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Kooragang RRF

Surface Water Mitigation and Monitoring Plan

Prepared for Boral Resources

July 2024

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Surface Water Mitigation and Monitoring Plan

Boral Resources

E230697 RP1

July 2024

Version	Date	Prepared by	Reviewed by	Comments
V1	28 February 2022	Chris Kucera	Phil Towler	Issued to EPA
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Approved by

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19 July 2024

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Executive Summary

ES1 Report purpose

Boral Recycling Pty Limited (Boral) owns and operates a resource recovery facility at 1/24 Egret Street, Kooragang Island (the 'facility' or 'site'). The facility produces a range of road base products by separating, crushing and blending various recovered construction and demolition wastes. The facility is licensed by the NSW Environment Protection Authority (EPA) under the Protection of the Environment Operations Act 1997, Environment Protection Licence (EPL) number 11968 (EPL 11968).

In 2015, Boral applied to expand operations through a State Significant Development (SSD 15_7038). The SSD application was approved by the then Minister for Planning on 10 July 2019. The approval requires the expansion to be staged as follows:

- Stage 1 – an increase in processing capacity and some site modifications.
- Stage 2 – expansion of the facility footprint and increase in the maximum material storage limit.

The consent conditions and EPL 11968 require several water management related studies to be prepared. The initial study to be prepared was a Surface Water Discharge Characterisation Assessment (SWDCA). This study was submitted to the EPA in November 2019 and included detailed information on the facility's existing water management system and certain water quality issues.

This report documents a Surface Water Mitigation and Monitoring Plan (SWMMP) for Stage 1. It applies the outcomes of the SWDCA and proposes a suite of measures to improve the capture and containment of stormwater runoff from the facility. The SWMMP has been prepared to address Consent Condition B15 and EPL 11968.

SWMMP (Version 1) was submitted to the EPA on 28 February 2022. The EPA provided feedback to Boral via several letters and meetings. This document is SWMMP (Version 3), which has been updated to address feedback provided by the EPA on aspects SWMMP (Version 1). Further updates can be made to respond to any residual concerns from the EPA or other government agencies.

ES2 Existing water quality

The water quality of runoff from the facility has been characterised using data from the SWDCA sampling program completed in 2019. Surface water runoff from the facility is characterised as being alkaline (ie high pH) and containing elevated concentrations (relative to default guideline values) of nitrogen (primarily in oxidised form), cyanide and several metals: aluminium, chromium (primarily in hexavalent form), cobalt, copper, molybdenum, vanadium and zinc.

The contaminated stormwater is assessed to be associated with water contact with concrete washout, which is one of the materials processed at the facility. Typically, concrete washout is allowed to age (or hydrate) for approximately six to eight weeks in incoming stockpiles before it is blended to make road base products, which are stored in the product stockpiles. Both the incoming and product stockpiles are assessed to be sources of contamination.

Contaminants are assessed to be mobilised when water infiltrates through a stockpile and seeps into the stormwater system. As the stockpiles can absorb a significant amount of water, seepage from stockpiles tends to commence after approximately 50 mm of rainfall.

ES3 Mitigation approach

Boral propose to reconstruct and modify the water management system to significantly improve the capture and containment of stormwater runoff from the yard, which is known to have poor water quality. The proposed works include:

- replacing the existing infiltration swale with a concrete lined drain;
- installing a new low permeability geosynthetic clay liner within the yard;
- repurposing the existing 0.35 ML concrete basin and installing 1.25 ML of new storage (primarily in water tanks) to provide 1.6 ML of stormwater storage; and
- installing water supply infrastructure to enable captured stormwater to be used for concrete production at the adjoining concrete plant that is operated by Boral.

Collectively these works will enable stormwater runoff from the yard to be captured in the stormwater storages. The 1.6 ML of storage is equivalent to 100 mm of runoff from the 1.6 ha yard area. Allowing for rainfall losses, approximately 120 to 170 mm of rainfall would be required to produce 1.6 ML of runoff. Water captured in the storages will be used for onsite dust suppression (dry weather only), product conditioning and concrete production to restore capacity after rainfall. The system will occasionally overflow when the storages fill. Overflows will occur from the concrete basin into an existing concrete lined drain that is located to the west of the facility and drains to the south, entering the Hunter River estuary near the coal ship loaders. Overflows are expected to only occur for short periods of time during and shortly after significant rainfall events (ie 120 to 170 mm over several days). Rainfall events of this magnitude occur once to twice per year (on average).

Boral propose to construct the works in a staged manner to allow for the continued operation of the facility. An implementation schedule and monitoring and validation plan is provided in the main report.

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1 Introduction

1.1 Background

Boral Recycling Pty Limited (Boral) owns and operates a resource recovery facility at 1/24 Egret Street, Kooragang Island (the 'facility' or 'site'). The facility produces a range of road base products by separating, crushing and blending various recovered construction and demolition wastes. The facility is licensed by the NSW Environment Protection Authority (EPA) under the Protection of the Environment Operations Act 1997 (POEO Act), Environment Protection Licence (EPL) number 11968 (EPL 11968).

1.1.1 Consent modification

The facility historically operated under a consent granted by Newcastle City Council in 2003 (DA 01/2716) which allowed for the processing of up to 100,000 tonnes per annum of building and demolition, asphalt and concrete waste. In 2015, Boral applied to expand operations through a State Significant Development (SSD 7038). Key aspects of the proposal included:

- an increase in the facility footprint from approximately 2.10 to 3.45 ha;
- an increase in the permissible stockpile height and maximum waste storage limit (from 100,000 to 144,000 tonnes);
- a modification to the materials permitted to be processed onsite; and
- an increase in processing capacity (from 100,000 to 350,000 tonnes of material per year).

The SSD application was approved by the then Minister for Planning on 10 July 2019. The approval requires the expansion to be staged as follows:

- Stage 1 – an increase in processing capacity and some site modifications.
- Stage 2 – expansion of the facility footprint and increase in the maximum material storage limit.

Schedule 2 of the consent includes 15 water management related conditions. Condition B15 requires the preparation of a Surface Water Mitigation and Monitoring Plan (SWMMP). Further information on this condition is provided in Section 2.2.

1.1.2 EPA correspondence

Following a review of the SSD application, on 25 May 2018, the EPA varied EPL 11968 to include a requirement for a Surface Water Discharge Characterisation Assessment (SWDCA) and SWMMP to be prepared. A SWDCA was prepared by EMM Consulting Pty Ltd (EMM) and was submitted to the EPA in November 2019. Boral then commenced preparing a SWMMP and provided the EPA with an update on the proposed mitigation approach in a meeting dated 23 June 2021. In September 2021, the EPA provided feedback on the SWMMP proposal (in a letter dated 29 September 2021) and varied EPL 11968 to:

- remove the SWDCA from the licence as this study was completed; and
- revise the scope for the SWMMP.

The revised SWMMP scope in EPL 11968 is broadly consistent with the SWMMP scope described in Condition B15. Further information on SWMMP conditions are provided in Section 2.1.

It is also noted that while not captured in the revised EPL, the EPA's letter dated 29 September requested further information on the suite of analytes assessed in the SWDCA. Further information on this request is provided in Section 2.1.2.

SWMMP (Version 1) was submitted to the EPA on 28 February 2022. The EPA provided feedback to Boral via several letters and meetings. This document is SWMMP (Version 3), which has been updated to address feedback provided by the EPA on aspects SWMMP (Version 1). On 13 October 2023, the EPA varied the EPL 11968 to incorporate the mitigation and monitoring measures proposed in SWMMP (Version 3).

On 16 May 2024, Boral request a further EPL variation to allow for the low permeability pavement design that was proposed in SWMMP (Version 3) to be replaced with an alternative design that includes a geosynthetic clay liner. On 5 June 2024 the EPA varied EPL 11968 to incorporate the requested change. Following the EPL variation, the SWMMP was updated to Version 4 to incorporate the changes.

1.2 Report purpose

This report documents a SWMMP for Stage 1 of the proposed expansion. It addresses relevant EPL and consent conditions and provides an overview of the existing facility and SWDCA outcomes; proposed mitigation approach and implementation timeframes; and describes the expected overflow regimes (both quality and quantity) once mitigations are implemented. The SWMMP will be updated as required to respond to any residual concerns from the EPA or other government agencies.

Boral propose to prepare a Water Management Plan (WMP) once the proposed water management system is operational. The WMP will follow a standard industry template and will describe the water management system, operating procedures and surface and groundwater monitoring and reporting requirements.

1.3 Report structure

This report is structured as follows:

- Chapter 2 reproduces EPL requirements and consent conditions that relate to this SWMMP;
- Chapter 3 provides and overview of the existing facility and key outcomes from the SWDCA;
- Chapter 4 describes a mitigation plan;
- Chapter 5 describes the overflow regimes (both quantity and quality) from the proposed water management system;
- Chapter 6 describes a monitoring and verification plan; and
- Chapter 7 describes monitoring plans and detailed designs that will be prepared following approval of this SWMMP.

2 Plan requirements

This chapter reproduces relevant EPL requirements and consent conditions and explains how each requirement is addressed in this SWMMP.

2.1 EPA requirements

2.1.1 Pollution reduction studies

Section 8 of EPL 11968 describes pollution studies and reduction programs. Pollution Reduction Study (PRS) no.1 related to the SWDCA which has been completed. PRS 2 relates to this SWMMP. Table 2.1 reproduces the requirements of PRS 2 and explains how each requirement has been addressed.

Table 2.1 PRS 2 conditions

EPL condition	Requirements	Assessment overview
U1	**PRS 2 – Surface Water Mitigation and Monitoring Plan** The purpose of the SWMMP is to identify and assess all practical mitigation and management measures to protect surface and groundwater from contamination.	This has been adopted as an objective for this SWMMP.
U1.1	The Licensee must engage a suitably qualified and experienced person to prepare a SWMMP.	This assessment has been prepared by Chris Kuczera (Associate Water Resources Engineer at EMM) who is suitably qualified and experienced. Chris has been endorsed by the Department of Planning and Environment to undertake similar assessments on other projects.
U1.2	The SWMMP must be submitted to the EPA by 28 February 2022.	SWMMP (version 1) was provided to the EPA on 28 February 2022.
U1.3	The SWMMP must be based on the results of the Surface Water Discharge Characterisation Assessment (EMM 2019) and the EPA's letter dated 29 September 2021 and must include at a minimum:	A proposed mitigation plan has been developed. The plan is informed by the outcomes of the SWDCA, feedback from the EPA and includes a suite of measures to improve the capture and containment of stormwater runoff from the facility. The mitigation plan is described in Chapter 4 and residual impacts are described in Chapter 5.

Table 2.1 PRS 2 conditions

EPL condition	Requirements	Assessment overview
U1.3.1	An assessment of all practical mitigation and management measures to prevent stormwater and groundwater contamination including: • covering and sealing of the waste stockpile storage and processing areas; • the use of low permeability hardstands(s) under waste stockpile storage and processing areas; • the lining or treatment of drains and swales onsite to prevent the infiltration of potentially contaminated stormwater to groundwater; • increased captured stormwater storage capacity, to minimise discharges and increase the availability of water for dust suppression in dry times; • management measure that will be put in place to prevent over irrigation of potentially contaminated stormwater that may leach contaminants from materials on-site; • management measures that will be put in place that will prevent the depth and permeability of any sub-surface hardstand being compromised by daily use of mobile plant at the premises; and • management measure that will be put in place that will prevent the permeability of drains and swales being compromised during cleaning operations.	A Mitigation Plan has been developed that includes most of these suggested measures. Section 4.2 specifically address this condition. It contains a table that reproduces each of these suggested measures and notes if each measure is proposed. A brief description is provided for measures that are proposed and justification is provided for measures that are not proposed.
U1.3.2	Identification of contingency options to account for any mitigation measures that do not adequately address the site water pollution risks.	Contingency options are discussed in Section 4.1.3.
U1.3.3	Design concepts of a surface water management system for the Premises, including specifications for the proposed permeability of sub-surface hardstands and drains/swales.	Design concepts and specifications for key components of the proposed water management system modifications are provided in Section 4.1. It is also noted that following approval of the SWMMP, a detailed design of the proposed civil works will be prepared (as required by Consent Condition B22. Chapter 6 describes a monitoring and validation plan.
U1.3.4	A list of all works and measures that will be put in place, including timelines for completion, to prevent the contamination of surface water and groundwaters.	A list of works and measures is provided in Section 4.1. Section 4.1.2 provides a program to complete works.
U1.3.5	An ongoing water and groundwater monitoring program for the premises.	Chapter 6 describes a monitoring and validation plan.

2.1.2 Other information requested

In a letter dated 29 September 2021, the EPA requested further information on the analytes considered in the SWDCA. The EPA request is reproduced below and is addressed in Section 3.3.3.

3. Additional analytes to consider in wastewater

During the meeting on 23 July 202, the EPA asked if a range of additional analytes were considered in the assessment as set out in the EPA's letter of 27 March 2020. The EPA raised concerns about the response which was provided by Boral in the letter dated 21 April 2020.

In particular, the EPA is concerned with the comments following the paragraphs at point 7, starting with "*To address the EPA observations on the wastewater data*" and in particular: "*Other potential pollutants.*"

It is recommended that the Surface Water Mitigation and Monitoring Plan clearly documents how these analytes have been addressed including levels in managed overflows to the swale that may enter the groundwater system 1 to 2 times per year on average.

2.2 Consent Condition B15

On 10 July 2019, Boral received conditional consent to increase the processing capacity of the facility to 350,000 tpa with a maximum storage capacity of 144,000 tonnes at any one time (Consent SSD 7038). The consent included 15 conditions associated with site water management. Consent Condition B15 relates to the SWMMP and is addressed in this report. Table 2.2 reproduces this consent conditions and explains how each sub-condition has been addressed.

Table 2.2 Summary of relevant consent conditions

Consent condition	Requirements	Assessment overview
Surface Water Mitigation and Monitoring Plan		
B15	Prior to the commencement of Stage 1 construction and Stage 2 construction, the Applicant must prepare a SWMMP to the satisfaction of the Planning Secretary. The SWMMP must:	
a)	be prepared by a suitably qualified and experienced person(s);	This assessment has been prepared by Chris Kuczera (Associate Water Resources Engineer at EMM) who is suitably qualified and experienced. Chris has been endorsed by the Department of Planning and Environment to undertake similar assessments on other projects.
b)	be prepared in consultation with the EPA;	Boral has consulted with the EPA to develop this plan (see Section 1.1.2). Boral will continue to consult with the EPA until the SWMMP is finalised.
c)	be based on the results of the SWDCA identified in Condition B13, and investigate all practical mitigation and management measures to prevent stormwater and groundwater contamination including the covering or sealing of the waste stockpile storage and processing areas;	A mitigation plan has been developed. The plan is informed by the outcomes of the SWDCA, feedback from the EPA and includes a suite of measures to improve the capture and containment of stormwater runoff from the facility. The mitigation plan is described

Table 2.2 Summary of relevant consent conditions

Consent condition	Requirements	Assessment overview
		in Chapter 4 and residual impacts are described in Chapter 5.
d)	identify contingency options to account for any mitigation measures that do not adequately address the site water pollution risks; and	Contingency options are discussed in Section 4.1.3.
e)	update the SWMMP to address and changes to the surface water management system.	The SWMMP can be updated if material changes to the proposed water management system are required in the future.

3 SWDCA overview

This chapter provides and overview of the SWDCA and includes descriptions of the existing facility, the existing water management system, existing water quality characteristics and the receiving waters.

