was to attempt to define the depth interval of the zone of diffusion (i.e. depth and thickness of the freshwater and saltwater interface). Results for Areas 4A and 5A are presented in Table 3 and 4 respectively.

Table 3 Electrical Conductivity values for two groundwater wells in Area 4A

Well ID	Depth (m)	pH	EC (µS/cm)	ORP (mV)
PS13D	1	7.9	3258	-58.5
	2	7.8	3704	-57.1
	3	7.63	5051	-50.4
	4	7.45	7419	-30.8
	5	7.31	9963	-1.8
	6	7.24	11327	1.7
	7	7.25	11544	-9.3
	8	7.27	12722	-29.0
	9	7.25	38858	-60.0
	10	7.22	31776	-66.9
BH1	1	6.85	5072	-95.4
	2	6.85	5076	-97.0
	3	6.85	5130	-105.2
	4	6.91	5181	-110.0

BH1

Groundwater quality parameters within BH1 are consistent down to 4 m bgl. The pH is neutral, the water is slightly saline and the ORP remained negative (reducing). These results suggest that the 4 m of groundwater at BH1 is within the zone of diffusion (mixing of freshwater and saltwater).

PS13D

Within PS13D, groundwater pH slightly decreases with depth to 10 m bgl but remains neutral. The ORP increases (becomes more positive) from the surface to 6 m bgl before decreasing and returning to reducing conditions from 7 - 10 m bgl. In addition, groundwater is brackish to 3 m bgl before becoming saline and steadily increasing to very saline between 9 and 10 m bgl. Although not well defined (likely due to tidal flows and mixing within the surficial aquifer sands), the saltwater interface appears to be prominent deeper than 8 m bgl at the proposed pump station 13.

Table 4 Electrical Conductivity values for two groundwater wells in Area 5A

Well ID	Depth (m)	pH	EC (µS/cm)	ORP (mV)
BH13	1	7.18	3091	-149.8
	2	7.14	3266	-149.0
	3	7.14	3250	-148.2
	4	7.21	5438	-141.2
	5	7.25	21375	-152.8
	6	7.28	13012	-161.9
BH16	1	7.38	4497	-149.2
	2	7.5	5212	-177.4
	3	7.56	5679	-186.6
	4	7.6	6251	-190.4
	5	7.64	5853	-195.3
BH9A	1	7.3	1119	-121.4
	2	7.19	2408	-82.9
	3	7.19	2432	-77.9
	4	7.2	2608	-75.8
	5	7.23	2609	-95.6
	6	7.65	2072	-176.6
PS7D	1	7.8	3706	-9.8
	2	7.68	4700	-6.0
	3	7.5	6614	-2.4
	4	7.37	9065	37.3
	5	7.29	10832	42.2
	6	7.26	11448	44.9
	7	7.27	11717	35.9
	8	7.29	12162	23.0
	9	7.25	32794	-47.9
	10	7.27	36484	-53.3
BH21	1	7.06	4488	-30.8
	2	7.07	4436	-36.1

BH13

Within BH13, groundwater pH remained consistently neutral down to 6 m bgl. Between 1 - 3 m bgl, groundwater is brackish before turning saline from 3 - 6 m bgl. The ORP decreases slightly (becomes more reducing) down the profile.

BH16

Groundwater pH within BH16 is neutral at each interval down to 6 m bgl, the water is slightly saline with only small variations at depth and the ORP values become very reducing towards 6 m bgl.

BH9A

Groundwater pH within BH9A is neutral at each interval down to 6 m bgl, the water is slightly brackish with only small variations at depth and the ORP values are all reducing with heavily reducing conditions at 6 m bgl.

PS7D

Within PS7D, groundwater pH remained consistently neutral down to 10 m bgl. Groundwater is brackish between 1 - 2 m bgl before turning saline from 3 - 10 m bgl. The ORP is slightly reducing down to 3 m bgl before becoming oxidising between 3 – 8 m bgl and switching back to reducing conditions at 9 and 10 m bgl.

BH21

Groundwater quality parameters within BH21 are consistent down to 2 m bgl. The pH is neutral, the water is slightly saline and the ORP remained negative (reducing). These results suggest that the 4 m of groundwater at BH1 is within the zone of diffusion (mixing of freshwater and saltwater).

Summary

Monitoring at each of the locations (to the depths tested) has revealed that groundwater pH is generally neutral with only slightly variation either way (i.e. slightly acidic or slightly alkaline).

The zone of diffusion (i.e. where fresh and salt water are mixing) cannot be determined based purely on the results above. The results above in Table 3 and 4 suggest that there is saline groundwater at depth; however the interface is not well defined along the Estuary across both Areas. This may be due to the following reasons:

- Tidal flows (average daily tidal fluctuations ranging between approximately 0.1 – 1.0 m)[2];
- Site topography (assuming groundwater has a higher hydraulic gradient and a higher volume of fresh water is flowing through the aquifer towards the sea, pushing the interface boundary seaward); and/or

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[2] *Source: Bureau of Meteorology (2012)*

- Active saltwater encroachment caused by local residents pumping for irrigation purposes (if pumping of fresh groundwater is of sufficient intensity to cause the cone of depression to intersect with the shoreline, then active saltwater encroachment will occur).

Generally groundwater within the top 2 m bgl, which is typically where most of the dewatering for this project will be abstracted from, is brackish to slightly saline. It is likely however that if continuous dewatering for long periods for construction of the pressure mains and open trench gravity-fed sewers in both Areas is conducted, very saline water may be drawn up the groundwater profile and dewatered as a consequence. This may have implications on the disposal of the dewatering effluent.

3.6.2 Groundwater Laboratory Analyses

General

A summary of the most recent groundwater results are presented in Appendix A. Most of the wells were sampled using a 12 vt "high flow" groundwater pump to abstract groundwater samples however samples within the deeper pump station bores (PS7D and PS13D) were collected using a low flow peristaltic purging method (which does not disturb the wider aquifer and obtains a representative sample from the chosen depth interval). "High flow" sampling (6 L/min) results in at least 3 well volumes being purged prior to sampling and mimics (on a smaller scale) dewatering and how groundwater parameters may change during dewatering. ""Low flow" sampling (0.5 L/min) from the deeper bores provides an accurate indication of how saline the groundwater is at depth.

Based on groundwater analytical results from nine monitoring wells onsite (BH1, PS13S, BH13D, BH9A, BH13, BH16, PS7S, PS7D and BH21) collected during October 2012, groundwater quality across both Areas indicates that the groundwater is neutral to slightly alkaline pH with low total acidity (< 40 mg/L), high alkalinity (> 200 mg/L) with generally high levels of total metals (specifically aluminium and iron) however significantly lower dissolved metals.

Metals

Groundwater at PS13D and BH1 contain dissolved aluminium concentrations that exceed the Fresh Waters criteria of 0.055 mg/L with results of 1.81 mg/L and 1.05 mg/L respectively.

With the exception of PS7D, all samples returned elevated total iron concentrations which exceed the ANZECC guidelines for Fresh Waters (2000) with values ranging from 1.3 mg/L (BH21) to 18.7 mg/L (BH9A). Dissolved iron concentrations were significantly lower than total concentrations with values ranging from < 0.05 mg/L (BH21, BH9A and PS14B) up to 3.4 mg/L (PS7S) however PS7S, PS13S, PS13D and BH1 all exceeding the dissolved iron concentration for Fresh Waters (ANZECC, 2000).

The sample for PS7S returned a dissolved arsenic concentration of 0.032 mg/L, which exceeds the Fresh Water guideline of 0.013 mg/L.

The samples collected from BH9A, PS7S, PS13D and BH1 had dissolved cobalt concentrations equal to the Marine waters trigger value of 0.0001 mg/L (ANZECC, 2000). Furthermore, BH21, PS7S, PS13D and BH1 as well as PS14B recorded dissolved copper values exceeding the Marine waters trigger value.

There were no other ANZECC (2000) guideline exceedances recorded for any of the samples from the other wells.

Oxidation of Sulfides

Chemical indicators that may indicate the oxidation of sulfides include:

- An alkalinity:sulfate ratio less than 5;
- A chloride:sulfate ratio less than 2; and/or
- A pH of less than 5
- A soluble aluminium concentration of greater than 1 mg/L *Source: DEC, 2011*

Only two samples, PS13D and BH1, had soluble aluminium concentrations greater than 1 mg/L.

None of the samples collected across the Areas have chloride:sulfate ratios less than 2. However care must be taken when assessing the chloride:sulfate ratios in areas of interface between brackish and fresh water (DEC, 2011). The ratio of chloride (Cl) to sulfate (SO_4) (by mass) in seawater is generally constant, at approximately 7.2 (in seawater the concentration of chloride is approximately 19,400 mg/L and sulfate is approximately 2,700 mg/L). Estuaries can be expected to have a similar $Cl:SO_4$ ratio and therefore in these environments, the alkalinity:sulfate ratio is more relevant. All nine samples collected during the baseline monitoring event returned alkalinity:sulfate ratios less than 5 indicating that the groundwater has been or is being subject to an extra source of sulfate from previous sulfide oxidation (DEC, 2011)

However, none of the samples contain pH values less than 5. This may be, in part, explained by the inherently high pH values associated with coastal groundwater systems and the dissolution of the limestone bedrock allowing high concentrations of carbonate ions to be released into the groundwater providing inherent buffering capacity. In either case, the groundwater should contain adequate buffering capacity to maintain pH levels in the future.

Results from the latest monitoring event for each well are considered to represent baseline groundwater geochemistry across the Site. It should be noted however that groundwater geochemistry may change between the time this report is written and the commencement of construction. As such, groundwater sampling should be undertaken two weeks prior to commencement of construction of the sewer.

3.6.3 Groundwater Vulnerability to Acidification

To determine the vulnerability of groundwater to acidification (and therefore where groundwater liming treatment may be required as part of dewatering activities), pH, acidity and alkalinity were graphed using results from the latest groundwater monitoring rounds running from the northeastern corner of Area 5A down to the southeastern corner of Area 4A (Appendix B). The graph can be viewed as a generalised “cross section” of the groundwater quality along Estuary Rd, from the northern end of Area 5A (BH21) to the southern end of Area 4A (BH1).

The graph shows that pH remains within a tight neutral tending slightly alkaline range of pH 7.45 to 8.05, acidity remains below 40 mg/L and alkalinity remains above 200 mg/L. Total alkalinity is at least 10 times the total acidity in each of the wells therefore indicating that groundwater has significant buffering capacity which should be adequate to maintain pH levels against incidental acid generation from any PASS onsite.

3.6.4 Potential Groundwater Treatment Areas

For the purposes of groundwater risk assessment, a groundwater acidification risk matrix table has been prepared to summarise geochemical data collected from the recent baseline groundwater monitoring event undertaken by GHD in October 2012 (Appendix C). A summary of this matrix is presented in Table 5 to characterise the risk of groundwater acidification and determine where groundwater treatment (liming, aeration or settlement with geofabric) may be required as part of proposed dewatering works.

Table 5 Groundwater Acidification Risk across Areas 5A and 4A

Area	Well ID	Date	Groundwater Acidification Risk	Groundwater treatment likely to be required
5A	BH21	07/09/2012	Low	Unlikely
5A	PS7S	15/10/2012	Low	**Possible**
5A	PS7D	15/10/2012	Low	Unlikely
5A	BH16	16/10/2012	Low	Unlikely
5A	BH13	16/10/2012	Low	Unlikely
5A	BH9A	16/10/2012	Low	Unlikely
4A	PS13S	15/10/2012	Low	**Possible**
4A	PS13D	15/10/2012	Low	**Possible**
4A	BH1	15/10/2012	Low	**Possible**

Generally, the risk of groundwater acidification across both Areas is low. Based on the groundwater geochemistry, it is not anticipated that groundwater will require lime dosing. However aeration and settlement (with geofabric curtains) will likely be required for groundwater abstracted from PS13S, PS13D and BH1 (all wells in Area 4A). The samples from these wells returned elevated total and/or dissolved aluminium concentrations (> 1 mg/L). This will likely be the case for any dewatering effluent abstracted from in the vicinity of pump station No. 7 (PS7S) which returned elevated total and dissolved iron concentrations (> 1 mg/L). Disturbance as a result of dewatering may result in mobilisation of these colloidal and /or particulate iron and aluminium compounds.

It is recommended that a dewatering system that incorporates aeration, settlement and geofabric filtration processes is set up and used as a minimum level of dewatering treatment, to remove suspended (particulate/colloidal) iron/aluminium compounds.

It is recommended that a lime dosing unit be kept on standby for all discharge locations in the event that the groundwater does begin to show signs of acidification. This will prevent excavation/dewatering works from ceasing while mobilising a unit to site.

3.6.5 Aquifer Permeability Testing

Slug testing was conducted on eight wells across both Areas (three in Area 4A and five in Area 5A). Slug testing is a particular type of aquifer test where a known volume of water is quickly added or removed from a groundwater well, and the change in hydraulic head is monitored through time, to determine the near-well aquifer characteristics. It is a method used by hydrogeologists and civil engineers to determine the transmissivity/hydraulic conductivity and storativity of the material the well is completed in.

The testing involved lowering (and removing) a 50 mm diameter solid cylinder into the well’s water column to achieve an abrupt rise (and fall) in local water level. Utilising a down hole pressure logging device and laptop, real time data was observed during the tests to ensure reliable field data was collected and that slug testing was an appropriate method (depending on the properties of the aquifer and the size of the slug, the water level may return to pre-test levels very quickly thus complicating accurate collection of water level data).

Hydraulic conductivity values are estimated using the data gathered by analysis in AQTESolv (aquifer test solving software). Bouwer-Rice solutions were used to estimate hydraulic conductivities as it is one of the more representative solutions for surficial, unconfined aquifers.

3.6.6 Permeability Estimations

Results from the field hydraulic conductivity tests are given below in Table 6 (interpretation method used in AQTESolv is given). The data was interpreted as slug tests with both drawdown and recharge curves being analysed in AQTESolv to produce values for hydraulic conductivity. AQTESolv outputs are presented in Appendix D.

Table 6 Hydraulic Conductivity Estimations (generated from AQTESolv)

Area	Well ID	Hydraulic conductivity (m/s)	Length of Screened Interval (m bgl)	Screened Interval (m bgl)	AQTESolv Interpretation Solution	Superficial Aquifer Conductivities based on Lithology (Davidson, 1995)
5A	BH21	1.25E-05	2	1.0 - 3.0	Bouwer-Rice	Fine SAND
5A	PS7S	3.30E-05	3	0.97 - 3.97	Bouwer-Rice	Fine to medium SAND
5A	PS7D*	-	3	6.98 - 9.98	Bouwer-Rice	-
5A	BH16A	1.80E-05	4	1.26 - 5.26	Bouwer-Rice	Fine SAND
5A	BH13A	2.14E-05	4.5	1.26 - 5.76	Bouwer-Rice	Fine SAND
5A	BH9A	3.42E-06	4.5	0.46 - 4.96	Bouwer-Rice	Very Fine SAND

4A	PS13S	4.32E-06	3	0.79 - 3.79	Bouwer-Rice	Very Fine SAND
4A	PS13D	2.19E-05	3	4.95 - 7.95	Bouwer-Rice	Fine SAND
4A	BH1A	2.70E-05	4.5	0.3 - 4.8	Bouwer-Rice	Fine SAND

** The data for the slug test on PS7D was too erratic to be used and generate a meaningful conductivity value.*

Values of hydraulic conductivity between 3.42E-05 m/s (BH9A) and 3.30E-06 (PS7S) were calculated, with the average value along the foreshore being 1.77E-05 m/s. These values are within the range of literature values for very fine to medium sands (Davidson, 1995), and are reflective of the fairly consistent lithology along Estuary Rd (alluvial sands of variable density).

The highest conductivity value across the Site was obtained in the shallow well PS7S, at the site for the proposed pump station 7. The lowest conductivity value was obtained from well PS9A, just north of Hillway St along the Estuary Rd.

There are many assumptions associated with slug testing that do not always apply and it should be noted that the values presented in Table 6 are only estimations and specific to each of the localised well locations they were obtained from. Values are anticipated to vary due to the inherently heterogeneous soil profiles and the irregular occurrence of limestone bands noted in the GHD geotechnical report (2005) near pump station No. 7 and No. 13. along the foreshore area.

4. Acid Sulfate Soil Management Plan

4.1 Rationale

In accordance with DEC guidelines, *Treatment and Management of Soil and Water in Acid Sulfate Soil Landscapes* (2011), if works including excavation and/or dewatering are to occur in an ASS area, an acid sulfate soil and dewatering management plan (ASSDMP) is required to minimise any potential effects on the surrounding environment. Construction of the pressure main sewers and gravity fed sewers using open cut trenching in Reticulation Areas 4A and 5A along Estuary Road will result in the excavation of PASS. Furthermore it is anticipated that dewatering will be required in these areas identified as containing PASS, making it imperative that the soils be managed to prevent oxidation and subsequent acid generation onsite.

This management plan has been prepared on the assumption that excavation, construction and dewatering works will be completed by contractors that will be supervised by the Water Corporation's Superintendent.

4.2 Overview of Proposed Works

The proposed construction works for the installation of the pump stations and the sewer network in Dawesville will include;

- Stripping of topsoil (0 – 0.3 m bgl) and stockpiling for reuse onsite;
- It is understood that excess excavated PASS will likely be loaded onto plastic lined trucks and disposed at an appropriate facility where the necessary treatment and validation will be undertaken. It is anticipated that minimal PASS will be stockpiled onsite, treated and reused due to the lack of space along the Dawesville foreshore area;
- The excavation depth of open trenches along Estuary Rd for both Areas will be to a maximum depth of 2.0 m bgl;
- The excavation depth of caissons along Estuary Rd will range from 1.3 – 6.6 m bgl;
- The excavation depth of the caissons at pumping station 7 and 13 will be approximately 10 m and 8 m bgl respectively.
- It is anticipated that dewatering will be required along the pressure mains and gravity-fed sewer alignments in both Areas. These are planned to be open trench installations.
- Dewatering will be required to abstract water contained in the caissons along Estuary Rd once sewers have been installed between caissons.

A staged construction sequence for works along Estuary Road is presented in Section 6.1.

4.1 Protection of Access Chambers from ASS attack

Precast concrete pumping station and access chamber structures to be installed in boring caissons will not need protection from ASS or saltwater attack as the caissons will provide a protective barrier.

4.2 Treatment Areas

4.2.1 Area 4A Foreshore

Construction of the gravity fed sewer, pressure main and Pump Station 13 in Reticulation Area 4A will result in the excavation of PASS and dewatering will likely be required in these areas identified as containing PASS.

The ASS investigation undertaken by GHD (2007) indicated that PASS is generally present in soils from 0.5 to 3 m bgl at the locations where BH1-BH5 and PS No. 13 (formerly known as "PS14A") were drilled. No PASS was encountered in BH6 to 3 m bgl and BH7 to a depth of 1 m bgl. The results from the 2007 investigation are presented in a summary table in Appendix E.

Based on these results, PASS will likely be disturbed when constructing the:

- Open trench Pressure Main from PS No. 13 heading north to Hillway Street with an invert level within 1.5 m bgl, running from CH0-CH110 on GHD drawing IP06-2-1-B covering a distance of approximately 110 m;
- Open trench gravity-fed sewer from caisson (C) 7767 south to access chamber (AC) 7772 with an invert level ranging between 1.5 – 2.3 m bgl, covering a distance of approximately 200 m;
- Boring caissons C7749, C7750, C7751, C7767, C7783, C7788, C7790, C7793 and interconnecting sewers along Estuary Rd from 0.5 m bgl – invert level;
- Access chambers/maintenance shafts including AC7768, AC7773, AC7774, AC7748, AC7752, AC7753, AC7754, AC7784, AC7789, , AC7791, AC7792, AC7794 and interconnecting sewers along the western verge of Estuary Rd from 0.5 m bgl – invert level; and
- Gravity-fed sewer, to be installed using trenchless technology, from C7767 to C7790 (distance of approximately 640 m) with invert levels ranging within 4.0 m bgl. It is not anticipated that significant volumes of PASS will be disturbed during this activity however any material excavated during construction must be treated and managed as outlined in Section 4.3.

Figure 4 presents a map of the areas where excavation of soil for construction will require treatment. The depths and liming rates are listed in Table 11 of Section 5.

4.2.2 Area 5A Foreshore

Construction of the gravity-fed sewer, pressure main and Pump Station 7 in Reticulation Area 5A will result in the excavation of PASS and dewatering will likely be required in these areas identified as containing PASS.

The ASS investigation undertaken by GHD (2007) indicated that PASS is generally present in soils from 0.5 to 3.0 m bgl at locations where BH8, BH9 and BH11-BH16 were drilled. BH19 at a depth of 2.5 m bgl and BH21 at a depth of 0.5 m bgl also had net acidity exceedances indicating PASS. The results from the 2007 investigation are presented in a summary table in Appendix E.

Based on these results, PASS will likely be disturbed when constructing the:

- Open trench Pressure Main from PS No. 7 heading south to Loton Rd verge with an invert level within 1.6 m bgl, running from CH225-CH320 on GHD drawing IP07-2-2-B, covering a distance of approximately 95 m;
- Open trench gravity-fed sewer from C8054 south to C8055 with an invert level ranging between 1.3 – 2.0 m bgl, covering a distance of approximately 92 m;
- Open trench gravity-fed sewer from C8153 north to AC8156 with an invert level ranging between 1.3 – 1.6 m bgl, covering a distance of approximately 90 m
- Boring caissons C8039, C8040, C8041, C8042, C8043, C8044, C8045, C8046, C8047, C8048, C8049, C8050, C8051, C8052, C8053, C8054, C8135, C8137, C8138, C8149, C8150, C8153 and interconnecting sewers along Estuary Rd from 0.5 m bgl – invert level;
- Access chambers/maintenance shafts including, AC8055, AC8056, AC8057, AC8061, AC8062, AC8063, AC8064, AC8072, AC8081, AC8082, AC8083, AC8086, AC8136, AC8151, AC8152, AC8154, AC8155, AC8156, AC8157, AC8158, AC8179 and interconnecting sewers between 0.5 m bgl – invert level ; and
- Gravity-fed sewer, to be installed using trenchless technology, from PS No. 7 (C8039) to C8153 (distance of approximately 1,400 m) with invert levels ranging within 6.6 m bgl. It is not anticipated that significant volumes of PASS will be disturbed during this activity however any material excavated during construction must be managed as outlined in Section 4.3.

Figure 3 presents a map of the areas where excavation of soil for construction will require treatment. The depths and liming rates are listed in Table 12 of Section 5.

4.2.1 Lime Dusting Open Trenches

As a precautionary measure to attempt to prevent any acid generation onsite (and consequent groundwater acidification and mobilisation of heavy metals) from open trenching techniques, GHD recommends that all open trenches (bottom and sides) be lime dusted if any of the following events take place:

- If open trenches remain “open” for 18 hours or longer; OR
- If the open trench excavation has required dewatering to allow construction to occur; OR

- If PASS material, as identified in Section 4.2.1 and 4.2.2, has been removed and is disposed offsite (i.e. no soil has been treated and used as backfill onsite).

Fine agricultural grade lime with an effective neutralising value (ENV) of greater than 70% should be used for this purpose.

4.3 Management Options

The acidic soils may be managed by either:

1. **Avoidance of acidic/potentially acidic materials;**
2. **Excavation and offsite transport to a licensed ASS treatment facility; or**
3. **Onsite treatment and neutralisation.**

Where avoidance of ASS disturbance is not possible, the following strategies outlined in Sections 3 and 4 should be implemented to ensure minimal environmental harm occurs as a result of earthworks.

As presented in Figures 3 and 4, the gravity fed sewer, pressure main and certain caissons, access chambers and maintenance shafts along the foreshore in Areas 4A and 5A have been highlighted as traversing PASS zones that will requires treatment and management once excavated.

4.4 Roles and Responsibilities

For efficient and successful implementation of the ASSMP, the following parties will be responsible for each of the items detailed in Table 7 below.

Table 7 Roles and Responsibilities – ASS Management

Role	Responsibility
Principal (Water Corporation)	Definitive responsibility for implementation of the ASSMP
Superintendent (Appointed by Water Corporation)	Supervision that construction works are implemented in accordance with the ASSMP on behalf of the Principal
Principal Environmental Consultant (Appointed by Water Corporation)	Provide technical advice and services to Principal, Superintendent, contractors, governmental regulatory authorities regarding the ASSMP Ensure that ASSMP is technically sound and assess its effectiveness during construction by way of regular auditing of Earthworks Contractor and monitoring requirements.
Earthworks Contractor	Responsible for excavation of soils, soil

(Appointed by Water Corporation)	treatment/validation, offsite disposal, stockpile management including construction of guard layers and leachate collection ponds

4.4.1 Responsibility Flow Charts and Daily Field Record Sheets

A flow chart outlining the *Actions* and *Responsibilities* in relation to Acid Sulfate Soil management is included as Chart 1, Appendix F. It is anticipated that this flow chart will be distributed amongst the contractors at the start of the construction phase to compliment and disseminate the information contained within this management plan. An example Daily Contractor Field Sheet is also included in Appendix G. The daily field sheet outlines all daily field measurements that are required to be recorded, in relation to ASS management, by the appointed contractor and submitted to Water Corporation on a weekly basis.

4.5 Excavation of Potentially Acidic Soils

4.5.1 Topsoils (0 – 0.3 m bgl)

For the purpose of this project, topsoil is defined as material within the top 300 mm of the soil profile containing vegetative matter. The revised ASS management guidelines (DEC 2011) suggest that if topsoils have an *in situ* pH (pH_F) > 5.0 then neutralisation treatment is not required. This is due to the naturally acidic nature of topsoil sands in WA and the relatively low risk/ability of these materials to release metals and metalloids into the soil profile and induce acid generating reactions.

All topsoil results obtained from bore locations drilled along Estuary Drive in the 2007 investigation returned pH_F values > 5 and therefore will not require treatment or any specific management during construction.

4.5.2 Limestone

Any limestone rocks or boulders encountered during excavation within the identified ASS zones in Tables 11 and 12 will not require treatment or any specific management.

4.5.3 Potential Acid Sulfate Soils

Where soil is required to be disturbed within the identified ASS zones (as defined in Section 4.2), it will require treatment prior to backfilling as per the liming rates outlined in Table 11 and 12 in Section 5.2.4. If ASS is not being treated onsite, refer to Section 4.6.2.

Following excavation, untreated ASS can be openly stockpiled (prior to disposal offsite or reuse as backfill) without a guard layer as per the criteria outlined in Table 8.

Table 8 Short Term Stockpiling

Type of Material		Duration of stockpiling	
Texture Range	**Approx. clay content (%)**	**Days**	**Hours**
Coarse Texture	< 5	Overnight	18 hours
Medium Texture	5 - 40	2.5 days	70 hours
Fine Texture	> 40	2.5 days	70 hours

As identified by the soil investigation, the coarse texture range should be adopted (as a conservative measure). Accordingly, the maximum time the material may be stockpiled without treatment will be 18 hours. **This does not remove the requirement for treatment. The term 'without treatment' applies to stockpiling purposes only.**

If the material unable to be treated within 18 hours then the stockpile must be placed on purpose built limestone guard layer. The specifications for the guard layer construction and stockpiling methodologies are detailed in Section 4.5.3.

