EMRC

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Cardno
Shaping the Future

Advancing Perth's Eastern Region

Resource Recovery Facility

Task 6 - Red Hill Site Placement Study - Confidential Version

Prepared for EMRC

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Executive Summary

The Resource Recovery Project aims to develop an integrated waste management solution for the EMRC's Member Councils. As part of this project, the EMRC proposes to develop a Resource Recovery Facility (RRF) to process Member Council kerbside municipal solid waste (MSW). An RRF can sort and treat domestic waste collected from the kerbside (excluding comingled recyclables) to produce a valuable resource such as compost and/or energy and recyclables.

The process of establishing the RRF has recently included receipt of Expressions of Interest (EOI) from the international marketplace and the development of a Preferred Options Report for consideration by the EMRC and Member Councils. The Preferred Options Report considered a number of strategic planning decisions including, but not limited to technology type and site selection.

Giving due consideration to the Preferred Options Report the EMRC resolved to:

- Select Red Hill Waste Management Facility (WMF) as the preferred site for the RRF; and
- Select Anaerobic Digestion (AD), Gasification, Pyrolysis or Combustion Technologies (with plasma technology only being considered if it is an integral part of one of these technologies).

The EMRC requested under Task 6 of the EMRC RRF Project, that Cardno undertakes an investigation into site placement of the proposed RRF on the preferred Red Hill WMF site. The EMRC shortlisted five potential sites for the RRF within the Red Hill WMF for further investigation including the:

- Red Hill Farm west of the proposed Hills Spine Road in Lot 12 (Site A);
- Green waste facility footprint in the north east corner of Lot 1 (Site B1);
- North west corner of Lot 12 (Site B2);
- Community Drop Off Waste Transfer Station within Lot 2 and intruding onto the adjoining completed putrescible landfill cell in Lot 11 (Site C); and
- Completed putrescible landfill cell in the south west corner of Lot 11 (Site D).

Due to the nature of the Red Hill WMF, a number of factors were investigated that could potentially limit the placement of the RRF at the proposed locations. The factors investigated included the following:

- Engineering risk and costs;
- Proximity to residences;
- Landfill airspace loss;
- Impact on current operations;
- Connection to the electricity grid; and
- Impact on flight paths associated with the Perth Airport.

Engineering Risk and Costs

The primary engineering parameters considered for each site were topography and soil bearing capacity. As the site is undulating and the RRFs under consideration are of a considerable size (1 – 4 ha) and require an essentially flat site, excavation and/or filling will be necessary for each of the proposed sites. Due to the geotechnical nature of general refuse in landfill, particularly the limited bearing capacity and likely subsidence due to microbial breakdown of organics in the waste, piled (with pre-drilling) foundations will be required to maintain stability of the RRF structure in landfill areas.

Particular components of the RRF technologies have high foundation loadings. These include the digesters in AD technology and gasifiers or furnaces in gasification and combustion technologies. The foundation loadings for the AD digesters selected for this study are very high at approximately 33 tonnes / m^2. This is higher than the bearing capacity of the soils within the Red Hill WMF (150 kPa). Therefore, piling is likely for AD technology (depending on the AD technology eventually selected) regardless of the location onsite. Piling would only be required under the digester and not the remaining building footprint in non-landfilled areas. Like the requirement for pilings, the thickness of concrete slab foundations for the RRF will be dependent on the foundation loading of the RRF components and building and whether or not piling is utilised. The range of concrete thicknesses assumed for this study is between 200mm and 300mm.

A methane extraction system (in addition to that already constructed by Landfill Gas and Power) would also be required for RRFs located over Site C or D due to the risk of methane (a highly flammable, non-toxic asphyxiate) entering the facility from the underlying landfill cells.

The engineering cost summary for each technology (and plant capacity) for each proposed RRF location is outlined below in **Table E1**. A range of RRF capacities have been assessed based on the likely minimum and maximum annual tonnages processed. As Site B2 has been considered late in the process, the engineering requirements have not been undertaken. For the purposes of this report it can be assumed that the engineering requirements are similar to Site B1

Table E1: Engineering cost summary for each site and technology ($)

	60,000 tpa AD	150,000 tpa AD	90,000 tpa Gasification	90,000 tpa Combustion	200,000 tpa Gasification	200,000 tpa Combustion
A	$980,000	$1,600,000	$560,000	$2,700,000	$1,300,000	$3,100,000
B 1/2	$1,200,000	$1,800,000	$620,000	$2,900,000	$1,400,000	$3,500,000
C	$9,700,000	$11,100,000	$2,000,000	$11,100,000	$5,300,000	$12,300,000
D	$14,200,00	$16,300,000	$4,500,000	$16,600,000	$6,700,000	$18,500,000

Site A has the lowest site engineering costs overall, ranging $560,000 - $3,100,000, followed closely by Site B1/2 ($60,000 - $400,000 cost increase). Due to Sites C and D being partially or completely over landfill, the engineering costs significantly increase ($2,000,000 - $18,500,000). Gasification has the lowest site costs due to the technology requiring a relatively small footprint and loadings. AD and combustion exhibit similar (yet high) costs due to the large footprints, piling for AD digesters and thick concrete slab (300mm) for the combustion furnace.