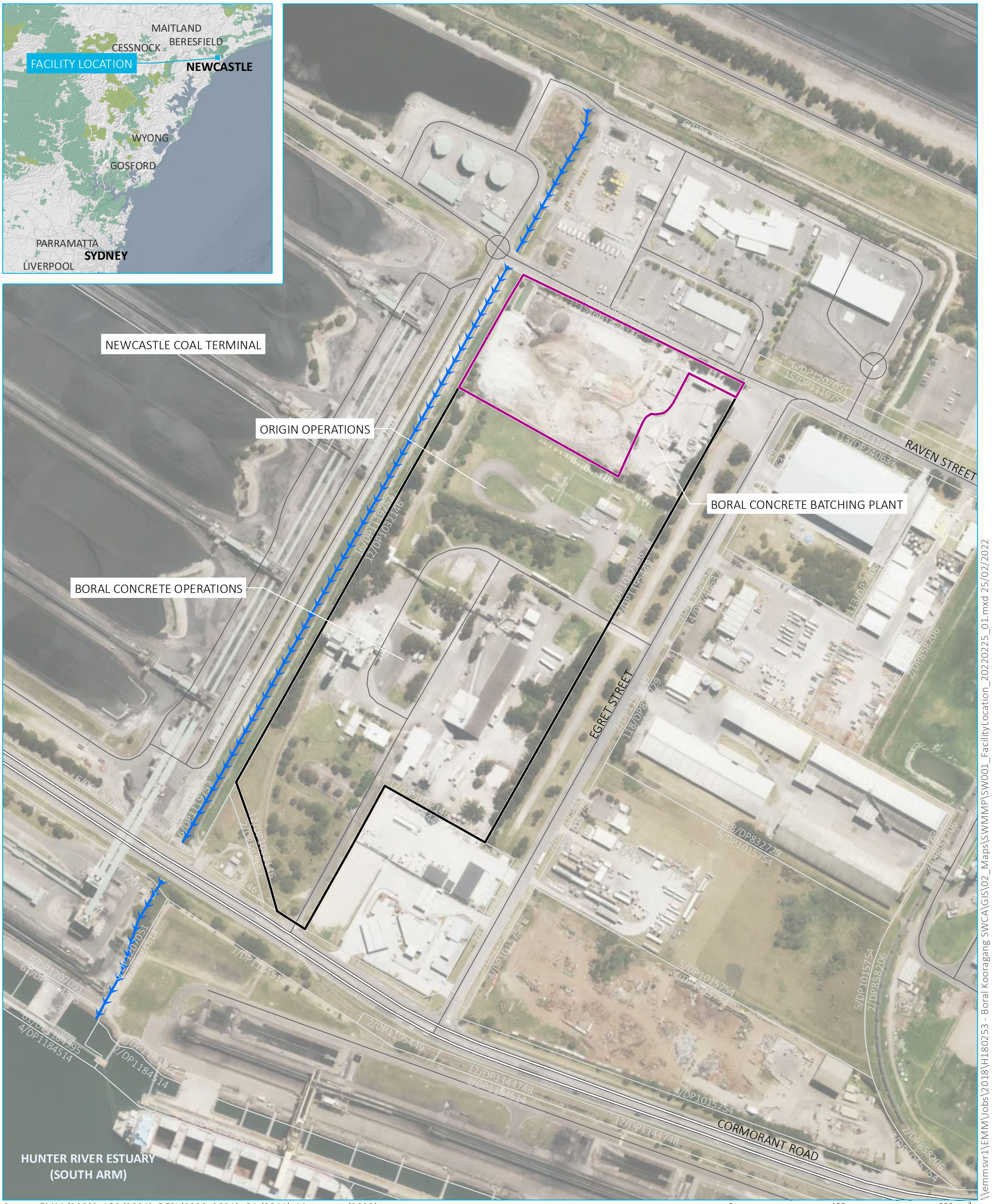
3.1 Facility description

3.1.1 Location

The facility is located centrally within the industrial precinct on Kooragang Island (Figure 3.1). Surrounding land uses include:

- the Newcastle Coal Terminal – immediately to the west of the facility;
- the Kooragang Coal Terminal – to the north of the facility;
- a Boral-operated concrete plant – immediately to the east of the facility; and
- Origin and Boral cement operations – to the south of the facility.

The facility is located within the northern portion of Lot 12 DP 1032146 (the lot), which is wholly owned by Boral Cement. The lot has an area of approximately 12.45 ha. The Boral-operated concrete plant, and the Origin and Boral cement operations are also located within this lot. A concrete lined drain is located to the west of the facility and the lot. The drain flows to the south into the southern arm of the Hunter River Estuary and outlets adjacent to coal ship loading infrastructure.



Source: EMM (2022); ABS (2021); DFSI (2020, 2021); GA (2011); Metromap (2022)

0 100 200 m
GDA 1994 MGA Zone 56
N

KEY

- Facility area
- Lot 12 DP1032146
- Existing surface drain
- Major road
- Minor road
- Cadastral boundary

INSET KEY

- Major road
- NPWS reserve
- State forest

Facility location

Kooragang Island Resources Recovery Facility
Surface Water Mitigation and Monitoring Plan
Figure 3.1

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3.1.2 Facility description

The existing facility broadly includes (Figure 3.2): incoming material stockpiles; processed material stockpiles; access roads; water management infrastructure; a weighbridge and wheel wash; and a car parking area.

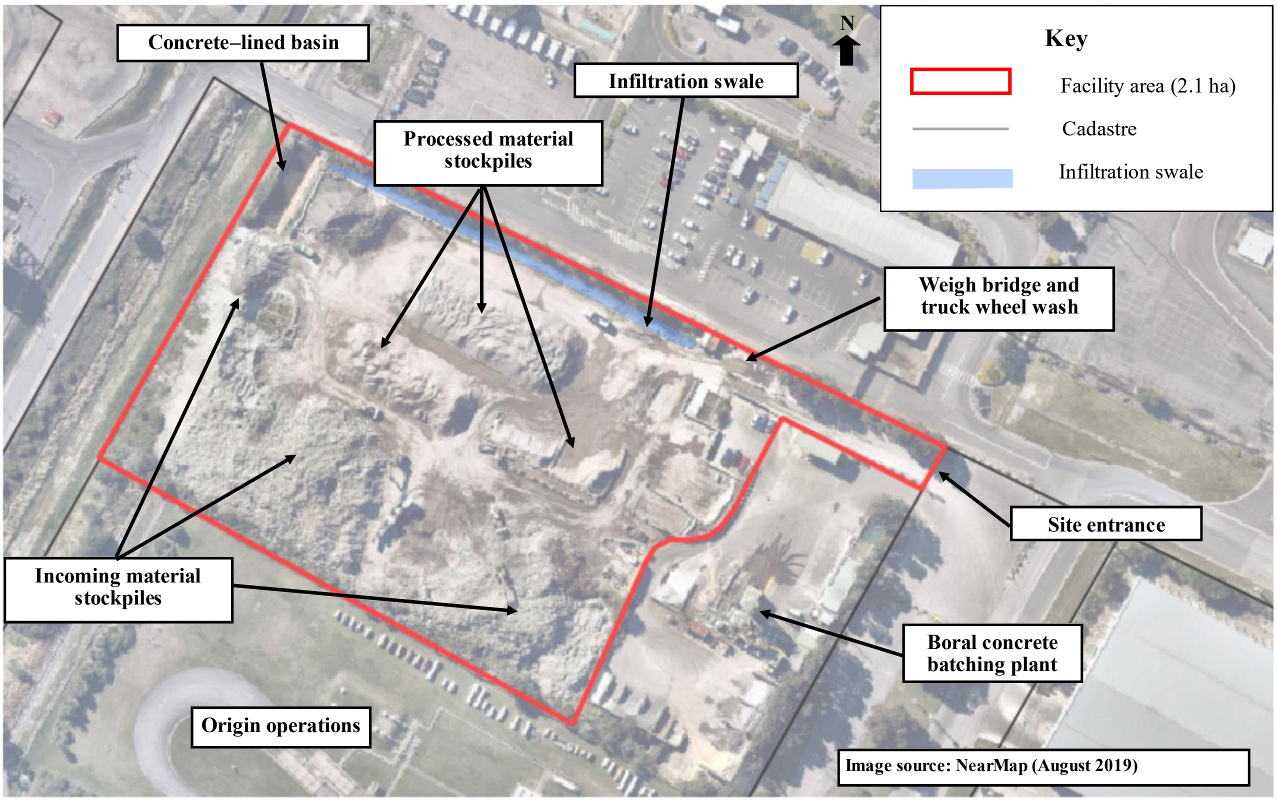


Figure 3.2 Existing facility

Source: SWDCA (EMM 2019)

Most of the facility is utilised to stockpile incoming and processed materials (Figure 3.2). This area is referred to as the 'yard' in both the SWDCA and in this report. Surface water runoff from the yard drains to the infiltration swale along the northern boundary.

During the SWDCA period (June 2018 to August 2019), the incoming materials were:

- asphalt waste;
- construction and demolition waste (predominantly concrete and brick materials); and
- concrete washout waste.

Incoming materials were processed to produce a range of road base products.

3.1.3 Geotechnical characteristics

The SWDCA was informed by a geotechnical investigation that characterised the near-surface ground conditions and estimated infiltration rates within the yard and swale. This investigation concluded that:

- Encountered subsurface conditions comprised sandy gravel, gravelly sand and sand and gravel fill material. The material in the yard was interpreted to be compacted. No groundwater was intercepted in any of the shallow bores that were drilled as part of the investigation.

- The yard was assessed to have a moderate permeability, with the measured saturated hydraulic conductivity ranging from 2.2 x 10^{-5} to 8.0 x 10^{-7} m/s and averaging 6.8 x 10^{-6} m/s.

- The swale was assessed to have a moderate to high permeability, with the saturated hydraulic conductivity ranging from 3.5 x 10^{-5} to 1.5 x 10^{-6} m/s and averaging 4.8 x 10^{-5} m/s.

- The measured saturated hydraulic conductivity was lower than expected for the material encountered. This was interpreted to be due to apparent compaction of the yard and the potential presence of thin lower-permeability layers within the fill strata.

- The permeability of unsaturated material could be up to one order of magnitude lower than the saturated hydraulic conductivity.

Refer to the SWDCA and the geotechnical report that is provided as an appendix to the SWDCA for further information.

3.2 Existing water management system

The facility's existing system manages stormwater runoff from the yard area and provides water for operational uses such as dust suppression and product conditioning. This section describes the system functionality, operating practices, and EMM site observations over the SWDCA period.

The yard has been established on compacted fill that is assessed to have moderate permeability when saturated and sits above a shallow unconfined groundwater system (described in Section 3.4). Surface levels range from approximately 6 m AHD in the southern portion of the yard to approximately 4 m AHD in the northern portion of the yard. Surface water runoff from the yard drains through several discrete surface drains to the infiltration swale located along the northern boundary (see Photograph 3.1 - taken after 50 and 80 mm of rain). Water in the swale slowly infiltrates into the underlying groundwater system.

The swale overflows into a concrete-lined basin (the concrete basin) (see Photograph 3.2). Water captured in the concrete basin is used for operational uses such as dust suppression and product conditioning. During dry periods, additional water is sourced from mains water.

Photograph 3.1 **Infiltration swale - the image on the left was taken in March 2019, after 50 to 60 mm of rainfall. Only minor amounts of surface water runoff occurred from this event. The image on the right was taken in August 2019 after approximately 80 mm of rain. Significant surface runoff from the yard occurred from this event.**

Photograph 3.2 **The concrete basin**

The site was visited by EMM numerous times over the SWDCA period to collect samples. Site visits were undertaken either during or shortly after wet weather conditions. Key observations are:

- There is minimal surface water runoff from rainfall events with less than 50 mm of rainfall. This is interpreted to be due to the high water-absorption capacity of the stockpiles and because the yard is not sealed.

- There was significant surface water runoff from the yard for rainfall events with more than 50 mm of rainfall and for smaller rainfall events shortly following earlier rainfall events. During these conditions, the swale was observed to fill and spill into the basin.
- Puddles were observed to remain within the yard for several days following the cessation of rainfall – indicating rapid infiltration from the yard does not occur.
- No surface water discharge from the site was observed.

During extended periods of wet weather, Boral have historically applied surplus water to stockpiles to maximise water absorption in the stockpiles. Boral ceased this practice during wet weather following a review of initial water quality results which indicated that applying water to stockpiles can increase the mobilisation of metals. When the basin is full, Boral currently spray water centrally within the site (not on stockpiles) to manage surplus water volumes.

Figure 3.3 shows the conceptual framework of the water management system and Figure 3.4 shows the water management system layout. The indicated surface levels were sourced from a 2015 survey that is provided as an appendix to the SWDCA.

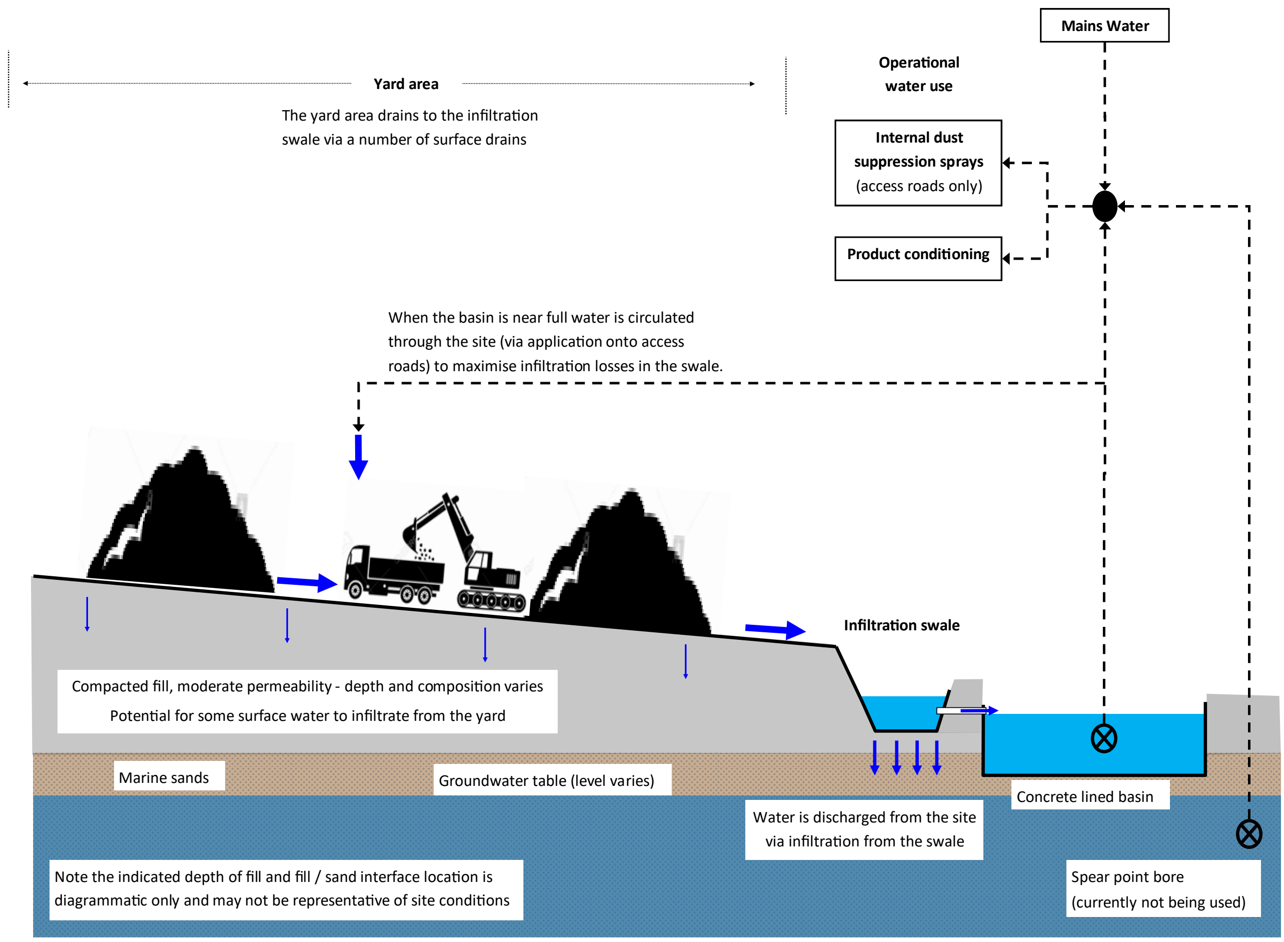


Figure 3.3 Conceptual framework of the water management system

Source: SWDCA (EMM 2019)