4.5.4 Stockpile and Neutralisation Methodologies

The following guard layer construction and stockpiling methodologies should be adhered to if excavated ASS is not treated within an 18 hour period of excavation:

1. Specified areas of the site will be set aside for neutralisation activities.
2. A limestone containment area, underlain by a robust limestone guard layer, will be constructed at the neutralisation site upon which acidic materials will be treated. The purpose of the guard layer will be to prevent/neutralise potential leakages of acid and potentially acidic materials from the stockpile to the underlying ground surface and the surrounding environment.
3. The guard layer will be constructed with a thickness of 250 mm +/- 25 mm of "pit-face" limestone material, neither crushed nor screened, containing occasional stones to a maximum of 75 mm, overlain by a thickness of 100 mm agricultural lime (particle size < 0.3 mm).
4. A crushed limestone bund with a minimum height of 300 mm above the finished surface of the guard layer will be constructed around the perimeter of the guard layer to contain any leachate and divert stormwater around the treatment area.
5. Drainage from the bund will be collected in one or more collection basins with an impermeable (HDPE or GCL) lining and a layer of crushed lime, and with a combined minimum capacity of 50 m^3.
6. Any leachate will be monitored for pH and TAA, with the results recorded and sent to the Principal's Environmental Consultant for advice on management.
7. All components of the limestone containment area and leachate pond will be inspected daily by the EC and repairs will be made accordingly to maintain the integrity of the infrastructure.

8. If the Contractor elects to treat ASS onsite, excavated acidic soils that will exceed the short-term stockpiling specifications (Table 8) will be carted directly to the treatment area for neutralisation.

9. The maximum height of the stockpiles **should not exceed 2 m**.

10. The sides of the stockpiles will be battered to prevent excess runoff and scouring.

Note: All stockpiles should be appropriately labelled clearly stating the following information:

– Date and time of when the first material was excavated and stockpiled (e.g. chainage, ASS zones, etc); and
– Soil texture of the stockpile.

These labels should be checked daily ensuring that ASS materials are appropriately treated and/or managed through strategies mentioned in this document.

4.6 Neutralisation Methodologies

4.6.1 Onsite treatment

It is preferred that the identified ASS material is treated onsite and reused as backfill in the pipeline trench (although it is noted that there is generally a lack of space within the infill areas and that, due to the emplacement of pipe and bulking factors, excess spoil is likely to be generated). The treatment methodology is not defined in this management plan and is left to the discretion of the Contractor. Provided that the validation sampling (as detailed in Section 4.6.3) indicates that the ASS has been effectively neutralised then the treatment objective is deemed to have been met.

Standard industry practice for neutralising ASS includes;

- Automated treatment and mixing machinery e.g. LAT 150; and
- Manual methods e.g. front end loader, disc harrows, agricultural cultivators etc.

The preferred method for treating the ASS material is the automated treatment and mixing machinery (such as LAT 150) however the use of this machinery is expensive.

The benefits of this method of treatment include:

- Liming rates can be set/adjusted and are automatically administered
- Liquid lime (CaOH) is injected to effectively neutralise any existing acidity and AgLime granules are also added to provide ongoing buffering for any potential acidity generation.
- Neutralising agent is evenly distributed throughout the material and the machines generally remain effective with saturated soils with a high clay fraction.
- Given the accuracy and even distribution of the neutralising agent administration within the machine, validation testing requirements can be reduced to include limited confirmatory

SPOCAS testing only. The SPOCAS results are then used to basically calibrate the machine and the calculated liming rates.

- The use of these machines is the Department of Environment and Conservation and GHDs preferred method for onsite ASS treatment.

4.6.2 Offsite treatment

If the Contractor elects to excavate and transport soils offsite to a licensed treatment facility, it is recommended that the soils are immediately dispatched to the facility after excavation. Where the Contractor cannot immediately dispatch samples to the facility, it will be necessary to stockpile soils onsite as per Section 4.5.3. The duration of stockpiling of excavated soils is subject to the criteria outlined in Table 8. If the contractor elects to dispose of PASS offsite, the nominated licensed treatment facility should be consulted as to what information they require. Offsite treatment facilities will generally require analytical test results (i.e. SPOCAS or CRS results) for calculating liming rates and treating the PASS accordingly. However, there may be instances where the licensed treatment facility will collect pre-validation stockpile samples and analyse them for pH screening and then schedule SPOCAS testing to obtain more representative net acidity values for each stockpile delivered to the facility. In either case, as long as the facility undertakes the correct pre-validation sampling (if required) and validation sampling in accordance with the minimum number of samples for stockpiles as per Table 9 in Section 4.6.3 below, and the resulting net acidity for the treated soil is below 18.7 mol H^+/t, the soil will be considered effectively neutralised.

4.6.3 Validation Sampling

If the Earthworks Contractor elects to excavate and treat PASS onsite, the Contractor will liaise with the Principal's Environmental Consultant to arrange for validation sampling of the neutralised material prior to reuse of the material. The preferred approach to validation sampling is for it to be undertaken directly by the Principals' Environmental Consultant. However, where this may prove logistically difficult and impractical, alternative arrangements can be established in order to reduce costs and stand down time on the project. Such arrangements may include onsite training for the contractor by the Principal's Environmental Consultant (to allow the contractor to carry out the validation sampling and pH screening testing). This arrangement will require strict instructions from the environmental consultant as to sample collection and how to conduct the pH screening tests. Occupational health and safety measures will need to be implemented as the testing involves the use of 30% hydrogen peroxide. This arrangement should be supplemented with regular auditing of the validation sampling and testing process during the course of the project (auditing to be aligned with other site visits e.g. routine groundwater and dewatering effluent monitoring to save on mobilisation and disbursement costs).

The number of samples required will be determined in accordance with *Table 4 of Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DEC, 2009) are presented in Table 9.

Table 9 Minimum Number of Validation Samples to be collected from stockpiles (DEC, 2009)

Volume (m^3)	Number of Samples
< 250	2
251 to 500	3
501 to 1000	4
> 1,000	1 per 500 m^3

The samples will require testing at a rate of 100% for pH screening testing with approximately 25% analysed for the confirmatory SPOCAS testing. The 25% of samples selected for SPOCAS analysis will comprise the sample/s with the lowest recording pH_{FOX} value (from the pH screening testing). SPOCAS analysis should only be undertaken by a NATA accredited environmental laboratory.

Neutralisation will be deemed successful if the net acidity value (determined from SPOCAS analysis of the stockpile sample with the lowest recording pH_{FOX} value) is less than 18.7 mol H^+/tonne (0.03 %S equivalent). The confirmatory results along with pH screening results will be collated for use in the closure report for the project. If the Principal elects to have a laboratory analyse treated ASS samples, the EC should allow for a period of approximately 48-72 hours (excluding weekends) for the receipt of pH screening results and a further 72-96 hours for receipt of SPOCAS results. In total, a period of approximately 1 week (excluding weekends) should be allowed for the receipt of laboratory validation results.

Experience has indicated that average pH_{FOX} screening results > 6 return SPOCAS results with net acidity less than the DEC Action Criteria. This approach ensures works are not held up by lack of space or reusable materials. If the average validation sample result does not comply with the pH criteria, additional treatment by the EC should occur within 24 hours, and retesting will need to be undertaken. Alternatively, material can remain stockpiled to wait for confirmatory laboratory results (i.e. SPOCAS results).

If validation sampling returns net acidity greater than DEC action criteria of 18.7 mol H^+/tonne (or 0.03% S), the following courses of action are suggested:

- Reliming of the stockpile, remixing and retesting;
- Revision and potential increase of liming rate to prevent reoccurrence; and/or
- Mixing method revised.

4.6.4 Reuse of Treated Material

Provided the validation sampling results are acceptable (net acidity < 18.7 mol H^+/t), treated material can be stockpiled for reuse, or blended and reused as part of ongoing earthworks.

4.6.5 Reporting

The Earthworks Contractor will prepare and maintain a log of the treatment operation. The log will track the total volume of ASS disturbed, the quantity and type of neutralising agent used, the dates over which the treatment operation ran and the stockpile location of the excavated material. The log will be submitted to the Principal's Environmental Consultant and Superintendent at the end of each week. An example Daily Field Record Sheet has been included in Appendix F.

The reporting requirements have been outlined in Table 10.

Table 10 Reporting Requirements – ASS Management

Responsibility	Item	To Whom	Timing
Earthworks Contractor	A clear method statement of their proposed treatment regime for ASS material	**Superintendent**	As requested prior to award of contract.
Earthworks Contractor	Log of the excavation and treatment operation. The log will track the total volume of ASS disturbed, the dates over which the operation ran, the quantity and type of neutralising agent used and (if applicable) stockpile location.	**Principal Environmental Consultant**	At the end of each week.
Principal Environmental Consultant	Soil validation sampling results and advice.	**Superintendent / Contractor**	Within 48-72 hours of receipt of samples (field tests only) (Monday to Friday Only)
Principal Environmental Consultant	Final closure report.	**Principal / DEC (if requested by the Principal)**	On completion of earthworks and dewatering.

5. Liming Rate Calculation

5.1 Introduction

Guidance on the determination of liming rate is provided in DEC document, *Treatment and management of soils and water in acid sulfate soil landscapes* (DEC, 2011). For the purposes of this management plan, an example for the calculation of effective neutralising value (ENV) has been provided in Appendix H. It should be noted that this is only an example to aid the Contractor in determining the liming rate for the site.

It is very important that the information in Section 5.2 is read in conjunction with the details in the rest of this section as a number of fundamental underlying assumptions have been made. If for any reason there is a change in the underlying assumptions, the AgLime application rate would need to be correspondingly, using the formula provided in Section 5.2.

The most probable change anticipated at this stage would be an adjustment to the Effective Neutralisation Value (ENV), should there be either a change in the grading of the lime material being supplied and/or a change in the supplier. It is important that product information sheets (PIS) that are representative of the lime being supplied are periodically obtained from the supplier and used to confirm or re-calculate the ENV.

If excavation in any part of the subject area is undertaken to a greater depth than the notional depth of excavation or previously tested, the Contractor must collect additional samples to assess the acid generating potential which may result in the implementation of an alternative liming rate.

The maximum net acidity value in each Area has been utilised for calculation of the lime application rate.

5.2 Calculation of Liming Application Rate

The following formula is used to calculate the AgLime application rate (sourced from DEC, 2011):

Lime Application Rate (kg/m^3 of ASS material) =

Target Liming Rate (kg $CaCO_3$/t of soil) x soil density x ENV (100/ % ENV value)

5.2.1 Target Liming Rate

The target liming rate is calculated using the results of SPOCAS testing and is based on pure fine AgLime ($CaCO_3$) assuming a Neutralisation Value (NV) of 100% and using a safety factor of 2. Formulae for calculating the Target Liming Rate and tables of Target Liming Rates for various values of equivalent S% obtained from SPOCAS tests are provided in DEC (2011).

For the purposes of this project, it should be noted that the target liming rate has been calculated utilising the highest net acidity identified on Site (within each Area).

5.2.2 Soil Density

The soil density that is required in the formula is the density of the soil at the time it is being treated, and hence would vary depending on whether the soil is in a loose or compacted state. Dry soil masses should be used since analyses are reported on a dry weight basis. An approach that has been undertaken by contractors in the industry is to adopt the *in situ* dry soil density quoted in geotechnical reports, (dry bulk density). A conservative approach may be to use the Maximum Dry Density (AS 1289.5.1.1) for the materials being treated – which means that “loose” materials would be “overdosed”.

As a conservative approach, a density of 1.9 tonne/m^3 can be adopted for the purposes of the calculations of the application rate for AgLime for treatment in the absence of actual soil density tests for the site.

5.2.3 Effective Neutralisation of AgLime (ENV)

The Effective Neutralisation Value of commercial grade lime is dependent on several factors including the following:

- The fineness of the AgLime influences the effectiveness and reactivity of the material; and
- Particle size of the AgLime will affect the ENV.

The Product Information Sheet (PIS) provided by the AgLime supplier should contain the calculated Neutralising Value for the AgLime and should also contain a particle size grading for the AgLime. Section 4.4 of DEC (2011) provides details of how to use the NV and grading of the AgLime to calculate the ENV. The proportions of the AgLime with respect to the 0.3 mm and 0.85 mm particle sizes are critical to the calculation.

The moisture content of the AgLime at the time of use will also influence the application rate.

5.2.4 Indicative Liming Rates

On the basis of the above assumptions, indicative liming rates for Areas 4A and 5A are presented in Table 11 and 12.

Table 11 Summary of Liming Application Rates for Area 4A

Area	Sewer/PM	Depths (m bgl)	Net Acidity (mol H^+/t)	Conversion Factor (kg H_2SO_4/t)	Conversion Factor ($CaCO_3$)	Safety Factor	Target Liming Rate	Bulk Density	ENV (70%)	Liming Application Rate	Liming Application Rate - rounded (kg $CaCO_3/m^3$ soil)
4A	Open Trench Pressure Main	0.5 m bgl – invert level	97	0.049	1.02	2	9.70	1.9	1.43	26.32	**27**
4A	Open Trench Gravity Sewer	1.5 m – 2.3 m bgl	374	0.049	1.02	2	37.39	1.9	1.43	101.47	**102**
4A	Concrete Storage Caissons (and connecting sewer network)	0.5 m bgl – invert level	374	0.049	1.02	2	37.39	1.9	1.43	101.47	**102**
4A	Access Chambers / Maintenance Shafts (and connecting sewer network)	0.5 m bgl – invert level	374	0.049	1.02	2	37.39	1.9	1.43	101.47	**102**
4A	Trenchless Gravity-Fed Sewer Network	0.5 m bgl – invert level	256	0.049	1.02	2	25.59	1.9	1.43	69.46	**70**

NOTE: The liming rates in this Table have been calculated using an Effective Neutralising Value (ENV) of 70%. These liming rates should be recalculated once the contractor has been provided with the product information sheet for the lime being supplied onsite or at the treatment facility.

Table 12 Summary of Liming Application Rates for Area 5A

Area	Sewer/PM	Depths (m bgl)	Net Acidity (mol H^+/t)	Conversion Factor (kg H_2SO_4/t)	Conversion Factor ($CaCO_3$)	Safety Factor	Target Liming Rate	Bulk Density	ENV (70%)	Liming Application Rate	Liming Application Rate (kg $CaCO_3/m^3$ soil)
5A	Open Trench Pressure Main	0.5 m bgl – invert level	141	0.049	1.02	2	14.09	1.9	1.43	38.26	**39**
5A	Open Trench Gravity Sewer	1.3 m - 2.0 m bgl	132	0.049	1.02	2	13.19	1.9	1.43	35.81	**36**
5A	Concrete Storage Caissons (and connecting sewer network)	1.3 – 1.6 m bgl	239	0.049	1.02	2	23.89	1.9	1.43	64.85	**65**
5A	Access Chambers / Maintenance Shafts (and connecting sewer network)	0.5 m bgl – invert level	239	0.049	1.02	2	23.89	1.9	1.43	64.85	**65**
5A	Trenchless Gravity-Fed Sewer Network	0.5 m bgl – invert level	239	0.049	1.02	2	23.89	1.9	1.43	64.85	**65**

NOTE: The liming rates in this Table have been calculated using an Effective Neutralising Value (ENV) of 70%. These liming rates should be recalculated once the contractor has been provided with the product information sheet for the lime being supplied onsite or at the treatment facility.

6. Dewatering Management Strategy

6.1 Construction Sequence

The overall dewatering effluent disposal strategy is to pump all effluent to the Caddadup WWTP via a connection to the existing sewer system. **No dewatering effluent shall be discharged to the Peel Inlet.**

1. **First Stage – Installing Works to Assist Dewatering Effluent Disposal – Dry Conditions**

The first stage of the construction strategy is to construct a DN300 connecting sewer from an existing temporary Pumping Station (PS) near Cunderdin Loop to a recently constructed PS in Dandaragan Drive. A section of PS No.7 Pressure Main (PM) will also be constructed from the corner of Loton Road and Estuary Drive to the discharge point where the PM connects to the existing sewer system in Boyanup Road. This DN300 connecting sewer and section of PM are above the groundwater table and therefore will not require dewatering (Refer Drawing HK42-3-6).

2. **Second Stage – Installing Works to Assist Dewatering Effluent Disposal – Dry/Wet Conditions**

Once the DN300 connecting sewer and PM are installed, the section of PS No.7 PM from Loton Road to PS No.7 will be constructed. This section of the pressure main has been designed to be as shallow as possible and will be constructed using open trenching methods. It is anticipated that this section of pressure main (315 m) will need to be dewatered.

Any groundwater will be pumped out of the pipe trench and to the existing sewer system via temporary pipework to the already installed section of PM and DN300 connecting sewer for treatment and disposal. An aeration/settling system with geofabric curtains will be installed between the pumps and PM if there are too much suspended solids in the effluent.

3. **Third Stage – Construction of Sewers Using Trenchless Technology**

Once the DN300 connecting sewer and PM are installed the first of the boring caissons will be installed at the PS No.7 site in Estuary Road near Crocos Place.

The caissons are 4.3 m internal diameter concrete cylinders cast *in situ* and lowered into position by excavating from within the caisson and allowing the weight of the concrete caisson to force the caisson into the ground. Once the caisson is installed, a concrete base is the poured while the groundwater is still inside the caisson using a special type of concrete. When the concrete base has set, a pump is lowered into the caisson and a pipe connected to the PM. Groundwater is then pumped out of the caisson and to the sewer system via the PM and DN300 connecting sewer for treatment and disposal. An aeration/settling system with geofabric curtains will be installed between the pumps and PM if there are too much suspended solids in the effluent.

Once two caissons have been installed boring operations can commence. The sewer pipe is jacked in behind the boring machine. The process is repeated until all of the sewer pipes have been installed. Dewatering effluent will be pumped out of the caisson under construction to the downstream caisson, where it will flow through the already installed sewer pipe to the caisson to be used for PS No.7 which is the lowest caisson. Pumps installed in this caisson will then pump the dewatering effluent to the the existing sewer system and previously installed sections of the PM and DN300 connecting sewer. This methodology will reduce the amount of temporary pipework that would be required for disposal of dewatering effluent and hence disruption to the community.

4. **Fourth Stage – Construction of the Remaining Foreshore Sewers by Trenchless Technology and Open Trenching**

The order of construction for the remaining foreshore sewers will be;

1. Construction of sewers north of PS No. 7 by trenchless technology.
2. Construction of sewers north of PS No. 7 by open trenching.
3. Construction of sewers south of PS No. 7 by trenchless technology.
4. Construction of sewers south of PS No. 7 by open trenching.
5. Construction of PM for PS No. 13 together with some reticulation sewers close to the PM.
6. Construction of PS No. 13 caisson.
7. Construction of sewers north of PS No. 13 by trenchless technology.
8. Construction of sewers north of PS No. 13 by open trenching.
9. Construction of sewers south of PS No. 13 by trenchless technology.
10. Construction of sewers north of PS No. 13 by open trenching.

During construction of the caissons inlets for reticulation sewers that will connect to the caisson will also be constructed some of which will require minor dewatering. Other reticulation sewer and other work that do not require dewatering would be constructed concurrently with works along the foreshore.

6.2 General

Groundwater was present at approximately 0.5 - 1.0 m bgl (ranging from -0.26 – 0.57 mAHD) along the Estuary Rd foreshore during the October 2012 groundwater monitoring. It is expected that lowering of groundwater will be required for construction operations and hence exposure and oxidation of PASS may occur. The use of trenchless technology as well as the use of caissons for construction of pump stations 7, 13 and the access (and maintenance) chambers will reduce the amount of excavation and dewatering required.

It is anticipated that dewatering will be required for the following construction activities in **Area 5A**:

- Installation of the open trench sewer from AC8156 – AC8153 (in the north eastern corner of Area 5A);
- Installation of the open trench pressure main from pump station No. 7 to the Loton Rd verge; and

- Installation of the open trench sewer from AC8054 – AC7793 (in the south eastern corner of Area 5A).

It is anticipated that dewatering will be required for the following construction activities in **Area AA**:

- Installation of the open trench pressure main from pump station No. 13 to the Hillway Street connection; and
- Installation of the open trench sewer from AC7767 – AC7772 (in the south eastern corner of the Area).

Potential dewatering areas have been estimated using an additional 0.5 m depth on the latest sewer design invert levels (as a buffer to account for any variances in actual surface levels and excavation depths, and potential tidal flows resulting in higher groundwater level,). The latest sewer design invert levels were taken from the following design drawings:

- HK42-1-1-B (site plan for Area 5A);
- HK35-1-1-B (site plan for Area 4A);
- IP07-2-2-B (pressure main for Area 5A);
- IP06-2-1-B (pressure main for Area 4A);
- HK42-3-1-B, HK42-3-2-B, HK42-3-3-B, HK42-3-4-B (reticulation plans for Area 5A); and
- HK35-3-1-B (reticulation plans for Area 4A).

The October 2012 groundwater levels (recorded by GHD, 2012) were considered to be the most representative of expected groundwater levels as they are the most recent. Ultimately, the extent of dewatering required will be dependent on many factors including the timing of the construction and the construction methodology.

Based on the information presented in Section 3.6.3, it is anticipated that the dewatering effluent abstracted to allow construction of the sewer will not require liming dosing. It is anticipated that the groundwater along Estuary Rd has sufficient buffering capacity to mitigate against changes to pH and acidity levels. It is however recommended that all dewatering effluent be pumped through a dewatering system that includes aeration, settlement and geofabric processes. This will assist in removal colloidal/particulate iron and aluminium prior to discharge.

Contingencies need to be in place in the event groundwater and/or dewatering effluent begin to show signs of acidification, high total suspended solids and potentially salinity (pending comment from Caddadup WWTP service delivery team).

This dewatering management strategy includes the following sections:

- **Groundwater Abstraction;**
- **Dewater Effluent Disposal;**
- **Dewatering Effluent Treatment;**
- **Discharge Approvals; and**

- **Responsibilities during Dewatering.**

6.3 Groundwater Abstraction

6.3.1 General

It is anticipated that if open trenching is carried out at the site as planned, without any form of hydraulic containment, dewatering is likely to involve moderate to low groundwater abstraction to maintain groundwater levels a nominal 0.5 m below the sewer invert levels.

Values of hydraulic conductivity between 3.42E-05 m/s (BH9A) and 3.30E-06 (PS7S) have been calculated, with the average value being 1.77E-05 m/s. These values are within the range of literature values for very fine to medium sands (Davidson, 1995), and are reflective of the fairly consistent lithology along Estuary Rd (alluvial sands of variable density over Tamala limestone bedrock).

Based on the hydraulic conductivity estimates generated by GHD (2012), permeabilities between 3.42E-06 m/s (BH9A) and 3.30E-05 (PS7S) are estimated for the shallow soil strata in both Areas along the Estuary Rd foreshore. As a result, it is anticipated that in-pit sump pumping and/or low dewatering spear density (double row of spears either side of the excavation approximately every 2 m along the open trench pressure main and gravity-fed alignments) will likely be sufficient to achieve the required dewatering rates and drawdown.

The scale of dewatering required relates to the depth of excavation and local hydrogeological conditions. The following are relevant factors that will govern the scale of dewatering required:

- Depth of groundwater is shallow across both Areas (ranged from 0.41 to 0.98 m bgl in October 2012).
- The hydraulic conductivity of the strata investigated was found to be moderate to low; within the typical range for very fine to fine sands.
- The groundwater appears to be influenced by tidal fluxes from the Peel Inlet.

It is noted that the DEC presents the following guidance in relation to dewatering programs:

"In situations where the radius of influence of dewatering extends less than 50 m from each dewatered excavation and/or pumping of each excavation is less than 7 days in duration (whichever is smaller), DEC will not require any further assessment of dewatering other than requiring a standard monitoring program to be undertaken during the dewatering program.

Otherwise, DEC may require that site-specific investigations and groundwater flow modelling are undertaken to better quantify the potential impacts of dewatering on the local groundwater flow regime. Under these conditions, proponents will be required to implement measures to reduce the extent of the cone of depression of the water table and reduce the duration of dewatering in any given excavation."

The moderate to low hydraulic conductivity values for strata within the areas and the assumption that dewatering at any one point will not occur for longer than 7 days, suggests that specific measures to reduce the extent of the cone of depression are not likely to be required (i.e. open trenching techniques are assumed to be a suitable construction technique along the foreshore).

The DEC (2011) also give the following general rules for dewatering:

1. *Standing water levels within any surface water bodies with environmental value should not be lowered as a result of groundwater disturbance;*
2. *Groundwater levels immediately adjacent to any surface water bodies with environmental value should not be lowered by more than 10 cm;*
3. *The cone of depression should not extend beyond the site boundary;*
4. *Groundwater drawdown should not be allowed to impact on surrounding users of groundwater;*
5. *Groundwater drawdown should not be allowed to impact on surrounding built infrastructure; and*
6. *Groundwater drawdown should not exceed 10 cm at a distance of 100 m from the dewatering point.*

With the exception of Point 4 above, all of the general rules should be adhered to for this project. With reference to Point 4:

There are residents within the reticulation areas who have groundwater bores and use them primarily for irrigation. Given the variability in the thickness of the zone of diffusion (freshwater and saltwater interface) and the very saline groundwater at depth, there is a possibility that during dewatering, the freshwater lens is removed (temporarily) and saline water is drawn closer to the surface and within the bore depth interval for these users. As detailed in Section 7.4, all residents within the reticulation areas should be notified of the works, the potential for this to occur and have their bores checked for functionality prior to and after the cessation of the dewatering works.

With reference to Point 1 and 2:

The Peel Inlet is classed as a RAMSAR site and is considered the most sensitive environmental receptor of this project. It is anticipated that the sheer volume and storage of the Peel Inlet (estimated at 61,000 mega litres) will be far greater than the abstraction rates required for all of the shallow open trench excavation/dewatering works along the foreshore. The maximum cone of depression for dewatering the deepest pressure main invert near pump station No. 7 is estimated to be 25 m, which is the approximate distance to the Peel Inlet shoreline to the east. Cone of depression estimates are discussed further in Section 6.2.1.

6.3.2 Cone of Depression Calculations

There are a number of sections of the proposed pressure main and sewer that are planned to be installed via open trenching methods.

As a minimum, DEC require a preliminary assessment of the radial extent of the cone of depression for all dewatering operations in ASS areas. As per the DEC guidelines (2011), the cone of depression estimates have been calculated assuming linear disturbances in a rectangular dewatering areas that abut each other and that are pumped sequentially.

GHD has implemented the DEC approved equations into an Excel based model and the outputs from this Excel based model are provide in Appendix J.

For the purpose of carrying out the calculations, it is assumed in each case that:

- the pressure main and sewer alignments will be installed in sections that are 20 m long and 1 m wide to the deepest proposed sewer invert depth of each; and
- groundwater was assumed to be at 0.5 m bgl.

Once construction methodology has been confirmed, this calculation can easily be revised to take into account the actual dimensions of the dewatering sections.

For the purposes of calculating approximate cone of depression radius values, Sichardt's equation was employed.

The Sichardt's equation is detailed below:

$$R_o = 3000(H - h)\sqrt{K}$$

Where: *Ro = radius of cone of depression of water table*

H = saturated thickness of the aquifer undisturbed by pumping (m)

h = saturated thickness of the aquifer at maximum drawdown (m)

K = hydraulic conductivity of aquifer matrix (units of m/s)

The saturated thickness of the aquifer undisturbed by pumping (H) is assumed to be a maximum of 10 m.

