

Appendix C – Landform, settlement, staging and capacity assessment



SITA Australia Pty Ltd
Lucas Heights Resource Recovery Park Project
Landform, settlement, staging and capacity assessment

September 2015

Executive summary

This report provides a summary of the basis of the design of the proposed reprofiling works and results of the associated settlement, capacity and staging modelling. This shows that the final landform would meet the requirements of the NSW EPA landfill guidelines in terms of having minimum slopes of no less than 5%, that suitable provision is made for ongoing settlement and the staging of the development, and that the final surface would be suitable for future passive recreational uses by the community.

The report describes the proposal and the regulatory, existing and future constraints to the proposed reprofiling works. It then outlines the methodology used to prepare the proposed baseline and post-settlement final landform surfaces, and the associated settlement modelling.

The height of the constructed surface will not exceed RL 184.9 m AHD (includes waste and final cap) and is expected to provide a capacity of 8.3 million m³. The landform is expected to settle to a height of RL 179.9 m (includes waste and cap).

An additional 8.3 million cubic metres of waste would be placed on the site to achieve the proposed final surface.

The adopted settlement analysis methodology for this project has been taken from Sowers (1973) as presented in Qian et al (2002), and the parameters and results are outlined in Section 5. Based on a 30 year secondary settlement period, the range of predicted settlement is 3% to 22% of the landfilled waste thickness.

The proposed post-settlement final landform is presented and the surface confirmed to meet the grade requirements. The landscape plans, prepared by Taylor Brammer Landscape Architects, have been based on this proposed post-settlement final landform surface.

This report also provides a summary of the assessment of the capacity provided by the proposed final landform and how the filling will be staged to minimise surface water interactions, leachate generation and odour impacts.

The report concludes that the proposed final landform would meet the design objectives.

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- Appendix B – Figures and sketches
- Appendix C – Settlement model
- Appendix D – Final landform slope analysis
- Appendix E – Staging plans

1. Introduction

1.1 Purpose of this report

SITA Australia (SITA)¹ is proposing a number of activities at the Lucas Heights Resource Recovery Park (LHRRP) in Lucas Heights (referred to in this report as ‘the proposal’). This report has been prepared by GHD Pty Ltd on behalf of SITA to provide a summary of the basis of the design of the proposed final landform and results of associated modelling undertaken as an input to the environmental impact statement. Due to the existing operational arrangements at LHRRP, Sutherland Shire Council (SSC) is a joint applicant for the proposal. The environmental impact statement is being prepared by GHD in accordance with the requirements of Part 4 of the NSW *Environmental Planning and Assessment Act 1979* (the EP&A Act).

1.2 Objectives

The objectives of the landform design are to provide a final landform which:

- Meets the requirements of the NSW EPA’s Environmental Guidelines: Solid Waste Landfills (the landfill guidelines) in terms of final slopes being no less than 5%;
- Make provision for ongoing settlement and staging of the development of the landfill and
- Provide a suitable surface for future passive recreational use by the community.

An additional 8.3 million cubic metres of waste would be placed on the site to achieve the proposed final surface,

1.3 Proposal overview

The LHRRP consists of approximately 205 hectares (ha) in two ownerships. 89 ha is owned by SITA and 116 ha owned by Australian Nuclear Science and Technology Organisation (ANSTO) and leased to SITA for waste management or other agreed purposes. The following activities are proposed at the LHRRP and are collectively referred to as ‘the proposal’. The proposal would not have a significant impact on the community. In addition to the proposal detailed below, SITA is committed to improving environmental outcomes by the application of best practice prevention, mitigation and rectification measures:

- **Reprofiling of existing landfill areas to provide up to 8.3 million cubic metres of additional landfill airspace capacity.** This is equivalent to approximately 8.3 million tonnes of waste, assuming 1 tonne of waste utilises 1 cubic metre of waste disposal airspace. As the process of reprofiling would include removal and replacement of capping material over previously landfilled waste and augmentation of gas and leachate collection systems, the environmental performance of the site would be ultimately improved by reducing the infiltration of stormwater into the landfill (resulting in reduced landfill leachate in the longer term) and increase the overall amount of landfill gas recovered from the site.

As part of the proposal, SITA is seeking permission to increase the approved quantity of waste landfilled at the site from 575,000 to 850,000 tonnes per year. This would enable the reprofiling of the site to be completed in 2037.

¹ SembSITA Australia Pty Ltd (SembSITA) is the holding company for the SITA Australia (SITA) group of companies in Australia. SembSITA is the parent company of both SITA and WSN Environmental Solutions Pty Ltd (WSN). WSN owns part of the land on which the LHRRP is situated, and leases the remainder from ANSTO. SITA holds the environmental protection licence (EPL), and so is the operator of the facilities at LHRRP. For simplicity, the term ‘SITA’ is used to refer to all of these organisations in this report.

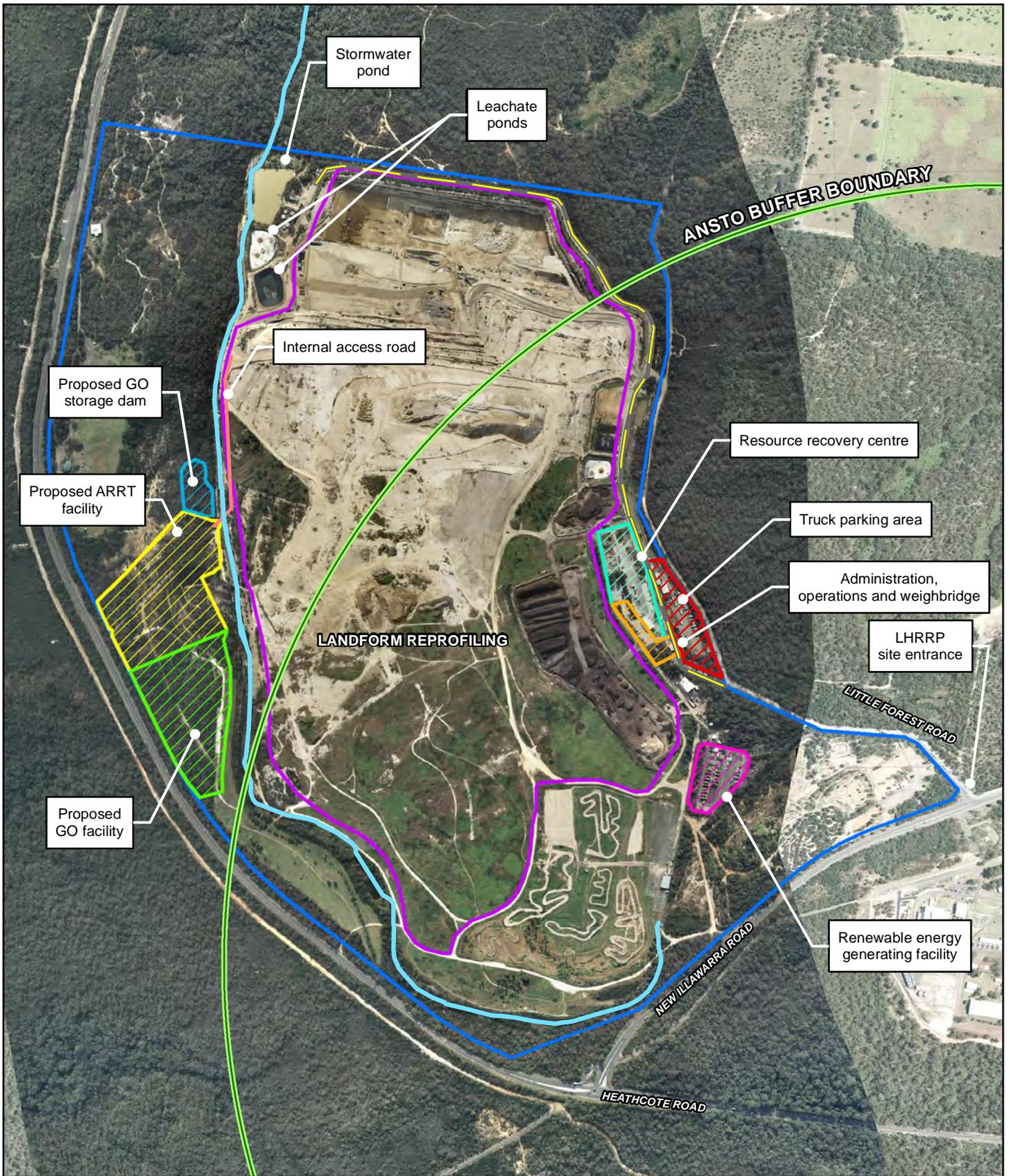
- **Relocation and expansion of the existing garden organics (GO) facility.** The existing garden organics facility would be relocated to the western side of the site adjacent to Heathcote Road. Approval is being sought to increase the approved capacity from 55,000 to 80,000 tonnes of green waste and garden waste received per year at the facility. The new facility would include the partial enclosure, active aeration and covering of the first four weeks of the active composting process, which coincides with the period of highest potential for odour generation, to enable more effective control of odour. Relocation of the facility would result in increased separation distances from the current nearest occupied land at ANSTO, existing residential areas and the proposed new residential area at West Menai.
- **Construction and operation of a fully enclosed advanced resource recovery technology (ARRT) facility.** The ARRT facility would be located on the western side of the site adjacent to the GO facility and would process and recover valuable resources from up to 200,000 tonnes of general solid waste per year, reducing the amount of waste disposed to landfill to approximately 60,000 tonnes per year. This would divert up to 140,000 tonnes of waste per year from landfill. SSC and other councils would have the opportunity to have their municipal waste processed by the ARRT facility.
- **Community parkland.** The landfill reprofiling would increase the area available for future passive recreation following site closure from 124 ha (existing approved parkland) to a total of 149 ha, an increase of approximately 25 ha. Landfilling would cease in 2037 after which time the site would be rehabilitated and converted to a community parkland, with capping and landscaping to be completed and the site made available for community use in 2039.