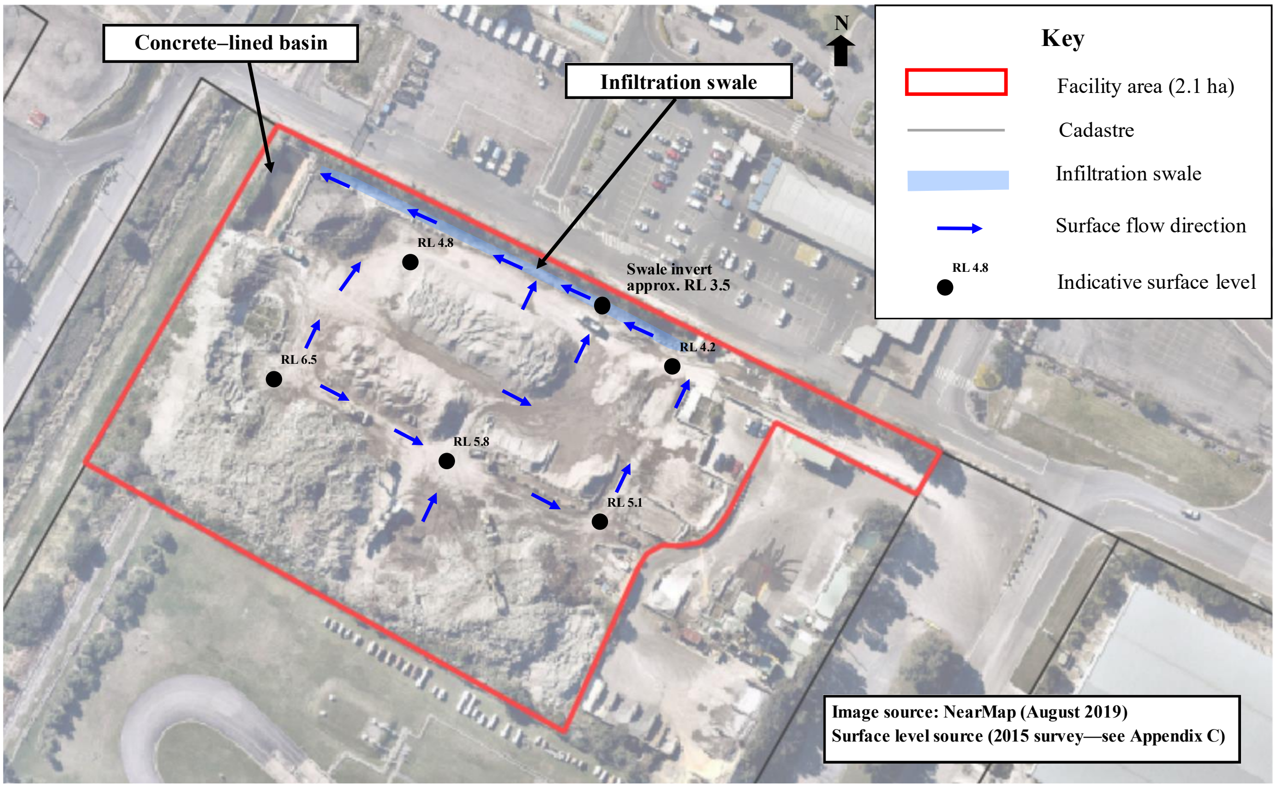


Figure 3.4 Water management system layout

Source: SWDCA (EMM 2019)

3.3 Water quality characteristics

This section provides a summary of the key results and conclusions from the SWDCA. The EPA's request for additional information regarding additional pollutants (see Section 2.1.2) is also addressed.

3.3.1 Summary of sampling analysis results

A surface water quality characterisation program was completed by EMM to inform the SWDCA. The program comprised sampling and analysis of surface water within the facility from five independent rainfall events between June 2018 and August 2019 (the SWDCA period). Samples were collected from the yard, swale and basin and were analysed for a comprehensive suite of physico-chemical parameters and metal and organic toxicants. Table 3.1 provides a summary of the SWDCA results for analytes that were either above detection limits or exceeded default guideline values (DGVs). Refer to the SWDCA for more detailed information.

Table 3.1 SWDCA: sampling and analysis results summary

			Yard			Swale[5]			Basin		
	Units	DGV[1]	No. samples	Min/20P[4]	Max/80P[4]	No. samples	Min	Max	No. samples	Min	Max
Physio-chemical parameters											
pH	-	6.5-8.0	6	**9.4**	**12.3**	4	**9.6**	**10.9**	5	6.7	**10.6**
Electrical conductivity	µS/cm	200-300	6	**3,690**	**15,400**	4	**716**	**5,860**	5	**415**	**4,760**
Turbidity	NTU	6-50	6	24	**146**	4	13	**125**	5	16	**63**
Suspended solids	mg/L	-	6	41	193	4	<5	104	5	16	56
Total dissolved solids	mg/L	-	6	1,340	10,300	4	367	3,070	5	241	2,500
Total hardness (as $CaCO_3$)	mg/L	-	4	597	1,180	3	70	363	4	41	420
Total alkalinity (as $CaCO_3$)	mg/L	-	2	204	728	1	62	62	2	29	54
Analytical results – nutrients (as N or P)											
Ammonia	mg/L	0.02	6	**0.33**	**1.04**	4	**0.10**	**0.20**	5	**0.04**	**0.16**
Oxidised nitrogen	mg/L	0.04	6	**3.35**	**32.80**	4	**1.51**	**2.66**	5	**0.43**	**1.16**
Total kjeldahl nitrogen	mg/L	-	6	1.7	5.9	4	0.9	2.1	5	0.5	8.6
Total nitrogen	mg/L	0.35	6	**9.2**	**36.4**	4	**2.7**	**4.8**	5	**1.4**	**9.0**
Reactive phosphorus	mg/L	0.02	6	<0.01	<0.01	4	<0.01	<0.01	5	<0.01	<0.01
Total phosphorus	mg/L	0.025	6	0.02	**0.26**	4	<0.01	**0.04**	5	<0.01	**0.05**
Analytical results – inorganics											

Table 3.1 SWDCA: sampling and analysis results summary

			Yard			Swale[5]			Basin		
	Units	**DGV[1]**	**No. samples**	**Min/20P[4]**	**Max/80P[4]**	**No. samples**	**Min**	**Max**	**No. samples**	**Min**	**Max**
Cyanide	mg/L	0.007	6	0.006	**0.030**	4	<0.004	0.006	5	<0.004	<0.004
Analytical results – metals (0.45µm field filtered)											
Aluminium (Al)	mg/L	0.055	10	**1.05**	**2.57**	4	**0.40**	**1.07**	5	0.05	**0.64**
Boron (B)	mg/L	0.37	10	<0.05	0.10	4	<0.05	0.24	5	<0.05	**0.43**
Hexavalent chromium (Cr)	mg/L	0.001	6	**0.08**	**0.16**	4	**0.02**	**0.08**	5	<0.01	**0.02**
Total chromium (Cr)	mg/L	0.001[2]	10	**0.068**	**0.134**	4	**0.026**	**0.093**	5	**0.011**	**0.020**
Cobalt (Co)	mg/L	0.0014[3]	10	**0.002**	**0.006**	4	<0.001	<0.001	5	<0.001	<0.001
Copper (Cu)	mg/L	0.0014	10	**0.025**	**0.058**	4	**0.008**	**0.019**	5	**0.002**	**0.011**
Iron (Fe)	mg/L	0.3[3]	10	<0.05	0.21	4	<0.05	**0.34**	5	<0.05	0.25
Nickel (Ni)	mg/L	0.011	10	0.024	**0.065**	4	0.001	0.004	5	0.018	0.006
Molybdenum (Mo)	mg/L	0.034[3]	10	0.004	0.008	4	0.012	**0.167**	5	<0.001	0.002
Vanadium (V)	mg/L	0.006[3]	10	<0.01	**0.02**	4	<0.01	**0.02**	5	<0.01	**0.02**
Zinc (Zn)	mg/L	0.008	10	<0.005	**0.019**	4	<0.005	**0.009**	5	<0.005	0.008

Notes: 1. The DGV for physico-chemical parameters and nutrients refer to the values for physical and chemical stressors in south-east Australia (lowland river) that are reported in Tables 3.3.2 and 3.3.3 of ANZECC/ARMCANZ (2000). The DGV for toxicants refer to the values for slightly – moderately disturbed freshwater ecosystems that are reported in Table 3.4.1 of ANZECC/ARMCANZ (2000) unless otherwise stated.
2. For Cr (VI).
3. Refers to a low reliability DGV or an indicative working level sourced from ANZECC/ARMCANZ (2000) Volume 2.
4. If less than 10 samples are available, the minimum value is reported instead of the 20th percentile value and the maximum value is reported instead of the 80th percentile value.

5. Samples from Event 4 that are included in SWDCA Table 4.5 were not included in the presented minimum and maximum values. This is because the Event 4 sample was collected during a rainfall event that resulted in minimal runoff into the swale (see SWDCA Table 4.2). As a result, concentrations of some analytes were significantly elevated relative to the other swale samples that were collected during larger runoff events. Data from this event is not considered to be representative of typical runoff quality from the yard area, which would be a blend of runoff from stockpiles and cleaner runoff from road areas.

Bold denotes DGV is exceeded.

3.3.2 Key conclusions

i Water quality description

Surface water runoff from the facility is characterised as being alkaline (ie high pH) and containing elevated concentrations (relative to DGVs) of nitrogen (primarily in oxidised form), cyanide and several metals: aluminium, chromium (primarily in hexavalent form), cobalt, copper, molybdenum, vanadium and zinc. These water quality characteristics are interpreted to be associated with water contact with concrete washout, which is one of the materials processed at the facility. The concentrations of nitrogen and metals are generally higher in the yard samples (which were collected from small puddles near stockpiled material) than the swale samples (which include runoff from access roads as well as stockpiles). This indicates that the stockpiled material is the primary source of the high pH, nitrogen, cyanide and metals.

The water quality results from the concrete basin were more variable than the swale results. This is likely because the basin was used to hold imported mains water during dry periods over the SWDCA period and only received surface water inflows when the swale was full and overflowing into the basin. Material overflows into the basin did not occur in all sampling events.

ii Source of contamination

The concrete washout that is within the stockpiled material is assessed to be the source of the high pH, nitrogen, cyanide and metals. Typically, concrete washout is allowed to age (or hydrate) for approximately six to eight weeks in incoming stockpiles before it is suitable for use in blended road base products. The following preliminary analysis indicates that surface water runoff/leachate from incoming and processed material stockpiles have similar water quality:

- Samples collected from puddles near incoming and processed material stockpiles had similar water quality.
- Boral laboratories applied the AMIRA leaching method to assess metal concentrations in leachate from two washout samples over an eight-week period. This analysis did not identify any decline in metal concentrations over the eight-week period.

3.3.3 Justification of SWDCA analyte suite

The SWDCA for the Kooragang RRF was informed by the outcomes of a water characterisation assessment completed at Boral’s Widemere RRF (RHDHV 2017a), the Widemere SWCA. Boral’s Widemere RRF is a similar but larger scale facility to the Kooragang RRF. Both facilities receive and process concrete washout waste, which has been identified as the source of poor water quality. Accordingly, the outcomes of the Widemere SWCA are relevant to the Kooragang RRF and visa a versa. This section describes the Widemere SWCA and Kooragang SWDCA approaches and justifies the Kooragang SWDCA analyte suite (as requested by the EPA – see Section 2.1.2).

i Widemere SWCA approach

The Widemere SWCA was informed by the results from nine surface water sampling rounds that occurred between 14 December 2016 and 23 March 2017. For each round, samples were collected from the lower dam, which receives runoff from the site area and occasionally overflows. All samples were analysed for a comprehensive suite of over 400 analytes. It is noted that the associated laboratory costs were approximately $5,000 per sample.

An initial list of analytes of concern was established applying the following methodology:

- Trigger levels were established for all analytes that had concentrations above laboratory detection limits on at least one occasion. The trigger levels were established using the methods documented in the ANZECC/ARMCANZ (2000) guidelines for slightly-to-moderately disturbed ecosystems (for toxicants) and physical and chemical stressors (for stream health indicators). It is noted that trigger levels for toxicants that did not have published guideline values were established as Environmental Concern Levels (ECLs) using the methods documented in the ANZECC/ARMCANZ (2000) guidelines.

- Analytes that exceeded the established trigger levels on at least one occasion were identified as potential analytes of concern.

This assessment method was conservative as the trigger values were representative of chronic (ie long term exposure) and incorporated results from samples collected during dry weather, which may not be representative of water quality during overflow conditions.

Following feedback from the EPA, the results were further assessed as part of the Water Quality Risk Assessment and Proposed Sampling Plan (RHDHV 2017b). This assessment established that the potential water quality risks associated with overflows that occur for short durations during elevated streamflow conditions are acute (ie due to short term exposure) rather than chronic (ie due to long term exposure). Accordingly, acute trigger values were established for each of the initial toxic analytes of concern that were identified in the Widemere SWCA. The list of analytes of concern was then revised applying the following methodology:

- The results from dry weather sampling events were omitted as the data from wet weather samples was considered to be more representative of the water quality characteristics of site overflows.

- Any non-toxic analyte that exceeded the relevant stream health indicator on at least one occasion was identified as an analyte of concern.

- Any toxicant that exceeded the DGV on at least one occasion was identified as an analyte of concern for chronic exposure scenarios.

- Any toxicant that exceeded the acute trigger values on at least one occasion was identified as an analyte of concern for acute exposure scenarios.

Table 3.2 provides the resulting analytes of concern.

Table 3.2 Widemere SWCA: analytes of concern

Non-toxic analytes of concern	Toxic analytes of concern	
	Chronic exposure scenarios	Acute exposure scenarios
pH, salinity, suspended solids, total phosphorus and oxidised and total nitrogen.	Nitrate, aluminium, barium, chromium (VI), copper, strontium, vanadium, fluoride, cyanide, carbendazim, anionic surfactants, chlorine.	Aluminium, chromium (VI) and copper.

ii Justification for Kooragang

The Kooragang SWDCA commenced in June 2018 after the Widemere SWCA had been completed and was therefore informed by the outcomes of the Widemere SWCA. The analyte suite for the Kooragang SWDCA included a comprehensive range of physico-chemical parameters and metal and organic toxicants. All of the analytes of concern identified in the Widemere SWCA were included except for carbendazim. Carbendazim (a fungicide residual) concentrations at Widemere exceeded the chronic trigger value in 3 out 6 samples. The maximum exceedance was approximately two times the chronic trigger value but well below the acute trigger value (RHDHV 2017b). Similar magnitude exceedances are possible at the Kooragang RRF.

Further investigations were not undertaken to inform this SWMMP as the presence or non-presence of carbendazim (or any other toxicant) at non-acute concentrations would not change the proposed mitigation approach, which is to minimise water discharges from the facility.