The saturated thickness of the aquifer at maximum drawdown (h) is not expected to vary significantly along the pressure main and gravity fed sewer alignments. Two solutions are provided in Table 13, one allowing for up to a metre of drawdown (likely) and the other allowing 1.5 m of drawdown (unlikely but conservative). Thus, the thickness of the aquifer at maximum drawdowns (h) in each case listed in Table 13 are assumed to be 9 m and 8.5 m respectively.

The hydraulic conductivity values used in the following calculations were estimated in AQTESolv from the slug testing. In each case, the most permeable wells near the proposed alignments were used.

The minimum and maximum hydraulic conductivities of the soil used were 3.42E-05 m/s (BH9A) and 3.30E-06 (PS7S) respectively.

The dewatering calculations for the anticipated dewatering works in Areas 4A and 5A are presented in Table 13.

In Area 5A, these include:

- The open trench sewer from AC8156 to AC8153

- The entire length of open trench pressure main from PS No. 7 to Loton Rd verge
- The open trench sewer from C8054 to Hillway Street verge (AC7793)

In Area 4A, these include:

- The entire length of open trench pressure main from PS No. 13 (C7749) to AC7793
- The open trench sewer from AC7767 to AC7772

Table 13 Estimated Cone of Depressions for Sewer Alignment requiring Open Trenching

						Estimated Cone of Depression	
Area	**Sewer/PM**	**Approximate Length of Sewer/PM Requiring Dewatering**	**Reference Points**	**Closest Wells to Works**	**Hydraulic Conductivity (m/s)**	**Minimum**	**Maximum**
5A	Open Trench Sewer	70 m	AC8156 (north) - AC8153 (south)	BH21	1.25E-05	10.6 m	15.9 m
5A	Open Trench Pressure Main	300 m	C8039 (PS7) - southern end of Loton Rd	PS7S (north), BH16 (south)	3.3E-05 *	17.2 m	25.9 m
5A	Open Trench Sewer	100 m	C8054 (northeast) - AC7793 (southeast)	BH9A	3.42E-06	5.6 m	8.3 m
4A	Open Trench Pressure Main	350 m	AC7793 (north) - C7749 (PS13)	PS13S & PS13D (south)	2.19E-05 **	14.0 m	21.1 m
4A	Open Trench Sewer	200 m	AC7767 (north) - AC7772 (south)	BH1	2.70E-05	15.6 m	23.4 m

** Hydraulic conductivity of PS7S used as it is the highest value estimated cross the site and therefore provides the most conservative estimate of the cone of depression.*

*** Hydraulic conductivity of PS13D used as it is the highest value estimated between the wells and therefore provides the most conservative estimate of the cone of depression.*

The calculations given in this assessment are based on a number of assumed nominal values.

Once the construction method has been confirmed with the subcontractor then these values should be revised to ensure that the cone of depression and dewatering duration does not significantly differ from the values provided herein.

This assessment has been based on a very conservative assessment of the groundwater conditions and therefore represents a “worst case” scenario. As a result, small variations from the assumptions given are unlikely to significantly alter the overall conclusions of this assessment.

The results of the dewatering calculations are summarised as follows:

- All estimates (using minimum and maximum hydraulic conductivity values from the aquifer permeability testing) generated cone of depression radii less than 50 m with the duration of dewatering predicted to be less than 7 days.
- Dewatering for installation of the pressure main in Area 5A will likely cause the largest cone of depression. The radius of the cone of depression for the minimum and maximum adopted hydraulic conductivity values are less than 50 m (approximately 17.2 m – 25.9 m) and the duration of dewatering is predicted to be less than 7 days.

In situations where the radius of influence of dewatering extends less than 50 m from each dewatered excavation and/or pumping of each excavation is less than seven days in duration, DEC will not require any further groundwater modelling. Based on the calculations in Table 13, no further groundwater modelling is required and a standard groundwater monitoring program (as outlined in the DEC guidelines and provided in Table 14 of Section 7) is required to be carried out as a minimum during dewatering as part of groundwater management.

Once the construction method and timing (important for groundwater levels) has been confirmed with the earthworks contractor, the dewatering contractor should revise the dewatering calculations provided herein to ensure that the cone of depression and dewatering duration do not significantly differ from the values provided within this report (i.e. do not approach the “worst case” scenario indicated). Once dewatering commences, groundwater level from a minimum of two groundwater wells (wells either side of the dewatering works along the foreshore) should be monitored daily by the dewatering contractor. This information should be forwarded to the Environmental Consultant to assess potential drawdown impacts during dewatering.

6.3.3 Estimations of Abstraction Rates and Volumes

Estimated dewatering requirements for the project are presented in Appendix I. For the purposes of the estimates, it is has been assumed that:

- The sewers will be constructed at a rate of 20 m per day;
- The pressure main will be constructed at a rate of 40 m per day;
- A conservative average dewatering rate of 5 L/s will be required;
- There will be a 1 day of dewatering in advance of construction for the pressure main and any access chambers or maintenance shafts; and

- The pressure mains in Area 4A and 5A will likely take 9 days each to complete.

Area 4A

Based on the assumptions listed above and the proposed designs for the sewers, mains and caissons:

- the total volume of dewatering anticipated for Area 4A is 26,462 kL;
- the total volume to be abstracted from the eight caissons installed along the foreshore is 305 kL;
- the maximum abstraction is likely to be required when dewatering for installation of the pressure main and dewatering caisson 7751 and connecting reticulation sewers.

Area 5A

Based on the assumptions listed above and the proposed designs for the sewers, mains and caissons:

- the total volume of dewatering anticipated for Area 5A is 28,315 kL;
- the total volume to be abstracted from the 22 caissons installed along the foreshore is 1,013 kL;
- the maximum abstraction is likely to be required when dewatering for installation of the pressure main.

In summary, the total volume of dewatering anticipated for the project is 54,779 kL (which is approximately 38% of the anticipated total volume pump station No.7 will pump over a 12 month period, assuming a pump rate of 18.3 L/s and pumping 6 hours per day for 12 months – total of 144,277 kL).

These estimates are approximations only and will vary according to the following:

- groundwater levels (subject to seasonal variations from rainfall events, human use and tidal fluxes);
- any construction schedule changes;
- any sewer invert level changes;

6.4 Treatment and Disposal of Dewatering Effluent

6.4.1 Dewatering Effluent Disposal Option

The sewer network for Areas 4A and 5A are to be installed between the verges of resident properties and the existing roads. As such, there is very limited workspace onsite along the sewerage network and dewatering effluent cannot be contained on the public roads, adjacent to the sewer excavations.

Reinjection of the dewatering effluent by reversing the suction pump and pumping it through spears left *in situ* from previous trenching is impractical. Given the estimates of aquifer permeability (empirical range for very fine to fine sands), it is likely this would cause groundwater to mound and potentially create sub-surface voids (leading to settlement). Large trenches (approximately 100 - 200 m in length) would need to remain open if the chosen disposal option was to reinfiltrate the effluent into previously excavated trenches. There are obvious safety issues associated with large open trenches, and related social/community aspect of blocking off numerous driveways.

NOTE: No dewatering effluent is to be discharged directly into the Peel Inlet.

At this time, the Water Corporation has declared that the only disposal option is to pump all dewatering effluent into the existing sewers which will ultimately be pumped into the Caddadup WWTP. If the dewatering effluent chemistry meets the sewer acceptance criteria set by the service delivery team overlooking the Caddadup WWTP, all dewatering effluent will be pumped into the existing sewer during construction works.

As outlined in an email from Stephen Jerkovic (Investigations Supervisor, Service Delivery at the Water Corporation):

"C&IS require clear clarity as to the timing, anticipated volumes, anticipated discharge time during a 24hr period and expected discharge rate (when discharging to the sewer). This information is necessary for internal review (along with the quality parameters). Once deemed acceptable then an Acceptance and Conditions document shall be issued to the relevant signatory on the One Off Discharge (OOD) application form (that needs to be completed first). Internal billing can be organised via appropriate network activity (NWA)."

Additional discharge disposal options may need to be employed in the event the service delivery team responsible for the WWTP aren't satisfied with the dewatering effluent chemistry. This may involve employing water tanks to pump fresh water into the sewer with the effluent to dilute the salinity, chloride, sulfate and sodium concentrations.

6.4.2 Approvals from the Caddadup WWTP Service Delivery Team (Water Corporation)

The Service Delivery team responsible for the Caddadup Waste Water Treatment Plant (WWTP) was contacted regarding the potential dewatering effluent disposal option listed in Section 6.3.1. To gain approval to discharge into the sewers which will ultimately flow into and be processed by the Caddadup WWTP, Arash Shafizadeh and Stephen Jerkovic requested that, as a minimum, the following analytes be analysed from a minimum of two groundwater wells in the vicinity of the works:

- pH;
- Conductivity;
- Total Suspended Solids;
- Dissolved metals (As, Cd, Cr, Ni, Pb, Zn, Cu);
- Mercury;
- Biological Oxygen Demand (BOD);
- Chemical Oxygen Demand (COD);
- Total Kjedahl Nitrogen (TKN);
- Total Phosphorus; and
- Sulfur.

All groundwater results (monitored in the field and issued by the laboratory) will be forwarded to Arash and Stephen as well as the anticipated timing, anticipated volumes, anticipated discharge time during a 24 hour period and expected discharge rates. They will also be informed of the potential for very saline water to be drawn up from long periods of continuous dewatering at depths below 2 m bgl and dewatering works in close proximity to the pump stations.

If the Service Delivery team make any further requests (for example, additional testing of the groundwater or monitoring during dewatering), these will be forwarded onto the Water Corporation project team for approval before being added into a revised version of this ASSDMP.

The contacts at the Water Corporation responsible for the approval of discharges to the sewer system (at the time of writing) are:

Stephen Jerkovic

Investigations Supervisor

Service Delivery

Water Corporation

T: (08) 9371 4027 **|** **F:** (08) 6330 6692 **|** **M:** 0429 370 990

Arash Shafizadeh

Investigations Officer

Service Delivery

Water Corporation

T: (08) 9371 4028 **|** **F:** (08) 6330 6691**|** **M:** 0427 479 759

Stephen and Arash should be sent the nominated dewatering contractor's details prior to commencing these works. The contractor should notify the Caddadup WWTP operators as often as is practically possible as to the timing, anticipated volumes, anticipated discharge time during a 24hr period and expected discharge rate (when discharging to the sewer).

6.4.3 Dewatering Effluent Treatment

Based on the groundwater geochemical data collected by GHD in 2007 and 2012, the groundwater acidification risk (from dewatering) across both Areas is low. It is unlikely that lime dosing of dewatering effluent abstracted across both Areas will be required however dissolved oxygen levels, REDOX conditions and metal concentrations (specifically total and dissolved iron and aluminium) will need to be carefully monitored. If these parameters indicate that effluent may form iron precipitates at the point of discharge or contain low oxygen levels (i.e. reducing REDOX conditions), the lime dosing treatment will be required. Indicators that this treatment step is required include:

- pH decreases < 6; or
- Acidity > 40 mg/L; or
- Effluent contains visible Total Suspended Solids (TSS).

Effluent can be neutralised by the addition of a suitable alkaline material to maintain a pH of between 6.5 and 8.5 and acidity below 40 mg/L $CaCO_3$. Dosing tanks can be automatically set to achieve this pH and acidity range. It is recommended that all dewatering effluent however should be pumped through an appropriate aeration/settlement/filtration system (for example, sea container setup with geofabric curtains). Sufficient time should be allowed for the mixing and aeration process to flocculate and settle solids (typically 5 to 6 hours) however this is dependent on the size of the settlement tank and the amount of TSS.

Trigger levels and the necessary treatment options are listed in Table 16.

When approvals are obtained for discharge to the Caddadup WWTP via the existing sewer network, it is likely that no treatment will be required for the groundwater acidity and heavy metal concentrations. The most concerning parameters that WWTP operators are likely to be concerned with are:

- Salinity (highly saline EC value of 33,900 µS/cm in PS13D);
- Total Dissolved Solids (15,900 mg/L in PS13D);
- Sulfate (1,130 mg/L in PS13D);
- Sodium (4,210 mg/L in PS13D); and
- Chloride (8,350 mg/L in PS13D)

It should be noted that all of these elevated levels were encountered at approximately 6 m bgl in the deepest well installed at pump station No. 13. Values for these analytes are significantly lower in the top 2 m of water table (Appendix A).

The dewatering contractor will need to monitor water quality daily from the inlet of the dosing tank and the outlet of the aeration/settlement system (in accordance with Section 5). If the effluent is not being treated, only water quality from the outlet will need to be monitored.

Water quality meters and/or sensors should be used onsite during the dewatering works to identify if saline water is being drawn up from depth and abstracted as effluent. This will likely guide the treatment and management the service delivery team for Caddadup WWTP determine is necessary. Mixing saline water drawn from depth with relatively fresh to brackish groundwater drawn from the upper groundwater lens before discharging to the sewer may be one possible management option however this will need to be approved by service delivery team for Caddadup WWTP and arranged with the dewatering contractor prior to implementation.

6.4.4 Decommissioning of Treatment Facilities

At the completion of the works, the environmental consultant nominated by Water Corporation, will be responsible for collection of samples of the accumulated sediments at the base of each tank and/or pond used or constructed (if any) to determine the appropriate decommissioning requirements.

Sample analyses will include (but not be limited to):

- SPOCAS and/or S_{CR}; and
- Metals (Al, As, Cr, Cu, Mn, Pb, Ni, Se and Zn).

Once laboratory analysis is completed, sediments will be classified based upon the *Landfill Waste Classification and Waste Definitions* (DoE, 1996, as amended December 2009) and disposed offsite at an appropriate waste disposal facility.

The Earthworks Contractor shall be responsible for the restoration of all areas affected by construction, dewatering and treatment operations.

6.5 Impact Minimisation Strategy

To minimise potential impacts, the following should be adhered to for the duration of the contract:

- All dewatering effluent should be pumped through the monitoring/treatment system to ensure, at all times, that the pH of water being discharged is pH 6.5 - 8.5 (and has a TTA < 40 mg/L $CaCO_3$) prior to discharge; and
- Standing groundwater levels, pH, EC, TTA, DO and Eh of groundwater should be monitored in a minimum of two wells (by the Contractor twice daily during dewatering) in groundwater wells installed by GHD either side of the dewatering works in order to monitor drawdown and to ensure that groundwater acidification is not occurring or to check if very saline groundwater is being drawn up as a result of dewatering.

6.6 Responsibility Flow Charts and Daily Field Record Sheets

A flow chart outlining the *Actions* and *Responsibilities* in relation to dewatering effluent and groundwater management is included as Chart 2, Appendix F. It is anticipated that this flow chart will be distributed amongst the earthworks / dewatering contractors at the start of the construction phase to compliment and disseminate the information contained within this management plan. An example Daily Contractor Field Sheet is also included in Appendix G. The daily field sheet outlines all daily field measurements of the dewatering effluent and groundwater that are required to be recorded by the appointed Dewatering Contractor and submitted to Water Corporation on a weekly basis. These records should be forwarded promptly to the principal and appointed Environmental Consultant.

7. Monitoring Program

7.1 General

Groundwater monitoring is an integral part of the management of soils and groundwater as it allows for any changes in land and water quality to be monitored pre, during and post construction, giving an indication as to the success of the management strategies implemented. Groundwater results will be used and compared to relevant assessment criteria (ANZECC 2000) as well as baseline data to monitor any significant changes in water quality. All existing groundwater wells within the proposed infill areas will be utilised for groundwater monitoring during construction works and are listed below:

- BH21
- PS7S
- PS7D
- BH16
- BH13
- BH9A
- PS13S
- PS13D
- BH1

There are a total of nine groundwater wells scattered across Areas 4A and 5A as presented in Figure 1 and 2.

If any groundwater wells are rendered unusable as a result of construction, they will be required to be replaced as soon as possible after the well has been determined to be unusable. Water Corporation and the Environmental Consultant are to be informed immediately when a well has been damaged or rendered unusable.

Similarly, if dewatering is required in areas where no monitoring wells exist within 200 m (this includes all of Area 4A and 5A works), the environmental consultant should be consulted to assess the risk of groundwater acidification. The environmental consultant may recommend to the Principal that a monitoring well/s be installed as soon as possible to ensure no change to groundwater quality has/is occurring.

7.2 Assessment Criteria

According to DEC (2011), chemical indicators that may indicate that groundwater is being affected by the oxidation of sulfides include the following:

- A chloride/sulfate ratio of less than 2;
- An alkalinity/sulfate ratio of less than 5;
- A pH of less than 5; and/or
- A soluble aluminium concentration of greater than 1 mg/L.

The Swedish Environmental Protection Agency developed a risk-ranking scheme to estimate the vulnerability of groundwater to acidification based on alkalinity and pH. The DEC has adopted this scheme, as shown in Table 14.

Table 14 Vulnerability of Groundwater to Acidification Risk Ranking Scheme

Class	Designation	Alkalinity (mg/L)	pH Range	Description
1	Very high alkalinity	> 180	> 6.5	Adequate to maintain acceptable pH in the future.
2	High alkalinity	60- 80	< 6.0	Adequate to maintain acceptable pH in the future.
3	Moderate alkalinity	30 - 60	5.5 - 7.5	Inadequate to maintain stable, acceptable pH level in areas vulnerable to acidification.
4	Low alkalinity	10 -30	5.0 - 6.0	Inadequate to maintain stable, acceptable pH level.
5	Very low alkalinity	< 10	< 6.0	Unacceptable pH level under ALL circumstances

7.2.1 ANZECC Guidelines

Given that the Peel Harvey Inlet (closest environmental receptor) is a saline estuary, it is considered that groundwater should be compared against the marine water assessment criteria specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000). Where marine guidelines do not exist, fresh water guidelines have been used.

7.3 Water Monitoring Program – Roles and Responsibilities

The water monitoring program including roles and responsibilities outlined in Table 15, should be undertaken during dewatering operations (assuming that Water Corporation and the nominated dewatering contractor are happy with the arrangements). Table 16 provides the dewatering effluent and groundwater well monitoring schedule and the analytical requirements of each.

Table 15 Roles and Responsibilities during the Water Monitoring Program

Responsibility	Task
Dewatering Contractor	• Continuously monitoring the dewatering discharge rate and volume at any section of the sewer that requires dewatering. The average daily rates and approximate total dewatering discharge volume should be recorded. • Continuously monitoring the dewatering effluent pH, electrical conductivity (EC), total acidity (TTA), total alkalinity (TAAlk), dissolved oxygen (DO) and Oxidation-Reduction Potential (Eh) during dewatering. As a minimum, water quality parameters should be recorded every half hour during dewatering. All results obtained during dewatering will be compared to trigger values outlined in Table 16, *Dewatering Effluent and Groundwater Monitoring Matrix: Monitoring Frequency, Analytes, Trigger Levels and Actions*. The frequency of monitoring should be altered accordingly when required. • Twice daily (morning and afternoon) monitoring and recording of groundwater levels, pH, EC, TTA, TAAlk, DO and Eh in a minimum of two groundwater monitoring wells (installed by GHD) either side of the dewatering works. All results obtained during dewatering will be compared to background results obtained from monitoring wells pre-works and trigger values outlined in Table 16, *Dewatering Effluent and Groundwater Monitoring Matrix: Monitoring Frequency, Analytes, Trigger Levels and Actions*. The frequency of monitoring should be altered accordingly when required. • Twice daily (morning and afternoon) monitoring and recording of surface water pH, EC, TTA, DO and Eh from the closest location to the dewatering works. • Geofabric curtains (if employed) should be checked daily to ensure they are “clean” and still functioning efficiently. • All records are logged and sent to the principal and nominated environmental consultant. A template for the weekly groundwater, surface water and dewatering effluent checklist sheets are presented in Appendix G.
Environmental Consultant	• Fortnightly sampling and laboratory analysis of the groundwater wells and surface water within the vicinity of the dewatering works as well as the dewatering effluent. The sampling frequency required is specified in the analytical suites for both dewatering and groundwater monitoring are outlined in Table 16, *Dewatering Effluent Monitoring*

	Matrix: Monitoring Frequency, Analytes, Trigger Levels and Action. Additional testing to that stated in Table 16 may be added based on requests from the service delivery team responsible for maintaining the Caddadup WWTP (these tests will be subject to approval by the Superintendent's representative). • Provide advice to Water Corporation and the dewatering contractor regarding the water monitoring and laboratory results. • Upon the completion of the dewatering program, collect samples of the accumulated sediments at the base of each tank or pond (if used) to determine the appropriate decommissioning requirements in accordance with Section 6.3.5. • Implementing response actions as outlined in this DMP that are approved by Water Corporation. • Review all monitoring results and report to the Water Corporation for onward transmission to the DEC.

A detailed scope of works for the environmental consultant during the project is outlined in Section 9.

Table 16 Dewatering Effluent and Groundwater Monitoring Matrix: Monitoring Frequency, Analytes, Trigger Levels and Actions (adapted from DEC 2011)

Monitoring Level	Trigger	Action	Monitoring
1.	Total titratable acidity < 40 mg/L **AND** pH > 6	Continue field measurements	**Twice Daily** – ***field measurement***: pH, electrical conductivity (EC),Total Titratable Acidity (TTA), total alkalinity (TAAlk), dissolved oxygen (DO), REDOX potential (ORP) **Fortnightly** - ***laboratory analysis***: pH, EC, TTA, TAAlk, Total Dissolved Solids (TDS), Total Suspended Solids (TSS)
2.	Total titratable acidity < 40 mg/L **AND** pH in range of 4 to 6	Undertake neutralisation treatment (liming) [1]	**Twice Daily** – ***field measurement***: pH, EC, TTA, TAAlk, DO, ORP **Fortnightly** - ***laboratory analysis***: pH, EC, TTA, TAAlk, TDS, TSS
3.	Total titratable acidity in range 40 mg/L to 100 mg/L **AND** pH < 6	Undertake neutralisation treatment (liming) [1] Effluent should be aerated to precipitate dissolved iron and directed to a series of settlement tanks with geofabric curtains or other treatment system to allow removal of iron and other metals	**Twice Daily** – ***field measurement***: pH, EC, TTA, TAAlk, DO, ORP **Weekly** - ***laboratory analysis***: pH, EC, TTA, TAAlk, TDS, TSS
4.	Total titratable acidity in range 40 mg/L to 100 mg/L **OR** pH in range of 4 to 6	Undertake neutralisation treatment (liming) [1] Effluent should be aerated to precipitate dissolved iron and directed to a series of settlement tanks with geofabric curtains or other treatment system to allow removal of iron and other metals	**Hourly** – ***field measurement***: pH, EC, TTA, TAAlk ,DO, ORP **Weekly** - ***laboratory analysis***: pH, EC, TTA, TAAlk, TDS, TSS **Fortnightly** - ***laboratory analysis***: TTA, TAAlk, pH, sulfate, chloride, total iron[2], dissolved iron (filtered), total aluminium, dissolved aluminium (filtered), total arsenic, total chromium, total cadmium, total manganese, total nickel, total zinc, total selenium, ammoniacal nitrogen, hydrogen sulfide, EC, TDS, TSS, total nitrogen (TN), total phosphorus (TP)
5.	Total titratable	Increase neutralisation treatment rate	**Hourly** – ***field measurements***: pH, EC, TTA, TAAlk, DO, ORP

	acidity >100 mg/L **OR** pH < 4 **OR** Total alkalinity < 30 mg/L	(liming)[1] Effluent should be aerated to precipitate dissolved iron and directed to a series of settlement basins/trenches or other treatment system to allow removal of iron and other metals Advise Department of Environment and Conservation (DEC) Contaminated Sites Branch (CSB) immediately. CSB may advise appropriate action which may include ceasing dewatering	**Weekly** - ***laboratory analysis***: TTA, TAAlk, pH, sulfate, chloride, total iron[2], dissolved iron (filtered), total aluminium, dissolved aluminium (filtered), total arsenic, total chromium, total cadmium, total manganese, total nickel, total zinc, total selenium, ammoniacal nitrogen, hydrogen sulfide, EC, TSS, TDS, TN, TP. May be required to undertake investigations to determine the size of the "acidic footprint" created and manage this impact appropriately
6.	Total titratable acidity >100 mg/L **AND** 25% higher than baseline values	Upgrade to 'Dewatering Management Level 2' including implementation of groundwater quality monitoring program	Monitoring requirements: Dependent upon value of TTA and pH as per DEC guidance
7.	pH decrease > 1 pH unit from baseline values	Upgrade to 'Dewatering Management Level 2' including implementation of groundwater quality monitoring program	Monitoring requirements: Dependent upon value of TTA and pH as per DEC guidance

Additional notes:

[1] A slurry made from crushed limestone is the generally preferred neutralisation material. Other neutralising agents, such as hydrated lime or quick lime can be used, however they quickly increase the receiving waters' pH and can result in pH overshoot.

[2] Measurement of metal concentrations in dewatering effluent should be as total concentrations from an unfiltered water sample. These concentrations should then be used to determine appropriate treatment options for the effluent and to identify any emerging trends in groundwater quality. It is not the intention that these values for total metals be directly compared against environmental or health-based criteria for dissolved metals. However, when determining treatment options, it should be borne in mind that: a) any metals contained within suspended solids have the potential to be mobilised if pH and/or REDOX conditions change (which is obviously fairly common in ASS environments); and b) if dewatering effluent is to be discharged into a receiving environment then these suspended solids will be discharged along with the water.

7.4 Residential Bores Affected by Dewatering Operations

Many properties within and adjoining the works have bores for producing water for their gardens. As the functionality of these bores and the quality of water may be affected by the dewatering work required for the construction of the sewers, property owners/occupiers will have to be notified of the works and have their bores inspected.

7.4.1 Advice of Commencing Work

Included in the 'Infill Sewerage Specification - Preliminaries Section A', is a requirement for the Contractor to advise property owners/occupiers of intending construction work by issuing a 'Notice of Commencement of Sewer Works' letter soon after commencing construction and a separate 'Notice of Entry' letter 7 to 14 days prior to entry onto a property for construction works.

The Contractor shall amend the 'Notice of Commencement of Sewer Works' letter to advise owner/occupiers that; where dewatering is to be carried out, their properties will be inspected to determine the presence and condition of bores and reticulation systems. A similar letter shall be given to owners/occupiers of properties adjacent to the proposed sewer lines independent of whether the properties are to be connected to the proposed sewer line or not.

7.4.2 Inspections of Bore and Reticulation Systems

Where dewatering is to occur within a street, the Contractor shall;

- Inspect all properties either side of the proposed sewer line (independent of whether the properties are to be connected to the proposed sewer line or not) to determine if there is a bore on the property;
- Obtain the owner/occupiers permission and test the bore to confirm whether the bore is in working order or not;
- If the bore is working then confirm which of the sprinkler or other outlets are in working order;
- Obtain the owner/occupiers signature on a 'pro forma' letter and plan of sprinkler system to confirm they agree with results of the inspection;
- Leave the original signed letter and plan with owner/occupier, and retain a copy for Contractor records;
- Leave a letter with the owner/occupier advising them of the start and finish date of dewatering work that will affect their property and advising them that they should not use the bore until advised by the Contractor;
- Reinspect each property with a working bore following completion of dewatering work and confirm that what equipment was working satisfactorily before, is still working satisfactorily;
- Obtain the owner/occupiers signature on the 'pro forma' letter and plan of the sprinkler system to confirm they are satisfied with results of the final inspection.