As part of the proposal SITA has committed to entering into an agreement with SCC in the form of a Voluntary Planning Agreement which includes 'environmental undertakings'. In addition operational environmental management plans have been prepared for the landfill, GO facility, ARRT facility and post closure measures to manage potential environmental impacts, reflect regulatory requirements and provide guidance for site operators to undertake activities in an environmentally sound manner.

A Planning Proposal is being submitted in parallel with this State Significant Development Application. The Planning Proposal seeks to include new local provisions on the LHRRP site within the Sutherland Local Environmental Plan 2015 (SLEP), which would allow the proposal (a waste or resource management facility) to be undertaken on the proposal site.

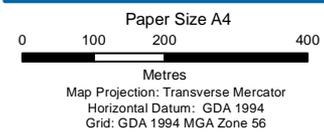
The expansion of the LHRRP which is outlined in this EIS would permit the proposed future use of the land for recreational purposes, which is currently approved and would occur when the existing facility ceases operation in 2025. The proposal would however extend the timeframe for which the land would be unavailable for recreational purposes until 2037, due to the extension of operations at the proposed LHRRP.

These key components of the proposal are shown on Figure 1-1. The proposed final landform and preliminary masterplan for the parkland are shown in Figure 1-2.



LEGEND

- | | | |
|-----------------------|--|---|
| ANSTO buffer boundary | Proposed GO facility | Renewable energy generating facility |
| Mill Creek | Proposed ARRT facility | Lucas Heights Resource Recovery Park boundary |
| Internal access road | Resource Recovery Centre | Landform reprofiling boundary |
| Existing access road | Administration, operations and weighbridge | Truck parking area |



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Date | 28 May 2015

Key existing infrastructure and proposed facility layout

Figure 1.1



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Revision	A
Date	24 June 2015

Proposed parkland master plan **Figure 1.2**

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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Data source: Taylor Brammer Landscape Architects Pty Ltd. Created by:jrichardson

1.4 Definitions

The following terms are used within this report when referring to the proposal site and surrounding areas:

- The 'LHRRP' refers to the entire Lucas Heights Resource Recovery Park. The boundary of the LHRRP is shown as the blue line on Figure 1.3
- The 'proposal site' refers to the areas where the activities described in Section 1.2 would be located. The boundary of the proposal site is shown as the red line on Figure 1.3

1.5 Location of the proposal

1.5.1 Existing

The proposal would be located within the boundary of the existing LHRRP. The LHRRP is located within the Sutherland local government area, approximately 30 kilometres (km) south west of the Sydney city centre. The site is bound to the west by Heathcote Road and New Illawarra Road to the south.

Specifically, the proposal would be located on:

- Lot 101 DP 1009354
- Lot 3 DP 1032102
- Lot 2 DP 605077

It is noted that the proposal directly affects only a portion of each of these lots. There is minimal encroachment into the SICTA leased land (part of Lot 3 DP 1032102).

The proposal site, within the boundary of the LHRRP, is shown on Figure 1.3.

The site is currently accessed from Little Forest Road, off New Illawarra Road.

Current facilities at the LHRRP include:

- Landfill
- Resource recovery centre and waste collection point
- GO facility for processing garden organics
- Renewable energy production (operated by Energy Developments Ltd)
- Truck parking area
- Community use areas (mini bike area at the southern extent of the site run by the Sutherland Police Citizens Youth Club and the Sydney International Clay Target Association (SICTA) leased land on the north western side of the site)

There are also several ancillary buildings and structures (e.g. weighbridge, machinery workshop, administration offices, stormwater and leachate dams).

The following land uses are located in the immediate vicinity of the LHRRP:

- Bushland areas that form part of ANSTO's exclusion zone (to the east and south)
- ANSTO's facilities (to the east on the opposite side of New Illawarra Road)

Land uses in the surrounding area include:

- Holsworthy Military Reserve (to the west, northwest and southwest)

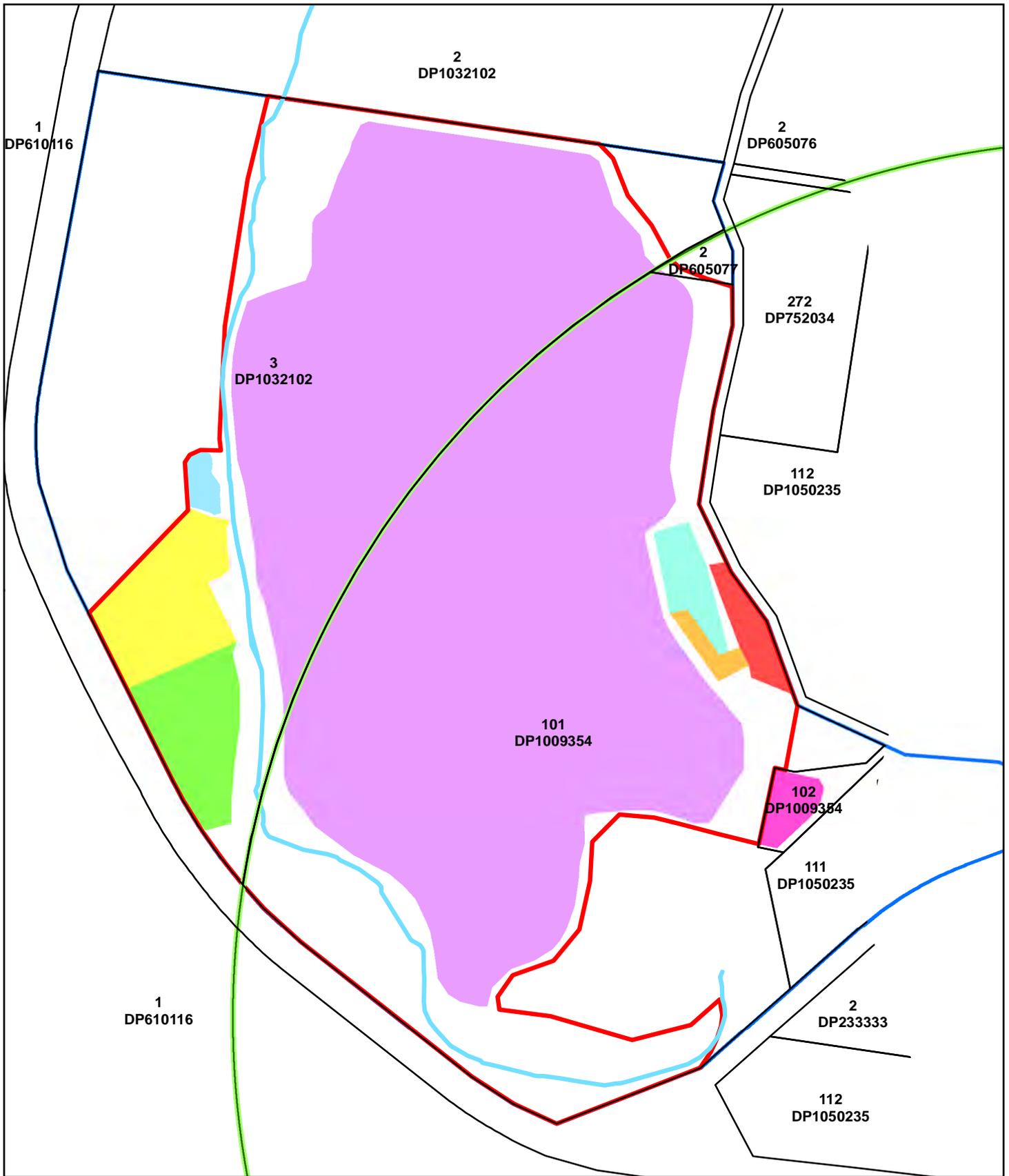
- The Ridge Sports Complex, a major regional sporting facility being developed on the site of the former Lucas Heights Waste and Recycling Centre (approximately 2.5 km to the north east)
- Lucas Heights Conservation Area (immediately to the north of the LHRRP)
- The suburbs of North Engadine (approximately 2 km to the east) and Barden Ridge (approximately 3 km to the north east)