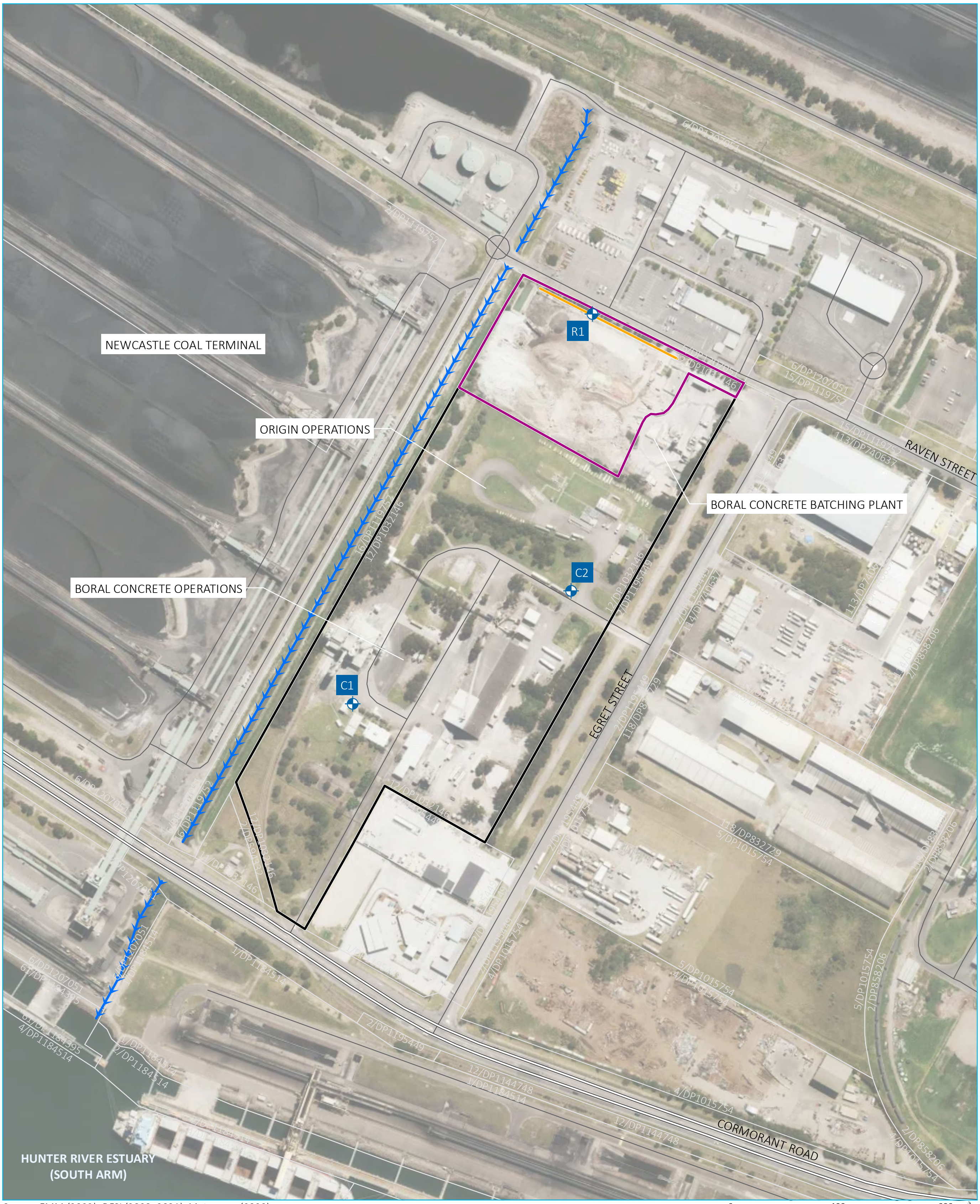
3.4 Receiving environment

Surface water is discharged via infiltration from the swale that is located along the northern boundary of the facility (see Section 3.2). Hence, the underlying groundwater system is the immediate receiving environment.

The receiving groundwater system is described in the Soil and Water Assessment: Kooragang Recycling Facility EIS (SLR 2015) which references a 2012 groundwater investigation that was undertaken by AECOM. Collectively these studies were informed by installing three monitoring bores within Lot 12 DP 1032146 and a single round of monitoring groundwater level and quality. Monitoring bore locations are shown in Figure 3.5.

The local groundwater system is characterised in these studies as follows:

- Lot 12 DP 1032146 is recorded as being partly located on man-made fill, comprising spoil and slag deposited as part of the reclamation of the south-eastern section of Kooragang Island in the mid-1900s. Where present, the fill is recorded to be underlain by a mixture of silt, clay and estuarine sediments that are natural deposits of Kooragang Island.
- The groundwater table across the site ranged from 2.53 to 2.62 m AHD, which is approximately 1 m below the invert of the infiltration swale and 1.5 to 3.5 m below the yard surface levels.
- Two water-bearing zones, separated by a low permeability unit of clay, were encountered when drilling monitoring bore C1 adjacent to the offices of Boral Cement Works (the bore location is shown in Figure 3.5). An unconfined shallow perched aquifer was observed within an upper sand unit (2.6 to 2.8 m below ground level) and a deeper confined aquifer within a lower sand unit (4.0 to 4.5 m below ground level). Both zones are interpreted to have high permeability due to the sand media.
- Groundwater monitoring was undertaken by SLR in 2015 from monitoring bores R1 and C1 (the bore locations are shown in Figure 3.5). The monitoring identified non-trivial concentrations of PAH and TRHs. These were interpreted to be associated with the former use of spoil and slag as fill. All analysed metal concentrations were below DGVs for 95% species protection (freshwater) except for zinc.
- Regional groundwater flow is interpreted to be in a southerly direction towards the southern arm of the Hunter River Estuary, which is located 700 m from the facility. However, some groundwater from the facility area may also flow into the concrete lined drain that is located immediately to the west of the facility. This drain also flows in a southerly direction and enters the southern arm of Hunter River Estuary near the coal loading facilities (see Figure 3.5).



Source: EMM (2022); DFSI (2020, 2021); Metromap (2022)

0 100 200 m
GDA 1994 MGA Zone 56
N

KEY

- Existing monitoring bore
- Facility area
- Lot 12 DP1032146
- Existing surface drain
- Infiltration swale
- Major road
- Minor road
- Cadastral boundary

Groundwater monitoring bores

Kooragang Island Resources Recovery Facility
Surface Water Mitigation and Monitoring Plan
Figure 3.5

EMM
creating opportunities

\\emmsvr1\EMM\Jobs\2018\H180253 - Boral Kooragang SWCA\GIS\02_Maps\SWMMP\SW002_GroundwaterMonitoringBores_20220225_01.mxd 25/02/2022

4 Mitigation plan

This chapter describes a mitigation plan that has been developed to address EPL condition U1.3 and Consent Condition B15. Section 4.1 describes the plan and includes information on the functionality of the proposed system, proposed works, specifications, an implementation schedule and contingency measures.

Residual impacts associated with the operation of the proposed system are described in Chapter 5 and a monitoring and validation plan is provided in Chapter 6.

4.1 Proposed plan

4.1.1 Description of works

Boral propose to reconstruct and modify the water management system to significantly improve the capture and containment of stormwater runoff from the yard, which is known to have poor water quality. The proposed works include:

- replacing the existing infiltration swale with a concrete lined drain;
- installing a new low permeability geosynthetic clay liner with a 500 mm protective layer within the yard;
- repurposing the existing 0.35 ML concrete basin and installing 1.25 ML of new storage (primarily as tanked storage) to provide 1.6 ML of stormwater storage; and
- installing water supply infrastructure to enable captured stormwater to be used for concrete production at the adjoining concrete plant that is operated by Boral.

Collectively these works will enable stormwater runoff from the yard to be captured in the stormwater storages. The 1.6 ML of storage is equivalent to 100 mm of runoff from the 1.6 ha yard area. Allowing for rainfall losses, approximately 120 to 170 mm of rainfall would be required to produce 1.6 ML of runoff. Water captured in the storages will be used for onsite dust suppression (dry weather only), product conditioning and concrete production to restore capacity after rainfall. The system will occasionally overflow when the storages fill. Overflows will occur from the concrete basin into an existing concrete lined drain that is located to the west of the facility and drains to the south, entering the Hunter River estuary near the coal ship loaders. Overflows are expected to only occur for short periods of time during and shortly after significant rainfall events (ie 120 to 170 mm over several days). Rainfall events of this magnitude occur once to twice per year (on average).

Figure 4.1 and Figure 4.2 are conceptual diagrams that show the functionality and layout of the proposed system. Detailed descriptions of the proposed works, specifications and maintenance and management approaches are provided in Table 4.1. The following documents will be prepared following approval of the SWMMP:

- a detailed design of the proposed civil works. The design will apply the specifications provided in Table 4.1 and will address Consent Condition B22.
- maintenance and management measures will be incorporated into a WMP that will be prepared prior to the operation of the new water management system.

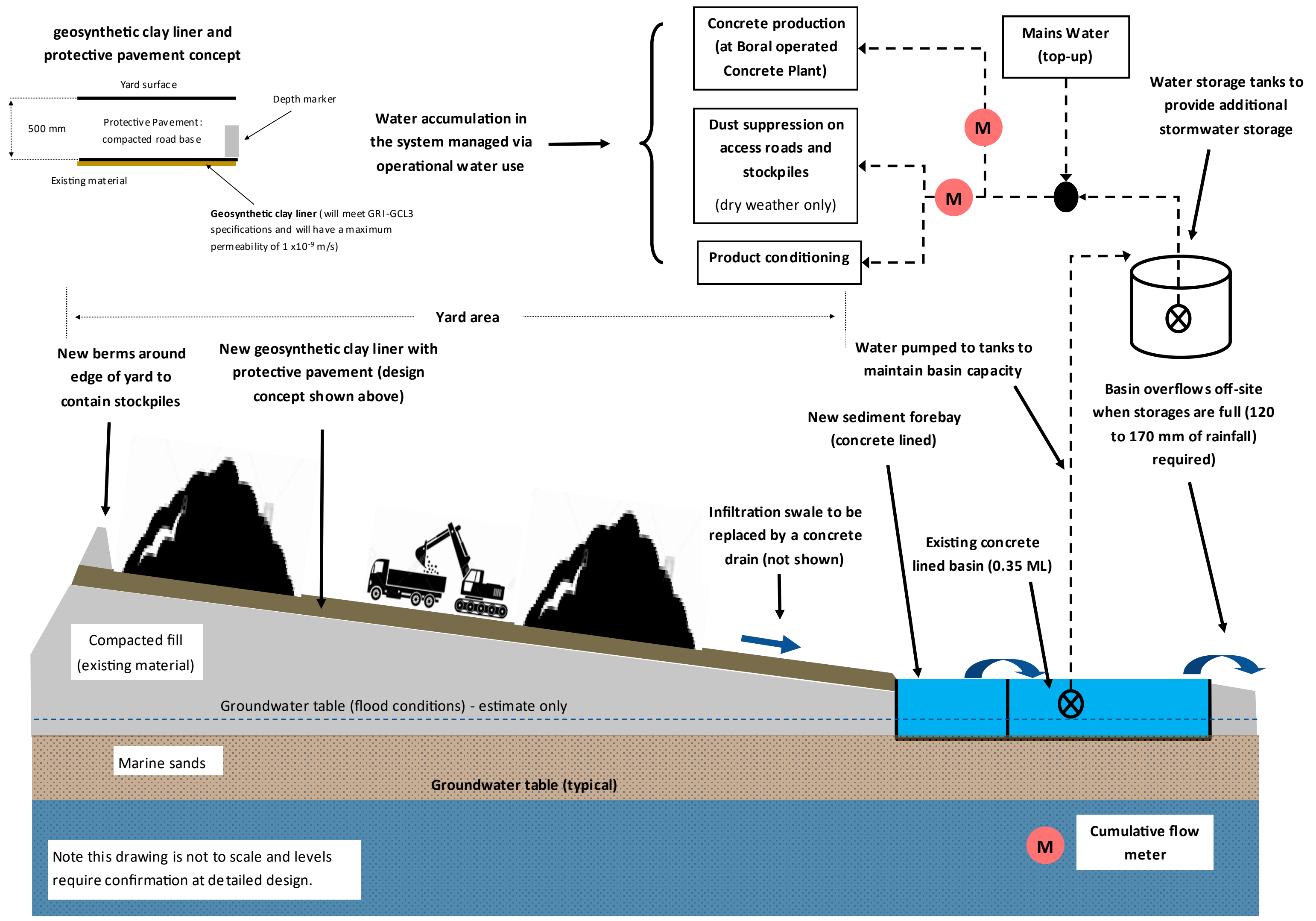


Figure 4.1 Proposed system functionality

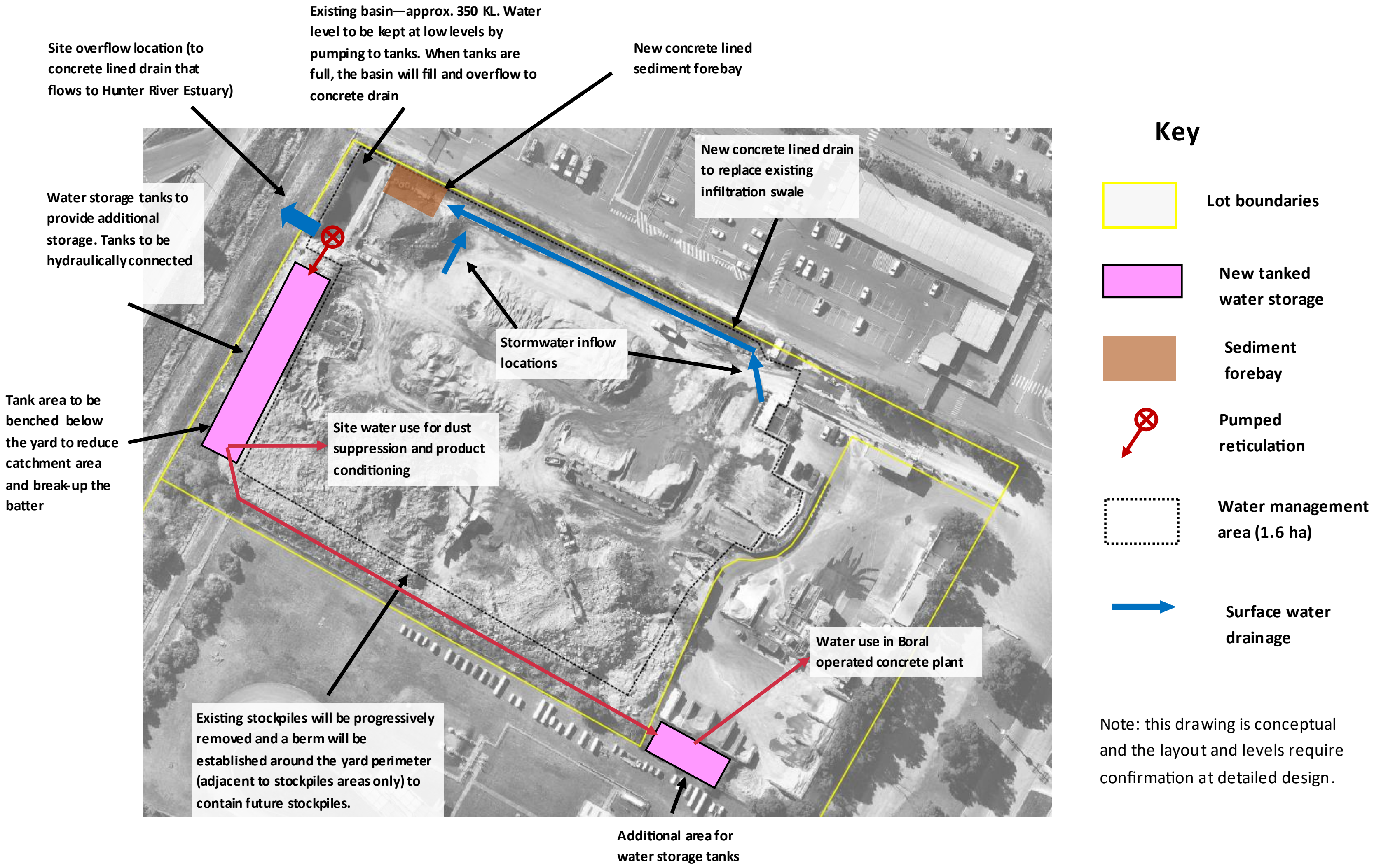


Figure 4.2 Conceptual layout: proposed system

Table 4.1 Proposed works and management measures

	Description of proposed works/operational measures	Design specifications	Maintenance and management
Yard grading	The yard will be graded so that all runoff drains to the proposed sediment forebay (see Figure 4.2), which will overflow into the existing concrete basin. All stockpiles around the perimeter of the yard will be progressively removed to enable the low permeability geosynthetic clay liner to be installed. Berms will be installed to contain future stockpiles within the water management area (see Figure 4.2). The works will be undertaken in a staged manner to allow for the continued operations. An implementation schedule is provided in Section 4.1.2.	All runoff from the yard is to drain to the proposed sediment forebay, which will overflow into the existing concrete basin. The yard will be graded so that all runoff drains to the proposed sediment forebay and to ensure the base of stockpiles are free draining. Berms will be constructed around the yard perimeter to contain stockpiles within the water management area.	The yard requires regular maintenance to manage the accumulation of residual stockpile material. This is currently and will continue to be done via: • regular (ie every 6 months) survey of yard levels; and • trimming and where necessary re-compaction of the yard surface. Stockpiles will be maintained within the water management area, as marked by the proposed perimeter berms.
Drainage works	The existing infiltration swale will be replaced with a concrete lined drain that will convey stormwater runoff from the yard to the proposed sediment forebay. A sediment forebay will be constructed upstream of the existing concrete basin to improve the capture and management of sediment in stormwater runoff. The forebay will also provide stormwater storage (above the overflow level to the concentrate basin).	A berm will be constructed along the northern boundary of the yard to prevent any unintentional stormwater overflows occurring across the northern site boundary. The sediment forebay will be sized based on an expected event-based sediment load and will also be concrete lined to prevent infiltration.	Both the concrete drain and sediment forebay will require regular clean out to remove accumulated sediment.
Low permeability geosynthetic clay liner with a 500 mm protective layer	A new low permeability geosynthetic clay liner will be installed within the yard. The liner will have a maximum permeability of 1 x10^{-9} m/s and will be protected by an overlying 500 mm protective pavement that will be constructed using compacted road base. The protective pavement will be maintained by trimming and re-compaction as required. The pavement design concept is shown in Figure 4.1. The pavement will be installed within the yard in three stages (see Section 4.1.2).	The **low permeability geosynthetic clay liner** will meet GRI-GCL3 specifications and will have a maximum permeability of 1 x10^{-9} m/s. The **protective pavement** will be a 500 mm compacted road base pavement that will overly the low permeability liner. Depth markers will be installed to allow for wearing of the protective pavement to be identified. The finished surface levels of both pavements will be surveyed to enable future	The yard surface will be surveyed every six months. The surveyed levels will be compared to the finished surface levels of the protective and underlying geosynthetic clay liner to identify areas where wearing or material accumulation is occurring. Depth markers will also be installed near the bottom of the protective pavement. Exposure of the markers will allow for wearing of the protective pavement to be identified by the site team. In areas that wearing is identified (via either survey or depth markers), the protective pavement will be repaired via