7.4.3 Records of Bore and Reticulation System Inspections

The format of the Infill Sewerage Specification 'Notice of Entry 'letter can be used as a basis for the 'pro forma' bore and reticulation system letter.

The Contractor shall maintain a file of copies of the 'bore and reticulation system' letters endorsed by the owner/occupier. A copy of the letters shall be provided to the Superintendent at each site meeting.

Upon request by the Contractor, the Superintendent will supply a list of the owners and occupiers to the Contractor.

7.5 Groundwater Contingency Plan

7.5.1 Oxidation of Sulfides

In the event that groundwater monitoring results indicate the oxidation of sulfide bearing minerals has occurred through site works, based either on daily field measurements taken by the Contractor or from laboratory results collated by the Principal's environmental consultant, Water Corporation will be informed and dewatering may be stopped immediately. No further effluent should be allowed to be discharged until the issue is addressed by an appropriate groundwater contingency plan. Oxidation of ASS may be occurring if the values in Table 17 are obtained during dewatering. Groundwater in the project Areas is naturally slightly alkaline with high alkalinity and low acidity and the likelihood of groundwater acidification is low.

Table 17 Groundwater Trigger Criteria

Analyte	Trigger Criteria
pH	< 6
Acidity	> 40 mg/L
Chloride/Sulfate ratio	< 2
Alkalinity/Sulfate ratio	< 5 (or 1 unit less than baseline values)
Dissolved Aluminium or Iron	> 1 mg/L (or 25% higher than baseline values if already exceeded)

If any of the criteria above are breached during dewatering, the following treatment options (or combinations of) may be used:

- Additional liming treatments (addition of AgLime or small quantities of hydrated lime / quick lime for immediate pH adjustment). Care must be taken when using either hydrated lime or quick lime as both can result in pH 'overshoot' (excessively high pH).
- Aeration/settlement systems will need to be employed and long settlement/flocculation times may be necessary to settle fine sediments. This may involve having more tanks and/or ponds to handle the volume of discharge abstracted.
- Use of geofabric curtains in conjunction with settlement tanks to remove additional total suspended solids and/or iron oxy-hydroxide floc.
- Suitable toxicant filtration/flocculation method.

The environmental consultant should be consulted at all times to interpret groundwater quality data. It is recommended that the environmental consultant be given the authority to halt dewatering.

7.5.2 Dewatering Excessive Saltwater

As discussed in Section 3.6, the depth of the freshwater:saltwater interface along the Estuary foreshore is not well defined and it is possible that continuous dewatering will draw saline water to the surface, rapidly increasing the salinity (measured by electrical conductivity), total suspended solids, sodium, chloride and sulfate concentrations.

In the event that daily monitoring by the contractor indicates elevated conductivity and total suspended solids (or the laboratory results indicate elevated chloride and sulfate concentrations) then the dewatering contractor should ensure there is contingency measure in place in the event the Caddadup WWTP operators are not satisfied with the dewatering effluent chemistry. Such measures may include storing fresher dewatering effluent in sea containers and/or large tanks or having a tanker full of fresh water on standby so that fresher water can be simultaneously pumped with the effluent into the existing sewer in an effort to dilute the concentrations of the aforementioned analytes.

7.6 Reporting

The reporting requirements outlined in Table 18 shall be followed.

Table 18 Reporting Requirements – Dewatering Management Plan

Responsibility	Item	To Whom	Timing
Earthworks/Dewatering Contractor	Results of the daily soil and water monitoring along with actions taken to achieve soil and water quality targets including soil validation quality of the dewatering effluent.	Water Corporation and Environmental Consultant	Within 24 hours of water quality falling outside the parameters in Table 17, *Groundwater Trigger Criteria*. At the start of each working week for all other results.
Principal's Environmental Consultant	**Initial Closure Report** (detailing all elements and results pertaining to groundwater, surface water and dewatering management).	Water Corporation	On completion of earthworks, management, and all laboratory testing.
	Post-Dewatering Monitoring Closure Report	Water Corporation	On completion of post construction groundwater monitoring program (if required), and all laboratory testing.

8. Role of the Environmental Consultant

This section of the management plan lists the tasks that the nominated environmental consultant should undertake, as a minimum, to fulfil the role as the Environmental Consultant during construction of the sewer network.

The Environmental Consultant will ensure all of the appropriate measures (in line with the DEC guidelines and ASSDMP prepared by GHD) are implemented to reduce the footprint that construction and dewatering could potentially have on the groundwater and surface water systems across the Site.

At this time, it is anticipated that the earthworks and dewatering contractor/s (selected by the Principal) will agree to undertake and handle all of the roles and responsibilities listed herein.

Below is a breakdown of the scope of works the environmental consultant should complete for the project including:

- **Task 1:** Baseline Groundwater and Surface Water Sampling;
- **Task 2:** Pre-Construction Kick-off Meeting;
- **Task 3:** Construction Phase Monitoring and Sampling including Contractor training;
- **Task 4:** Contractor Auditing during Construction;
- **Task 5:** Initial Closure Report Auditing of Dewatering Management during Construction;
- **Task 6:** Post Dewatering Groundwater and Surface Water Monitoring; and
- **Task 7:** Final Closure Report.

8.1 Task 1: Baseline Groundwater and Surface Water Sampling

The environmental consultant should undertake another baseline round of groundwater and surface water monitoring and sampling within the two weeks leading up to the commencement of site works to obtain representative results of groundwater and surface water geochemistry. This will enable comparison and assessment of the latest results to be compared against the relevant ANZECC (2000) and DEC (2009) guideline values to determine if construction and dewatering is having any impact on the local groundwater and surface water systems and whether any changes can be attributed to seasonal variations. Previously collected groundwater and surface water data will also be used in this assessment.

8.2 Task 2: Pre-Construction Kick-off meeting

A kick-off meeting should be held to formally introduce all project leads and disseminate all relevant documents and information among the relevant parties.

This kick-off meeting with the Principal, Earthworks/Dewatering Contractors and the service delivery team responsible for Caddadup WWTP, will help to determine the necessary roles and responsibilities, authorities and the expectations of all parties before site works commence.

8.3 Task 3: Construction Phase Monitoring and Sampling including Contractor training

The proposed scope of works for Task 3 should be as follows:

Contractor Training

At this time, it is anticipated that the contractors will undertake the necessary soil and water monitoring as they will be onsite every day of the project. To ensure the ASSDMP is implemented, during the first week of the project, the nominated environmental consultant should spend at least one day onsite assisting the earthworks contractors, to enable them to fulfil their role as outlined in the ASSDMP (soil sampling, soil pH testing procedures, visual and olfactory identification of ASS, calculation of liming rates, mixing methods and data recording requirements). **NOTE:** The above training will apply if the principal elects to treat ASS onsite. If this is not the case and all ASS is sent offsite to be treated, the contractor will only be required to keep a record of where the soil was excavated from and the volume as well as all of the receipts from transporting the soil to the treatment facility.

The environmental consultant should spend at least a day with the dewatering contractor to ensure they understand how to undertake the necessary daily monitoring of the dewatering effluent, groundwater wells in proximity of the works, surface water and the expected reporting requirements as stipulated in the ASSDMP.

Soil Validation Sampling

The environmental consultant should assist the Earthworks Contractor to develop a system that will allow ASS to be appropriately managed onsite. The environmental consultant will produce checklists for use by the Earthworks Contractor to ensure all of the correct information is being recorded and accurate records of soil treatment is documented for the closure reporting.

The environmental consultant will show the contractor how to undertake the following:

- soil stockpile sampling (as per Table 9 of Section 4.6.3 in the ASSDMP);
- soil pH testing procedures (pH_F and pH_{FOX});
- sending samples to a NATA accredited laboratory for confirmatory testing; and
- logging of all necessary information.

Although the Earthworks Contractor is responsible for the validating testing of the soil treatment method, third party validation of the treatment method is required according to the ASSDMP. These third party validation sampling events task will be undertaken by the environmental consultant.

All soil sampling undertaken onsite by the contractor or consultant will be undertaken as per Table 9 of Section 4.6.3 in the ASSDMP.

If the principal elects to send all ASS offsite to a licensed treatment facility, the environmental consultant should provide advice and recommendations

It should be noted that the ASSDMP stipulates that any material excavated between the chainages and depths as outlined in Section 4.2.1 and 4.2.2 be treated before reuse onsite or disposal. Validation of the treatment method is required as per the requirements of the ASSDMP. This applies to any material excavated within the zones given in Table 11 and 12 that is stockpiled, backfilled, or disposed offsite.

Groundwater Sampling

It is anticipated that the nine groundwater monitoring wells present onsite can be utilised during and after the construction program to determine groundwater quality and levels.

It is assumed that the dewatering contractor is able to conduct the twice daily field monitoring requirements outlined in Section 7.3 of Table 15). Results recorded by the dewatering contractor are to be forwarded to the Superintendents Representative and GHD Project Manager on a weekly basis.

The environmental consultant will be responsible for collecting samples (for laboratory analyses) from a minimum of two monitoring wells (wells either side of the dewatering works) on a fortnightly basis.

Field duplicates should be collected each sampling event for Quality Assurance and Quality Control purposes. More intensive monitoring and sampling measures will be required if surface water, groundwater or dewatering effluent quality begin to decrease during dewatering and exceed trigger values outlined in *Table 16 of Section 7.3 of the DMP; Dewatering Effluent and Groundwater Monitoring Matrix: Monitoring Frequency, Analytes, Trigger Levels and Actions (GHD 2012*).

Dewatering Effluent Sampling

It is assumed that the dewatering contractor is able to conduct the daily field monitoring requirements outlined in the DMP (GHD, 2012). Results recorded by the dewatering contractor are to be forwarded to the GHD Project Manager and Superintendent Representative on a weekly basis.

The environmental consultant will be responsible for collecting samples (for laboratory analyses) from all dewatering systems (inlets and outlets if applicable) being used onsite. Field duplicates will be collected each sampling event for Quality Assurance and Quality Control purposes. More intensive monitoring and sampling measures will be required if surface water, groundwater or dewatering effluent quality begin to decrease during dewatering and exceeds trigger values outlined in *Table 16 of Section 7.3 of the DMP; Dewatering Effluent and Groundwater Monitoring Matrix: Monitoring Frequency, Analytes, Trigger Levels and Actions (GHD 2012*).

It is the responsibility of the environmental consultant to report to the superintendent if the laboratory results for the dewatering effluent samples are exceeding any of the trigger guidelines outlined in Table 16 of Section 7.3.

Surface Water Sampling

Fortnightly surface water sampling will be undertaken by the environmental consultant to determine if construction and dewatering is having any impact on the local surface water systems and whether any changes can be attributed to seasonal variations. Field duplicates will be collected each sampling event for Quality Assurance and Quality Control purposes.

It is the responsibility of the environmental consultant to report to the superintendent if the laboratory results for the surface water samples are exceeding any of the trigger guidelines outlined in Table 16 of Section 7.3.

Laboratory Analysis

The following laboratory analysis will be completed for the groundwater and dewatering effluent samples:

Soil Analyses

If ASS is treated onsite and the contractor elects to collect soil validation samples following lime treatment, the laboratory analyses conducted on the soil will consist of (but is not limited to):

- pH screening testing (pH_F and pH_{FOX});
- Suspension Peroxide Oxidisable Combined Acidity and Sulfate (SPOCAS);
- Chromium Reducible Sulfur (CRS); and
- Acid Neutralising Capacity (as per *Sullivan et al 2012*).

Groundwater Analysis

With reference to the ASSDMP (GHD, 2012), the standard analytical suite for the groundwater samples will comprise:

- pH;
- Acidity;

- Alkalinity;
- Electrical Conductivity (EC);
- Total Dissolved Solids (TDS); and
- Total Suspended Solids (TSS).

Dewatering Effluent Analysis

The standard analytical suite for laboratory analysis of dewatering effluent samples at the inlet of the dosing unit (where present) and the outlet of the dewatering system after the treatment process will comprise:

- pH;
- Acidity;
- Alkalinity;
- EC;
- TDS; and
- TSS.

8.4 Task 4: Contractor Auditing during Construction

8.4.1 Site Audits

For the first two weeks of dewatering, the environmental consultant will be onsite for half a day per week auditing the management and treatment of all excavation and dewatering works being undertaken by the contractors. Following the first two weeks, the environmental consultant should be onsite one day per fortnight for the duration of the project.

Site auditing visit will include the following tasks:

8.4.2 Auditing of ASS Management

The ASS management related auditor activities should cover the following:

- Contractor soil sampling and soil testing procedures;
- Suitability of liming rates and mixing method;
- Suitability of limestone treatment pad (if applicable); and
- Accuracy and authenticity of contractor monitoring records;

8.4.3 Auditing of Groundwater Management

The groundwater management related auditor activities should cover the following:

- Recording of daily monitoring requirements (i.e. level and general water quality parameters as outlined in Table 15 of Section 7.3)
- Calibration of contractor monitoring equipment (e.g. pH meter);
- Correct procedure for total acidity testing;
- Accuracy and authenticity of contractor monitoring records;
- Groundwater monitoring well integrity;
- Contractor monitoring methodology (e.g. sufficient purging of wells during collection of field parameters to ensure representative samples); and

- Sensitive environmental receptors (auditors should undertake routine checks of the environmental receptors).

8.4.4 Auditing of Dewatering Management

The dewatering management related auditor activities should cover the following:

- Recording of daily monitoring requirements (i.e. dewatering discharge rates, volumes and general water quality parameters as outlined in Table 15 of Section 7.3);
- Dewatering disposal;
- Visual assessment of dosing units, aeration/settlement ponds/tanks and/or reinjection units (if applicable); and
- Geofabric curtain and/or pond integrity (if applicable).

8.4.5 Auditing of Surface Water Management

- Recording of daily monitoring requirements (i.e. general water quality parameters)
- Calibration of contractor monitoring equipment (e.g. pH meters)
- Explanation of determining total acidity
- Accuracy and authenticity of contractor monitoring records.

An audit report will be prepared upon completion of the construction works demonstrating the contractor's compliance with the GHD DMP (2012). In the event of breaches or non-compliances with the ASSDMP, the Water Corporation Superintendent and Project Manager will be notified immediately by phone and a memorandum containing the relevant details will be forwarded within 2 working days.

8.5 Task 5: Initial Closure Reporting

The environmental consultant will submit an initial closure report (within six weeks following completion of earthworks) which will incorporate the results of baseline surface water and groundwater monitoring, dewatering effluent and groundwater monitoring undertaken at the Site during construction, and provide summaries of the soil validation results.

This report will be completed ready for on forwarding to the DEC but will only be forwarded at the request of the Water Corporation.

8.6 Task 6: Post Dewatering Groundwater and Surface Water Monitoring

In accordance with current DEC (2011) guidelines, the environmental consultant should complete six months of bimonthly post dewatering groundwater and surface water monitoring (3 rounds every two months). Because of the lag time between the project commencing and finishing, and the length of the project site then the two month period shall be based on a well by well basis. As a result, post dewatering monitoring shall start two months from the date on which dewatering activities have been completed in the immediate vicinity of the well (within 100 m radius). The monitoring results will be used and compared to baseline and dewatering monitoring data to monitor any significant changes in water quality as a result of the onsite works.

Groundwater and Surface Water Analysis

With reference to the DMP (GHD, 2012), the extended analytical suite for post dewatering groundwater and surface waters samples will comprise:

- Acidity, alkalinity, pH, EC, TDS, TSS;
- Nutrients (Nitrite, Nitrate, Phosphorus, Ammonia, TKN), filterable reactive phosphorus;

- Sulfate, Chloride;
- Major anions (Cl, SO_4, alkalinity);
- Major cations (Ca, Mg, Na, K);
- Dissolved metals (Al, As, Cd, Cr, Fe, Mn, Ni, Se, Zn); and
- Total metals (Al, Fe).

8.7 Task 7: Final Closure Reporting

A separate post-dewatering monitoring report will be submitted (within six weeks of completion of the final post dewatering monitoring round) which will identify if any major deviation is noted in the parameters in groundwater or surface waters. This report will also summarise the findings of the initial closure report. Any further action (if necessary) will be incorporated as recommendations.

9. References

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Parson Brinckerhoff (2007)*, Water Corporation Acid Sulfate Soil and Dewatering Management Strategy*, Perth, WA. July 2007.

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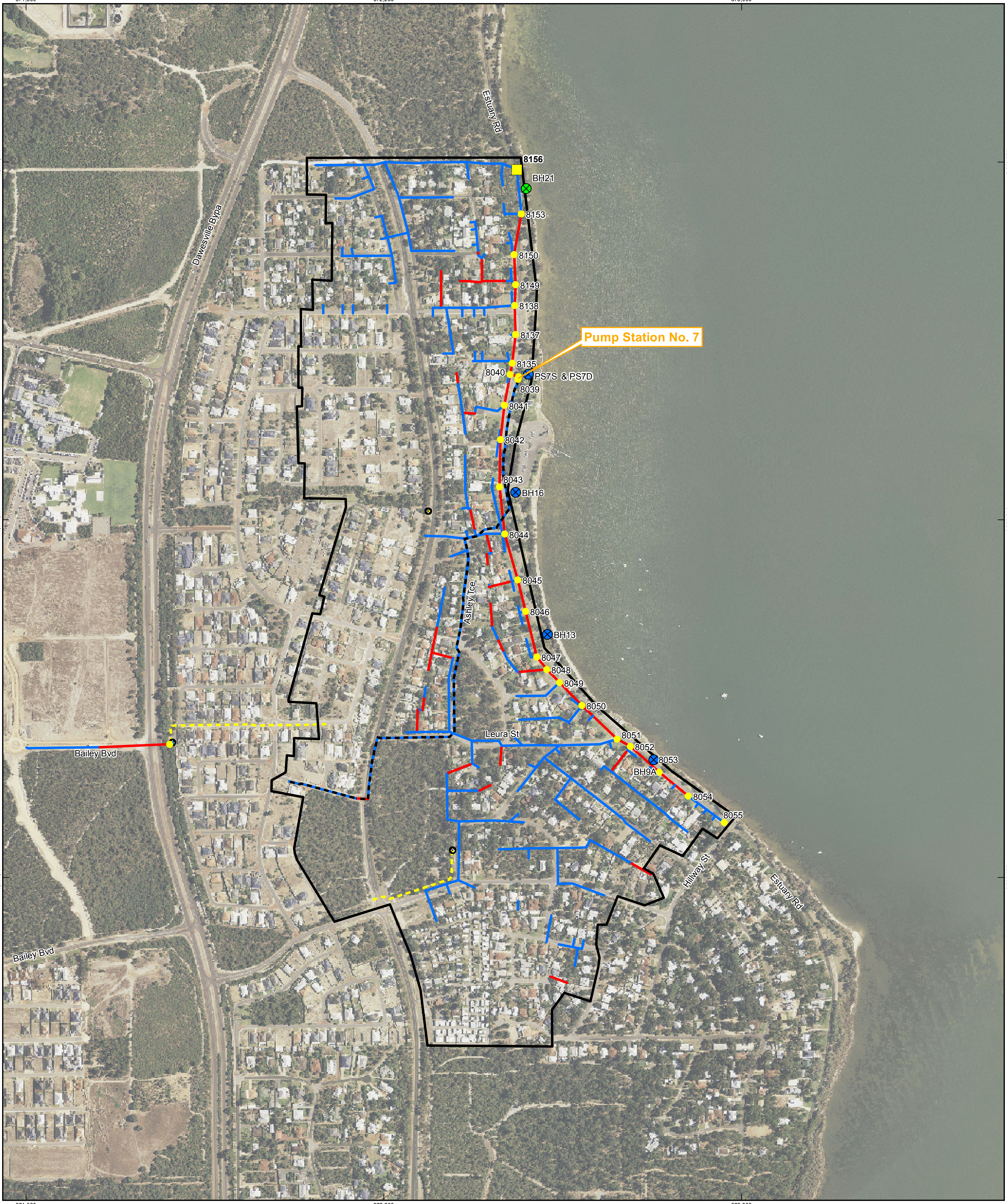
Figures



LEGEND

Monitoring Wells

- Groundwater Well (GHD, 2007)
- Groundwater Well (GHD, 2012)
- Caissons
- Access Chamber / Maintenance Shaft
- Temporary Pump Station
- Proposed Pump Station
- Opencut Pressure Main
- Temporary Pressure Main
- Opencut Pressure Main
- Trenchless Pressure Main
- Opencut Sewer
- Trenchless Sewer
- 5A Boundary

1: 7,500 (at A3)

0 37.5 75 150 225 300 375

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

Water Corporation
Dawesville 4A/5A Infill Sewerage Works

Reticulated Area 5A
Aerial Overview with Proposed Sewer Network and Groundwater Well Locations

Job Number	61-27593
Revision	0
Date	09 Nov 2012

Figure 1

G:\61\27593\GIS\Maps\MXD\6127593_G003_Fig1_Rev0.mxd

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data source: GHD: Opencut Sewer - 20120808, Trenchless Sewer - 20120808, Caissons - 20120808, Temporary Pressure Main - 20120817, Opencut Pressure Main - 20120807, Pump Station - 20120817; Landgate: 2012 Metro South Mosaic - 20121031, Monitoring Well - 20121031; Access Chamber / Maintenance Shaft - 20121109, 5A Boundary - 20121031, Temporary Pump Station - 20120817, Proposed Pump Station - 20120817. Created by: cagilbert, erice

LEGEND

Monitoring Wells

- Groundwater Well (GHD, 2007)
- Groundwater Well (GHD, 2012)
- Caissons
- Access Chamber / Maintenance Shaft
- Opencut Pressure Main
- Pump Station
- Opencut Sewer
- Trenchless Sewer
- Opencut Pressure Main
- Trenchless Pressure Main
- 4A Boundary

1: 2,500 (at A3)

0 12.5 25 50 75 100 125

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

Water Corporation
Dawesville 4A/5A Infill Sewerage Works

Reticulated Area 4A
Aerial Overview with Proposed Sewer Network and Groundwater Well Locations

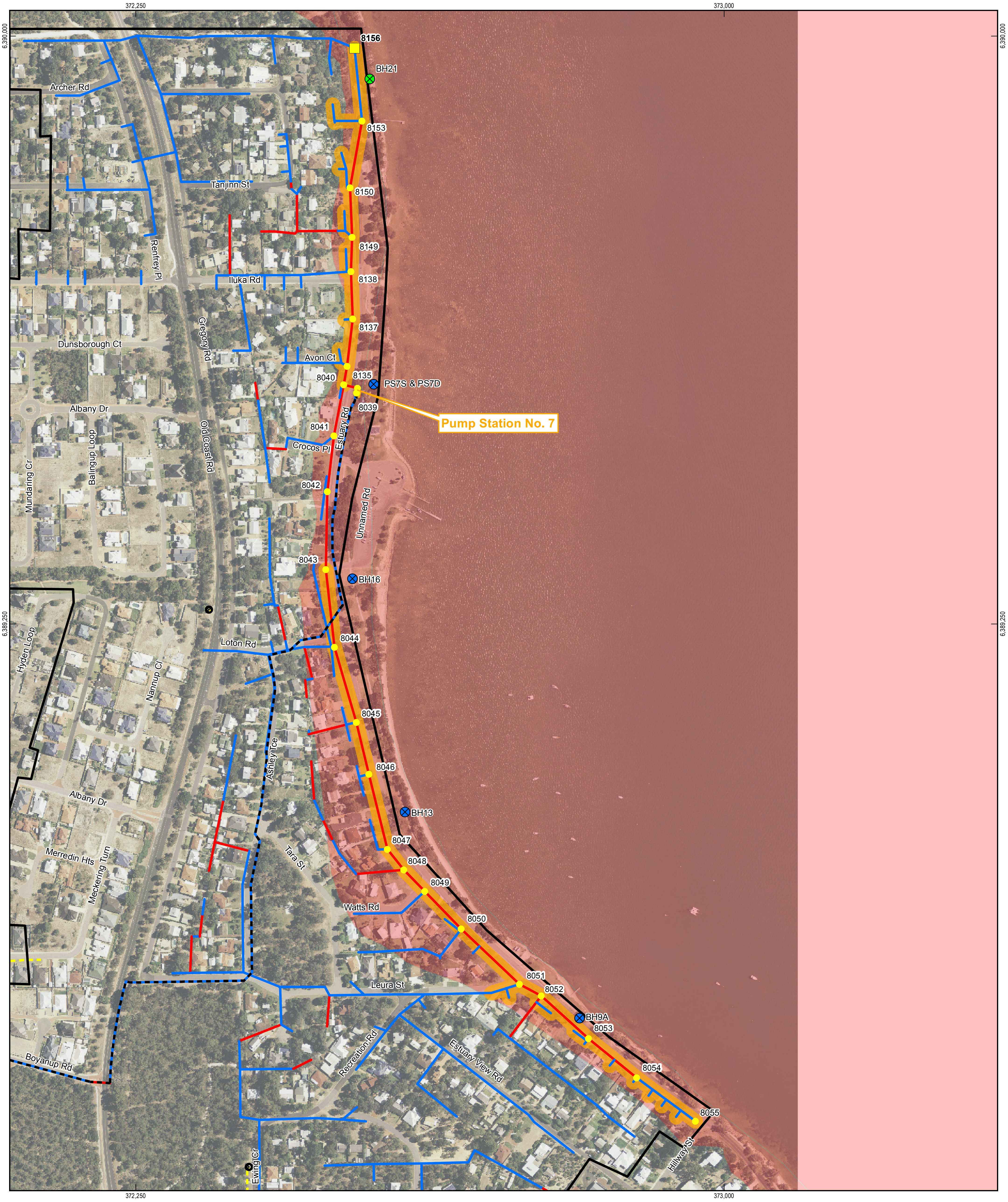
Job Number	61-27593
Revision	0
Date	09 Nov 2012

Figure 2

G:\61\27593\GIS\Maps\MXD\6127593_G004_Fig2_Rev0.mxd

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: GHD: Opencut Sewer - 20120808, Trenchless Sewer - 20120808, Caissons - 20120808, Opencut Pressure Main - 20120807, Monitoring Wells - 20121031, 4A Boundary - 20121031, Access Chamber / Maintenance Shaft - 20121109, Trenchless Pressure Main - 20120807, Opencut Pressure Main - 20120807 Landgate: 2012 Metro West Mosaic - 20121031. Created by: cagilbert, erice



LEGEND

Monitoring Wells

- Groundwater Well (GHD, 2007)
- Groundwater Well (GHD, 2012)
- Caissons
- Access Chamber / Maintenance Shaft
- Temporary Pump Station
- Proposed Pump Station
- Opencut Pressure Main
- Temporary Pressure Main
- Opencut Pressure Main
- Trenchless Pressure Main
- Opencut Sewer
- Trenchless Sewer
- 5A Boundary
- ASS Treatment Zones

Acid Sulfate Soil Risk Map

- High to moderate ASS disturbance risk (<3m from surface)

1: 4,500 (at A3)