Figure 1.4 shows these key areas.

1.5.2 Potential future surrounding land uses

The Gandangara Local Aboriginal Land Council (GALC) is proposing a development in the West Menai area. The West Menai State Significant Site contains 849 ha of mostly undeveloped land, covering parts of Menai, Barden Ridge and Lucas Heights.

The western boundary of the proposed development is Heathcote Road and the site extends east across Mill Creek to the edge of the existing Menai residential area close to New Illawarra Road. The location of the proposed West Menai State Significant Site is shown on Figure 1.4.



LEGEND

- | | | |
|---|--------------------------|--|
| ANSTO buffer boundary | Truck parking area | Administration, operations and weighbridge |
| Mill Creek | Proposed GO facility | Renewable energy generating facility |
| Cadastre | Proposed ARRT facility | Landform reprofiling boundary |
| Proposal site boundary | Resource Recovery Centre | |
| Lucas Heights Resource Recovery Park boundary | | |

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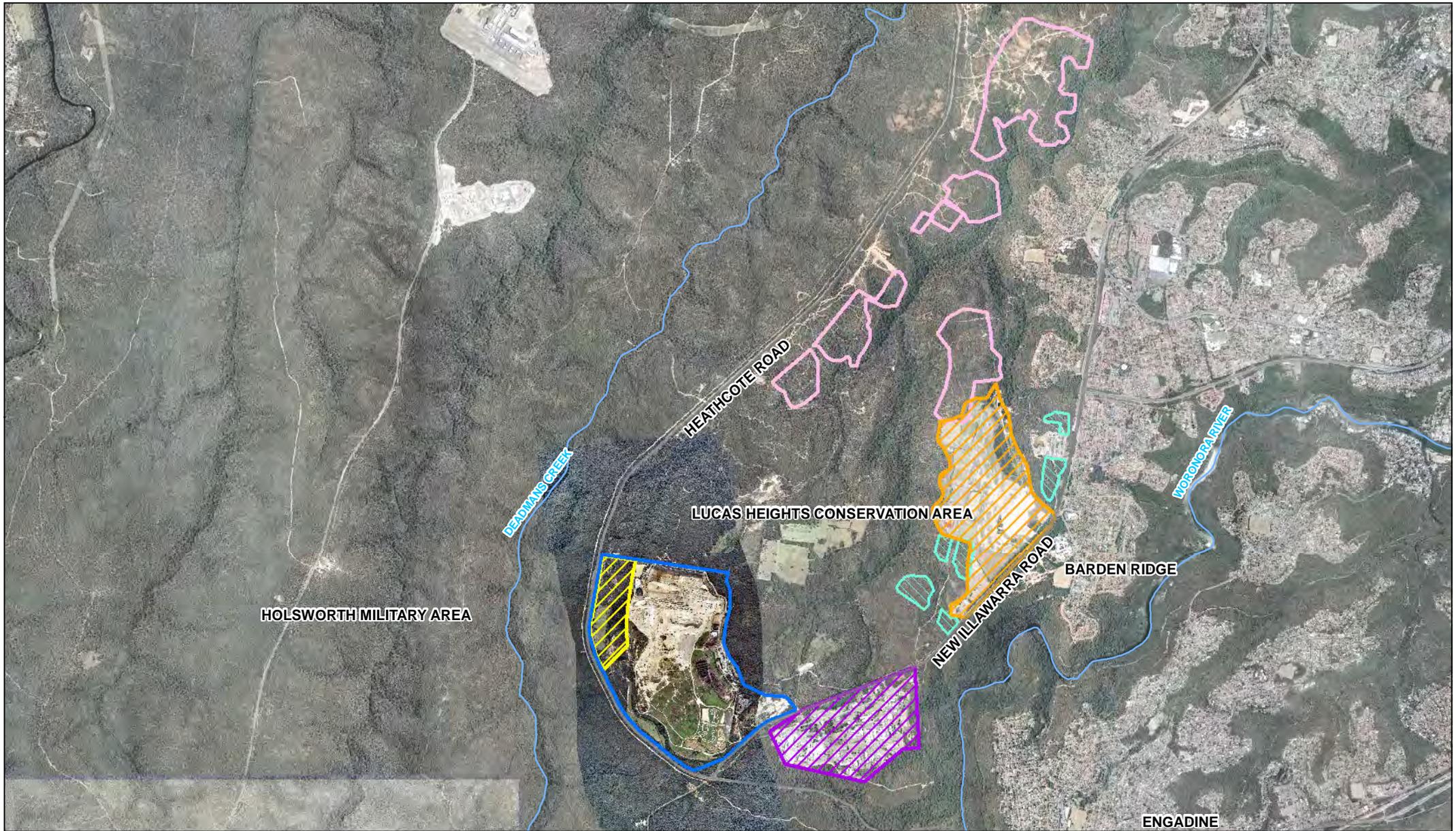


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The proposal site

Figure 1.3



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 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 56



Legend

- LHRRP boundary
- SICTA boundary
- ANSTO
- Barden Ridge Sports Complex

- Potential future receptors
- Future receptors – Residential



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Date	14 Aug 2015

Surrounding landuses

Figure 1.4

1.6 Scope and structure of the report

1.6.1 Scope of report

This report:

- Summarises the basis of the design of the proposed final landform;
- Outlines the methodology applied in developing the baseline and post-settlement proposed final landforms;
- Describes the baseline and post-settlement proposed final landforms;
- Provides the results of the settlement modelling; and
- Estimates of capacity and describes the staging of the reprofiling works.

1.6.2 Structure of report

- **Section 1 – Introduction** – This chapter introduces the proposal, the proponent and describes the proposal area
- **Section 2 – Basis of landform design** – This chapter describes the regulatory, existing and future constraints to the proposed reprofiling works
- **Section 3 – Methodology** – This chapter provides a description of design methodology
- **Section 4 – Proposed baseline landform** – This chapter provides a description of proposed baseline landform surface
- **Section 5 – Settlement analysis** – This chapter outlines the settlement modelling parameters and results
- **Section 6 – Proposed post-settlement landform** – This chapter provides a description of proposed post-settlement landform surface
- **Section 7 – Landform assessment**– This chapter provides a summary of the capacity calculations and staging for the reprofiling works

2. Basis of landform design

2.1 General

The design of the proposed final landform was based on industry standards, the existing site arrangement and the proposed final arrangement for the site.