Table 4.1 Proposed works and management measures

	Description of proposed works/operational measures	Design specifications	Maintenance and management
		assessment of changes to the protective pavement depth to be made.	trimming and recompacting the existing material and/or new material.
Increased storage	The proposed drainage works will redirect all runoff from the yard to the concrete basin, which has an estimated storage volume of 350 kL (0.35 ML). An additional 1.25 ML of storage will be installed collectively between the new sediment forebay and tanked storage. Water will be pumped from the basin into the tanks. Pumping will continue until the tanks are full.	The total system storage will be 1.6 ML. The pump transfer from the concrete basin to the storage tanks will be an automated system that has capacity to transfer the 1-year ARI event without overflows occurring (due to pump capacity). This aligns with the likely system overflow frequency (ie 1 to 2 overflows per year). A diesel-powered back-up pump will be kept on site.	The tanks and pump transfer system will be maintained in good working order.
Site water use	Captured stormwater will be used for: • dust suppression on access roads and stockpiles (during dry conditions only); • product conditioning; and • concrete production at the adjoining concrete plant that is operated by Boral. The site water use rate will vary due to weather, production schedules and seasonal trends, but will restore capacity in the storages within 3 to 6 weeks following a filling event.	Cumulative flow meters will be installed to measure the volumes of water used in the yard (ie for dust suppression and product conditioning) and sent to the concrete plant. Cumulative flow meter locations are indicated in Figure 4.1.	**Site water use** • Water will only be used for dust suppression purposes during dry weather. • Any water applied to stockpiles will be done in a controlled manner that avoids saturation of stockpiles. **Concrete plant water use** • The concrete plant will use water exported from the facility once water captured in the concrete plant's stormwater system is depleted.
Overflow arrangements	System overflows will occur occasionally when either the pump capacity is exceeded or when the storages are full. All overflows will occur from the concrete basin into the concrete lined drain that is located to the west of facility. This drain flows in a southerly direction and enters the Hunter River Estuary near the coal ship loaders. The overflow location is indicated in Figure 4.2	Nil	The following monitoring will be undertaken during site overflow events: • Site overflows will be monitored daily based on site observations and basin levels • Water quality monitoring will be undertaken daily during any overflow event – up to 2 samples per overflow event. The proposed monitoring is described further in Chapter 6.

4.1.2 Scheduling of works

To enable the continued operation of the facility, it is proposed to construct the new water management system and pavement over several stages. The sequencing of works has been optimised so that the new water management system is operational prior to the construction of the new pavement. Table 4.2 describes the proposed scheduling of works and includes information on the water management approach during construction and the timing of each stage. Figure 4.3 shows the pavement construction stages.

It is noted that plans for Stage 2 (ie the expansion area included in the consent -see Section 1.1.1) will be provided separately at a future date.

Table 4.2 Proposed scheduling of works – Stage 1

	Proposed works	Water management during construction	Timing
Detailed design	• Detailed design of the proposed water management system, yard and new pavement.	The existing water management system will continue to be operated until the new system is constructed.	Within 2 months of approval of this SWMMP
Construct new water management system	• Remove stockpiles from the proposed tank storage area. • Earthworks to achieve design levels in tank storage area. • Construct new tanked storage and pump transfer systems. • Construct new concrete sediment forebay. • Fill the infiltration swale and construct new concrete drain that will convey stormwater runoff into the sediment forebay.	The infiltration swale will be maintained until the new tanked storage is operational. Once the new tanked storage is operational, the swale will be replaced with the concrete drain and sediment forebay. The operation of the new water management system will commence once these works are competed.	Within 5 months of approval of this SWMMP[1] (ie 3 months after completion of detailed design).
Construct new low permeability geosynthetic clay liner with protective layer	The new liner and pavement will be constructed over three stages (see Figure 4.3). Each stage will comprise the following works: • Removal or relocation of existing stockpiled material from the works area • Earthworks to achieve design levels • Install new geosynthetic clay liner with overlying protective pavement. • Complete a work-as-executed survey of the finished surface levels	All surface water runoff from the yard will be managed in the new water management system.	Within 12 months of approval of this SWMMP[1] (ie 10 months after completion of detailed design).

Notes: 1. timeframe does not make allowance for government review and approval of detailed design (which is not required by Consent Condition B22).

Figure 4.3 New pavement construction stages

4.1.3 Contingency measures

If future monitoring indicates that the SWMMP outcomes are not being achieved, Boral will engage a suitably qualified professional to review the water management system and identify improvements that can be practically implemented. Table 4.3 lists some contingency measures that could be considered.

Table 4.3 Possible contingency measures

Measure	Trigger	Outcome
Additional tanked storage	If the water management system overflows occur more frequently than stated in this SWMMP	More storage will reduce the frequency and magnitude of overflows
Review pavement and liner design	If the permeability specifications are not achieved If the geosynthetic clay liner is damaged by machinery damage	The protective pavement can be locally replaced with alternative solutions in areas where machinery damage occurs or if the permeability specifications are not achieved.

4.2 Assessment of measures noted in the PRS 2

Condition U1.3 in PRS 2 notes several measures that are to be considered in the SWMMP (see Table 2.1). Table 4.4 reproduces these suggested measures and notes if the measure is proposed. A brief description is provided for measures that are proposed and justification is provided for measures that are not proposed.

Table 4.4 Assessment of measures noted in the PRS

Measures noted in PRS Condition U1.3	Status	Comments
Covering and sealing of the waste stockpile storage and processing areas.	**Not proposed**	**Justification** – water quality investigations concluded that there are no point sources of contamination, with both the incoming and product stockpiles being sources of contamination (see Section 3.3.2). Covering stockpiles is not considered to be practical given that most of the yard would need to be covered and the structures would need to accommodate the maximum stockpile height plus allow for machine access. Covering some stockpiles would be counterproductive as contaminated runoff would continue to occur from uncovered stockpiles and the higher runoff volume from covered impervious areas would reduce the system's containment capacity.
The use of low permeability hardstands(s) under waste stockpile storage and processing areas.	**Proposed**	A low permeability geosynthetic clay liner is proposed in the yard – see Table 4.1 for details.
The lining or treatment of drains and swales onsite to prevent the infiltration of potentially contaminated stormwater to groundwater.	**Proposed**	The existing infiltration swale will be replaced with a concrete drain – see Table 4.1 for details.
Increased captured stormwater storage capacity, to minimise discharges and increase the availability of water for dust suppression in dry times.	**Proposed**	1.6 ML of storage is proposed. This storage will have capacity to capture runoff from 120 to 170 mm of rainfall. This is discussed further in Chapter 5.
Management measures that will be put in place to prevent over irrigation of potentially contaminated stormwater that may leach contaminants from materials on-site.	**Proposed**	Water application to stockpiles will only occur during dry conditions and at controlled rates. This will avoid stockpiles becoming saturated – see Table 4.1 for details.
Management measures that will be put in place that will prevent the depth and permeability of any sub-surface hardstand being compromised by daily use of mobile plant at the premises.	**Proposed**	The geosynthetic clay liner will be protected by an overlying 500mm compacted road base pavement (the protective pavement). The protective pavement will be progressively maintained (via trimming and re-compaction) as part of the facility's routine maintenance program. The integrity of the pavement will be validated via six monthly survey of yard surface levels and annual infiltration tests – a monitoring and validation plan is provided in Chapter 6.
Management measure that will be put in place that will prevent the permeability of drains and swales being compromised during cleaning operations.	**Proposed**	The new concrete drain and sediment forebay will accumulate sediment and require regular clean out. Both structures will be constructed using reinforced concrete and can cleaned using machinery without being compromised.

5 Residual impacts

This chapter describes the residual impacts associated with overflows from the facility. It includes descriptions of overflow regimes (quantity and quality) and possible residual impacts.

5.1 Overflow regime summary

Table 5.1 provides a summary of the overflow regime (both quantity and quality) using information presented in this report and the results from a water balance model that was prepared to estimate the frequency and magnitude of overflows from the proposed water management system. The water balance model is described in Appendix A. These descriptions have been applied to assess residual impacts.

Table 5.1 Water management system: overflow regime

	Description	Supporting information
Mechanism	Overflows from the water management system will occur when either the storages are full or the capacity of the pump transfer system from the concrete basin to the storage tanks is exceeded. Overflows will occur from the concrete basin into an existing concrete lined drain that is located to the west of the facility and drains to the south, entering the Hunter River estuary near the coal ship loaders (see Section 4.1 for further details).	
Frequency	Overflows are expected to occur approximately 1 to 2 times per year (on average). The rainfall thresholds for overflows will vary depending on a range of factors including rainfall intensity, antecedent conditions, site conditions (especially the extent of stockpiles) and seasonality. The likely thresholds are: • overflows are unlikely for events that comprise less than 120 mm of rainfall; • overflows are possible for events than comprise 120 to 170 mm of rainfall; and • overflows are likely for events that comprise more than 170 mm of rainfall.	This description is informed by the water balance model which predicts 1.25 overflow per year (on average). The stated overflow frequency (ie 1 to 2 times per year (on average) and rainfall thresholds have been informed by both the water balance model results and adjusted to account for both uncertainty in the model and the variation in the factors that influence overflows.
Duration	Overflows will occur near the end of significant rainfall events following an initial storage filling period. Once an overflow commences, it will continue until rainfall ceases. In some cases, overflows may occur intermittently for several days after a storage filling event occurs.	This description has been informed by water balance model results (see Appendix A) and based on the expected functionality of the proposed water management system.
Volume	The water balance model estimated that the average annual overflow volume would be equivalent to: • 18% of the average annual runoff volume from the yard; or • 6% of the average annual rainfall volume that occurs over the yard.	The estimated overflow volumes are informed by water balance model results (see Appendix A).

Table 5.1 Water management system: overflow regime

	Description	Supporting information
	It is noted that most of this overflow volume is associated with very large rainfall events (ie > 170 mm) that exceed the design capacity.	
Water quality	The quality of water that overflows from the system is assessed to be similar to the water quality in the existing swale, which receives runoff from the yard. The quality characteristics of water in the existing swale are described in Table 3.1.	The water quality samples from the swale were collected during or after rainfall events that resulted in material surface water runoff from the yard. The proposed mitigation approach is to significantly improve the capture and containment of stormwater runoff, no changes to the water quality of runoff are expected. Accordingly, the water quality results from the swale are assessed to be representative of the water quality of system overflows.

5.2 Residual impacts

Overflows from the facility will only occur during and shortly after significant rainfall events that would result in substantial runoff entering the drain that is located immediately to the west of the facility. Accordingly, any concentration impacts are likely to be both temporary and mitigated by mixing with other catchment runoff.

6 Monitoring and validation plan

This chapter describes a monitoring and validation plan. The plan includes monitoring the performance of the new pavement, surface water overflows and local groundwater. The monitoring data will be used to validate the performance of the new pavement and water management system against the specifications and expected outcomes that are reported in this SWMMP. Specifically, the monitoring data will be used to validate that:

- the protective pavement is providing adequate cover and protection of the underlying low permeability geosynthetic clay liner;
- the geosynthetic clay liner has and maintains a saturated hydraulic conductivity of 1 x10^{-9} m/s; and
- overflows from the water management system only occur during and after significant rainfall events that will typically comprise 120 mm or more of rainfall.

The following sections describe a pavement validation plan, surface and groundwater monitoring plans and assessment and reporting approach.

6.1 Pavement validation plan

The purpose of the pavement validation plan is to demonstrate that:

- the geosynthetic clay liner and protective pavement is constructed to the design specifications;
- the protective pavement is maintained overtime; and
- the geosynthetic clay liner maintains a saturated hydraulic conductivity of 1 x10^{-9} m/s.

The plan is described in Table 6.1.

Table 6.1 Pavement validation plan

	Validation Plan
Validation of the constructed pavement and geosynthetic clay liner installation	**During construction** • Quality control during construction to ensure that the geosynthetic clay liner is installed to manufactures recommendations and design specifications for the protective pavement are met. **Following construction** • Following construction, two infiltration rate tests (see section 6.1.1) will be undertaken in each of the three stages (six in total). • The finished surface levels of the geosynthetic clay liner and protective pavements will be surveyed to enable future assessment of changes to pavement surface levels. Note this survey is referred to as a work-as-executed survey in this document. • An independent technical report will be submitted to the EPA that provides information to demonstrate the geosynthetic clay liner was constructed to design specifications and the infiltration test results.

Table 6.1 Pavement validation plan

	Validation Plan
Ongoing validation	• The yard surface will be surveyed every six months. The surveyed levels will be compared to the work-as-executed levels to identify any areas where wearing of the protective pavement or material accumulation is occurring. • Annual infiltration tests will be undertaken at two random locations within the yard that are safe and will not restrict operations. The initial tests will be undertaken approximately 12 months after the construction validation tests. • An independent technical report will be provided each year as part of the annual water management review (see Section 6.4). The report will include recommendations to address any identified issues. • The program will be reviewed after two years.

6.1.1 Infiltration rate test methodology

Infiltration rate tests will be undertaken using a Double-Ring Infiltrometer with a Sealed Inner Ring. This test takes approximately two days to complete and is an accepted method for soils or material with infiltration rates between 1 x 10^{-7} to 1 x 10^{-10} m/s. A standard test method for this test is provided as Appendix B.

6.2 Surface water monitoring

Surface water monitoring is proposed to record overflows (both quantity and quality), water use rates in the yard and water export rates to the adjoining concrete plant. The surface monitoring plan is described in Table 6.3.