0 22.5 45 90 135 180 225

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

GHD

WATER CORPORATION

powered by SLIP ENABLER

Water Corporation
Dawesville 4A/5A Infill Sewerage Works

Reticulated Area 5A
Inferred ASS Treatment Zones

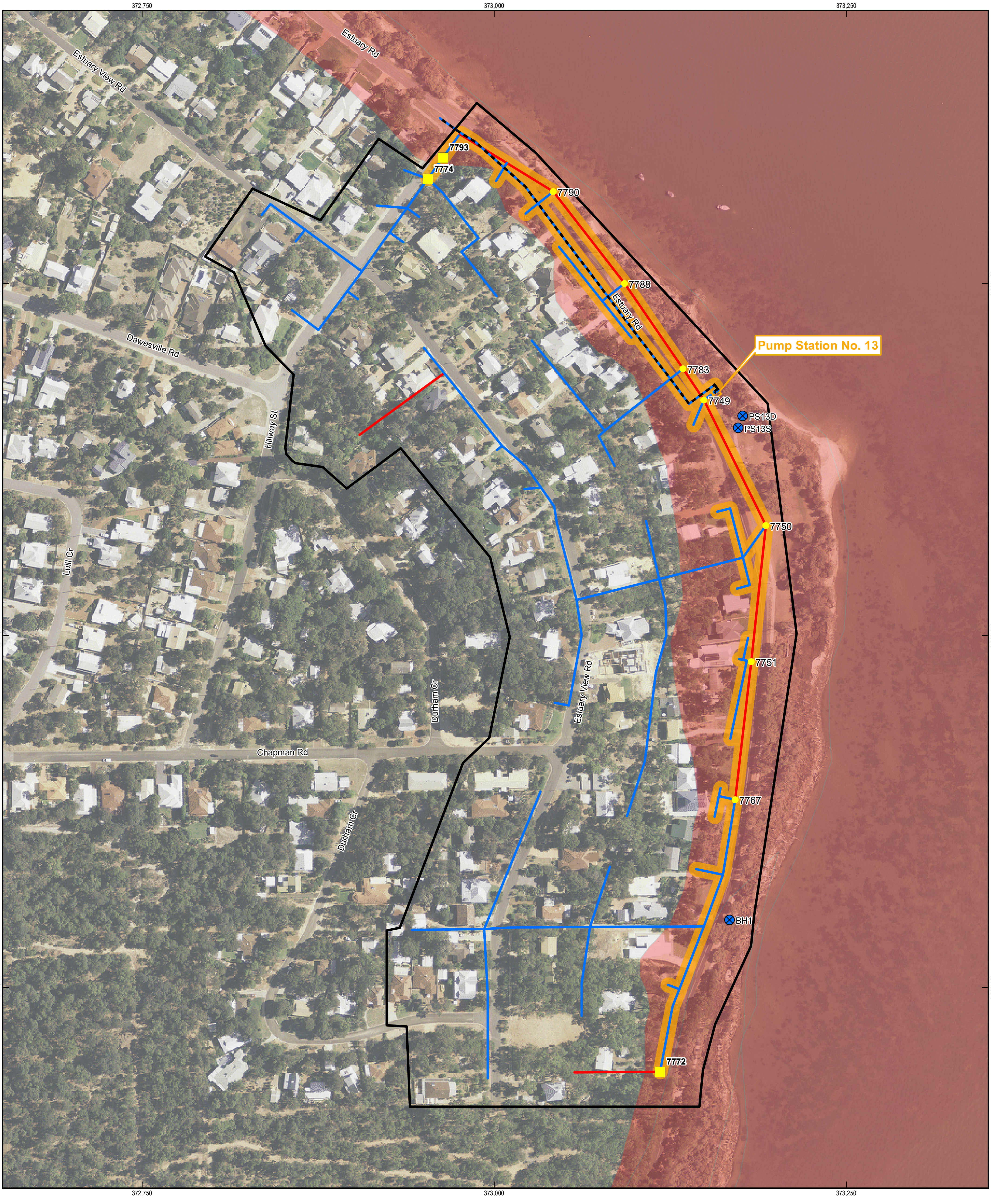
Job Number 61-27593
Revision 0
Date 12 Nov 2012

Figure 3

G:\61\27593\GIS\Maps\MXD\6127593_G005_Fig3_Rev0.mxd

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data source: GHD: Temporary Pump Station - 20120808, Proposed Pump Station - 20120808, Opencut Pressure Main - 20120807, Trenchless Presure Main - 20120817, Opencut Sewer - 20120808, Trenchless Sewer - 20120808, Casissons - 20120808, Temporary Pressure Main - 20120817, Opencut Pressure Main - 20120807, Pump Station - 20120817, ASS Treatment Zones - 20121109, Monitoring Well - 20121031, Access Chamber / Maintenance Shaft - 20121109, 5A Boundary - 2012103; Landgate: 2012 Metro West Mosaic - 20121031; DEC: Acid Sulfate Soil Risk Map - 2009. Created by: cagilbert, erice



LEGEND

Monitoring Wells
- Groundwater Well (GHD, 2007)
- Groundwater Well (GHD, 2012)
- Caissons

- Access Chamber / Maintenance Shaft
- Opencut Pressure Main

- Pump Station
- Opencut Sewer
- Trenchless Sewer

- Opencut Pressure Main
- Trenchless Pressure Main
- ASS Treatment Zones

Acid Sulfate Soil Risk Map
- High to moderate ASS disturbance risk (<3m from surface)
- 4A Boundary

1: 2,500 (at A3)

0 12.5 25 50 75 100 125
Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

Water Corporation
Dawesville 4A/5A Infill Sewerage Works

Reticulated Area 4A
Inferred ASS Treatment Zones

Job Number	61-27593
Revision	0
Date	09 Nov 2012

Figure 4

G:\61\27593\GIS\Maps\MXD\6127593_G006_Fig4_Rev0.mxd

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data source: GHD: ASS Treatment Zones - 20121109; Opencut Sewer - 20120808, Trenchless Sewer - 20120808, Caissons - 20120808, Opencut Pressure Main - 20120807, Monitoring Wells - 20121031, 4A Boundary - 20121031, Access Chamber / Maintenance Shaft - 20121109; DEC: Acid Sulfate Soil Risk Map - 2009; Trenchless Pressure Main - 20120807, Pump Station - 20120807, Opencut Pressure Main - 20120807. Landgate: 2012 Metro South Mosaic - 20121031. Created by: cagilbert, erice

Appendices

Appendix A - Groundwater Summary Table

(Data collected by GHD, 2012)

Groundwater Summary Table
Water Corporation
Dawesville 4A/5A Infill Sewer

Sampling Details		General Analytes										Indicators of Sulfide Oxidation		Total Metals		Dissolved Metals													Nutrients		Oxygen Demand	
Groundwater Well ID	Sample Date	pH	Electrical Conductivity	Total Dissolved Solids	Total Suspended Solids	Total Alkalinity	Total Acidity	Sulfate as SO_4^{2-}	Sulfur as S	Chloride	Sodium	Chloride / sulfate ratio	Alkalinity / Sulfate ratio	Aluminium	Iron	Aluminium	Arsenic	Cadmium	Chromium	Cobalt	Copper	Lead	Iron	Manganese	Mercury	Nickel	Selenium	Zinc	Total Kjeldahl Nitrogen	Total Phosphorus	Chemical Oxygen Demand	Biological Oxygen Demand
LOR		pH Unit	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-	-	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
		0.01	0.01	1	1	1	1	1		1		-	-	0.1	0.05	0.01	0.001	0.0001	0.001	0.001	0.001	0.001	0.05	0.001		0.001	0.01	0.005	0.050	0.010	5	2
Chemical indicators		< 6				-	40	-	-	-	-	< 2	< 5.0	-	-	> 1	-	-	-				-	-		-	-	-			-	-
Marine Waters		-				-	-	-	-	-		-	-	-	0.3 (total)	0.055	0.013[a]	0.0055	0.0275	0.0010	0.0013	0.0044	0.3 (total)	1.9	0.0004	0.07	0.011	0.015	-	-	-	-
Water Corporation Sewer Acceptance Criteria**		6<pH>10		20,000						15,000		-	-																		6000	3000
BH21	07/09/2012	7.65	4950	-	-	393	32	161	-	1200	607	7.45	2.44	0.77	1.31	0.01	0.007	<0.0001	<0.001	<0.001	0.002	<0.001	<0.05	0.018	-	<0.001	<0.01	<0.005	1.3	0.19	-	-
PS7D	15/10/2012	7.87	16300	9880	12	260	10	513	178	4200	2070	8.19	0.51	0.02	0.16	0.01	<0.001	<0.0001	<0.001	<0.001	0.001	<0.001	0.09	<0.001	<0.0001	0.003	<0.01	<0.005	0.8	3.9	82	<2
PS7S	15/10/2012	7.57	5420	-	-	560	29	166		1270	699	7.65	3.37	2.11	5.02	0.72	0.032	<0.0001	0.011	0.001	0.004	0.002	3.4	0.025	-	0.005	<0.01	0.009	1.6	1.6	-	-
BH16	16/10/2012	7.82	7050	-	-	298	10	273	-	1810	935	6.63	1.09	9.5	11.9	0.01	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.07	0.035	-	0.002	<0.01	<0.005	1	0.23	-	-
BH13	16/10/2012	7.73	9510	-	-	307	16	330	-	2160	1150	6.55	0.93	9.28	15.3	0.02	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.95	0.027	-	0.001	<0.01	<0.005	0.6	0.05	-	-
BH9A	16/10/2012	8.05	5630	-	-	204	6	99	-	655	323	6.62	2.06	8.05	18.6	0.02	0.002	<0.0001	<0.001	0.001	<0.001	<0.001	<0.05	0.044	-	0.002	<0.01	<0.005	2.7	0.17	-	-
PS13S	15/10/2012	7.71	2270	-	-	235	12	98	-	572	286	5.84	2.40	0.42	2.5	0.1	0.004	<0.0001	0.001	<0.001	<0.001	<0.001	1.85	0.034	-	0.002	<0.01	<0.005	1.8	7	-	-
PS13D	15/10/2012	7.68	33900	15900	33	207	19	1130	364	8350	4210	7.39	0.18	3.4	4.84	1.81	0.001	0.0002	0.009	0.001	0.004	0.002	2.19	0.129	<0.0001	0.005	<0.01	<0.005	0.9	4.9	131	<2
BH1	15/10/2012	7.45	5810	-	-	380	36	126	-	1390	728	11.03	3.02	7.83	13.7	1.05	0.009	<0.0001	0.013	0.001	0.008	0.005	2.84	0.03	-	0.006	<0.01	0.012	2.2	7.6	-	-
PS14B	07/09/2012	7.75	3010	-	-	233	18	116	-	724	403	6.24	2.01	2.26	2.86	0.02	<0.001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.05	0.003	-	<0.001	<0.01	<0.005	3.4	0.22	-	-

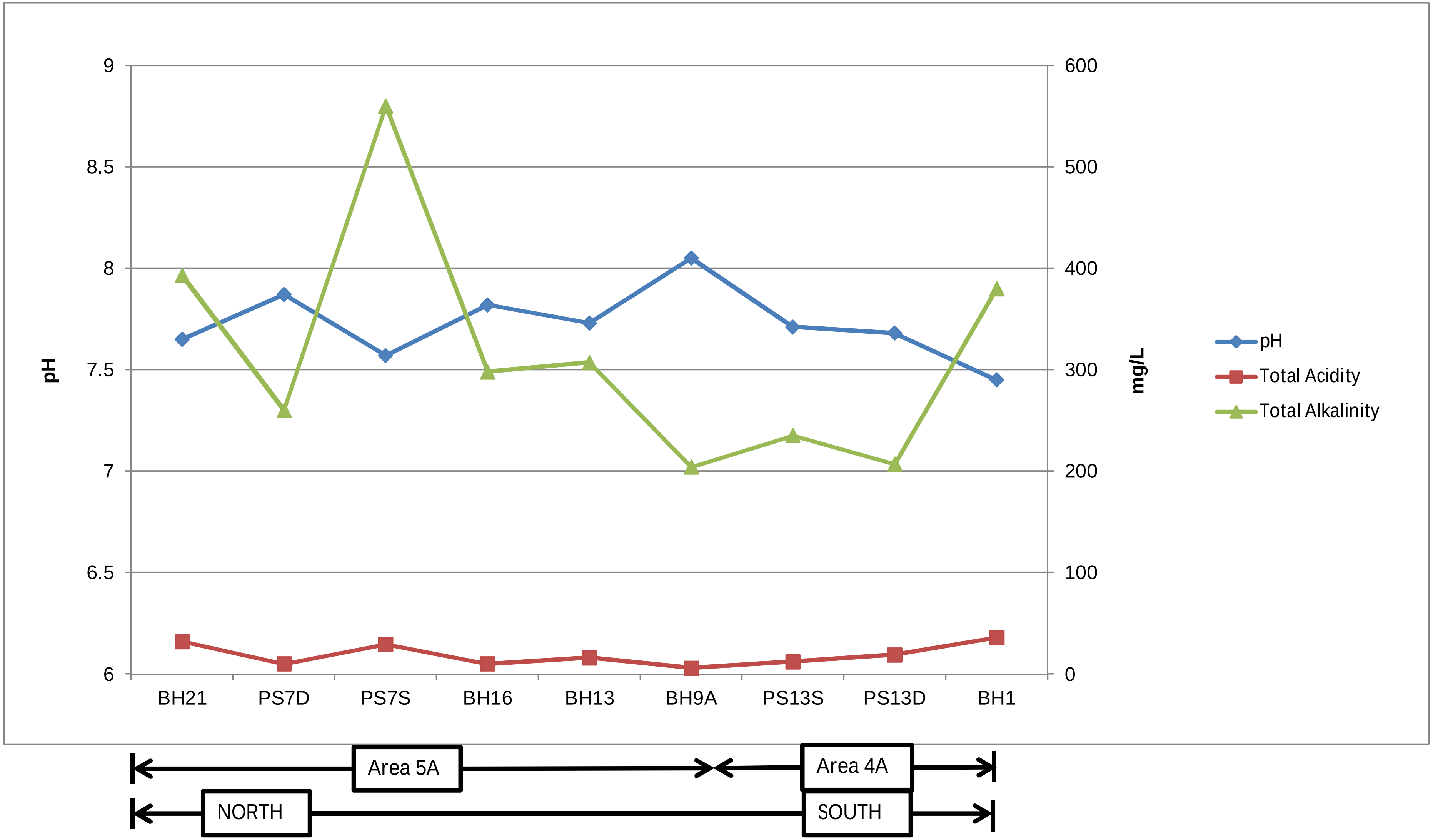
Notes:

244	indicates value is within the range of DEC key chemical indicator values for ASS-affected groundwater (DEC, 2009)
1	indicates value is above the 95% ANZECC Freshwater Aquatic Criteria (ANZECC, 2000)
5	indicates value is above the 95% ANZECC Marine Aquatic Criteria (ANZECC, 2000). Where a Marine trigger value did not exist, Freshwater criteria was used.
600	indicates value is outside of the typical acceptance criteria for discharge to Water Corporation Waste Water Treatment Plants (WWTPs).
	this well was sampled for baseline however will likely be destroyed as part of the pump station construction works
a	as As(V)
b	assessment level for Cr(VI) used where Cr(unspeciated) value not available (DEC, 2010)

Appendix B - Graph showing Vulnerability of Groundwater to Acidification

(Data collected by GHD, 2012)

Groundwater Vulnerability to Acidification
Water Corporation
Dawesville 4A/5A Infill Sewer



Appendix C - Groundwater Risk of Acidification Matrix

(Data collected by GHD, 2012)

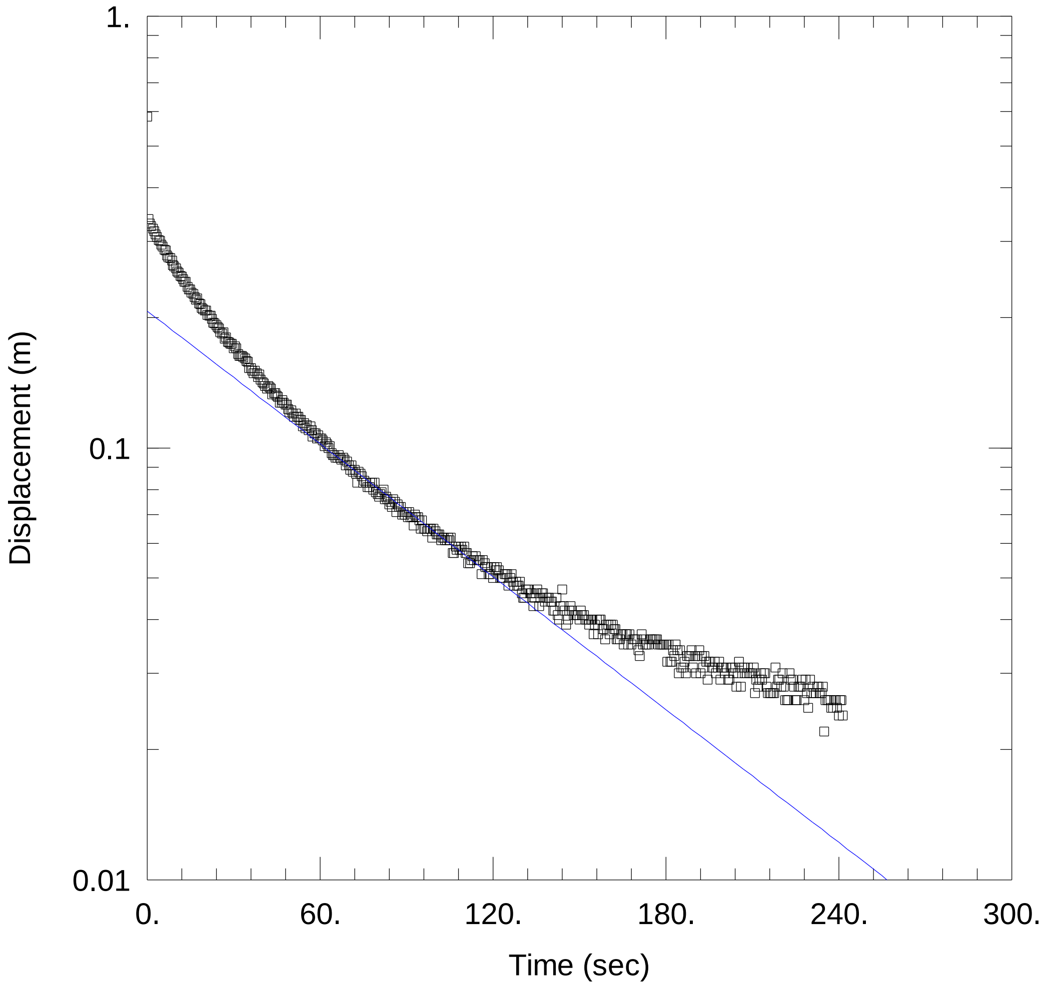
Groundwater Acidification Risk
Rockingham 25B Infill Sewerage Project
Water Corporation

Well ID	Date	Area	pH < 6	Net Alkalinity < Acidity	Alkalinity:Acidity ratio <2	Dissolved Aluminium > 1 mg/L	Dissolved Iron > 1 mg/L	Sulfate > 50 mg/L	Negative ORP*	Groundwater Acidification Risk	Groundwater treatment likely to be required
BH21	07/09/2012	5A	No	No	No	No	No	Yes	Yes	Low	Unlikely
PS7S	15/10/2012	5A	No	No	No	No	Yes	Yes	Yes	Low	Possible
PS7D	15/10/2012	5A	No	No	No	No	No	Yes	Yes	Low	Unlikely
BH16	16/10/2012	5A	No	No	No	No	No	Yes	Yes	Low	Unlikely
BH13	16/10/2012	5A	No	No	No	No	No	Yes	Yes	Low	Unlikely
BH9A	16/10/2012	5A	No	No	No	No	No	Yes	Yes	Low	Unlikely
PS13S	15/10/2012	4A	No	No	No	No	Yes	Yes	Yes	Low	Possible
PS13D	15/10/2012	4A	No	No	No	Yes	Yes	Yes	Yes	Low	Possible
BH1	15/10/2012	4A	No	No	No	Yes	Yes	Yes	Yes	Low	Possible

* Oxidation-reduction potential (ORP) recorded in the field, not analysed and reported by the laboratory.

Appendix D - AQTESolv Outputs

(Data collected and analysed by GHD, 2012)



WELL TEST ANALYSIS

Data Set: \...\BH21_2.aqt
Date: 09/11/12 Time: 15:17:06

PROJECT INFORMATION

Company: GHD
Project: 61/27593
Test Well: BH21

AQUIFER DATA

Saturated Thickness: 5. m Anisotropy Ratio (Kz/Kr): 1.

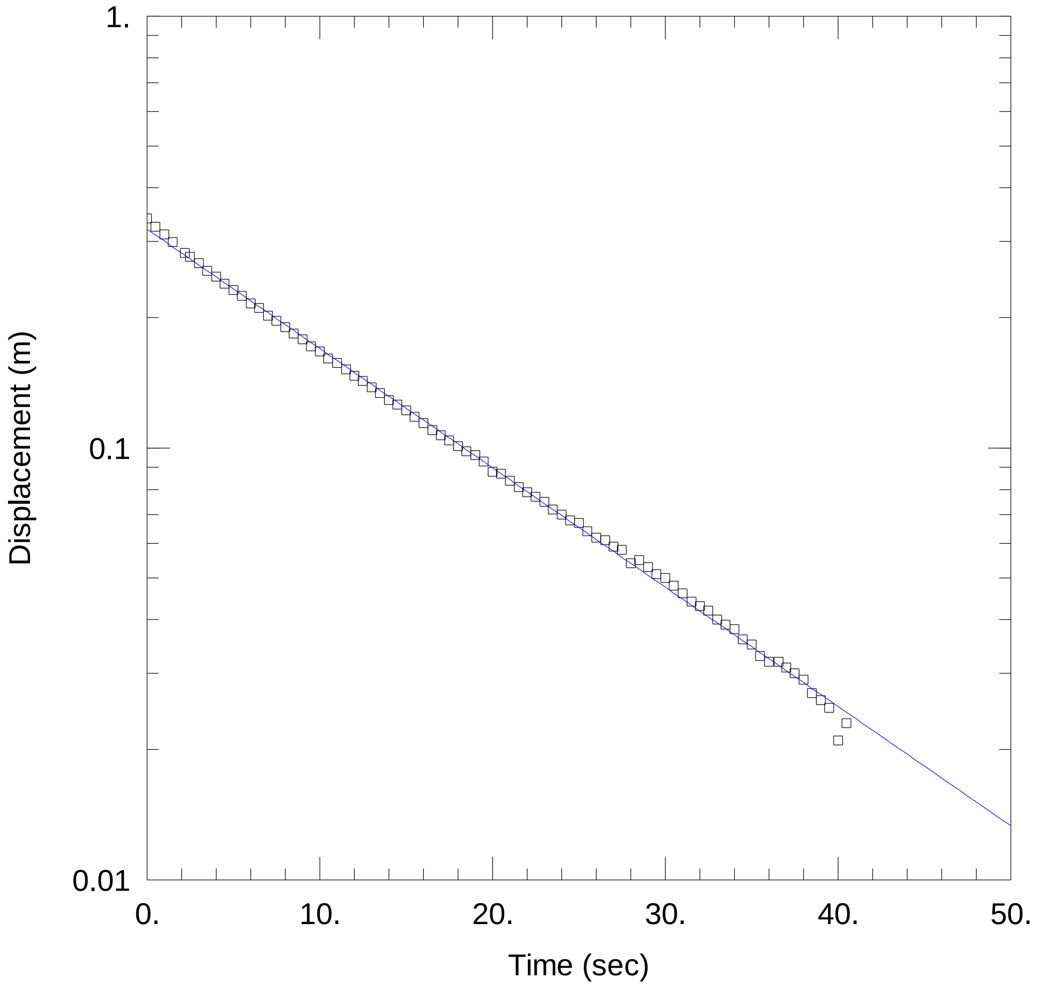
WELL DATA (BH21)

Initial Displacement: 0.585 m
Total Well Penetration Depth: 2.28 m
Casing Radius: 0.048 m
Static Water Column Height: 1.42 m
Screen Length: 2. m
Well Radius: 0.048 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 1.25E-5 m/sec y0 = 0.2075 m



WELL TEST ANALYSIS

Data Set: G:\61\27593\ASS\Permeability testing\Aqtesolv\PS7S.aqt
Date: 10/19/12 Time: 16:36:50

PROJECT INFORMATION

Company: GHD
Project: 61/27593
Location: Dawesville
Test Well: PS7S
Test Date: 12/10/2012

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

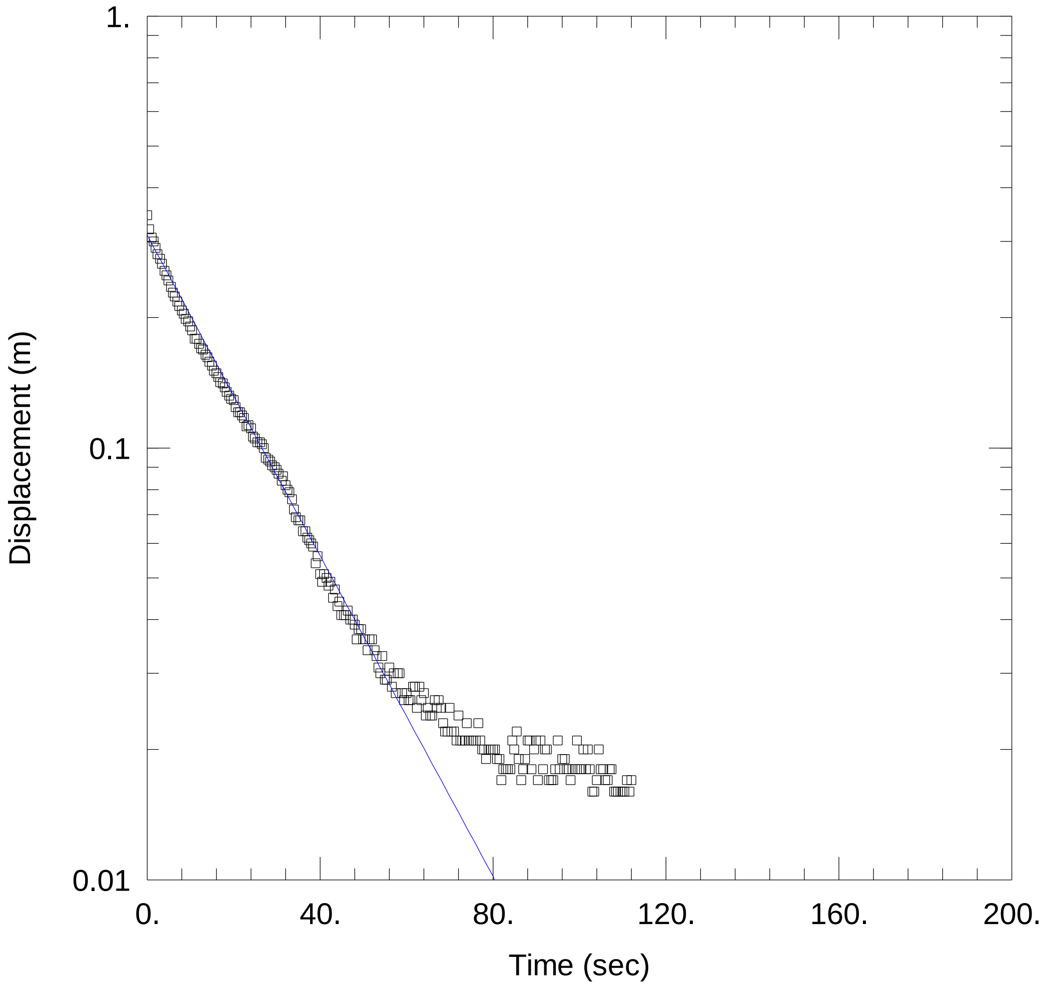
WELL DATA (PS7S)