2.2 Reliance

The following data has been relied upon in the preparation of this design:

- Lucas Heights Waste Management Centre Extension, Environmental Impact Statement, Landfill Technical Report, prepared by CMPS&F Pty Limited, dated December 1998;
- Lucas Heights Waste Processing and Disposal Centre, Review of Development Application and Environmental Impact Statement, prepared by Land Systems EBC for Sutherland Shire Council, dated May 1992;
- Environmental Guidelines: Solid Waste Landfills, prepared by NSW EPA, dated January 1996;
- Statement of Environmental Effects, Modification of Development Consent Lucas Heights Waste Management Centre, prepared by National Environmental Consulting Services for Waste Service NSW, dated December 2000;
- Volume 2 of Development Application Report for Lucas Heights 1 and Waste Management Centre, prepared by Hassell for Waste Service NSW and Sutherland Shire Council, dated December 1998;
- Waste Processing and Disposal Centre, Lucas Heights: Environmental Impact Statement, prepared by Mitchell McCotter & Associates Pty. Ltd. for Waste Management Authority of NSW, dated November 1991;
- Waste Processing and Disposal Centre, Lucas Heights: Supplementary Reports for Environmental Impact Statement, prepared by Mitchell McCotter & Associates Pty. Ltd. for Waste Management Authority of NSW, dated November 1991;
- Lucas Heights 2 Annual Reports from 1984-2004; and
- Landscape plans LA01 – LA10, LD01, LD02 Taylor Brammer Landscape Architects (2015).

2.3 NSW landfill guidelines

The NSW EPA's Environmental Guidelines: Solid Waste Landfills (the landfill guidelines) provide guidance on final landform design, specifically in Benchmark Technique 28 (site capping and revegetation). In regard to landfill contours, it states:

The final settlement of the seal bearing surface should leave a gradient of greater than 5% to defined drainage points.

The design of the proposed final landform was developed in accordance with these guidelines.

2.4 Existing landfill surface

At June 2014, the stockpile on site had a maximum elevation of approx. RL177.7 m AHD and the highest point of the landfilled area was approximately RL 169.7 m AHD.

The active landfilling area is located in the northern most part of the site and the southern areas of the landfill is vegetated with grass.

In undertaking the modelling, the existing surface utilised was that which existed in December 2013.

2.5 Existing approved final landform

A plan of the existing approved final landform is contained in Appendix B (21-20508-SK101). The existing landform has a maximum level of RL 172 m AHD, as shown in Appendix D.

A slope analysis of the existing proposed final landform (21-20508-SK102) shows that significant portions of the landform currently have slopes of less than 5%.

2.6 Proposed landform extent

The extent of the proposed landform was based primarily on the current approved footprint, with some exceptions:

- Eastern boundary: The landform extent was extended over areas currently occupied by portions of the garden organics (GO) facility, the GO pond and a clay stockpile. The GO facility is proposed to be relocated to the western side of the site.
- Northern boundary: The northern boundary was altered to be offset 20 m from the existing extent of excavation. The northern excavation batter of Cell 5.3 which is currently near-vertical may be regraded for safety reasons and to facilitate the construction of the lining system.

No additional filling will be undertaken over the PCYC area and the reprofiling footprint excludes this area. The extent aligns with the PCYC fenceline (based on survey points sent to GHD by SITA) with an additional offset provided for future drains and access.

2.7 Capping profile

For the purposes of this assessment, the final cap would generally consist of (from top to bottom):

- 100 mm good quality topsoil
- 250 mm revegetation layer
- 500 mm subsoil layer
- 600 mm compacted clay barrier
- 300 mm seal bearing layer

This final cap profile may be subject to review and revised in the future as an alternative equivalent profile may be selected.

Capping works will be undertaken progressively as the landfill reaches final levels. The cap will be vegetated with grass until to 2037.

Once landfilling has ceased at the site, the site will be converted to parkland, in accordance with the Landscaping Plan contained in Appendix A. The revegetation layer provided as part of site closure will be thickened from 250 mm to 400 mm over almost a quarter of the re-profiled area to support growth of larger plants. The post-closure cap is outlined in the Landscape Plan drawings contained in Appendix A.

2.8 Stripping of existing cover

Where areas of excessive soil fill over waste are identified, localised investigations are to be undertaken and additional capping or intermediate cover can be stripped back such that

previously land filled waste is not exposed. This will be applied to areas within the proposed re-profiling area which currently have existing final cap or intermediate cover.

On the day of placement of waste on a small area the remaining soil will be removed to promote leachate movement into the existing leachate collection system to reduce the potential for the perching of leachate.

2.9 Leachate collection

As part of the proposal, a dual gas/leachate management trench will be constructed near the perimeter of the re-profiling area. Sections of trench will be constructed as landfilling progresses.

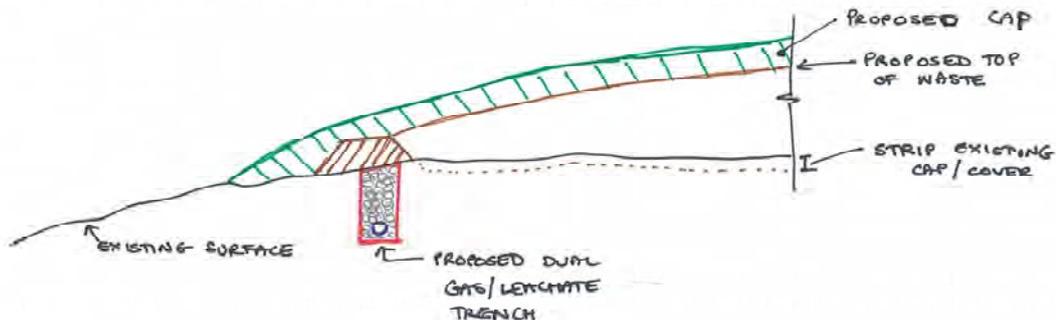


Figure 2-1 Proposed dual gas/leachate trench typical arrangement

The purpose designed trench will consist of a nominally 1.5 – 2 m deep trench within the existing waste mass backfilled with suitable drainage material and perforated pipe. The typical arrangement for the trench is illustrated in Figure 2-1. This trench will act as an extraction point for any sideways movement of leachate, should it occur.

Extraction risers would be located along the length of the trench, to allow leachate to be extracted and transferred to the existing leachate ring main. Detailed design of the system will be undertaken prior to installation and will include consideration of the predicted leachate flows, settlement and strength requirements.

2.10 Gas collection

The gas collection and extraction system will be progressively installed in the reprofiled areas as per the current practice.

2.11 Final land-use and revegetation/landscaping

The proposed final land-use of the site is open parklands for passive recreation.

The proposed parkland will have a total area of 149 ha, which is comparable in size to Sydney's Centennial Parklands, as illustrated in Figure 2-2. The parklands will include the reprofiling area and an additional 55.4 ha of natural land located to the west of the landfill.



Figure 2-2 Parklands scale comparison

The revegetation/landscaping of the final landform would be in accordance with the landscape drawings prepared by Taylor Brammer (2015), as included in Appendix A. An extensive planting program would be undertaken using a range of trees and shrubs to create a pleasant setting for passive recreational uses. In addition, pedestrian, cycle pathways and water features, combined with lawn areas and amenities buildings are proposed. The landscape plans have been developed utilising the proposed final landform surface discussed in Section 6.

2.12 Parkland recreation uses

The proposed parkland would comprise extensive area of open space, which would provide primarily for passive recreational uses. The area would comprise open grassed picnic areas, viewing areas, bridges and ponds.

2.12.1 Viewing points

The landform reprofiling would create a new broad ridgeline with maximum height of RL184.9 mAHD with lateral valleys that drain towards Mill Creek. The high point would be close to the central north-south axis of the site, slightly towards the eastern side.