Table 6.2 Surface water monitoring plan

Aspect	Approach
Monitoring of water use	Cumulate flow meters will be installed at the yard and concrete plant use points (see Figure 4.1). The meter readings will be recorded monthly and will be reported in the annual water management review.
Monitoring of overflows	**Recording overflows** Site overflows will be monitored daily based on site observations and basin levels. A record of overflows will be maintained on site and will be reported in the annual water management review. **Water quality monitoring** System overflows will occur once the storages are full and once commenced, may occur intermittently for several days. Water quality monitoring will be undertaken daily during any overflow event up to two samples per overflow event. The timing of the sample collection will be established based on site observations and forecast rainfall, with an objective to collect the initial sample shortly after overflows commence and the second sample near the end of the overflow event. Higher frequency sampling (ie every day that overflows occur) is not considered to be beneficial as the SWDCA demonstrated that the site water quality has consistent trends and there are no water quality targets proposed in this SWMMP. Samples will be collected from within the concrete basin, near the overflow location. The water quality monitoring will include analysis of pH, electrical conductivity, oxidised nitrogen, total nitrogen, aluminium, copper, chromium[2]. All analysis will be undertaken using calibrated field instruments (pH and electrical conductivity only) and/or by a NATA accredited laboratory. The proposed analytes were selected as they significantly exceeded DGVs in most surface water samples collected during the SWDCA (see Table 3.1) and are therefore considered to be the most suitable indicators of surface water quality.

Table 6.2 Surface water monitoring plan

Aspect	Approach
Plan commencement	The surface water monitoring plan will commence once the construction of the new water management system is completed.
Reporting	Results will be reported in the annual water management review and as required by the EPL. The annual water management review will include recommendations to address any identified issues.

Notes: 1. All metals samples will be field filtered using a 0.45 µm filter.

2. Chromium is known to exist in surface water primarily as Cr(VI). It is proposed that total Cr speciation analysis is undertaken and it is assumed that 100% of Cr is Cr (VI). This approach will provide a conservative assessment of potential water quality risks associated with Cr.

6.3 Groundwater monitoring

Any stormwater that infiltrates within the site will enter the local unconfined sand aquifer that exists beneath the site. It is interpreted that this groundwater system is recharged by rainfall recharge and stormwater infiltration from the surrounding area. Groundwater flow is interpreted to be predominantly to the south towards the Hunter River estuary but may also flow to the west into the concrete lined drain when groundwater levels are elevated during wet weather.

It is proposed to monitor groundwater at four bores located near the yard perimeter and at two additional bores located on adjoining Boral owned land. The monitoring will be undertaken twice annually, with one event targeting dry conditions and the other targeting after wet conditions. Water quality analysis will be undertaken for the key analytes that were identified in the SWDCA.

The objective of the monitoring will be to understand groundwater flow direction and assess potential changes to groundwater quality due to the operation of the site. This will be done by comparing groundwater quality results from upgradient and downgradient bores to identify any material changes. The groundwater quality will also be compared to:

- the known water quality profile of surface water (as described in Section 3.3); and
- the relevant DGVs.

The groundwater monitoring plan is described in Table 6.3.

Table 6.3 Groundwater monitoring plan

Aspect	Approach
Locations	Groundwater monitoring will be undertaken at four bores that will be located near the yard perimeter and at two additional bores located on adjoining Boral owned land. Indicative locations of the bores are provided in Figure 6.1. Each bore will be screened in the upper unconfined sand aquifer, conceptual bore construction specifications are provided in Section 6.3.1. There is potential to utilise two existing monitoring bores (see Figure 6.1) if they are in a suitable condition.

Table 6.3 Groundwater monitoring plan

Aspect	Approach
Frequency	Groundwater monitoring will be undertaken at all locations twice annually, with one event targeting dry conditions and the other targeting after wet conditions (ie several days after a +100 mm rainfall event).
Monitoring parameters	Groundwater monitoring will include measurement and analysis of groundwater level, pH, electrical conductivity, oxidised nitrogen, total nitrogen, aluminium, copper, chromium[2]. All analysis will be undertaken using calibrated field instruments (groundwater level, pH and electrical conductivity only) and/or by a NATA accredited laboratory. These analytes were selected as they are they significantly exceeded DGVs in most surface water samples collected during the SWDCA (see Table 3.1) and are therefore considered to be the most suitable indicators of potential groundwater contamination from the operation of the facility.
Plan commencement	The groundwater monitoring plan will commence once the construction of the new water management system and pavement is completed.
Reporting	Results will be reported in the annual water management review and as required by the EPL. The annual water management review will include recommendations to address any identified issues.

Notes: 1. All metals samples will be field filtered using a 0.45 µm filter.

2. Chromium is known to exist in surface water primarily as Cr(VI). It is proposed that total Cr speciation analysis is undertaken and it is assumed that 100% of Cr is Cr (VI). This approach will provide a conservative assessment of potential water quality risks associated with Cr. Boral may elect to undertake speciation analysis if Cr is identified at non-trivial concentrations.

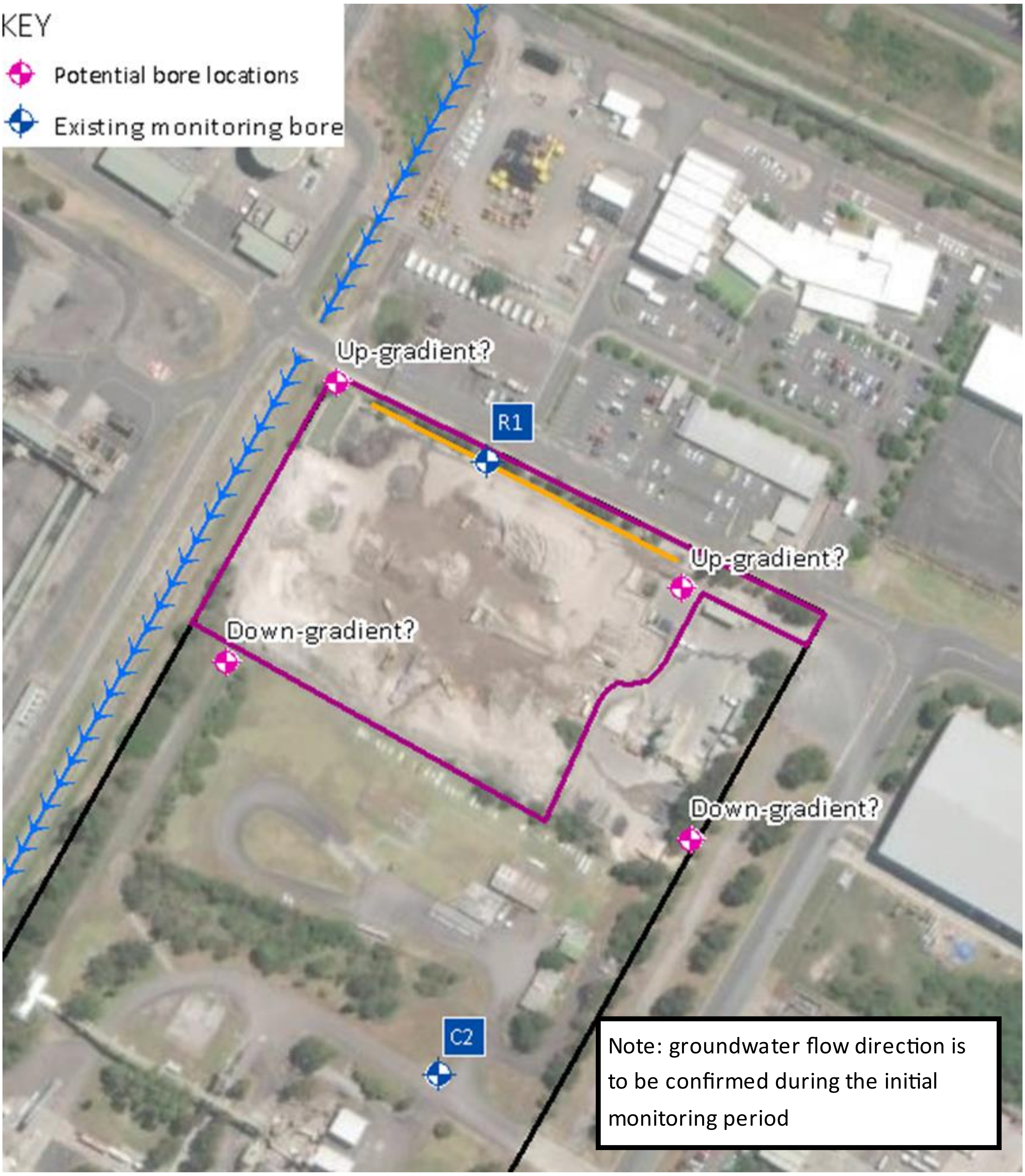


Figure 6.1 Indicative monitoring bore locations

6.3.1 Bore construction

Groundwater monitoring bores (bores) will be installed in line with the *Minimum Construction Requirements for Water Bores* (NUDLC 2020). Bores will be constructed from thread-jointed, class 18 uPVC, with a minimum 50 mm internal diameter. Bore constructed will generally align with the following methodology:

- A borehole will be drilled to sufficient depth below the groundwater table to facilitate installation.
- A sump will be placed at the base of the monitoring bore (approximately 0.5 m) to minimise sediment build up in the screen section of the bore.
- Sufficient screen length (nominally 3 m) will be installed above the sump, intersecting the groundwater table and allowing sufficient buffer for groundwater level fluctuations arising from rainfall infiltration, tidal influence and seasonal changes.
- Casing will extend from the top of the screen section to ground level.
- The annular void (i.e. area between the bore and borehole wall) will be backfilled with:
  - filter pack (nominally 3–5 mm washed sand) to approximately 0.5 m above the screen section;
  - bentonite, hydrated in-situ to approximately 3 m below ground level; and
  - cementitious grout to ground level.

Bores will be secured with a lockable monument (if installed in clear areas) or gattic cover (if installed in a trafficable area).

Installation methodologies and nominal depths will be confirmed by a suitably qualified and experienced hydrogeologist on site. An indicative installation diagram is provided in Figure 6.2.

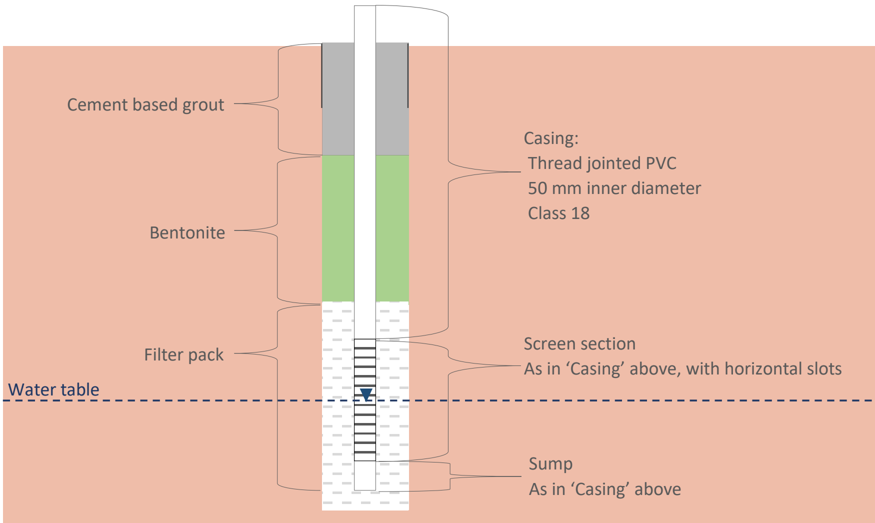


Figure 6.2 Ground water monitoring bore – conceptual installation

6.4 Reporting

A construction validation report will be provided once the new water management system and pavement is installed. Once the new system is operational, an annual water management review will be provided each year. This report will document the outcomes of the ongoing monitoring and validation. Table 6.4 describes the content and timing of these reports.

Table 6.4 Proposed reporting

Report	Content	Timing
Construction validation report	• An independent technical report that provides information to demonstrate that the pavement was constructed to design specifications. • Work-as-executed survey of the new pavement and water management system. • A statement that the new water management system has been constructed to design specifications.	• Two months after the completion of construction works.
Annual water management review	• An independent technical report that documents the outcomes of ongoing pavement validation plan (see Table 6.1). • All surface water and groundwater monitoring results. • Assessment of the performance of the new pavement and water management system against the specifications and expected outcomes that are reported in this SWMMP. • Assessment of potential changes to groundwater quality due to the operation of the facility. • Proposed measures to rectify any identified issues.	• The initial report will be provided 12 months after the completion of construction works and annually thereafter.

7 Commitments and program

Table 7.1 provides a summary of commitments made in the SWMMP.

Table 7.1 Summary of commitments and program

Commitment	Description	Targeted completion
Detailed design	Detailed design of yard levels, pavement and stormwater system.	Within 2 months of approval of this SWMMP
Construct new stormwater system	Construct new tanked storage, sediment forebay, replace infiltration swale with concrete drain, pumped reticulation (see Section 4.1 for further details).	Within 5 months of approval of this SWMMP[1]
Instal geosynthetic clay liner and protective pavement	To be constructed in three stages – see Table 4.2 for further details.	Within 12 months of approval of this SWMMP[1]
Install groundwater monitoring bores	Install new groundwater monitoring bores (see Section 6.3 for further details).	Within 12 months of approval of this SWMMP[1]
Construction validation report	A report that provides information to demonstrate that the new pavement and water management system was constructed to design specifications (see Table 6.4 for further details).	Two months after the completion of construction works.
Water management plan (operational plan)	A document that describes the water management system, operating procedures and monitoring and reporting requirements.	Two months after the completion of construction works.
Annual water management review	An annual report that includes all monitoring results and reviews the performance of the new pavement and water management system against the specifications and expected outcomes that are reported in this SWMMP (see Table 6.4 for further details).	The initial report will be provided 12 months after the completion of construction works and annually thereafter.
Stage 2 expansion	Expand the facility to the south (as per consent).	TBD

Notes: 1. timeframe does not make allowance for government review and approval of detailed design (which is not required by Consent Condition B22).

References

ANZECC/ARMCANZ 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australian and New Zealand.

EMM 2019, Kooragang Island resource recovery facility: Surface water discharge characterisation assessment (referred to as SWDCA in this report)

Environmental Property Services 2015, *Materials Recycling Facility Expansion: Environmental Impact Statement*

SLR 2015, *Soil and Water Assessment: Kooragang Recycling Facility EIS.*

RHDHV 2017a, Boral Widemere: Surface Water Characterisation Assessment (referred to as the Widemere SWCA in this report)

RHDHV 2017b, Water Quality Risk Assessment and Proposed Sampling Plan: Boral Widemere PRP

RHDHV 2017c, Boral Widemere: Surface Water Monitoring and Mitigation Plan

Appendix A

Water balance model description

A.1 Introduction

This technical appendix to the Surface Water Mitigation and Monitoring Plan (SWMMP) describes a predictive water balance model (WBM) that was developed to estimate the frequency and magnitude of overflows from the proposed water management system. The model is informed by information provided by Boral, site observations made by EMM during wet weather site inspections and data from Boral's RRF at Widemere that is documented in a SWMMP prepared for that facility (RHDHV 2017c).

This document describes the model, its assumptions and key results. The model results are referenced in the SWMMP along with other information to describe the expected overflow regime.

A.2 Model description

A WBM was developed for the proposed water management system using GoldSim v12.1, which is an industry standard water balance modelling platform. The following section describe the model and its key assumptions.

A.2.1 Water management system functionality

The model was developed to reflect the water management system functionality that is described in the SWMMP (see Section 4.1). It includes runoff from the yard area, the proposed 1.6 ML of stormwater storage and site water use for dust suppression and product conditioning. The objective of the model is to estimate the frequency and magnitude of overflows from the proposed stormwater system.

A.2.2 Weather data

The model was run using representative rainfall data from January 1990 to December 2021, a circa 30-year period. This period includes several dry, average and wet weather sequences and is therefore adequate for simulating overflows from the proposed stormwater system. Historic climate data for rainfall and evaporation was sourced from the Scientific Information for Landowners database, available from the Queensland Government.

A.2.3 Runoff model

The model uses the SimHyd conceptual rainfall-runoff model to simulate runoff from the yard area, which includes the following surface categories that have unique hydrologic properties: stockpiles, hardstand and water features. The SimHyd model simulates runoff as a function of rainfall, evaporation losses and soil moisture storage. The model parameters can be adjusted to achieve expected runoff characteristics for different surface categories. This was done for each surface category using relevant information from a water balance model calibration that was completed for the Widemere RRF (RHDHV 2017c). Importantly stockpiles are known to have low runoff potential as they absorb an initial rainfall volume (typically 50 mm) before runoff commences.