Initial Displacement: 0.34 m Static Water Column Height: 2.15 m
Total Well Penetration Depth: 4. m Screen Length: 3. m
Casing Radius: 0.048 m Well Radius: 0.048 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 3.302E-5 m/sec y0 = 0.3208 m



WELL TEST ANALYSIS

Data Set: G:\61\27593\ASS\Permeability testing\Aqtesolv\BH16.aqt
Date: 10/19/12 Time: 16:44:10

PROJECT INFORMATION

Company: GHD
Project: 61/27593
Location: Dawesville
Test Well: BH16
Test Date: 12/10/2012

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

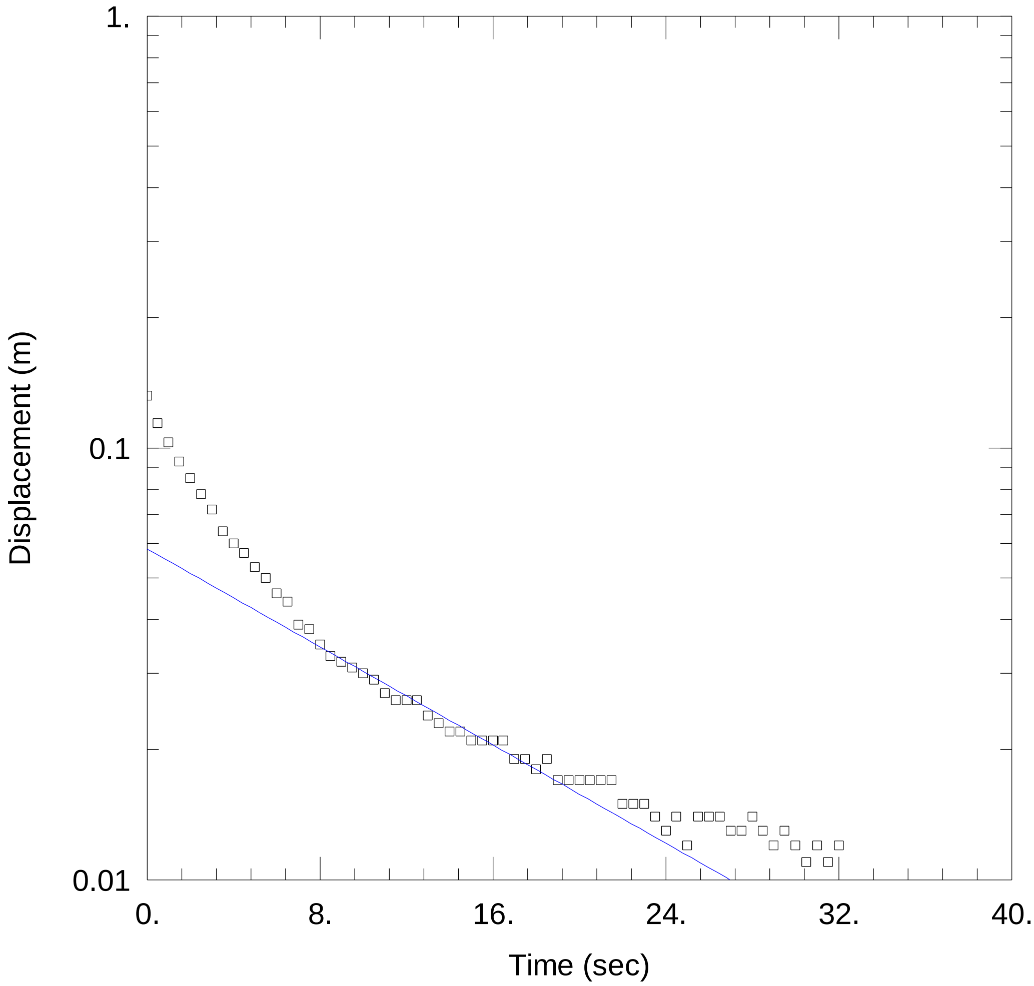
WELL DATA (BH16)

Initial Displacement: 0.345 m Static Water Column Height: 4.38 m
Total Well Penetration Depth: 5. m Screen Length: 4. m
Casing Radius: 0.048 m Well Radius: 0.048 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 1.796E-5 m/sec y0 = 0.3107 m



WELL TEST ANALYSIS

Data Set: G:\61\27593\ASS\Permeability testing\Aqtesolv\BH13.aqt
Date: 10/19/12 Time: 16:53:24

PROJECT INFORMATION

Company: GHD
Project: 61/27593
Location: Dawesville
Test Well: BH13
Test Date: 12/10/2012

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

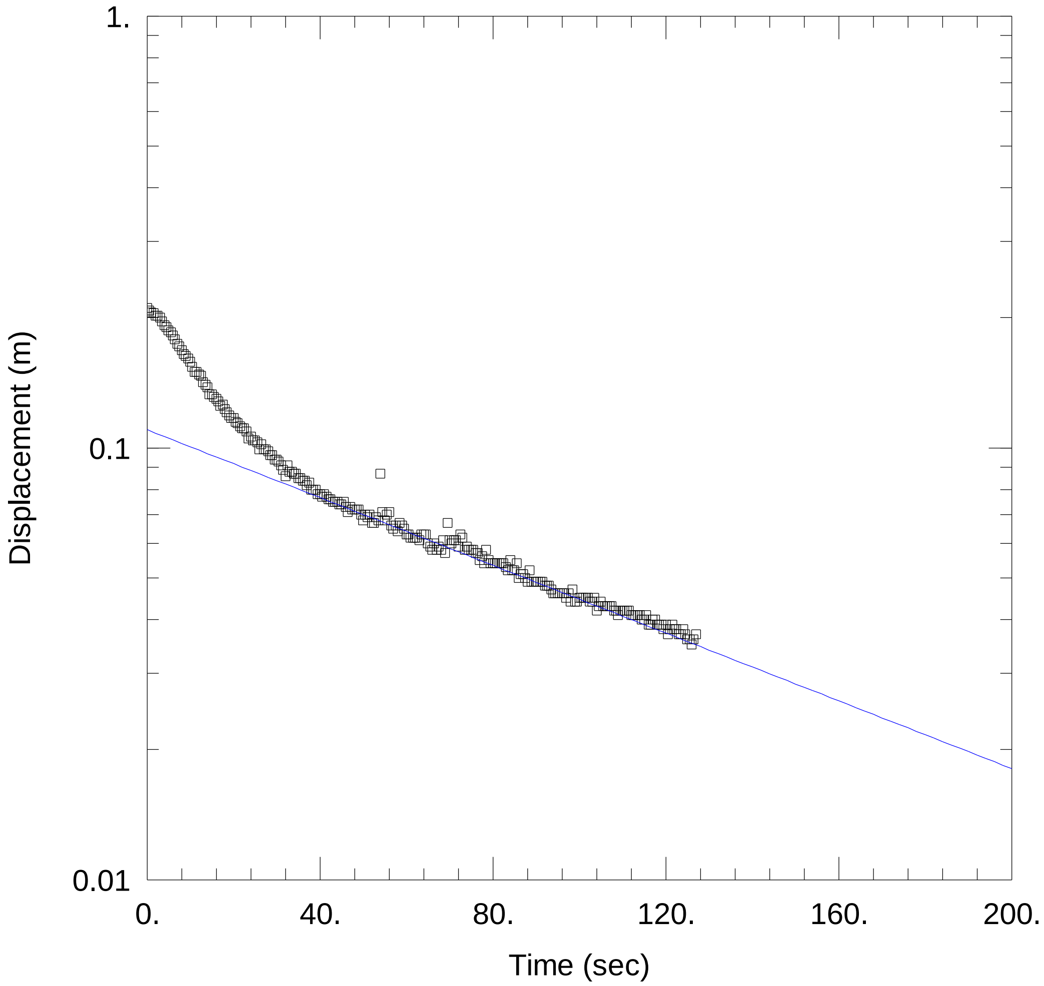
WELL DATA (BH13)

Initial Displacement: 0.132 m
Total Well Penetration Depth: 6. m
Casing Radius: 0.048 m
Static Water Column Height: 5.46 m
Screen Length: 5.5 m
Well Radius: 0.048 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 2.141E-5 m/sec y0 = 0.05833 m



WELL TEST ANALYSIS

Data Set: G:\61\27593\ASS\Permeability testing\Aqtesolv\BH9A.aqt
Date: 10/19/12 Time: 16:57:28

PROJECT INFORMATION

Company: GHD
Project: 61/27593
Location: Dawesville
Test Well: BH9A
Test Date: 12/10/2012

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

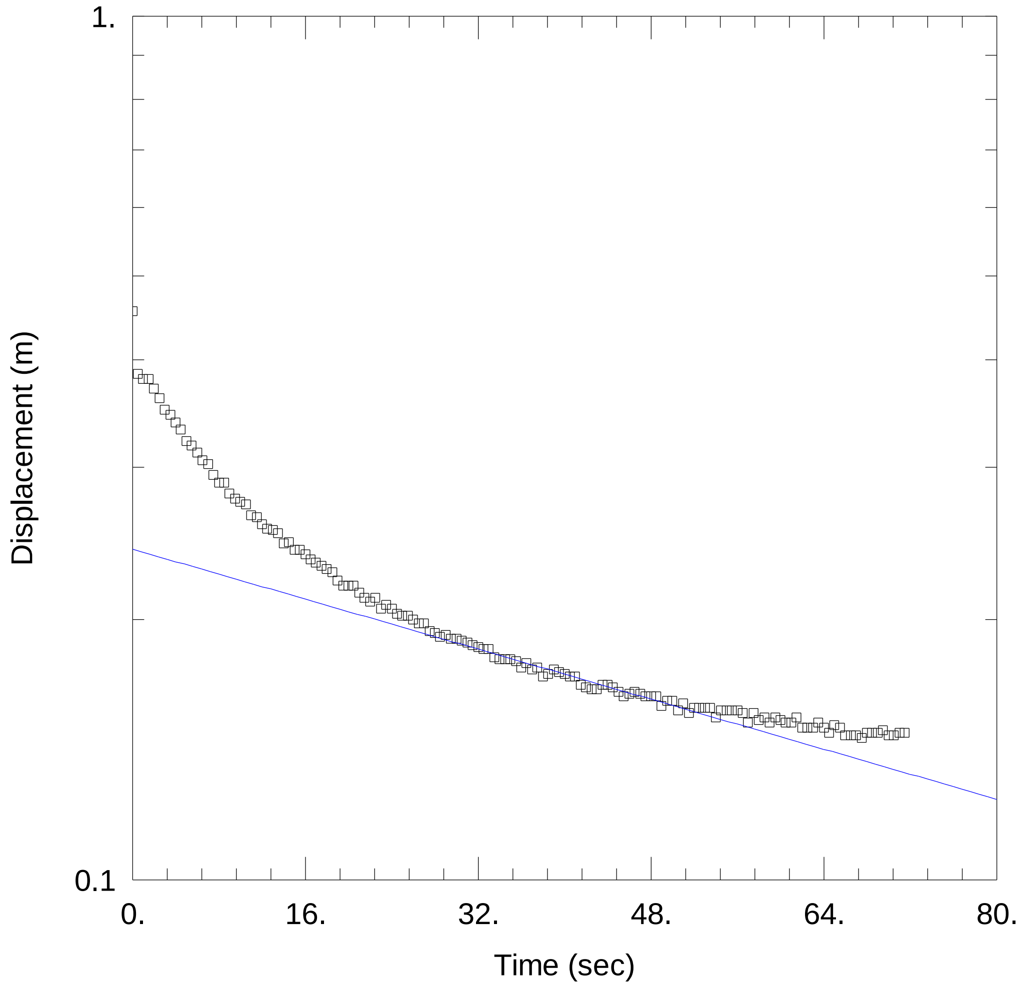
WELL DATA (BH9A)

Initial Displacement: 0.211 m
Total Well Penetration Depth: 5. m
Casing Radius: 0.048 m
Static Water Column Height: 4.19 m
Screen Length: 4.5 m
Well Radius: 0.048 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 3.42E-6 m/sec y0 = 0.11 m



WELL TEST ANALYSIS

Data Set: G:\61\27593\ASS\Permeability testing\Aqtesolv\PS13S.aqt
Date: 10/19/12 Time: 17:12:59

PROJECT INFORMATION

Company: GHD
Project: 61/27593
Location: Dawesville
Test Well: PS13S
Test Date: 12/10/2012

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

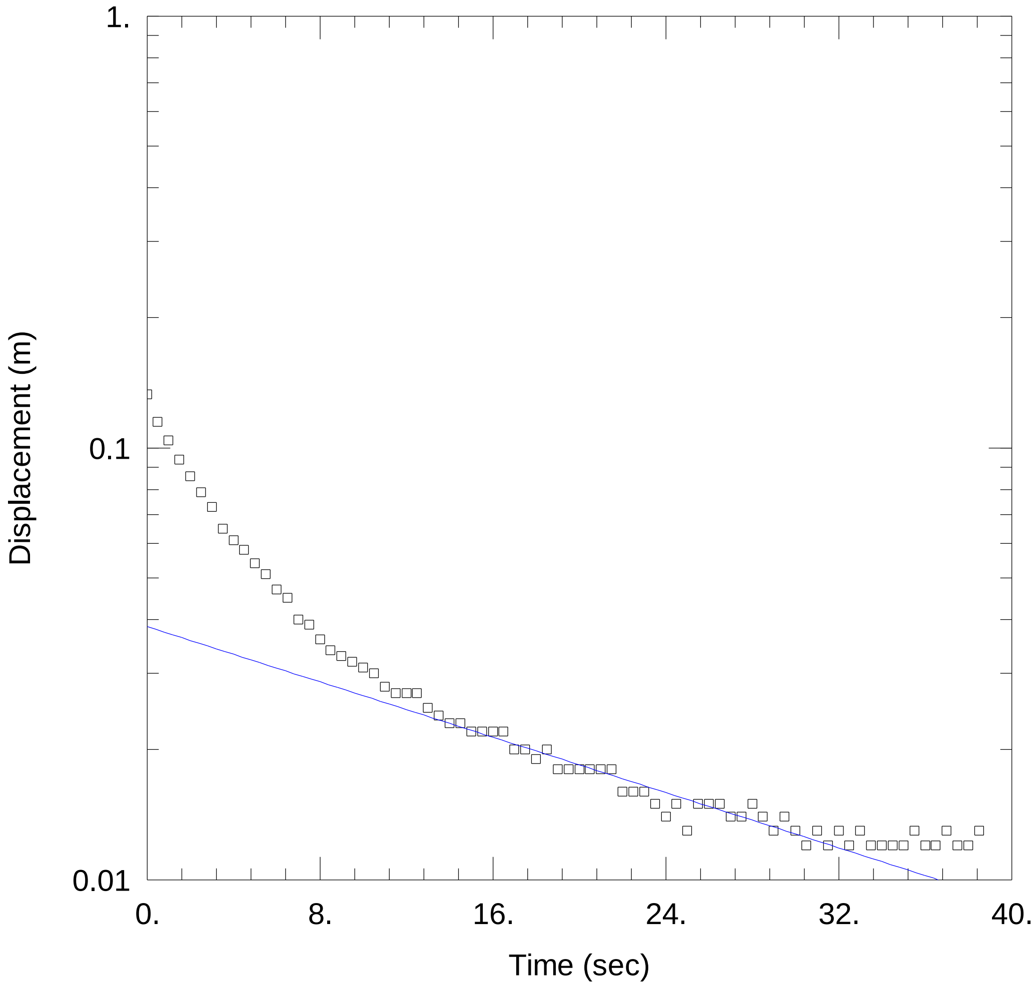
WELL DATA (PS13S)

Initial Displacement: 0.455 m Static Water Column Height: 3.41 m
Total Well Penetration Depth: 4. m Screen Length: 3. m
Casing Radius: 0.048 m Well Radius: 0.048 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 4.323E-6 m/sec y0 = 0.2413 m



WELL TEST ANALYSIS

Data Set: G:\61\27593\ASS\Permeability testing\Aqtesolv\PS13D.aqt
Date: 10/19/12 Time: 17:07:25

PROJECT INFORMATION

Company: GHD
Project: 61/27593
Location: Dawesville
Test Well: PS13D
Test Date: 12/10/2012

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 1.

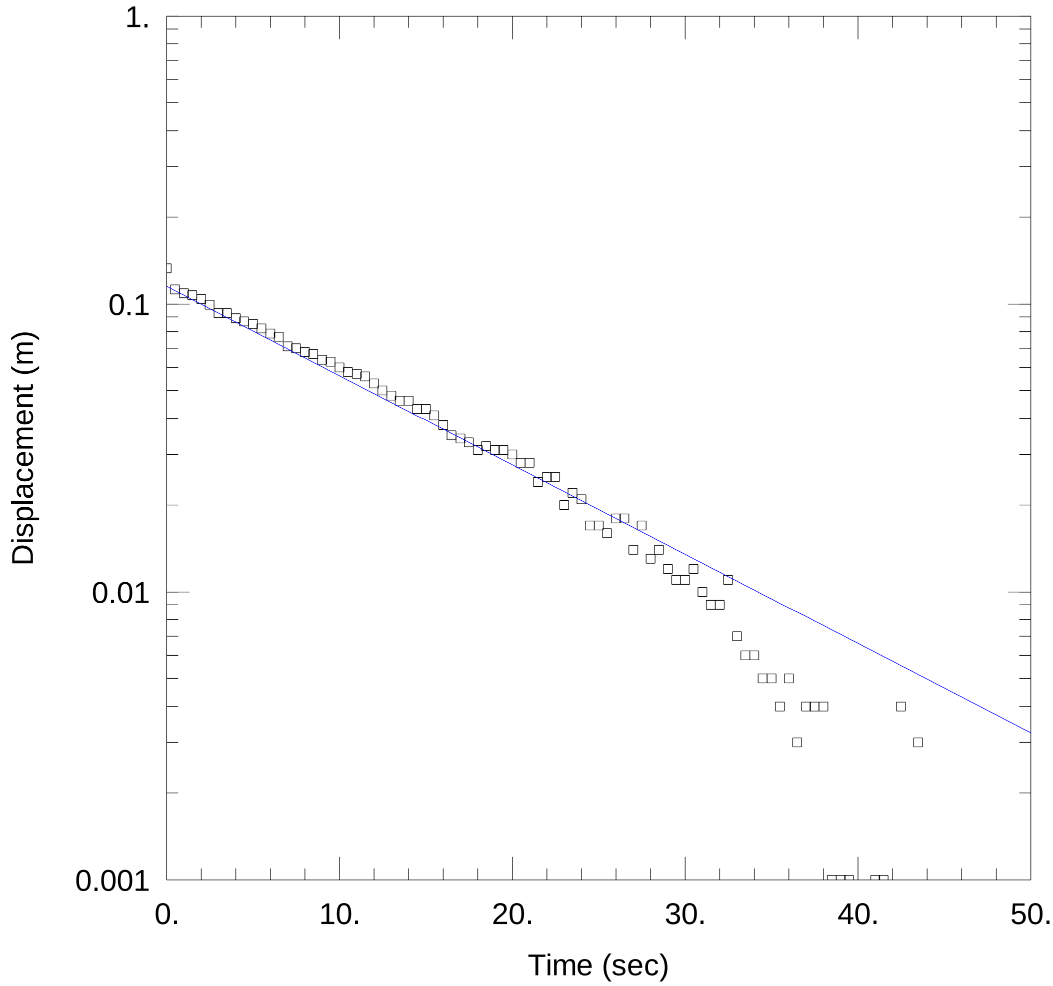
WELL DATA (PS13D)

Initial Displacement: 0.133 m
Total Well Penetration Depth: 8. m
Casing Radius: 0.048 m
Static Water Column Height: 7.63 m
Screen Length: 3. m
Well Radius: 0.048 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.186E-5 m/sec
y0 = 0.03853 m



WELL TEST ANALYSIS

Data Set: G:\61\27593\ASS\Permeability testing\Aqtesolv\BH1.aqt
Date: 10/19/12
Time: 17:21:05

PROJECT INFORMATION

Company: GHD
Project: 61/27593
Location: Dawesville
Test Well: BH1
Test Date: 12/10/2012

AQUIFER DATA

Saturated Thickness: 10. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH1)

Initial Displacement: 0.133 m
Total Well Penetration Depth: 5. m
Casing Radius: 0.048 m
Static Water Column Height: 5.34 m
Screen Length: 4.5 m
Well Radius: 0.048 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 2.704E-5 m/sec
y0 = 0.115 m

Appendix E - ASS Summary Tables

(Data collected by GHD, 2007)

Field Testing Results and Laboratory SPOCAS Testing Results

Sample ID						Field Test Results				Lab pH		Acidity								Calculations		
Location	Sample Interval	Duplicate Collected	Soil Horizon Boundary	Soil Colour	Soil Texture	pH_F	pH_{FOX}	ΔpH	Reaction	pH_{KCl}	pH_{OX}	TAA	TPA	TSA	POS	s-TAA	s-TPA	s-TSA	S_{POS}	Net Acidity	Net Acidity	ANC
						pH Unit			-	pH Unit		mole H^+ / t				% S				% S	mole H+ / t	
					Limit of Reporting	0.01	0.01	0.01	-	0.1	0.1	2	2	2	10	0.02	0.02	0.02	0.02	0.02	10	10
					Criteria	4	4	>2	-	4	4	18.7	18.7	18.7	18.7	0.03	0.03	0.03	0.03	0.03	18.7	
BH-1	0-0.5	-	0 - 0.45	Brown	Fine - coarse grained sand with gravel	7.8	5.4	2.4	Slight	8.5	6	<2	<2	<2	<0.02	<0.02	<0.02	<0.02	<10	<0.02	<10	
BH-1	0.5-1	-	0.45 - 0.73	Light brown	Fine - coarse grained sand	7.8	2.1	5.7	Extreme	7.4	3.8	<2	17	17	0.07	<0.02	0.03	0.03	43	0.07	43	
BH-1	1-1.5	-	0.73 - 2.1	Dark brown to greyish brown	Silty sand with trace organics fine to coarse grained, sulphur smell	7.7	2.3	5.4	Extreme	6.3	2.4	<2	143	143	0.26	<0.02	0.23	0.23	161	0.26	161	
BH-1	1.5-2	-	2.1 - 2.5	Light brown	Sand with limestone gravel	7.8	2	5.8	Extreme	6.6	3	<2	52	52	0.1	<0.02	0.08	0.08	60	0.1	60	
BH-1	2-2.25	-				8.2	5.9	2.3	Slight													
BH-2	0-0.5	-	0 - 0.76	Light brown	Sand fill, fine - medium grained	8.5	6.1	2.4	Slight	9.8	7.9	<2	<2	<2	30	<0.02	<0.02	<0.02	0.05	0.05	30	6450
BH-2	0.5-1	-	0.76 - 1.2	Dark grey	Silty sand, medium grained	8.5	5.3	3.2	Slight													
BH-2	1-1.5	x	1.2 - 1.34	Greyish - dark brown	Silty sand fine to coarse grained	8.3	2.8	5.5	Extreme	6.6	2.2	<2	322	322	374	<0.02	0.52	0.52	0.6	0.6	374	
BH-2	1.5-2	-	1.34 - 1.7	Grey	Fine - medium grained sand with 5 - 30 mm gravel	8.6	6.3	2.3	Slight													
BH-2	2-2.5	-	1.8 - 2.2	Beige	Gravel	8.4	6.4	2	Slight	9.6	7.8	<2	<2	<2	44	<0.02	<0.02	<0.02	0.07	0.07	44	13000
BH-3	0-0.5	-	0 - 0.79	Light brown - black	Silty sand, fine - medium grained	8.8	5.9	2.9	Extreme	9.9	7.9	<2	<2	<2	27	<0.02	<0.02	<0.02	0.04	0.04	27	5340
BH-3	0.5-1	x	0.96 - 1.2	Grey	Fine - coarse grained sand	8.4	1.9	6.5	Extreme	7.5	2.7	<2	78	78	108	<0.02	0.12	0.12	0.17	0.17	108	
BH-3	1-1.5	-	1.2 - 2.7	Beige	Fine - coarse grained sand with 2 - 10 mm gravel	8.2	6.3	1.9	Strong	9.5	8	<2	<2	<2	181	<0.02	<0.02	<0.02	0.29	0.29	181	7040
BH-3	1.5-2	-				8.1	6.2	1.9	Strong													
BH-3	2-2.5	-				8	6.2	1.8	Strong	9.5	8	<2	<2	<2	256	<0.02	<0.02	<0.02	0.41	0.41	256	6990
BH-3	2.5-2.8	-	2.7 - 2.8	Beige	Gravel, 10 - 35 mm	8.4	6.3	2.1	Slight													
BH-4	0-0.5	-	0 - 0.7	Light brown	Fine to coarse grained sand with silt trace	8.6	6.1	2.5	Strong	9.4	7.4	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	392
BH-4	0.5-1	-	0.7 - 1.1	Black	Fine to coarse grained silty clay, sulphur smell	8.4	4.8	3.6	Strong	8.5	7.1	<2	<2	<2	84	<0.02	<0.02	<0.02	0.13	0.13	84	379
BH-4	1-1.5	-	1.2 - 3.0	Grey	Medium grained sand, sulphur smell	8.1	1.8	6.3	Extreme	9.4	8	<2	<2	<2	66	<0.02	<0.02	<0.02	0.11	0.11	66	375
BH-4	1.5-2	-				8	1.9	6.1	Extreme													
BH-4	2-2.5	-				7.8	2.2	5.6	Extreme	6.5	2.7	<2	77	77	80	<0.02	0.12	0.12	0.13	0.13	80	
BH-4	2.5-2.75	-				7.9	2.2	5.7	Extreme													
BH-4	2.75-3	-				7.8	2.5	5.3	Slight	9	4.1	<2	25	25	72	<0.02	0.04	0.04	0.12	0.12	72	
PS-13	0.5-0.75	-	0 - 0.75	Black	Organic topsoil	8	5.6	2.4	Strong	8.9	6	<2	<2	<2	13	<0.02	<0.02	<0.02	0.02	0.02	13	
PS-13	0.75-1	-	0.75 - 0.9	Brown	Fine - coarse grained silty sand with roots	7.8	2	5.8	Extreme													
PS-13	1-1.5	x	0.9 - 2.4	Grey	Medium grained sand	7.8	1.9	5.9	Strong	6.4	2.8	<2	65	65	71	<0.02	0.1	0.1	0.11	0.11	71	
PS-13	1.5-2	-				7.9	2.2	5.7	Slight													
PS-13	2-2.5	-				7.8	2.6	5.2	Extreme	6.8	3.4	<2	72	72	97	<0.02	0.12	0.12	0.16	0.16	97	
PS-13	2.5-3	-	2.4 - 3.0	Greyish orangeish brown	Fine grained silty sand	8.5	5.9	2.6	Slight	8.9	7.5	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	214
PS-13	3-3.5	-	3.0 - 3.8	Brownish orange	Fine grained silty sand	7.4	5.5	1.9	Slight													
PS-13	3.75-4	-	3.8 - 5.5	Brownish orange	Medium grained sand	7.5	5.7	1.8	Slight	6.7	6.4	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
PS-13	4-4.5	-				7.9	5.5	2.4	Slight													
PS-13	4.5-5	-				8	4.9	3.1	Slight													
PS-13	5-5.5	-				7.8	5.3	2.5	Slight	7	6.3	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-5	0-0.5	-	0 - 0.72	Light brown - dark grey	Fine - medium grained sand - silty sand	8.5	6.3	2.2	Strong	9.5	7.7	<2	<2	<2	15	<0.02	<0.02	<0.02	0.02	0.02	15	3230
BH-5	0.5-1	-	0.72 - 1.03	Grey	Fine - coarse grained sand, sulphur smell	8.4	5.5	2.9	Slight	8.8	6.1	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-5	1-1.25	-	1.03 - 1.2	Greyish - brown	Fine - coarse grained silty sand	7.9	1.9	6	Extreme													
BH-5	1.5-2	-	1.2 - 2.34	Grey	Fine - coarse grained sand with roots, sulphur smell	7.9	2.2	5.7	Slight	7	2.8	<2	68	68	84	<0.02	0.11	0.11	0.14	0.14	84	
BH-5	2-2.5	-	2.34 - 2.5	Greyish - light brown	Fine - coarse grained sand with gravel 5 - 40 mm	8.7	6.3	2.4	Slight	9.7	7.8	<2	<2	<2	30	<0.02	<0.02	<0.02	0.05	0.05	30	11700
BH-6	0-0.5	-	0 - 0.48	Brown - beige	Fine - coarse grained sand with limestone gravels 5 - 35 mm	8.6	6.3	2.3	Strong	9.4	7.6	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	1530
BH-6	0.5-1	-	0.48 - 1.02	Brown - black	Silty - clayey sand fine - medium grained, sulphur smelling	8.4	6.1	2.3	Slight	9.2	7.5	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	259
BH-6	1-1.25	-	1.02 - 1.2	Dark brown	Fine - medium grained silty sand, sulphur smelling	8.2	1.9	6.3	Slight	9.7	7.6	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	432
BH-6	1.25-1.75	-	1.2 - 2.35	Light brownish grey	Fine - coarse grained sand	8.2	4.9	3.3	Moderate													
BH-6	2-2.5	-				8.2	5.7	2.5	Slight													
BH-6	2.5-3	-	2.35 - 3.0	Greyish light brown	Fine - coarse grained sand	8.1	5.8	2.3	Slight	8.9	6.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	40
BH-7	0-0.5	-	0 - 0.56	Brown - dark brown	Fine - medium grained sand - silty sand	7.3	6.2	1.1	Strong	9.2	7.4	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	464
BH-7	0.5-1	-	0.56 - 1.0	Black - beige	Silty sand to rock at 1.0 m	7.6	6.5	1.1	Slight	9.8	7.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	10100