The site's highest point (The Peak) and ridgeline would provide prominent views to the Sydney City and North Shore skyline.

2.12.2 Water bodies

The present course of Mill Creek includes a chain of ponds which have been shaped to suit available runoff recharge capacity and to meet functional needs. As part of the construction of the ARRT facility a part of the creek would be realigned. During creation of the parkland, Mill Creek would be retained with the addition of Mill Pond and Duck Pond (discussed below).

Mill Pond

As part of creation of the parkland, Mill Pond would be reinstated and shaped to create a visual landscape feature and amenity. A weir and spillway structure would be constructed to control the water level.

A bridge (Mill Bridge) would be constructed over a weir and would provide a strong visual element within the site. It would be constructed as a piped culvert with stone masonry walls. The bridge would provide access to the picnic area on the western side of the site.

Mill Pond would be maintained as a 'clear water' pond with densely grassed margins.

Duck Pond

A new water feature, termed Duck Pond, would be constructed in the south eastern part of the site. Duck Pond would be established with macrophyte planting to remove any nutrients and sediment from the water. Runoff from Heathcote Road would enter Mill Creek above this pond and the pond could be used to provide initial treatment for this runoff. Islands would be formed within the pond to serve as fauna protection habitats, especially for waterfowl.

A bridge (Paddock Bridge) would be constructed over the southern part of the pond and would provide a point of focus for the area. Paddock Bridge would be a piped culvert crossing with stone masonry walls.

Wetland

The existing water body next to the proposed North Entrance to the site would be retained. The pond would be used as a visual element and wildlife refuge as part of the final open space development.

Leachate lagoon

The existing leachate dam, in the north western corner of the site, would remain in its present location. It would be fenced and public access would be prohibited. A service road would be maintained for access to this area from Little Forest Road.

This portion of the site would be situated on steeply sloping land under an open tree canopy. Development of dense woodland plantings is proposed through the whole of the area westwards from the Woodlands drive. This would provide a screen for the leachate lagoon and ponds and other facilities remaining in the area. It would also create a visual and ecological extension of the Lucas Heights Conservation Area.

2.12.3 General open space areas

The site would contain extensive areas of open space. The parkland would provide primarily for passive recreational uses. The final structure of the parkland would not fully emerge until completion of the final stage in 2037.

Grading and landscaping of all site areas has been developed to provide maximum flexibility to accommodate possible needs of future generations. Large, gently undulating and sloping spaces edged with trees and pathways would be able to cater for a range of different activities.

Future uses of the open space areas could include (but are not limited to) model aeroplane flying areas (in a section on the northern boundary of the site in accordance with a Council resolution on the matter) and dog training. Picnic areas, walking tracks and bicycle tracks could be incorporated within the parkland.

The final uses of the each space would be determined by SCC based on community needs at the time. This would be done in 2035 in accordance with the Voluntary Planning Agreement and in consultation with the community and ANSTO as appropriate.

2.12.4 Access

Three vehicular access points are proposed into the parkland. The main entry point would be the North Entrance, from Little Forest Road. Two other entrances are proposed including to the

south (from New Illawarra Road) and to the west (from Heathcote Road). The Heathcote Road entry would be used for emergency/egress only. The New Illawarra Road entry would be primarily used as a service access point.

Two distinct circulation systems are proposed for the parkland. These are:

- Provision for light-duty vehicular (and occasional service vehicles) movement
- Provision for pedestrian, bicycle and other non-motorised movement.

Vehicular traffic

The vehicular tracks would circulate between the three access points. This system would be criss-crossed by many smaller trail links and would involve loop roads and parking areas which would allow movement completely within the park. The major vehicular links would be known as:

- Mill Run, linking New Illawarra Road and Heathcote Road through the site
- Woodlands Drive, connecting the western areas of the site to the northern parts of the site
- A service road, connecting the leachate dam and Little Forest Road

Roads and footpath pavements would be 6 m and 2.5 m wide respectively. Cement stabilised crushed sandstone with two coats of seal finish is proposed.

Future secondary road connections would include Meadow Lane, The Cutting, and The Ridgeway, providing vehicular connections to the highest point of the site and along the eastern boundary of the parkland.

Pedestrian/cycle traffic

A shared pedestrian and cyclist path would be provided on the site. It would be 2.5 m wide and would be made of compacted, crushed sandstone and would be stabilised with cement and spray seal. This path would link various parkland facilities throughout the site.

3. Methodology

3.1 General

The following methodology was undertaken for the design of the proposed final landform:

1. Initial modelling of the baseline landform that achieves the project requirements (refer Section 4);
2. Development of a settlement model and to conduct the settlement analysis (Refer Section 5); and
3. Use of settlement model to develop post-settled landform (Refer Section 6).

3.2 Settlement Modelling Methodology

3.2.1 Available methods

A number of different settlement analysis models were considered for this project, based on the models described in Babu et al. (2010). These models consider settlement of municipal solid waste (MSW) under different combinations of landfill conditions. They can generally be separated into the following categories:

- Soil-mechanics based models;
- Empirical models;
- Rheological models;
- Models incorporating biodegradation; and
- Constitutive models.

A comparison of these models conducted by Babu et al (2010) showed significant variation in settlement predictions, due to the differing assumptions and modelling parameters used.

3.2.2 Adopted methodology

The adopted settlement analysis methodology for this project has been taken from Sowers (1973) as presented in Qian et al (2002). This is a soil-mechanics based model and was chosen as it was considered to be the model which was most amenable to the available inputs and best suited the purpose of the project.

Whilst more complex models are available, which consider additional parameters such as biodegradation, they require a number of inputs which are not readily available for this project. Furthermore, based on comparisons made by Babu et al (2010), using a more complex model does not necessarily generate a more accurate prediction of settlement, as shown by the significant degree of variation between the various models (including the models considering additional landfill/waste parameters).

The adopted settlement model required that the site be split into multiple areas based on the inputs available for the site, with the aim of producing a suitable split of modelled areas which had similar input parameters (including similar waste age and waste thickness). GHD conducted a sensitivity analysis on a number of the modelling inputs to develop an understanding of the potential settlement which may occur at the site (see Section 5.3).

3.2.3 Description of methodology

The adopted method included both primary and secondary settlement of waste, expressed as:

$$\Delta H = \Delta H_c + \Delta H_\alpha$$

where ΔH = total settlement of solid waste;
 ΔH_c = initial primary settlement of solid waste; and
 ΔH_α = long-term secondary settlement of solid waste.

The initial primary settlement is expressed as:

$$\Delta H_c = C'_c \cdot H_0 \cdot \log \frac{\sigma_0 + \sigma_i}{\sigma_0}$$

where ΔH_c = initial primary settlement of solid waste;
 H_0 = initial thickness of the waste layer before settlement;
 C'_c = modified primary compression index;
 σ_0 = previously applied pressure in the waste layer;
 σ_i = total overburden pressure applied at the mid-level of the waste layer.

The long-term secondary settlement is expressed as:

$$\Delta H_\alpha = C'_\alpha \cdot H_0 \cdot \log \frac{t_2}{t_1}$$

where ΔH_α = long-term secondary settlement of solid waste;
 H_0 = initial thickness of the waste layer before settlement;
 C'_α = modified secondary compression index;
 t_1 = starting time of the secondary settlement;
 t_2 = ending time of the secondary settlement.

4. Proposed baseline landform

4.1 Description

The proposed baseline landform is contained in 21-23396-SK001 (Appendix B).

The baseline final design landform is a theoretical landform which represents the surface of the landform if all the waste was placed on the original landform, without any allowance for settlement. This is used to calculate the volume of airspace created by landfilling a certain amount of waste.

In reality, the waste would begin to settle as soon as it is placed and continues to do so for a number of years, dependent on the composition of the waste and the weight of waste placed above it. A settlement analysis for the proposed landform is provided in Section 5. Thus the baseline final design landform may never be achieved. In this case, the volume of waste or waste tonnages received are limited by the site approval or licence. A post settled (lower) landform will actually be achieved in practice. This is discussed in Section 6.