Table A.1 describes the catchment areas and the average annual runoff coefficient for each of the three surface categories. It is noted that event based runoff coefficients would be higher than the average annual runoff coefficient.

Table A.1 Runoff model assumptions

Surface category	Area	Average annual runoff coefficient
Stockpiles	1.0 ha	0.18 or 18% of rainfall **Comment**: low runoff due to the water holding capacity of the stockpiled material. The adopted average annual runoff coefficient was established from a

Table A.1 Runoff model assumptions

Surface category	Area	Average annual runoff coefficient
		calibrated WBM that was developed for the Widemere RRF (RHDHV 2017c) and is consistent with observations that minimal runoff from stockpiles occur during events that comprise less than 50 mm of rainfall.
Hardstand	0.54 ha	0.63 or 63% of rainfall **Comment**: The proposed pavement with an underlying geosynthetic clay liner would have a high runoff potential. The adopted average annual runoff coefficient is slightly less than a typical value for an asphalt road or roof (0.8 or 80% of rainfall) as small amounts of rainfall would be absorbed/retained on the hardstand surface and subsequently evaporated.
Basin and drains	0.06 ha	1.00 or 100% of rainfall **Comment**: assumes direct rainfall onto an open waterbody.
Total:	**1.6 ha**	**0.36** (area weighted average)

A.2.4 Water use assumptions

The model applies site water use to restore storage capacity after rainfall events. The following assumptions were applied:

- The dust suppression area is 1 ha (approximately 60% of the yard area).
- No water is used for dust suppression when daily rainfall exceeds daily evaporation.
- Water required for dust suppression calculated using the formula:

$$Volume_{dust\ suppression} = (Rainfall - Evaporation) \times\ Area_{dust\ suppression}$$

- The daily water usage requirement for product conditioning is 10 kL/day.
- No allowance for water export to the adjoining concrete plant was made. This is a conservative assumption.

A.2.5 Overflow event definition

The frequency of overflows from the water management system is described using independent overflow events rather than daily statistics. An overflow event is defined as a distinct period where overflows occur (potentially intermittently) once the storages are full. For the purposes of this assessment an overflow event is considered to end (ie be counted in the WBM) when the storages are reduced to 80% capacity. Typically, several days to a week of dry weather is required to enable the storages to be reduced to 80% capacity. Hence, if additional rainfall occurs during this period further overflows may occur within the given overflow event.

A.3 Results

Table A.2 presents WBM results for overflow frequency and volume.

Table A.2 WBM results

	WBM results
Overflow frequency	1.25 events per year (on average)

Table A.2 WBM results

	WBM results
	Overflows occurred in 18 of the 32 years assessed in the WBM. No overflow events were simulated in most dry years and several events were simulated in most wet years.
Overflow volume	18% of the average annual runoff volume from the yard; or 6% of the average annual rainfall volume that occurs over the yard. It is noted that most of this overflow volume is associated with very large rainfall events (ie > 170 mm) that exceed the design capacity of the stormwater system.

Appendix B

Infiltration test method statement

EMM
creating opportunities

Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring[1]

This standard is issued under the fixed designation D 5093; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This test method describes a procedure for measuring the infiltration rate of water through in-place soils using a double-ring infiltrometer with a sealed inner ring.

1.2 This test method is useful for soils with infiltration rates in the range of 1×10^{-7} m/s to 1×10^{-10} m/s. When infiltration rates $\geq 1 \times 10^{-7}$ m/s are to be measured Test Method D 3385 shall be used.

1.3 All observed and calculated values shall conform to the guide for significant digits and rounding established in Practice D 6026.

1.3.1 The method used to specify how data are collected, calculated, or recorded in this standard is not directly related to the accuracy to which the data can be applied in design or other uses, or both. How one applies the results obtained using this standard is beyond its scope.

1.4 This test method provides a direct measurement of infiltration rate, not hydraulic conductivity. Although the units of infiltration rate and hydraulic conductivity are similar, there is a distinct difference between these two quantities. They cannot be directly related unless the hydraulic boundary conditions, such as hydraulic gradient and the extent of lateral flow of water are known or can be reliably estimated.

1.5 This test method can be used for natural soil deposits, recompacted soil layers, and amended soils such as soil bentonite and soil lime mixtures.

1.6 The values stated in SI units are to be regarded as standard. The values in parentheses are for information only.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 3385 Test Method for Infiltration Rate of Soils in Field Using Double Ring Infiltrometers[2]

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock Used in Engineering Design and Construction[2]

D 6026 Practice for Using Significant Digits in Geotechnical Data[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *infiltration*—downward entry of liquid into a porous body.

3.1.2 *infiltration rate, I*—quantity of liquid entering a porous material (m^3) per unit area (m^2) per unit time (s), expressed in units of m/s.

3.1.3 *infiltrometer*—a device used to pond liquid on a porous body and to allow for the measurement of the rate at which liquid enters the porous body.

3.1.4 For definitions of other terms used in this test method, see Terminology D 653.

4. Summary of Test Method

4.1 The infiltration rate of water through soil is measured using a double-ring infiltrometer with a sealed or covered inner ring (Fig. 1). The infiltrometer consists of an open outer and a sealed inner ring. The rings are embedded and sealed in trenches excavated in the soil. Both rings are filled with water such that the inner ring is submerged.

4.2 The rate of flow is measured by connecting a flexible bag filled with a known weight of water to a port on the inner ring. As water infiltrates into the ground from the inner ring, an equal amount of water flows into the inner ring from the flexible bag. After a known interval of time, the flexible bag is removed and weighed. The weight loss, converted to a volume, is equal to the amount of water that has infiltrated into the ground. An infiltration rate is then determined from this volume of water, the area of the inner ring, and the interval of

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.04 on Hydrologic Properties of Soil and Rocks.

Current edition approved July 10, 2002. Published September 2002. Originally published as D5093–90. Last previous edition D5093–90(1997).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

***A Summary of Changes section appears at the end of this standard.**

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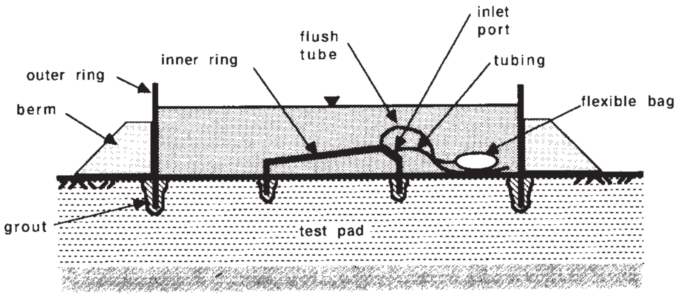

FIG. 1 Schematic Of A Double-Ring Infiltrometer With A Sealed Inner Ring

time. This process is repeated and a plot of infiltration rate versus time is constructed. The test is continued until the infiltration rate becomes steady or until it becomes equal to or less than a specified value.

5. Significance and Use

5.1 This test method provides a means to measure low infiltration rates associated with fine-grained, clayey soils, and are in the range of 1×10^{-7} m/s to 1×10^{-9} m/s.

5.2 This test method is particularly useful for measuring liquid flow through soil moisture barriers such as compacted clay liner or covers used at waste disposal facilities, for canal and reservoir liners, for seepage blankets, and for amended soil liners such as those used for retention ponds or storage tanks.

5.3 The purpose of the sealed inner ring is to: (*1*) provide a means to measure the actual amount of flow rather than a drop in water elevation which is the flow measurement procedure used in Test Method D 3385 and (*2*) to eliminate evaporation losses.

5.4 The purpose of the outer ring is to promote one-dimensional, vertical flow beneath the inner ring. The use of large diameter rings and large depths of embedments helps to ensure that flow is essentially one-dimensional.

5.5 This test method provides a means to measure infiltration rate over a relatively large area of soil. Tests on large volumes of soil can be more representative than tests on small volumes of soil.

5.6 The data obtained from this test method are most useful when the soil layer being tested has a uniform distribution of pore space, and when the density and degree of saturation and the hydraulic conductivity of the material underlying the soil layer are known.

5.7 Changes in water temperature can introduce significant error in the volume change measurements. Temperature changes will cause water to flow in or out of the inner ring due to expansion or contraction of the inner ring and the water contained within the inner ring.

5.8 The problem of temperature changes can be minimized by insulating the rings, by allowing enough flow to occur so that the amount of flow resulting from a temperature change is not significant compared to that due to infiltration, or by connecting and disconnecting the bag from the inner ring when the water in the inner ring is at the same temperature.

5.9 If the soil being tested will later be subjected to increased overburden stress, then the infiltration rate can be expected to decrease as the overburden stress increases. Laboratory hydraulic conductivity tests are recommended for studies of the influence of level of stress on the hydraulic properties of the soil.

NOTE 1—The quality of the result produced by this standard depends on the competence of the personnel performing it and the suitability of the equipment and facilities being used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing, sampling, inspection, etc. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself ensure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors

6. Apparatus

6.1 *Infiltrometer Rings*—The rings shall be constructed of a stiff, corrosion-resistant material such as metal, plastic, or fiberglass. The shape of the rings can be circular or square. However, square rings are recommended because it is easier to excavate straight trenches in the soil. The rings can be of any size provided: (*1*) the minimum width or diameter of the inner ring is 610 mm (24 in.); and (*2*) a minimum distance of 610 mm is maintained between the inner and outer ring. The following is a description of a set of rings that can be constructed from commonly available materials, incorporates the requirements described above, and has worked well in the field.

6.1.1 *Outer Ring*—A square ring (Fig. 2) comprised of four sheets of aluminum approximately 3.6 m by 910 mm by 2 mm (12 ft by 36 in. by 0.080 in.) The top edge of the aluminum sheet is bent 90° in order to provide rigidity. A hole is provided in the center of the top edge. One edge of each sheet is bent 90°. Holes are drilled along each side edge so that the sheets can be bolted at the corners. A flat rubber gasket provides a seal at each corner. A wire cable approximately 15 m long with a clamp may be needed to tie the top edges together.

6.1.2 *Inner Ring*—A square ring (Fig. 3), 1.52 m (5 ft) on a side, made of fiberglass provided with two ports. The top is shaped in such a way as to vent air from the ring as it is filled. A port is provided at the highest point so that any air that accumulates in the ring during the test can be flushed out. One port must be located at the top of the ring. The other port must be located beneath the top port. A150 mm (6 in.) skirt, that is embedded into the soil, is provided along the edge of the ring. Barbed fittings that accept flexible tubing are attached to the ports. Handles are provided at each corner of the inner ring.

6.2 *Flexible Bag*—Two clear flexible bags with a capacity of 1000 to 3000 mL. Intravenous bags available from medical

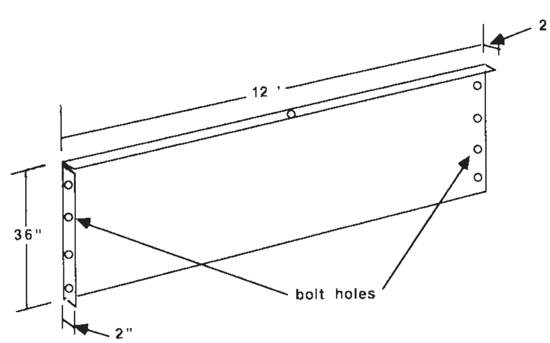

FIG. 2 Panel For Outer Ring

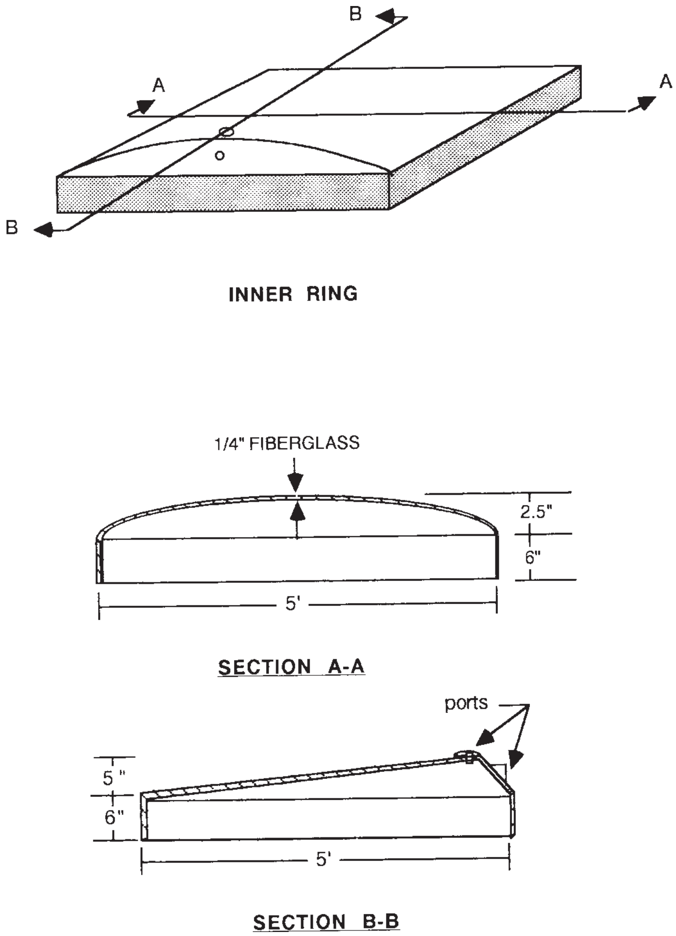

FIG. 3 Inner Ring

supply stores work well. A means for attaching a shut-off valve to the bag shall be provided. The shut-off valve shall be provided with a barbed fitting that will connect to the inlet tube on the inner ring.

6.3 *Tubing*—Clear, flexible tubing approximately 4.5 m (15 ft) long with a minimum ID of 6 mm (¼ in.)

6.4 *Scissors or Knife*.

6.5 *Excavation Tools*.

6.5.1 *Mason's Hammer*—Hammer with a blade approximately 120 mm long and 40 mm wide.

6.5.2 *Trenching Machine*—Capable of excavating a trench with a maximum width of 150 mm (6 in.) and a depth of 460 mm (18 in.)

6.5.3 *Chain Saw*—(Optional—see Note 2) Equipped with a carbide-tipped chain and bar.

6.5.4 *Hand Shovel*, garden type.

6.6 *Levels*—A surveyor's level and rod and a carpenter's level.

6.7 *Buckets*—Five buckets with a capacity of approximately 20 L (5 gal.)

6.8 *Blocks*—Cinder blocks to serve as a platform for the flexible bag.

6.9 *Cover*—An opaque cover to place on top of the outer ring. The cover can be a tarp or plywood supported by wooden beams.

6.10 *Grout*—A bentonite grout for filling the trenches and sealing the rings in place.

6.11 *Mixing Equipment*—A large (four bag) grout mixer for mixing the bentonite grout.

6.12 *Trowel*.

6.13 *Thermometer*—Readable to 0.5°C with a range of 0 to 50°C.

6.14 *Scale*—Capacity of 4000 g and an accuracy of 1 g.

6.15 *Watch*—Readable to 1 s.

6.16 *Water Supply*—Preferably water of the same quality as that involved in the problem being examined. Approximately 5600 L (1400 gal) are needed for this test.

6.17 *Splash Guard*—Plywood, rubber sheet, or burlap 600 by 600 mm (2 by 2 ft).

7. Test Site

7.1 The test requires an area of approximately 7.3 by 7.3 m (24 by 24 ft).

7.2 The slope to the test area should be no greater than approximately 3 %.

7.3 The test may be set up in a pit if infiltration rates are desired at depth rather than at the surface.

7.4 The test area shall be covered with a sheet of plastic to keep the surface from drying.

7.5 Representative samples of the soil to be tested shall be taken before and after the test to determine its moisture content, density, and specific gravity. The thickness of the layer being tested shall be determined as well as the approximate hydraulic conductivity of the layer beneath it.

8. Procedure

8.1 *Assembly of Outer Ring*—Wipe off gaskets and side edges of the outer ring. Align gasket between the edges and bolt edges together.