AREA 5A (GHD, 2007)

Field Testing Results and Laboratory SPOCAS Testing Results

Sample ID						Field Test Results				Lab pH		Acidity								Calculations		
Location	Sample Interval	Duplicate Collected	Soil Horizon Boundary	Soil Colour	Soil Texture	pH_F	pH_{FOX}	ΔpH	Reaction	pH_{KCl}	pH_{OX}	TAA	TPA	TSA	POS	s-TAA	s-TPA	s-TSA	S_{POS}	Net Acidity	Net Acidity	ANC
						pH Unit			-	pH Unit		mole H^+ / t				% S				% S	mole H+ / t	
					Limit of Reporting	0.01	0.01	0.01	-	0.1	0.1	2	2	2	10	0.02	0.02	0.02	0.02	0.02	10	10
					Criteria	4	4	>2	-	4	4	18.7	18.7	18.7	18.7	0.03	0.03	0.03	0.03	0.03	18.7	
BH-8	0.5	-	0 - 0.43	Light brown	Fine - medium grained sand	8.2	6.5	1.7	Slight													
BH-8	1	-	0.43 - 1.04	Brown - black - dark grey	Sand with limestone gravel, fine - medium grained silty sand, fine - medium grained clayey sand	8.2	6.4	1.8	Slight	9.2	7.5	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	327
BH-8	1.5	-	1.04 - 1.4	Brownish grey - grey	Fine - medium grained silty sand, fine to coarse grained sand, sulphur smell	8.4	5.9	2.5	Strong	9.3	7.8	<2	<2	<2	132	<0.02	<0.02	<0.02	0.21	0.21	132	1130
BH-8	2	-	1.4 - 2.0	Greyish - beige	Limestone gravels < 45 mm	8.7	6.5	2.2	Slight	9.7	7.9	<2	<2	<2	54	<0.02	<0.02	<0.02	0.09	0.09	54	13300
BH-9	0.5	-	0 - 0.64	Brown	Fine - medium grained sand	8.5	6.3	2.2	Slight	9.6	7.6	<2	<2	<2	16	<0.02	<0.02	<0.02	0.02	0.02	16	
BH-9	1	-	0.64 - 1.02	Light brown - black	Fine - medium grained silty sand - sand	8.3	5.5	2.8	Slight													
BH-9	1.5	-	1.02 - 1.3	Brownish dark grey	Fine - coarse grained silty sand, sulphur smell	8	2	6	Extreme	8.8	3.6	<2	25	25	53	<0.02	0.04	0.04	0.08	0.08	53	
BH-9	2	-	1.3 - 2.23	Grey	Fine - medium grained sand with some roots	8	5.7	2.3	Slight													
BH-9	2.5	-				7.7	5.8	1.9	Slight													
BH-9	3	-	2.23 - 3.0	Light brown	Fine grained sand	7.8	5.4	2.4	Slight													
BH-9	3.5	-				7.8	5.7	2.1	Slight	8.6	6.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-10	0.5	-	0 - 0.8	Brown	Fine - medium grained sand	8.1	5.8	2.3	Moderate	9.2	6.8	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-10	1	-	0.8 - 1.04	Black - dark brown	Fine - coarse grained silty sand	8.4	6.4	2	Slight													
BH-10	1.5	-	1.04 2.03	Grey	Fine - medium grained sand sulphur smell	8.1	5.8	2.3	Slight													
BH-10	2	-				8.4	5.7	2.7	Slight	9.7	7.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-10	2.5	-				8	6	2	Slight													
BH-10	3	-	2.03 - 3.86	Light brown	Fine - medium grained sand with some organics, sulphur smell	7.6	5.9	1.7	Slight													
BH-10	3.5	-				7.9	5.8	2.1	Slight	7.2	6.4	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-10	4	-	3.86 - 4.0	Beige	Limestone gravels < 45 mm	8.6	6.7	1.9	Slight	9.6	7.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-11	0.5	-	0 - 0.59	Light brown with black streaks	Fine - medium grained sand	8.5	5.9	2.6	Slight	9.4	7.2	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-11	1	-	0.59 - 0.92	Dark grey - black	Fine - medium grained silty sand - clayey sand, sulphur smell	8.4	4	4.4	Strong	7.6	2.5	<2	104	104	122	<0.02	0.17	0.17	0.2	0.2	122	
BH-11	1.5	-	0.92 - 1.05	Dark brown	Fine - medium grained silty sand	8.2	2.4	5.8	Extreme													
BH-11	2	x	1.05 - 2.62	Grey	Fine - medium grained sand	7.9	4.1	3.8	Extreme	9.1	8.2	<2	<2	<2	230	<0.02	<0.02	<0.02	0.37	0.37	230	
BH-11	2.5	-				7.4	3.3	4.1	Extreme													
BH-11	3	-	2.62 - 3.5	Light brown	Fine grained sand	7.6	2.2	5.4	Slight	6.8	5.2	<2	5	5	26	<0.02	<0.02	<0.02	0.04	0.04	26	
BH-11	3.5	-				7.6	5.5	2.1	Slight	6.7	6.1	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-12	0.5	-	0 - 0.59	Light brown	Fine - medium grained sand	8.4	6	2.4	Strong	9.8	7.8	<2	<2	<2	50	<0.02	<0.02	<0.02	0.08	0.08	50	
BH-12	1	-	0.59 - 0.89	Dark grey/brown - black	Fine - medium grained silty sand	8.1	1.4	6.7	Slight													
BH-12	1.5	-				7.8	1.4	6.4	Extreme	7	2.6	<2	128	128	151	<0.02	0.2	0.2	0.24	0.24	151	
BH-12	2	-	0.89 - 2.7	Grey	Fine - medium grained sand - roots throughout	7.5	2.4	5.1	Extreme													
BH-12	2.5	-				7.4	2.1	5.3	Extreme	6	2.8	<2	164	163	168	<0.02	0.26	0.26	0.27	0.27	169	
BH-12	3	-				7.2	1.7	5.5	Extreme	9.4	8	<2	<2	<2	54	<0.02	<0.02	<0.02	0.09	0.09	54	
BH-12	3.5	-	2.7 - 4.0	Light brown	Fine grained sand	7.2	2.2	5	Extreme													
BH-12	4	-				7.4	2.2	5.2	Slight	7.6	5.7	<2	<2	<2	17	<0.02	<0.02	<0.02	0.03	0.03	17	
BH-13	0.5	-	0 - 0.6	Light brown	Fine - medium grained sand	8.4	6.1	2.3	Strong	9.9	7.6	<2	<2	<2	33	<0.02	<0.02	<0.02	0.05	0.05	33	
BH-13	1	-	0.6 - 0.72	Black	Fine - medium grained silty sand - clayey sand, sulphur smell	8.1	2.4	5.7	Extreme	9.4	6.7	<2	<2	<2	56	<0.02	<0.02	<0.02	0.09	0.09	56	
BH-13	1.5	-	0.72 - 0.9	Dark brown	Fine - medium grained silty sand	7.6	2.2	5.4	Extreme													
BH-13	2	-	0.9 - 2.6	Grey	Fine - medium grained sand	7.6	2.4	5.2	Extreme	7.1	2.5	<2	170	170	187	<0.02	0.27	0.27	0.3	0.3	187	
BH-13	2.5	-				7.2	2	5.2	Extreme													
BH-13	3	-				7.5	2	5.5	Extreme	9.2	7.3	<2	<2	<2	58	<0.02	<0.02	<0.02	0.09	0.09	58	
BH-13	3.5	-	2.6 - 4.5	Light brown	Fine grained sand	7.6	2.1	5.5	Slight													
BH-13	4	-				7.6	2.1	5.5	Slight													
BH-13	4.5	-				7.4	2.4	5	Slight	7.7	6	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-14	0.5	-	0 - 0.880	Light brown	Fine - coarse grained sand	8.2	6.5	1.7	Strong	9.9	7.8	<2	<2	<2	37	<0.02	<0.02	<0.02	0.06	0.06	37	
BH-14	1	-	0.88 - 1.08	Black	Fine grained silty sand	9	6.7	2.3	Moderate													
BH-14	1.5	x	1.08 - 1.17	Greyish - dark brown	Fine - coarse grained silty sand, sulphur smell	8.1	4.8	3.3	Extreme	6.7	2.5	<2	126	126	148	<0.02	0.2	0.2	0.24	0.24	148	
BH-14	2	-	1.17 - 2.87	Grey	Fine to medium grained sand	7.7	4.5	3.2	Extreme													
BH-14	2.5	-				7.6	3.7	3.9	Extreme	6.8	2.6	<2	207	207	239	<0.02	0.33	0.33	0.38	0.38	239	
BH-14	3	-				7.5	2.6	4.9	Slight	9.4	7.9	<2	<2	<2	12	<0.02	<0.02	<0.02	<0.02	<0.02	12	
BH-14	3.5	-	2.87 - 5.0	Light brown	Fine - medium grained sand	7.8	4.2	3.6	Slight													
BH-14	4	-				7.7	3.1	4.6	Slight													
BH-14	4.5	-				7.7	4.9	2.8	Slight													
BH-14	5	-				7.6	2.4	5.2	Extreme	6.7	5.7	<2	2	2	16	<0.02	<0.02	<0.02	0.02	0.02	16	
BH-15	0.5	-	0 - 0.88	Brown	Medium grained sand	7.7	5.2	2.5	Moderate	7.8	4.1	<2	551	551	50	<0.02	0.88	0.88	0.08	0.08	50	
BH-15	1	-	0.88 - 1.0	Black	Fine grained silty sand	8.2	6	2.2	Moderate	9.5	7.1	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-15	1.5	-	1.0 - 1.24	Greyish brown	Fine - medium grained silty sand	7.4	2.5	4.9	Extreme	6.1	2.6	<2	92	91	115	<0.02	0.15	0.14	0.18	0.19	117	
BH-15	2	-	1.24 - 2.45	Brownish grey - grey	Fine - medium grained sand	7.3	2.4	4.9	Extreme	6	2.6	<2	130	129	140	<0.02	0.21	0.21	0.22	0.23	141	
BH-15	2.5	-				7.2	3.4	3.8	Slight	7.1	5.8	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-15	3	-				7.6	5.6	2	Slight													
BH-15	3.5	-				7.7	4.9	2.8	Slight													
BH-15	4	-	2.45 - 5.2	Brownish grey - grey	Fine - medium grained sand	7.8	5.5	2.3	Slight	6.8	6.3	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-15	4.5	-				7.7	5.5	2.2	Slight													
BH-15	5	-				7.7	5.7	2	Slight													
BH-15	5.2	-				7.7	5.3	2.4	Slight	6.8	6.3	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-16	0.5	-	0 - 0.72	Brown	Medium grained sand	7.9	4.6	3.3	Strong	7.2	6	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-16	1	-	0.72 - 1.06	Greyish black	Fine grained to Fine - medium grained silty sand	8	3	5	Strong	6.7	4	<2	<2	<2	20	<0.02	<0.02	<0.02	0.03	0.03	20	

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Field Testing Results and Laboratory SPOCAS Testing Results

Sample ID						Field Test Results				Lab pH		Acidity								Calculations		
Location	Sample Interval	Duplicate Collected	Soil Horizon Boundary	Soil Colour	Soil Texture	pH_F	pH_{FOX}	ΔpH	Reaction	pH_{KCl}	pH_{OX}	TAA	TPA	TSA	POS	s-TAA	s-TPA	s-TSA	S_{POS}	Net Acidity	Net Acidity	ANC
						pH Unit			-	pH Unit		mole H^+ / t				% S				% S	mole H+ / t	
					Limit of Reporting	0.01	0.01	0.01	-	0.1	0.1	2	2	2	10	0.02	0.02	0.02	0.02	0.02	10	10
					Criteria	4	4	>2	-	4	4	18.7	18.7	18.7	18.7	0.03	0.03	0.03	0.03	0.03	18.7	
BH-16	1.5	-	1.06 - 2.1	Grey	Fine - coarse grained sand	8	2.3	5.7	Extreme	6.8	3.7	<2	16	16	28	<0.02	0.02	0.02	0.04	0.04	28	
BH-16	2	-				7.5	2	5.5	Extreme													
BH-16	2.5	-	2.1 - 3.3	Brownish grey	Fine - medium grained sand	7.8	2.8	5	Slight	6.9	6.2	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-16	3	-				7.7	5.8	1.9	Slight													
BH-16	3.5	-	3.3 - 3.9	Brownish beige	Fine - coarse grained sand with <40 mm gravels	7.7	6.6	1.1	Slight													
BH-16	4	-	3.9 - 4.3	Light brown	Coarse grained sand	8.3	6.5	1.8	Slight													
BH-16	4.5	-	4.3 - 4.9	Light brown	Fine grained sand	8.4	6.6	1.8	Slight													
BH-16	5	-	4.9 - 6.0	Beige	Fine grained sand with gravels <25 mm	8.8	6.5	2.3	Slight	9.6	7.8	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-16	5.5	x				8.8	6.5	2.3	Slight													
BH-16	6	-				8.6	6.6	2	Slight	9.7	7.9	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-17	0.5	-	0 - 0.7	Reddish brown	Fine - medium grained silty sand	8.4	5.5	2.9	Moderate	9.5	7.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-17	1	-	0.7 - 1.05	Black - grey	Fine - medium grained silty sand to sand with silt	8.2	5.5	2.7	Slight													
BH-17	1.5	-	1.05 - 1.16	Brownish grey	Medium grained clayey sand, sulphur smell	8.1	5.5	2.6	Slight	9.6	7.6	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-17	2	-	1.16 - 2.1	Greyish brown - brownish grey	Fine - medium grained sand with trace silt, sulphur smell	8.2	4.6	3.6	Slight	9.4	7.1	<2	<2	<2		<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-17	2.5	-	2.1 - 2.28	Beige	Fine - coarse grained sand with gravels <45 mm	8.8	6.2	2.6	Slight													
BH-17	3	-	2.28 - 3.0	Grey	Fine - coarse grained sand with gravel < 15mm	9.1	6.3	2.8	Slight													
BH-17	4	-	3.0 - 3.9	Beige	Fine - coarse grained sand with gravels < 15mm	8.9	6.4	2.5	Slight													
BH-17	4.5	-	4.9 - 4.9	Light brownish beige	Fine grained silty sand	9.2	6.3	2.9	Slight													
BH-17	5	-	4.9 - 6	Beige	Fine - coarse grained silty sand with <40 mm gravels	9	6.4	2.6	Slight													
BH-17	5.5	x				9.1	6.5	2.6	Slight													
BH-17	6					9.3	6.6	2.7	Slight	9.9	7.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
PS-7	0.5	-	0 - 0.68	Brown	Fine - coarse grained sand	9.4	6.3	3.1	Moderate	9.6	7.6	<2	<2	<2	13	<0.02	<0.02	<0.02	0.02	0.02	13	
PS-7	1	-	0.68 - 0.9	Light brown	Fine - medium grained sand	9.3	6.4	2.9	Slight													
PS-7	1.5	-	0.9 - 1.42	Light brown	Fine - coarse grained sand	9	5.8	3.2	Slight	8	5.9	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
PS-7	2	-	1.42 - 2.37	Light grey	Medium grained sand	9	4.8	4.2	Moderate													
PS-7	2.5	-	2.37 - 2.45	Light brownish grey	Medium grained sand	8.3	5.7	2.6	Slight													
PS-7	3	-	2.45 - 3.0	Orangeish light brown	Medium- coarse grained sand	8.3	5.6	2.7	Slight	9.3	7.1	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
PS-7	3.5	-	3.0 - 4.5	Record loss insufficient samples		7.3	6.2	1.1	Slight													
PS-7	4	-				8.4	6.3	2.1	Slight													
PS-7	4.5	-	4.5 - 4.55	Beige	Fine - coarse grained sand	8.2	5.7	2.5	Slight													
PS-7	5	-	4.55 - 5.0	Brown	Medium - coarse grained sand	8.3	6.4	1.9	Slight													
PS-7	5.5	-	5.0 - 5.6	Orangeish brown	Medium grained sand	8.4	6	2.4	Slight													
PS-7	6	-	5.6 - 6.0	Brownish beige	Weakly cemented limestone gravel	8.8	6.5	2.3	Slight													
PS-7	6.5	-	6.0 - 6.6	Orangeish beige	Medium grained sand	8.6	6.5	2.1	Slight													
PS-7	7	-	6.6 - 7.0	Orangeish beige	Medium grained sand	8.7	6.5	2.2	Slight	9.5	7.8	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
PS-7	7.5	-	7.0 - 7.45	Beige	Medium coarse grained sand	8.8	6.5	2.3	Slight													
PS-7	8	-	7.45 - 8.0	Orangeish beige	Fine - medium grained sand	8.9	6.5	2.4	Slight	9.7	7.8	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-18	0.5	-	0 - 0.84	Orangeish brown	Fine - coarse grained sand	9	5.7	3.3	Slight	8.8	6.8	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-18	1	x	0.84 - 1.04	Black	Fine - medium grained silty sand	9.5	6.4	3.1	Moderate	8.9	7.8	<2	<2	<2	10	<0.02	<0.02	<0.02	<0.02	<0.02	10	
BH-18	1.5	-	1.04 - 2.68	Beige	Fine - coarse grained sand	9.2	6.4	2.8	Slight													
BH-18	2	-				9.2	6.4	2.8	Slight													
BH-18	2.5	-	2.68 - 2.75	Light brownish beige	Coarse grained sand	9.1	6.5	2.6	Slight													
BH-18	3	-	2.75 - 3.0	Beige and orangeish beige	Weakly cemented limestone rock and gravel	9.1	6.3	2.8	Moderate													
BH-19	0.5	-	0 - 0.69	Brown	Fine - medium grained sand with silt and <10 mm gravels	9.1	6	3.1	Slight	9.5	7.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-19	1	-	0.69 - 1.0	Light brown	Fine - medium grained sand	8.6	4.8	3.8	Slight													
BH-19	1.5	-	1.0 - 1.3	Black	Fine - coarse grained silty sand	8.6	6.1	2.5	Moderate	7.4	3.9	<2	<2	<2	22	<0.02	<0.02	<0.02	0.04	0.04	22	
BH-19	2	x	1.3 - 1.8	Brownish black	Fine - coarse grained silty sand	8.8	6.4	2.4	Slight													
BH-19	2.5	-	1.8 - 2.04	Greyish brown	Fine - coarse grained sand	9	6.6	2.4	Slight													
BH-19	3	-	2.04 - 5.0	Beige	Fine - coarse grained sand with <40 mm gravel	9.1	6.5	2.6	Slight	9.7	7.8	<2	<2	<2	16	<0.02	<0.02	<0.02	0.02	0.02	16	
BH-19	3.5	-				9	6.7	2.3	Slight													
BH-19	4	-				8.9	6.5	2.4	Slight													
BH-19	4.5	-				9.2	6.7	2.5	Slight													
BH-19	5	-				8.9	6.6	2.3	Slight	9.8	7.8	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-20	0.5	-	0 - 0.66	Light brown	Fine - medium grained sand	9.2	5.7	3.5	Slight	7.9	6.5	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-20	1	-	0.66 - 0.85	Black	Fine - coarse grained silty sand	8.2	2.8	5.4	Moderate													
BH-20	1.5	-	0.85 - 1.29	Black - grey	Fine - medium grained sand, sulphur smell	8.7	6.2	2.5	Slight	9.7	7.5	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-20	2	-	1.29 - 2.2	Beige	Medium - coarse grained	8.7	5.8	2.9	Slight													
BH-20	2.5	-	2.2 - 3.2	Greyish orange	Fine - medium grained sand	8.3	5.7	2.6	Slight													
BH-20	3	-	3.22 - 3.5	Beige	Fine - coarse grained sand <45 mm gravels	8.2	5.7	2.5	Slight													
BH-20	3.5	-				9.3	6.5	2.8	Slight	9.7	7.7	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-21	0.5	-	0 - 0.6	Light brown	Fine - medium grained sand	9.4	6.1	3.3	Slight	9.9	7.9	<2	<2	<2	47	<0.02	<0.02	<0.02	0.08	0.08	47	
BH-21	1	-	0.6 - 0.73	Black	Fine - medium grained silty sand	8.4	5.7	2.7	Slight													
BH-21	1.5	x	0.73 - 1.8	Greyish brown - grey	Fine - coarse grained sand - silty sand, sulphur smell	8.5	5.8	2.7	Slight	9.8	7.6	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
BH-21	2	-	1.8 - 2.5	Greyish light brown - light brown	Fine - medium grained sand	8.2	2.3	5.9	Extreme													
BH-21	2.5	-				8.3	6.5	1.8	Slight													
Duplicate 1	1.5	PS14	0.9 - 2.4	Grey	Medium grained sand	8	6.1	1.9	Slight													
Duplicate 2	1	BH18	0.84 - 1.04	Black	Fine - medium grained silty sand	9.4	5.9	3.5	Slight	9.2	7.9	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
Duplicate 3	1.93	BH19	1.8 - 2.04	Greyish brown	Fine - coarse grained sand	9	6.3	2.7	Slight													

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Field Testing Results and Laboratory SPOCAS Testing Results

Sample ID						Field Test Results				Lab pH		Acidity								Calculations		
Location	Sample Interval	Duplicate Collected	Soil Horizon Boundary	Soil Colour	Soil Texture	pH_F	pH_{FOX}	ΔpH	Reaction	pH_{KCl}	pH_{OX}	TAA	TPA	TSA	POS	s-TAA	s-TPA	s-TSA	S_{POS}	Net Acidity	Net Acidity	ANC
						pH Unit			-	pH Unit		mole H^+ / t				% S				% S	mole H+ / t	
					Limit of Reporting	0.01	0.01	0.01	-	0.1	0.1	2	2	2	10	0.02	0.02	0.02	0.02	0.02	10	10
					Criteria	4	4	>2	-	4	4	18.7	18.7	18.7	18.7	0.03	0.03	0.03	0.03	0.03	18.7	
Duplicate 4	1.4	BH21	0.73 - 1.8	Greyish brown - grey	Fine - coarse grained sand - silty sand, sulphur smell	8.5	2.6	5.9	Extreme	9.7	7.2	<2	<2	<2	<10	<0.02	<0.02	<0.02	<0.02	<0.02	<10	
Duplicate 5	5.6	BH16	4.9 - 6.0	Beige	Fine grained sand with gravels <25 mm	9.1	6.3	2.8	Extreme													
Duplicate 6	1.4	BH14	1.17 - 2.87	Grey	Fine to medium grained sand	8.6	3.3	5.3	Extreme	7.9	2.6	<2	106	106	142	<0.02	0.17	0.17	0.23	0.23	142	
Duplicate 7	5.4	BH17	4.9 - 6.0	Beige	Fine grained sand with gravels <25 mm	9.1	1.6	7.5	Extreme	9.7	7.8	<2	<2	<2	41	<0.02	<0.02	<0.02	0.07	0.07	41	
Duplicate 8	2.05	BH11	1.05 - 2.62	Grey	Fine - medium grained sand	8.5	6.3	2.2	Slight													
Duplicate 9	1.1	BH3	0.96 - 1.2	Grey	Fine - coarse grained sand	9	6.4	2.6	Slight													
Duplicate 10	1.4	BH2	1.34 - 1.7	Grey	Fine - medium grained sand with 5 - 30 mm gravel	8.8	6.5	2.3	Slight													

Appendix F - Action and Responsibilities Flow Charts

ASS Management Flow Chart

Dewatering Management Flow Chart

Chart 1: Management of Acid Sulfate Soils for the Dawesville 4A and 5A Sewerage Infill Project (in accordance with the ASSDMP, GHD 2012)