The levels to which the waste will actually be landfilled in each area need to consider the staging of filling, and the composition and age of each waste layer below it. The constructed level which will achieve the proposed post-settlement final landform will therefore be somewhere between the baseline and post-settlement model depending on the staging of filling.

The height of the constructed surface would not exceed RL 184.9 m AHD (includes waste and final cap). This would provide a capacity of 8.3 million m³, as discussed in Section 7.2.

4.2 Surface water management and landform grading

The final landform is proposed to be shaped and graded such that it allows for adequate surface water flow over the landform. Additionally, offsets were included for erosion and sediment control measures at the perimeter of the landform, including sediment controls and drains between Mill Creek and the landform extent.

The landform was developed with a minimum grade of 5% to allow for adequate shedding of surface water (as per NSW EPA's Environmental Guidelines: Solid Waste Landfills (the landfill guidelines)).

4.3 Pipe strengths

A consideration for the height of waste above the leachate collection pipework is their ability to withstand the weight of waste and not buckle. Calculations by GHD on Stages 5.2 and 5.3 (i.e. the north area) indicates that the leachate collection pipework for these cells can withstand a weight/cover height of 75 m. This was considered in the design for the proposed final landform (together with the pipework design for Stage 5.1 (not part of the deep dig). GHD does not have the details on the leachate collection pipework pre Stage 5, however issues around this unknown have been addressed in the groundwater assessment report (GHD, 2015).

4.4 Access

The designs of any service roads and access/maintenance tracks across the landform have not been considered for this project. The detailed design stage will give these for the operational phase, with the location of the roads on the final landform based on the landscaping plans prepared by Taylor Brammer (2015) and included in Appendix A. The detailed design of the access arrangements would be approved by SSC and ANSTO.

5. Settlement analysis

5.1 Modelling parameters

5.1.1 Landfill staging and fill phasing

Both the historical and future staging of the landfill was considered to develop an appropriate split for the modelled areas.

For the purposes of the model, the site was split into stages based on previous EIS documentation - Stages 1A, 1B, 1C, 2, 3, 4, 5.1, 5.2A, 5.2B and 5.3. These stages are shown on 21-23396-SK003 (Appendix B).

Based on the available data, the historical and future landfilling was split into the three distinct filling phases:

- Phase 1: Initial filling (approximately 1988-1998); and
- Phase 2: Initial overtopping (approximately 1999-current); and
- Phase 3: Reprofiling (current-closure).

These phases are indicatively shown in Appendix B(settlement modelling hand sketch).

Future landfill staging was developed as part of the modelling. The future stage boundaries are illustrated in Appendix B (21-23396-SK003) and further discussed in Section 7.3

5.1.2 Waste quantities and types

Historical waste quantities and types was based on data provided directly from SITA, data presented in the EIS documentation for the site, and data available in the annual reports for the site. Additionally, where no direct waste quantity data was available, volumetric airspace consumption figures were used to determine waste quantities based on compaction and placement parameters at the time.

Predicted future waste quantities are summarised in Table 5-1. This includes 4.5 million tonnes of waste that is currently approved to be landfilled on site and an additional 8.3 million tonnes of waste which would be used for the reprofiling works. For the purpose of the modelling, it is assumed that all future waste shall be municipal solid waste (MSW).

Table 5-1 Waste quantities (provided by SITA)

Year	Waste quantity (tonnes)
2014	329,301
2015	387,472
2016	671,435
2017	850,000
2018	850,000
2019	850,000
2020	850,000
2021	850,000
2022	850,000
2023	850,000
2024	850,000
2025	850,000

2026	850,000
2027	850,000
2028	850,000
2029	150,000
2030	150,000
2031	150,000
2032	150,000
2033	150,000
2034	148,215
2035	120,000
2036	120,000
2037	90,000
Total	12,816,423

5.1.3 Waste thickness

The waste thickness of the modelled areas was determined based on the information available and is outlined in Table 5-2. Appendix B contains an indicative cross section illustrating these phases of filling.

Table 5-2 Landform profiles

Profile	Source
Base of Phase 1	Estimated based on historical waste quantities and stage plan areas
Top of Phase 1 / Base of Phase 2	Based on 1998 site survey provided in the EIS documentation
Top of Phase 2 / Base of Phase 3	Based on December 2013 site survey as well as final excavated levels of Cell 5.3 as per excavation levels prepared by GHD
Top of Phase 3	Based on final landform developed as part of these works

5.1.4 Waste age

Waste age was estimated for each of the modelled stages based on the historical and future waste quantities (see Section 5.1.2), and the split for each of the three filling phases.

5.1.5 Waste compaction and applied pressure

Waste compaction was calculated with reference to historical and future compaction machinery used at the site (typical CAT landfill compactors), based on discussions with SITA and available historical information and observations.

5.1.6 Unit weight of waste

The unit weight of waste was assumed to be 11 kN/m³ based on Qian (2002).

5.1.7 Compression indexes

The primary and secondary compression indexes were developed based on formulas provided in Qian (2002) and the results of previous testing conducted by GHD on MSW for a nearby Sydney landfill. The results were inputted into the primary settlement formula to calculate the modified primary compression index (C'_c). The modified secondary compression index (C'_α)

was estimated by using the waste porosity results to calculate the initial void ratio, then estimating the index based on the ratio with consideration to Figure 6.11 in Qian (2002).

5.1.8 Duration of secondary settlement

The duration of secondary settlement was conservatively estimated to be thirty years based on available information provided by Qian (2002) and with reference to standard post-closure periods. After being landfilled for this 30 year period it is predicted that the majority of secondary settlement has occurred.

5.1.9 Foundation settlement

The geology of the site is mainly uniform, massive and thickly bedded Hawkesbury Sandstone of Triassic age with thin layers of Wianamatta shale overlying the sandstone in isolated ridges. GHD understands that the issue of foundation settlement may be investigated in a previous report for the site (*DJ Douglas & Partners Pty Ltd and Coffey Partners International Pty Ltd (May 1994) Report on Hydrogeology and Groundwater Monitoring, Waste Depot, Lucas Heights, Volumes 1, 2 and 3.*)

For the purposes of this project and with respect to the underlying strata, no settlement was considered for the landfill foundation. This is considered a suitable assumption for this project.

5.2 Results

The results of the settlement model can be found Appendix C. The range of predicted settlement is 3% to 22% of the landfilled waste thickness. These values are considered to be realistic when compared to Figure 6.12 in Qian (2002) which gives initial settlements up to about 10% of fill thickness increasing to over 25% for some landfill sites.

5.3 Sensitivity analysis

A number of assumed parameters were identified that may impact on the settlement analysis results, including the unit weight of waste, compression indexes, and the duration of secondary settlement. A sensitivity analysis was conducted on these parameters with the results discussed below.

Unit weight of waste

The unit weight of waste was assumed to be 11 kN/m³ based on Qian (2002). Table 6.3 in Qian (2002) gives a wide range of unit weight values between 3.1-13.2 kN/m³. Previous testing conducted by GHD on MSW for a nearby Sydney landfill indicated an average wet density of saturated waste of approximately 1050 kg/m³ (approx. 10.3 kN/m³). Gomes & Lopes (2011) report typical MSW unit weight values of between 6-12 kN/m³ to 4 m depth then between 8-16 kN/m³ at depth. With consideration to these reported values, the adopted value was considered appropriate.

Reducing the average unit weight to between 7 and 10 in the settlement model does not significantly influence the total calculated settlements, demonstrating that the settlement predictions are not very sensitive to average unit weight.

Modified primary compression index

A modified primary compression index of 0.2 was nominated based on the calculations described in Section 5.1.7. Figure 6.10 in Qian (2002) indicates a wide range of C'_c values as a function of initial void ratio depending upon waste type and compressible content, and a value of 0.17 – 0.36 (our nominated adopted value of 0.2 is at the lower end of this range). Gourc &

Olivier (2005) quote a range of values between 0.12 – 0.24 (our nominated adopted value of 0.2 is within this range).