8.2 *Excavation of Trenches*:

8.2.1 Place both rings on the area to be tested. Center the inner ring within the outer ring. Make sure that the outer ring is square by using the tape measure to check that the length of the diagonals are equal.

8.2.2 If plastic is covering the test area, cut out thin strips along the edge of each ring so that the trenches can be excavated. Leave as much of the plastic on as possible in order to keep the soil from drying.

8.2.3 Use the bottom edge of each ring to scribe a line on the ground to use as a guide for excavating the trenches.

8.2.4 Note the orientation of the rings and set them aside.

8.2.5 Use the surveyor's level and check the ground elevation where the corners of each ring will be. Note the high spots and excavate deeper in these areas so that the rings will be level.

8.2.6 Use the trenching machine and excavate a trench for the outer ring. The trench should be about 146 mm (18 in.) deep. Excavate deeper at high spots.

8.2.7 Use a small hand shovel to remove any loose material in the trenches.

8.2.8 Place the outer ring in the trench and use the carpenter's level to check that the top of the ring is reasonably level (±30 mm). Also check that the outer ring is square. Remove the ring and excavate any areas keeping the ring from being level and square.

8.2.9 Set the outer ring aside and cover the trenches to prevent the soil from drying.

8.2.10 Use the mason's hammer and excavate a trench 50 by 110 mm (2 by 4.5 in.) for the inner ring. Excavate deeper in high spots so that the inner ring will sit level in the trench. Excavate the trench carefully so that the surrounding soil is disturbed as little as possible. When using the mason's hammer, it is best to start by digging down several inches in one spot and then advancing the trench forward by chopping down on the soil. Do not pry the soil up as this tends to lift up large wedges of soil, opens cracks, and causes the trench to be oversized.

8.2.11 Place the inner ring in the trench to check the fit. Excavate any areas where the ring does not fit. Use a surveyor's level to check the elevation of the corners of the ring. The inner ring needs to be level or slightly tilted so that the back end is slightly lower than the front end.

8.2.12 Set the ring aside and cover the trenches.

NOTE 2—A chain saw that is equipped with a carbide-tipped chain and a bar may be used to excavate the trenches. Use of a chain saw will not only reduce the time needed to excavate the trench but will also greatly decrease the amount of grout needed to fill the trenches. If a chain saw is used, the trenches need only be 25 mm (1 in.) wide. A chain saw will not work well in some soils. A trial trench should be made to determine if it will work.

8.3 *Installation of Rings*:

8.3.1 Use the grout mixer to prepare enough grout to fill the trenches. The hydraulic conductivity of the grout should be less than approximately 1×10^{-8} m/s.

8.3.2 Fill the trenches to within 2.5 mm (1 in.) of the top of the trench. Rod or tamp the grout to remove any entrapped air.

8.3.3 Lift the inner ring and center it over the inner ring trench. Lower it into the trench and slowly push it down. Keep the ring level as it is pushed into place.

8.3.4 Use a surveyor's level to check that the ring is level.

8.3.5 Use a trowel to press the grout against the outside wall of the ring in order to ensure a good seal.

8.3.6 Cover the grout with plastic to prevent desiccation.

8.3.7 Lift the outer ring and center it over the outer ring trench.

8.3.8 Keep the ring level and push it into place.

8.3.9 Use the carpenter's level to make sure that the ring is level.

8.3.10 Use a trowel to push the grout against both the inside and the outside of the ring to ensure a good seal.

8.3.11 Cover the grout with plastic to prevent desiccation.

8.3.12 Place several cinder blocks between the inner and outer rings in the vicinity of the ports on the inner ring. These blocks will be used as a platform to stand on when connecting the fittings to the inner ring and also to support the flexible bags. The blocks should be no higher than 100 mm (4 in.)

8.3.13 Pile soil along the outside of the outer ring to a height of at least 30 cm (12 in.) This soil places an overburden pressure on the grout that will prevent it from being pushed out of the trench when the rings are filled with water.

8.4 *Filling the Rings*:

8.4.1 Fill two buckets with water and place one on each back corner of the inner ring. The buckets are placed on the inner ring to counteract the uplift force that acts on the ring as it is being filled. Make sure that the buckets are placed on the edge of the ring, not in the center as this may overstress the ring and cause it to crack. Do not to spill any water around the inner ring as this will make it difficult to check for leaks in the seal.

8.4.2 Place an empty bucket upside down on the ground near the top port on the inner ring. Place a second bucket on the first bucket. Fill the second bucket with water. Cut a length of the flexible tubing long enough to reach from the top bucket to the top port on the inner ring. Siphon the water from the bucket to the inner ring. Allow the siphoning to continue until the depth of the water in the inner ring is approximately 25 mm (1 in.). Avoid spilling any water around the inner ring during this filling process as this will make it difficult to check for leaks. Any other suitable method for adding the required volume of water to the inner ring may also be used.

8.4.3 Let the water stand in the inner ring for at least 30 min. Check for leaks in the inner ring seal and repair any that are found.

8.4.4 Start filling the outer ring slowly so as not to scour the soil and muddy the water. Direct the water so that it hits a splashboard first. Fill the outer ring until the water level is approximately 100 mm (4 in.) above the top of the inner ring. While the rings are being filled, use a board or shovel handle to gently tap the inner ring to dislodge air bubbles that are trapped inside. Continue tapping on the inner ring until bubbles cease to emerge from the top port.

8.4.5 Remove the buckets from the top of the inner ring.

8.5 *Installation of Fittings and Tubing*:

8.5.1 Wrap the threads of the two barbed fittings with TFE-fluorocarbon tape.

8.5.2 Saturate the fittings and connect them to the inner ring. Screw one of the barbed fittings into the top port and the other barbed fitting into one of the lower ports. Use caution when screwing the fittings into the ports as the threads in fiberglass inner rings can be easily damaged.

8.5.3 Cut two lengths of the clear flexible tubing, one 900-mm (3-ft) piece and one 1800-mm (6-ft) piece.

8.5.4 Saturate the tubing by placing it under water. Be sure to remove all air bubbles.

8.5.5 Connect one end of the 1.8-m (6-ft) piece to the fitting in the top port and seal the other end with a plug fitting. Do not let air into the tube during this process. This tube is the flush tube.

8.5.6 Connect the end of the 900-mm (3-ft) piece to the barbed fitting in the lower port. Prop the open end of this tube on the cinder block platform. Water is being drawn into this tube so be sure not to allow the open end of the tube to float to the surface and draw in air or sink to the bottom and draw in mud. This tube is the inlet tube.

8.6 *Covering the Rings*:

8.6.1 Cover the rings with either a tarp or plywood. The purpose of the cover is to minimize evaporation, minimize temperature changes, and inhibit the growth of algae.

8.6.2 Provide a means in the cover that makes it convenient to access the front of the inner ring to connect and disconnect the measurement bag.

8.7 *Maintaining the Water Level*:

8.7.1 Place a mark indicating the water elevation on the inside wall of the outer ring near the cinder blocks.

8.7.2 Observe the water level within the outer ring during the test and refill the ring to this mark before the water level drops more than 25 mm (1 in.) below the mark. Record the date, time, and the amount of water added.

8.8 *Purging the Inner Ring*—During the test, air may accumulate beneath the inner ring. This air may introduce error in flow measurements and consequently should be purged on a regular basis as follows.

8.8.1 Disconnect bag, if one is present, from end of inlet tube.

8.8.2 Lift the plugged end of the flush tube out of outer ring and below the water level in the outer ring so that water can be siphoned out of inner ring.

8.8.3 Remove plug from end of flush tube. Water and air if present will start to flow out of inner ring. If air completely fills the tube, the syphon will be lost. If this happens, saturate the tube and restart the siphon.

8.8.4 Allow water to flow from end of tube until air ceases to emerge from inner ring. Replace plug in end of flush tube and place tube back into outer ring. Note the approximate volume of purged air. Volume can be determined by multiplying the flow area of the flush tube by the height of the air bubbles which flow out of the tube.

8.8.5 Wait at least 30 min before taking any flow measurements.

8.8.6 Purge the inner ring on a weekly basis until no significant amount of air is found.

8.9 *Measurements*:

8.9.1 Attach the shut-off valve to the flexible bag and fill the bag with water. Remove all air bubbles from the bag. Use water that has been degassed or allow the bag to sit overnight so that the water can degas. If left to sit overnight, remove any air bubbles. Do not overfill the bag so that the water inside is under pressure.

8.9.2 Dry the outside of the bag and record its weight to the nearest gram.

8.9.3 With the shut-off valve closed, attach the bag to the open end of the inlet tube connected to the inner ring. Be sure not to trap any air bubbles in the inlet tubing or in the valve when attaching the bag. Lay the bag down on the cinder block platform.

8.9.4 Record the time, date, temperature of the water in the outer ring, and the depth of the water in the outer ring, and then carefully open the shut-off valve on the bag. Check that the inlet tube is not pinched and that the bag is arranged in such a manner that water can flow freely from it into the inner ring.

8.9.5 Sometime before the bag empties, close the shut-off valve, disconnect the bag from the inlet tube, and record the date, time, temperature of the water in the outer ring and the depth of the water in the outer ring. Be sure to prop the open end of the inlet hose as pointed out in 8.5.6. Do not leave the bag on long enough to empty as this will create a suction in the inner ring and cause leaks in the grout seal.

8.9.6 Dry the bag and record the weight of it to the nearest gram.

8.9.7 Refill the bag and repeat 8.9.2-8.9.6 until the infiltration rate (see Section 9) becomes steady or drops below a predetermined value.

NOTE 3—The reading times are governed primarily by the length of time the bag can remain connected to the inner ring without emptying. This length of time can only be determined through experience. Initially, flow rates will be high and the bag may need to be disconnected after several hours. As the test progresses, the flow rate will slow and the length of time it takes the bag to empty may increase to several days or weeks.

A second important factor that governs when readings should be made is the temperature of the water. In order to minimize the effects of temperature changes on the measured flow rate, the bag should be disconnected from the inner ring when the water is at the same temperature (within ±2°C) as when the bag was connected. More consistent readings are usually obtained if readings are made between 7 am and 9 am.

NOTE 4—It is not necessary to have the bag connected to the inner ring continuously. Flow only needs to be measured over timed intervals so that a plot of infiltration rate versus time can be constructed. The infiltration rate is not influenced by whether or not the bag is connected to the inlet tube. If the flow rate is high, it is more convenient to connect the bag to the inner ring for several hours a day and leave the inlet tube open in the outer ring for the remainder of the time.

NOTE 5—When connecting or disconnecting the bag from the inner ring, do not raise the bag above the level of the water in the outer ring with the shut-off valve open. This would cause an uplift force to act on the inner ring and could cause it to rise out of the trench.

8.10 *Ending Test*:

8.10.1 Remove the fittings and tubing from the inner ring.

8.10.2 Drain water from rings.

8.10.3 Excavate the grout from around the rings and pull the rings out of the ground.

8.10.4 Excavate a narrow trench in the area encompassed by the inner ring and take moisture content samples every 25 mm (1 in.) to a depth of 150 mm (6 in.) below the observed wetting front. An alternative to this is to push a thin-walled sampling tube into the soil, extrude the soil, and slice it every 25 mm (1 in.) for moisture content samples.

9. Calculation

9.1 Calculate the infiltration rate for each timed interval as follows:

$$I\ (\text{m/s}) = \frac{Q}{tA} \times 10^{-6} \quad (1)$$

where:

Q = volume of flow, mL,
= $W_1 - W_2$
W_1 = initial weight of bag, g,
W_2 = final weight of bag, g,

t = time of flow, s = $t_2 - t_1$,
t_1 = time shut-off valve on bag was opened,
t_2 = time shut-off valve was closed, and
A = area of inner ring, m^2.

9.2 Calculate the amount of flow which resulted from any temperature fluctuations for each timed interval (see Note 6). If the flow due to temperature fluctuations is greater than 20 % of the total flow measured, then correct the flow used to calculate the infiltration rate by this amount.

NOTE 6—Expansion and contraction of the inner ring due to temperature changes will cause water to flow into or out of the measurement bag. The inner ring should be calibrated to determine if the flow resulting from temperature change is significant compared to flow due to infiltration. Calibration can be performed by sealing the inner ring to the bottom of a small plastic pool. Fill the pool and ring with water and allow the temperature to reach equilibrium. Connect a measurement bag to the inner ring and add ice to the pool water to lower the temperature several degrees. Allow the temperature to reach equilibrium and remove the bag. Determine the weight loss/gain and convert it to a volume of water. Divide this volume of water by the change in temperature to obtain a calibration factor for temperature changes.

9.3 Note the volume of air expelled from the weekly purging of the inner ring. Compare this volume of air with the volume of infiltration that occurred during the time the air collected in the inner ring. If this volume is significant, (that is, 20 % of that used to determine infiltration in 9.1,) then adjust the infiltration rates in 9.1 to account for it.

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DATA FORM FOR SDRI TEST

Project: ____________
Inner ring info: ____________
Outer ring info: ____________
Liner thickness (m) : ____________

$I = \frac{Q}{A\,t} \times 10^{-6}$

I = infiltration (m/sec)
Q = quantity of flow (mL)
t = interval of time (sec)
A = area of inner ring (m2) ________

Date (on / off)	Initial time (sec)	Final Time (sec)	t Interval of Time (sec)	Initial Wt. of Bag (grams)	Final Wt. of Bag (grams)	Q Quan. of Flow (mL)	I Infiltration (m/sec)	Temp. (C) (on / off)	Water Depth (m) (on / off)

NOTES:

FIG. 4 Data Sheet For Infiltration Test Using A Double-Ring Infiltrometer With A Sealed Inner Ring

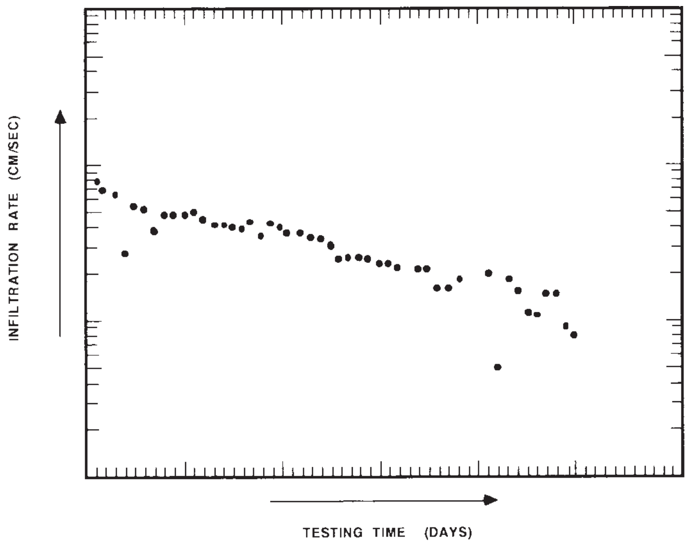

FIG. 5 Infiltration Rate Versus Time On A Semi-log Plot

10. Report

10.1 Report the following information:

10.1.1 A data sheet such as the one shown in Fig. 4,

10.1.2 A semi-log plot of infiltration versus time such as that shown in Fig. 5,

10.2 Additional optional information that can be presented in the report includes the following,

10.2.1 Thickness of layer tested,

10.2.2 A description of material beneath the layer tested,

10.2.3 Total and dry density of the layer tested,

10.2.4 Initial moisture content of the layer tested,

10.2.5 Initial degree of saturation,

10.2.6 Moisture contents of samples taken after termination of test,

10.2.7 Estimate of the depth to the saturation front.

11. Precision and Bias

11.1 *Precision*—Due to the nature of the soil or rock materials tested by this test method, it is either not feasible or too costly at this time to produce multiple specimens which have uniform physical properties. Any variation observed in the data is just as likely to be due to specimen variation as to operator or laboratory testing variation. Subcommittee D18.04 welcomes proposals that would allow for development of a valid precision statement.

11.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

12. Keywords

12.1 double ring infiltration; in-place infiltration; soil moisture infiltrometer

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the 1990(1997) edition.

(1) Requirement to follow Practice D 6026 added to Section 1.
(2) Standard note regarding quality of test results add to Section 5.
(3) Added Practices D 3740 and D 6026to Section 2.

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