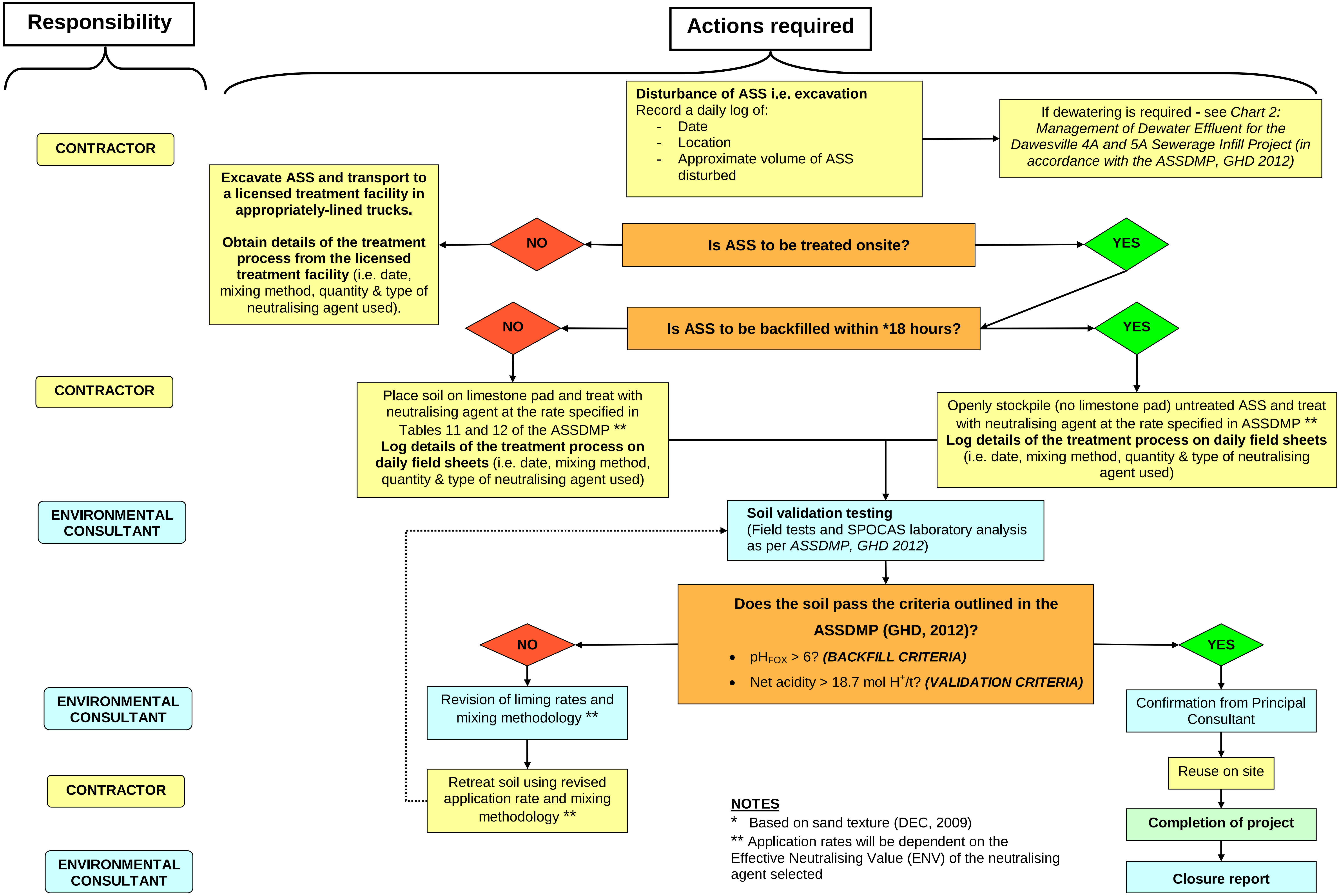
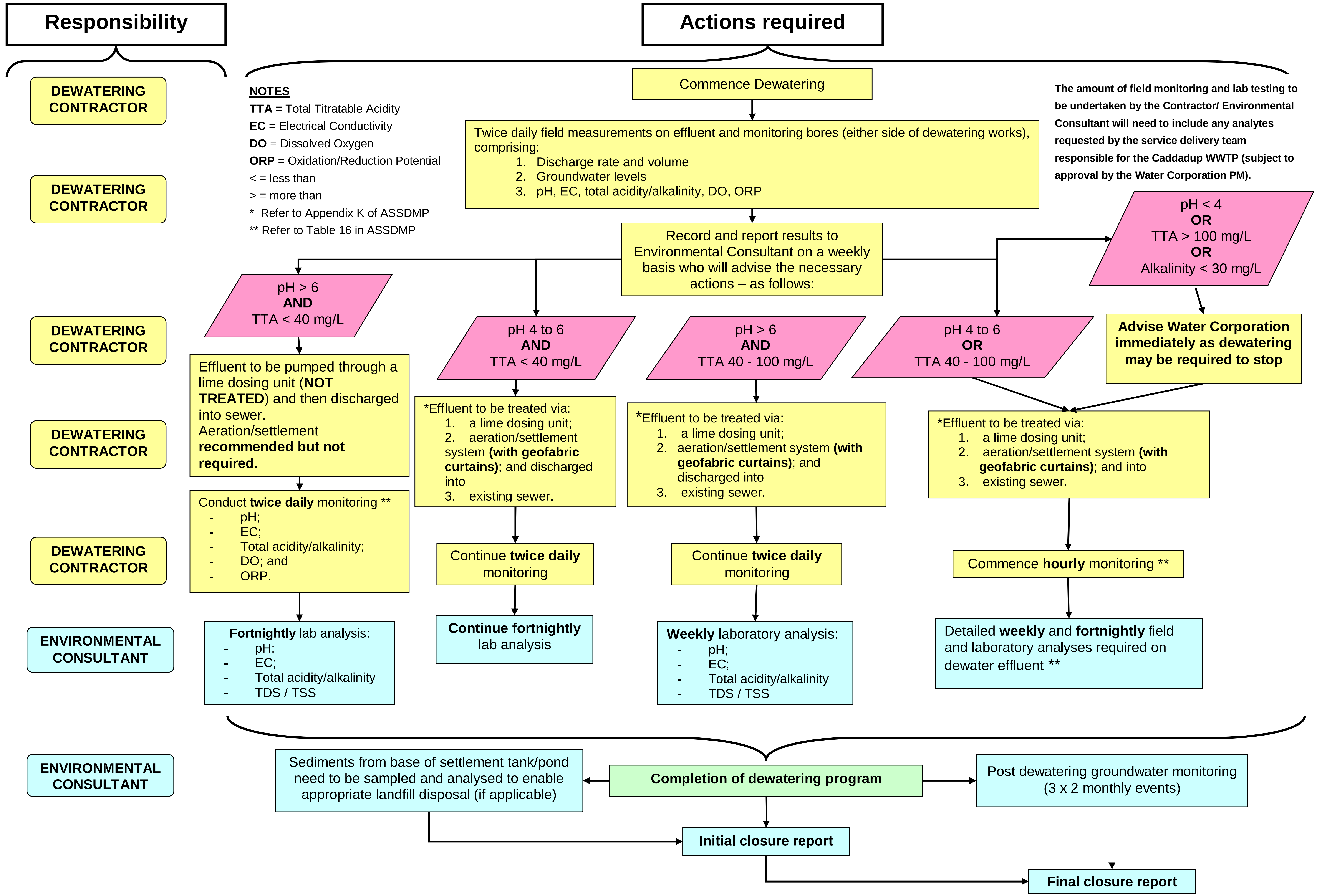


Chart 2: Management of Dewater Effluent for the Dawesville 4A and 5A Sewerage Infill Project (in accordance with the ASSDMP, GHD 2012)



Appendix G - Contractor Soil and Water Checklists - Examples

Supervisor / Construction Manager:

ASS FIELD TESTING RECORD

Date	Time	Sampler	Sewer/Pressure Main/Caisson	1st CH	2nd CH	Distance (m)	Sample ID (for lab)	Volume (m3)	Required Liming Rate (kg/m3 soil)	pHF	pHFOX	pHFOX > 6?	Volume of Excess (m3)	Passed SPOCAS?	Revised liming rate	pHF	pHFOX	Location Removed To	Comments

Supervisor / Dewatering Manager:

DEWATERING RECORD

Date	Time	Sewer/Pressure Main/Caisson	Section / Chainage / Reference	Flow rate (L/s)	Before Dosing Unit					After Dosing Unit					Water Quality Meter Calibrated?	Kg of Lime used	Aeration/Settlement Tank in use?	Are Geofabric Curtains in use? If so, condition and last time changed.	Infiltration Pond in use?	Bores in close proximity to works (i.e. on either side of works)	Total Volume of Dewatering Effluent (kL)	Comments
					pH	EC (µS/cm)	Temp (C°)	ORP (mV)	TTA (mg/L)	pH	EC (µS/cm)	Temp (C°)	ORP (mV)	TTA (mg/L)								

Groundwater, surface water and dewatering effluent pH is to remain above 6 while acidity is to remain below 40 mg/L. If water quality falls 'outside' the aforementioned criteria, the Principal (Water Corporation) and the Environmental Consultant should be notified immediately as treatment and more frequent monitoring will likely be required.

GROUNDWATER WELL MONITORING RECORDS

Date	Time	Sampler	Section / CH of works	Well ID	Total Depth of Bore	Depth to Water Level (m below top of casing)	Water Column (m)	Litres to purge	Litres purged	pH	EC (µS/cm)	TTA (mg/L)	TAAlk (mg/L)	Temp (C°)	ORP (mV)	Comments

SURFACE WATER MONITORING RECORDS

Date	Time	Sampler	Section / CH of works	Location	pH	EC (µS/cm)	TTA (mg/L)	TAAlk (mg/L)	Temp (C°)	ORP (mV)	Comments

Appendix H - Example – Effective Neutralising Value – Calculation

Example Calculation of Effective Neutralising Value

This calculation is based on the Effective Neutralising Value (ENV) for lime supplied by Redgate Lime. The Product Information Sheet (PIS) that was provided relates to an analysis undertaken on March 2008 (Laboratory No. a6034). The weighted average Neutralisation Value (NV) of the lime is quoted as being 93.1%. It should be noted that this calculation will need to be altered accordingly, once the lime supplier is determined. The following information has been gathered from a previous report undertaken by GHD, but has been provided to offer clarity in the calculations for the Contractor.

The Laboratory Test Report for the PIS was prepared by Ultra Trace Analytical Laboratories. Sieve sizes reported are 0.152, 0.250, 0.500 and 1.000 mm. GHD discussed these sieve sizes with Ultra Trace, who confirmed that these are the actual sieve sizes that they use in the laboratory to determine the particle size distribution for lime. Calculation of the ENV requires data on the proportions of the lime relative to the 0.3 and 0.85 mm sieves. Ultra Trace confirmed that they do not use these sieve sizes in their analyses. Hence, it is necessary to plot the particle size distribution data provided on the PIS and scale off the percentages passing the 0.3 and 0.85 mm sieves.

Data used to plot the grading curve for the lime is provided in Table 1.

Table 1 Sieve Analysis for Redgate Lime (Laboratory No. a6034)

Sieve Range (mm)	% Weight	Sieve Size (mm)	% Passing
0.000 – 0.125	1.9		
0.125 – 0.250	23.7	0.125	1.9
0.250 – 0.500	48.1	0.250	25.6
0.500 – 1.000	21.8	0.500	73.7
>1.000	4.5	1.0	95.5

The data in Table 1 was plotted and the % passing each sieve size determined from the graph.

For the reported NV of 93.1%, the ENV is calculated as shown in Table 2 using the particle size data determined above.

Table 2 Calculation of ENV for Redgate Lime (Laboratory No. a04865)

Particle Size	Proportion (%)	Utilising Factor	% Value
>0.850 mm	12	0.1	1.2
0.300 – 0.850 mm	53	0.6	31.8
<0.300 mm	35	1.0	35
Total	100		68
ENV = NV x % Value/100 = 93.1 x 68/100 = 63.3%			

The calculated ENV of 63.3% for the Redgate Lime is based upon the PIS for Redgate Lime. It is very important that once the lime supplier has been appointed for the site, the ENV will need to be re-calculated and applied as appropriate. The values presented above are purely for example purposes and not for use by the contractor.

Appendix I - Dewatering Volume and Flow Estimations

Dewatering Volumes Dawesville 4A **STORAGE CALC WITH 4.3m I.D. CAISSON**

	Caisson/PM	Sewer Invert Level at Caisson	Depth of Caisson plug below Sewer IL	Volume of Water Pumped out of Caisson	Ground Level	Length Sewer between Caissons or PM length	Caisson Plug Thickness	Construction Depth of Caisson	Time to Construct caisson	Time to Construct caissson	Time to Bore Sewer	Time Between Caissons	Time to Construct sewer/PM @ 20m/day/sewer & 40m/day PM+1 day set up+1 day for AC or MS	Time to Dewater sewers connecting to Caisson @ 5L/s+1 day set up+1 day for AC or MS	Time to Dewater PM @ 5L/s incl 1 day setup	Volume of Dewatering
		AHD	m	kL	AHD	m	m	m	13 days/Set Up	Per 1.8m lift	16m/day	Days	Days	Days	Days	kL
	PM					294							9		9	3888
	7793S	0.18			1.68	40							4			1728
	7748S	-0.23			1.45	38							4			1685
	7790C	-0.43	-1	20.77	0.92	83	1	3	13	2.15	5	20		4		1728
	7788C	-0.86	-1	27.02	1.15	74	1	4	13	3.07	5	21		6		2592
North	7783C	-1.24	-1	32.53	1.18	27	1	4	13	3.64	2	18		4		1728
	P/STN 13	-2.3	-3	76.97	1.5		2	9	13	9.72	0	23		0		0
South	7749C	-2.3	-1	47.93	1.5	8	2	7	13	6.94	1	20		4		1728
	7750C	-1.8	-1	40.67	1.05	100	2	6	13	5.63	6	25		8		3456
	7751C	-1.3	-1	33.41	1.18	97	1	4	13	3.72	6	23		9		3888
	7767C	-0.79	-1	26	1.52	99	1	4	13	3.49	6	23		0		0
	7769S	-0.51			1.4	54		2	13	0.15	3		5	2		2030
	7770S	-0.31			1.28	39		2	13	-0.29	2		4	2		1706
	7771S	0.02			1.52	61										
	7772S	0.62			2.12	47										
			Total:	305.30												

Dewatering Volumes Dawesville 5A **STORAGE CALC WITH 4.3m I.D.CAISSON**

	Caisson/PM	Sewer Invert Level at Caisson	Depth of Caisson plug below Sewer IL	Volume of Water Pumped out of Caisson	Ground Level	Length Sewer between Caissons or PM length	Caisson Plug Thickness	Construction Depth of Caisson	Time to Construct caisson	Time to Construct caissson	Time to Bore Sewer	Time Between Caissons	Time to Construct sewer/PM @ 20m/day/sewer & 40m/day PM+1 day set up+1 day for AC or MS	Time to Dewater sewers connecting to Caisson @ 5L/s+1 day set up+1 day for AC or MS	Time to Dewater PM @ 5L/s incl 1 day setup	Volume of Dewatering
		AHD	m	kL	AHD	m	m	m	13 days/Set Up	Per 1.8m lift	16m/day	Days	Days	Days	Days	kL
						315							9		9	3888
	8156	-0.22				93.3							7			2879
	8153	-0.7	-1	24.69	0.9	86.8	2	5	13	3.89	5	22		3		1296
	8150	-1.15	-1	31.23	1.37	62.9	2.5	6	13	5.86	4	23		0		0
	8149	-1.47	-1	35.87	1.6	43.8	2.5	7	13	6.63	3	22		0		0
	8138	-1.71	-1	39.36	2.69	60.9	3	8	13	9.17	4	26		0		0
	8137	-2.03	-1	44.01	2.73	60.6	3	9	13	9.67	4	26		0		0
North	8135	-2.35	-1	48.65	3.03	24.00	3.00	9	13	10.53	2	25		0		0
	P/STN 7	-4.06	-3	102.53	2.11		3.50	13	13	15.10	0	28		0		0
South	8040	-4.1	-1	74.07	2.52	18.00	3.50	11	13	12.94	1	27		0		0
	8041	-3.86	-1	70.58	2.19	66.20	3.50	11	13	12.15	4	29		0		0
	8042	-3.61	-1	66.95	2.29	71.90	3.00	10	13	11.25	4	29		0		0
	8043	-3.26	-1	61.87	1.76	99.60	3.00	9	13	10.03	6	29		0		0
	8044	-2.91	-1	56.79	1.3	99.60	2.50	8	13	8.21	6	27		8		3456
	8045	-2.56	-1	51.7	1.05	99.60	2.50	7	13	7.38	6	27		8		3456
	8046	-2.32	-1	48.22	1.08	68.2	2.5	7	13	7.08	4	24		8		3456
	8047	-1.98	-1	43.28	1.42	98.6	2.5	7	13	7.08	6	26		0		0
	8048	-1.85	-1	41.39	1.33	33.4	2.5	7	13	6.78	2	22		2		864
	8049	-1.71	-1	39.36	1.18	38.4	2.5	6	13	6.38	2	22		2		864
	8050	-1.47	-1	35.87	0.91	66.9	2	5	13	4.97	4	22		4		1728
	8051	-1.11	-1	30.65	1.76	102.4	2.5	6	13	6.35	6	26		2		864
	8052	-0.94	-1	28.18	1.65	31.5	2	6	13	5.26	2	20		0		0
	8053	-0.52	-1	22.08	1.45	81.1	2	5	13	4.40	5	22		2		864
	8054	-0.11	-1	16.12	1.87	79.1	2	5	13	4.42	5	22		2		864
	8055	0.35			1.63	90.7							7	4		2823
			Total:	1013.45												

Wk 54	Wk 55	Wk 56	Wk 57	Wk 58	Wk 59	Wk 60	Wk 61	Wk 62	Wk 63	Wk 64	Wk 65	Wk 66	Wk 67	Wk 68	Wk 69	Wk 70	Wk 71	Wk 72	Wk 73	TOTAL kL
	3888																			3888
												1728								1728
											1685									1685
									21	1728										1749
							27	2592												2619
					33	1728														1761
				77																77
											48	1728								1776
													41	3456						3497
															33	3888				3921
																	26			26
																		2030		2030
																			1706	1706
																				0
																				0
																			TOTAL	26463

Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9	Wk 10	Wk 11	Wk 12	Wk 13	Wk 14	Wk 15	Wk 16	Wk 17	Wk 18	Wk 19	Wk 20	Wk 21	Wk 22	Wk 23	Wk 24	Wk 25	Wk 26	Wk 27	Wk 28	Wk 29	Wk 30	Wk 31	Wk 32	Wk 33	Wk 34	Wk 35	Wk 36	Wk 37	Wk 38	Wk 39	Wk 40	Wk 41	Wk 42	Wk 43	Wk 44	Wk 45	Wk 46	Wk 47	Wk 48	Wk 49	Wk 50	Wk 51	Wk 52	Wk 53	TOTAL kL
	3888																																																				3888
																							2879																														2879
																					24.69	1296																															1321
																				31.23																																	31
																	35.87																																				36
																39.36																																					39
													44.01																																								44
											48.65																																										49
					102.53																																																103
								74.07																																													74
																							70.58																														71
																										66.95																											67
																												61.87																									62
																															56.79	3456																					3513
																																51.7	3456																				3508
																																			48.22	3456																	3504
																																				43.28	0																43
																																							41.39	864													905
																																									39.36	864											903
																																											35.87	1728									1764
																																													30.65	864							895
																																															28.18	0					28
																																																	22.08	864			886
																																																			16.12	864	880
																																																			2823		2823
																																																				TOTAL	28316

	Caisson Vol (m3)	PR (L/s)	time (hrs
Maximum vol	102.53	15	1.90
Minimum vol	16.12	15	0.30

Volume of PM (PS No.7)

PM ID (m)	Length (m)	Volume (m3)
0.15	1256	22.20

TOTAL VOLUME OF DEWATERING

AREA 4A	**26,462.90**	**kL**
AREA 5A	**28,315.85**	**kL**
TOTAL	**54,778.75**	**kL**

TOTAL VOLUME PUMPED IN 12MTHS BY PS NO. 7

PUMP RATE	**18.3**	**L/s**
12MTHS @6 HRS/DAY	**144,277**	**kL**

TRENCHLESS TECHNOLOGY

ITEM	NO. DAYS
Common Tasks & first 1.8m of excavation	
Mobilise per caisson, setup, excavate to GWL	1
Setup steel leading edge	0.5
Setup reinforcement and formwork	1
Pour concrete	0.5
Strip formwork and excavate	1
Pour concrete base plug	1
Pump water out of caisson	1
Remove soft top of base plug	1
Pour Concrete working floor	1
Setup tunnelling machine	5
Sub Total	13
Additional 1.8m deep Caisson shaft Sections	
Setup reinforcement and formwork	1
Pour concrete	0.5
Strip formwork and excavate	1
Sub Total	2.5
Boring and Installing Sewer Pipe	Rate (m/day)
Boring rate for all conditions (based on using appropriate machine for conditions)	16

Appendix J - Cone of Depression Calculations

Cone of Depression Calculations

Dawesville 4A/5A Infill Sewer

BH21

Equivalent Radius

a	1	width excavation	m
b	20	length excavation	m
pi	3.141592654		-
re	2.523132522	equivalent radius	m

Cone depression (Sichardt's equation)

1m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	9	Saturated thickness of the aquifer at maximum drawdown	m
K	1.25E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	10.61		

Cone depression (Sichardt's equation)

1.5 m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	8.5	Saturated thickness of the aquifer at maximum drawdown	m
K	1.25E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	15.91		

PS7S

Equivalent Radius

a	1	width excavation	m
b	20	length excavation	m
pi	3.141592654		-
re	2.523132522	equivalent radius	m

Cone depression (Sichardt's equation)

1m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	9	Saturated thickness of the aquifer at maximum drawdown	m
K	3.30E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	17.23		

Cone depression (Sichardt's equation)

1.5 m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	8.5	Saturated thickness of the aquifer at maximum drawdown	m
K	3.30E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	25.85		

BH16

Equivalent Radius

a	1	width excavation	m
b	20	length excavation	m
pi	3.141592654		-
re	2.523132522	equivalent radius	m

Cone depression (Sichardt's equation)

1m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	9	Saturated thickness of the aquifer at maximum drawdown	m
K	1.80E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	12.73		m

Cone depression (Sichardt's equation)

1.5 m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	8.5	Saturated thickness of the aquifer at maximum drawdown	m
K	1.80E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	19.09		m

BH9A

Equivalent Radius

a	1	width excavation	m
b	20	length excavation	m
pi	3.141592654		-
re	2.523132522	equivalent radius	m

Cone depression (Sichardt's equation)

1m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	9	Saturated thickness of the aquifer at maximum drawdown	m
K	3.42E-06	Hydraulic conductivity of aquifer matrix	m/s
Ro	5.55		m

Cone depression (Sichardt's equation)

1.5 m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	8.5	Saturated thickness of the aquifer at maximum drawdown	m
K	3.42E-06	Hydraulic conductivity of aquifer matrix	m/s
Ro	8.32		m

PS13D

Equivalent Radius

a	1	width excavation	m
b	20	length excavation	m
pi	3.141592654		-
re	2.523132522	equivalent radius	m

Cone depression (Sichardt's equation)

1m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	9	Saturated thickness of the aquifer at maximum drawdown	m
K	2.19E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	14.04		m

Cone depression (Sichardt's equation)

1.5 m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	8.5	Saturated thickness of the aquifer at maximum drawdown	m
K	2.19E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	21.06		m

BH1

Equivalent Radius

a	1	width excavation	m
b	20	length excavation	m
pi	3.141592654		-
re	2.523132522	equivalent radius	m

Cone depression (Sichardt's equation)

1m drawdown

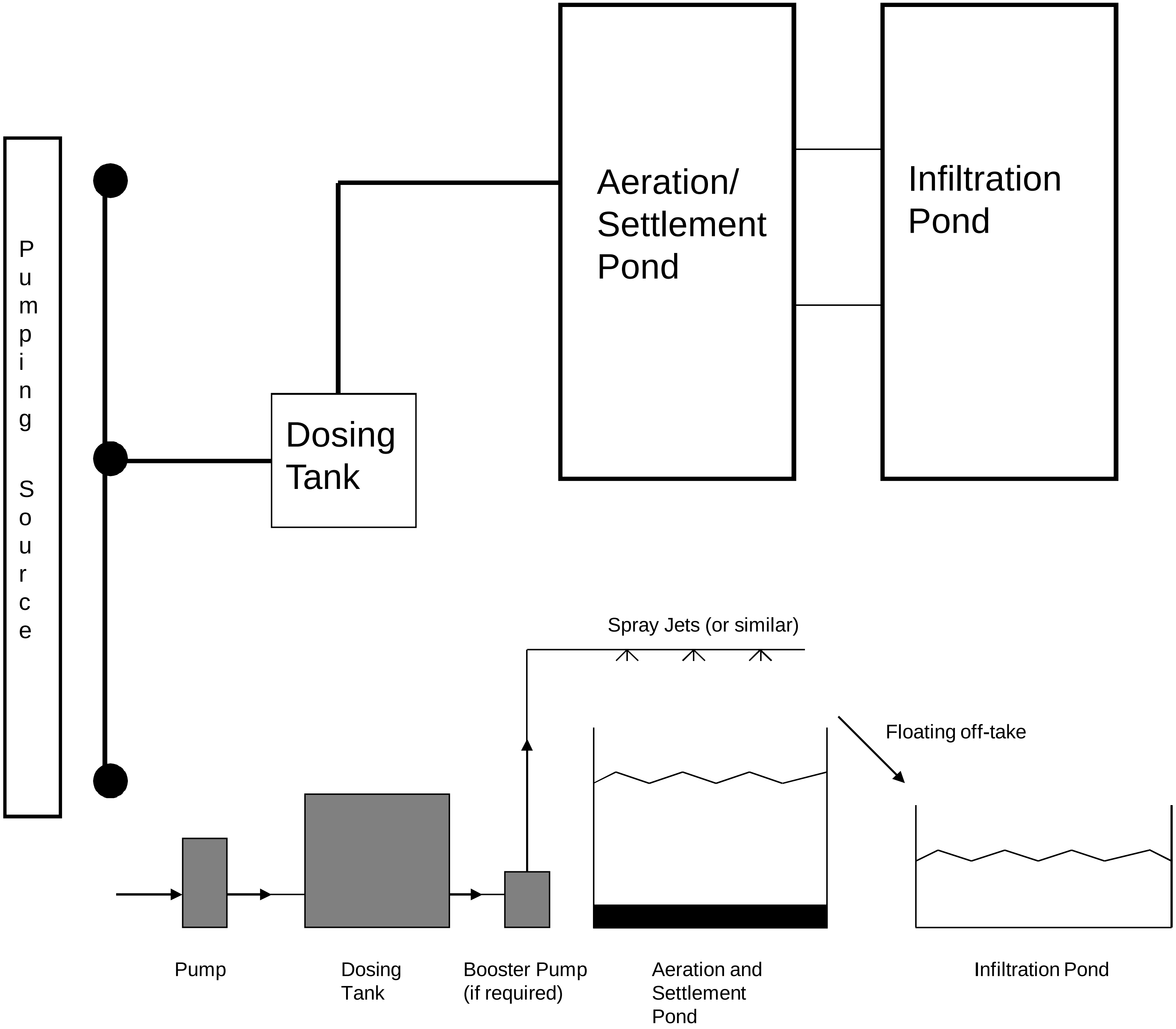
H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	9	Saturated thickness of the aquifer at maximum drawdown	m
K	2.70E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	15.59		m

Cone depression (Sichardt's equation)

1.5 m drawdown

H	10	Saturated thickness of aquifer undisturbed by pumping	m
h	8.5	Saturated thickness of the aquifer at maximum drawdown	m
K	2.70E-05	Hydraulic conductivity of aquifer matrix	m/s
Ro	23.38		m

Appendix K - Schematic of Recommended Dewatering Effluent Treatment System



Pumping Source
Dosing Tank
Aeration/ Settlement Pond
Infiltration Pond
Spray Jets (or similar)
Floating off-take
Pump
Dosing Tank
Booster Pump (if required)
Aeration and Settlement Pond
Infiltration Pond

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