The settlement calculations are, as expected, particularly sensitive to the value of C'_c adopted which is also a function of compressible layer thickness. However, given that the adopted value has been generated from relevant actual test data and that the value falls in the expected range nominated in available literature, the adopted value was considered appropriate.

Modified secondary compression index

A modified secondary compression index of 0.055 was nominated based on the calculations described in Section 5.1.7. Figure 6.10 in Qian (2002) indicates a wide range of C'_α values with lower limits between 0.01-0.03 and upper limits of approximately 0.1 (our nominated adopted value of 0.055 is within this range). Gourc & Olivier (2005) quote a range of values between 0.02 – 0.14 (our nominated adopted value of 0.055 is at the lower end of this range).

The settlement calculations are, as expected, particularly sensitive to the value of C'_α adopted. However, given that the adopted value has been generated from relevant actual test data and that the value falls in the expected range nominated in available literature, the adopted value was considered appropriate.

Duration of secondary settlement

As described above, the duration of secondary settlement was conservatively estimated based on available information provided by Qian (2002) and with reference to standard post-closure periods.

The settlement calculations are, as expected, particularly sensitive to the value of t_2 adopted. However, given that the basis of the adopted value, the adopted value was considered an appropriate conservative estimate.

6. Proposed post-settlement landform

6.1 Description

The post-settled landform represents the final landform following settlement and is depicted in Sketch 21-23396-SK002 (Appendix B). The post-settled landform was generated using the baseline landform and the results of the settlement model.

The landscape plans (Section 2.11) have been developed utilising this proposed post-settlement final landform surface.

6.2 Landfill grades

The post-settled landform was developed with respect to the required grades (i.e. for adequate shedding of stormwater).

A slope analysis for the proposed final landform demonstrates that post-settlement final landform achieves the minimum 5% design criteria as outlined above. The slope analysis is depicted in 21-23482-SK020 (Appendix D).

A portion of the perimeter areas would be constructed to have a maximum grade 1V:4H and at these slopes grass is able to be readily maintained. Other grades on the site would be constructed between 5% and 1 in 4 slopes.

Further discussion of the final landfill grades is included in Section 7.4.

7. Landform assessment

7.1 Comparison of landfill levels

In summary:

- The maximum level of the existing waste (June 2014) is approximately RL 169.7 m AHD.
- The maximum height of the existing stockpile (June 2014) is approximately RL 177.7 m AHD.
- The maximum level of the existing approved final landform is RL 172 m AHD
- The maximum level at which waste will be placed will be below the levels indicated by the baseline final landform. The actual height at which waste will be placed at any location will depend on the age of the layers of waste below (refer Section 4.1). The height of the constructed surface would not exceed RL 184.9 m AHD (includes waste and final cap), which is approximately 12.9 m above the level which is currently approved and approximately 7.2 m above the height of the existing stockpile.
- The waste will be placed to a level which will provide a proposed post-settlement final landform with maximum height of RL 179.9 m AHD (includes waste and final cap), which is approximately 7.9 m above the level which is currently approved and approximately 2.2 m above the height of the existing stockpile.

Cross sections showing the relative levels of these surfaces are provided in Appendix D.

7.2 Capacity calculation

The calculated increased capacity of the proposed final landform is 8.3 million cubic metres. A summary of the capacity calculations can be found in Table 7-1. A description of each of the items is provided below:

- Existing approved capacity: The existing development consent states that 'the expansion of the landfill capacity at the LHWMC shall not exceed 8.225 million tonnes beyond the remaining capacity of 8 million tonnes under the existing consent calculated as at 1 July 1997'. The total waste recorded as being received at the site from 1 July 1997 to December 2013 was 11,722,694 tonnes. The remaining approved tonnage at December 2013 was therefore 4,502,306 m³ and this has been converted to cubic metres assuming an airspace utilisation rate of 1 t/m³;
- Additional airspace (to top of baseline final landform): The additional airspace gained, taken from volume analysis of the 3D model using 12D modelling software. It measures the total airspace from the top of the landform to the existing surface (December 2013), including additional space gained from excavating the remainder of Cell 5.3, minus the existing approved capacity;
- Capacity gained from the partial recovery of the existing capping materials: Based on the area of the landform overlapping areas of existing capping and estimated recovery thickness (1.3 m);
- Capacity gained from the partial recovery of existing cover material: Based on the area of the landform overlapping areas of existing cover and estimated recovery thickness;
- Lining volume of Cell 5.3 (including leachate drainage layer): Based on design surfaces for Cell 5.3 developed by GHD;

- Capping material required: Calculated based on the surface area of the landform (taken from the 3D model) and the proposed final capping thickness (1.75 m); and
- Additional landfilling capacity (to proposed final landform): Existing approved capacity plus additional airspace plus capacity gained from stripping cover and capping minus capping and lining volumes.

Table 7-1 Capacity calculations

Item	Description	Quantity	Ref. ID	Calculation
1.01	Existing approved capacity	4,502,000 m ³	SITA	Provided by SITA (assume 1 t/m ³ for waste)
1.02	Additional airspace (to top of baseline proposed final landform)	9,561,000 m ³	12D	Total capacity to top of baseline proposed final landform - Existing approved capacity
1.03	Capacity gained from partial recovery of existing capping	498,000 m ³	12D, drawings	1.3m x existing capped areas
1.04	Capacity gained from partial recovery of existing cover	74,000 m ³	12D, drawings	0.15m x existing covered areas
1.05	Lining volume of Cell 5.3 (including leachate drainage layer)	80,000 m ³	12D	1.2m x basal area of Cell 5.3 + 0.9m x sidewall area of Cell 5.3
1.06	Capping material required	1,753,000 m ³	12D	1.75m x surface area of R5 (cap thickness of 1.75m)
1.07	Additional landfilling capacity (to proposed final landform)	8,300,000 m ³	See 1.01-1.06	Additional airspace (to top of the proposed baseline final landform) + Capacity gained from stripping of existing capping + Capacity gained from stripping of existing cover - Lining volume of Cell 5.3 (including leachate drainage layer) - Capping material required

7.3 Staging of filling works

Based on the overall site capacity, as discussed in Section 7.2, and the rates of waste placement as outlined in Section 5.1.1, the timeline of filling of the proposed final landform was estimated. The footprint of the remaining fill area has been split into nine filling stages, identified as Area A through to Area I, as outlined in 21-23396-SK003 (Appendix B).

In developing the boundaries for the areas, the following were considered:

- The diversion and collection of surface water around the areas;
- Reducing the impact of stripping of existing cover and cap material on leachate and odour generation by commencing the filling works over the uncapped portions of the site prior to removing existing cap;
- Maintaining access around the site and to the active areas;
- Prioritisation of achieving final levels in the southern portion of the site within the ANSTO buffer zone;

- Maintaining the existing garden organics areas until the proposed GO facility on the western side of the site is operational.

In preparing the timeline, it was assumed that:

- The current landfill cells (Cell 5.2B and Cell 5.3A& B contained in Area I and Area H) would continue to be filled until June 2016. It has been assumed that landfilling would consume space in these existing areas equally;
- In June 2016, filling over the older parts of the landfill would commence;
- The available airspace for each area takes into consideration the batters between the areas, the airspace made available by stripping of existing capping and cover and the space consumed by lining and capping materials;
- Airspace would be consumed at a rate of 1 t/m³;

The timeline is included in Appendix E and summarised in Table 7-2. This includes waste which is currently approved to be received for landfilling and additional waste that would be received as part of the reprofiling works.

Table 7-2 Staging of reprofiling works

Area	Capacity (t)	Start filling date	Finish filling date
E	915,600	June 2016	August 2017
D	798,000	August 2017	July 2018
B	865,600	July 2018	July 2019
A	425,400	July 2019	Jan 2020
C	931,200	Jan 2020	February 2021
F	654,400	February 2021	November 2021
I(refer note)	3,965,800	November 2021	December 2025
H	3,105,200	December 2025	June 2029
G	1,155,300	June 2029	December 2037
Total	12,816,500		

Note : The existing lease agreement with ANSTO requires that SITA must vacate ANSTO land by 1 January 2025. In order to complete filling in the portions of Area I which are within the leased area, Area I should be further partitioned to initially focus filling in the southern portions. SITA should aim to complete filling within the ANSTO lease area by mid 2024 to allow time for capping and installation of other infrastructure, such as surface water drainage and landfill gas wells.

7.4 Proposed landscaped landform

The revegetation/landscaping of the final landform will be in accordance with the landscape drawings prepared by Taylor Brammer (2015), as included in Appendix A and as discussed in Section 2.11 and Section 2.12.

Typical sections through the final landscapes landform are illustrated in Figure 7-1 and Figure 7-2.

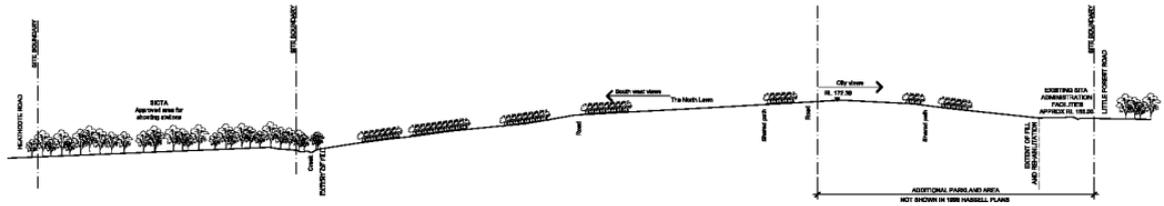


Figure 7-1 Typical landscaped final landform – view 1

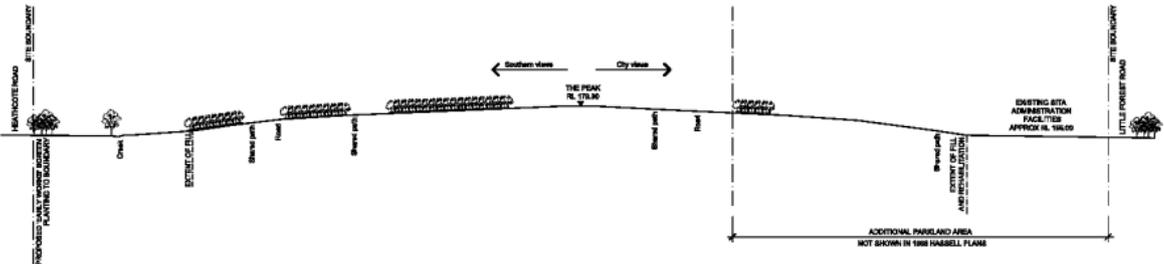


Figure 7-2 Typical landscaped final landform – view 2

The final landform provides grades which are appropriate for the proposed passive recreation uses, as discussed in Section 2.11. A breakdown of the grades and examples of equivalent slopes in existing parklands is provided in Table 7-3 and illustrated in Figure 7-3. The full slope analysis is depicted in 21-23482-SK020 (Appendix D).

Table 7-3 Reprofilng area slope analysis

Grade range	Park area (hectare)	Portion of park area	Example of equivalent slope
5 – 10%	52.4	35%	Barden Ridge Sporting Complex - Figure 7-4
10 – 18%	35.6	24%	Bicentennial Park - Figure 7-5
18 – 25%	4.6	3%	Cronulla Park - Figure 7-6

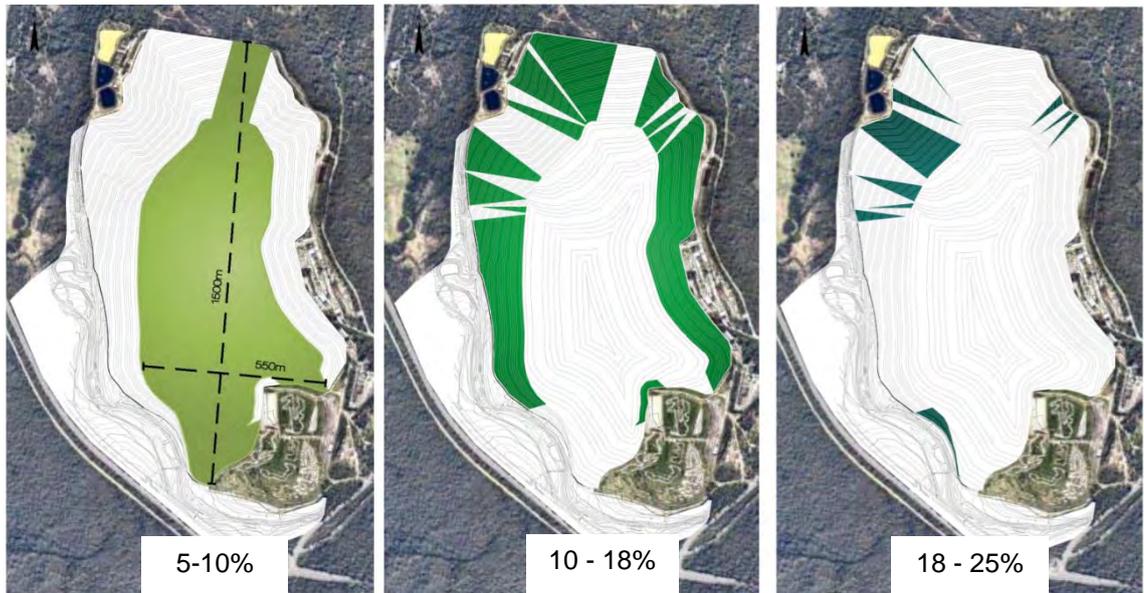


Figure 7-3 Slope analysis



Figure 7-4 Barden Ridge Sporting Complex – 5-10% grade



Figure 7-5 Bicentennial Park – 10-18% grade



Figure 7-6 Cronulla Park – 18 – 25% grade

8. Conclusions

Three dimensional modelling of a proposed final landform was undertaken along with settlement analysis of the waste to show that the proposed final landform is expected to meet the design objectives as outlined in Section 1.2.

The proposal would meet the requirements of the NSW EPA landfill guidelines by providing a final surface which has slopes of not less than 5%.

The proposed final landform would be constructed to a maximum level of RL 184.9 m AHD (including waste and capping works). It is predicted that this landform would settle to a level of RL 179.9 m AHD based on a thirty year settlement period. These are approximately 12.9 m and 7.9 m higher than the existing proposed final landform, respectively.

An additional 8.3 million cubic metres of waste would be placed on the site to achieve the proposed final surface, Preliminary staging plans for the re-profiling works have been provided to minimise impacts on the environment by minimising leachate, dust and odour generation and reducing the potential for contact of landfilled waste with surface waters.

The proposed final landform provides a surface which has grades appropriate for the proposed final land-use of open parklands.

9. References

- Babu et al., 2010, 'Prediction of Long-Term Municipal Solid Waste Landfill Settlement Using Constitutive Model', *Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, Vol. 14, Issue 2, 139-150.
- Gomes, C. C. & Costa Lopes, M. (2011). *Characterisation of municipal solid waste physical properties and their evolution with age*. Proc. ICE, Geot. Eng., Vol.165, February, Issue GE1, pp.23-34.
- Sowers G.F. 1973, 'Settlement of Waste Disposal Fills', Proc. 3rd International Conference on Soil Mechanics and Foundation Engineering, Vol. 2, 207–210.
- Qian, X, Koerner, R & Gray, D 2001. **Geotechnical Aspects of Landfill Design and Construction**, Prentice Hall, Sydney.

10. Limitations

This report: has been prepared by GHD for SITA Australia Pty Ltd and may only be used and relied on by SITA Australia Pty Ltd for the purpose agreed between GHD and the SITA Australia Pty Ltd as set out in Section 1.1 of this report.

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The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

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The modelling and associated calculations, material volumes and timelines are limited by the accuracy of the survey data and the modelling assumptions. The information presented within this letter has an associated level of accuracy based on conceptually developed work. This is the standard approach to the land use approval process in NSW.