Proximity to Residences

Due to the nature of an RRF, consideration needs to be given to their proximity to residences and the potential social impacts of the RRF. The Red Hill WMF has a number of residences in close proximity of its boundaries. This is especially the case to the south and east. The minimum distance to residences and number of residences within 1 kilometre of the site is outlined n **Table E2**.

Table E2: Distance to sensitive land uses (residential) from the proposed location of the RRF

Site	Description	Minimum distance to closest resident	No of residences with 1km
A	Red Hill Farm Lot 12	520m	10 - 15
B1	Green waste Facility Lot 1	550m	2
B2	North West Corner Lot 12	400m	4
C	Transfer Station Lot 11 and 2	950m	3
D	South West Corner Lot 11	820m	6

Site A has the potential to impact residents the greatest due to the site being in close proximity to a residence and having the greatest number of residence within 1km. Sites C and D have the greatest distance to residences. Site B1 is relatively close to two residences. Site B2 is in closest proximity to a residence (400 m).

Environmental

As the site is an active landfill and is predominantly cleared of vegetation, the environmental value of the site has been diminished over time. No remnant vegetation will need to be cleared for any of the proposed sites. The potential environmental impacts of excavating or filling Lot 11 (Site C and D) is difficult to determine without further field analysis, however it is likely that odour, leachate, dust and explosive risk could be issues if a RRF was constructed and excavation of the landfill was required.

Airspace Loss

As the proposed RRF sites are to be located over natural ground or existing landfill, which may be utilised for further landfilling in the future, construction of the RRF will result in future airspace loss. To analyse these effects, nine potential scenarios were developed by the EMRC for the Red Hill WMF, exclusive and inclusive of the RRF and other onsite infrastructure. The scenarios also estimated potential maximum heights of the final landform. The scenarios proposed are described in detail in the main report. Under all scenarios, Sites C and D both lose large amounts of airspace and also incur high engineering costs. On this basis these two sites are considered to be unsuitable (Scenarios 1, 4 and 6) and have not been further considered. Any additional landfilling on Lot 11 is also not recommended due to potential exacerbation of the current leachate issues (which is currently being contained). Scenarios (2, 3, 3a and 5) for Sites A, B1 and B2 were further considered.

The available future landfill airspace with these scenarios is shown in **Table E3**.

Table E3: Total Available Airspace for Sites A, B1 and B2 based on a range of technologies for Site A and the largest 4ha 200K combustion option for Site B1/2

Scenario	Available future airspace for Site A (m^3)	Available future airspace for Site B1 (m^3)	Available future airspace for Site B2 (m^3)
2	26,700,000 – 29,100,000	23,200,000	28,800,000
3	20,200,000 – 22,000,000	23,200,000	21,400,000
3a	25,600,000 – 28,000,000	25,700,000	29,500,000
5	11,200,000 – 13,000,000	14,200,000	12,400,000

Note: Technology options were only assessed by the EMRC for Site A. Site B1/2 is based on a worst case scenario of 4ha 200K combustion plant

The above table illustrates that there are advantages and disadvantages of locating the RRF at particular sites under different scenarios. Site A and B2 are preferred for scenario 2. Site B1 is preferred for scenarios 3 and 5. This is largely due to the assumption that the green waste facility must remain in its current position, when it could potentially be located at an alternate location on sight with appropriate topography. The greatest available airspace, overall, results from using Site B2, with approximately 29.5 million cubic metres of available airspace.

Whilst the placement of the RRF has implications on the available airspace at the Red Hill WMF, the RRF offsets this to an extent by reducing the amount of waste requiring landfill. Over a 20 year period the reduction in airspace required could range from 900,000m^3 for a 60,000tpa AD facility (70% diversion) to 3,000,000m^3 for a 200,000tpa thermal facility (90% diversion).

Impact of Current Operations

If the Perth-Adelaide Highway and the associated Hills Spine Road were not to be built, all five proposed sites will not have accessibility problems. An existing sealed road network would service Sites B1/2 and C, whilst new sealed roads would be required for Sites A and D. The proposed scenarios have implications on the extent of waste management services that the Red Hill WMF can provide. With the exception of scenario 3 and 5, the scenarios do not allocate space for the waste transfer station, green waste facility and / or the RRF. The placement of the RRF at Site C would result in the loss of the current waste transfer station. Sites A, B2 and D provide the possibility of retaining all existing infrastructure. The placement of the RRF at Site B1 has the potential for the loss of the green waste facility depending on the size of the facility. For the scenarios that require removal of infrastructure, this would incur costs for relocation.

One set of scenarios assumed that further landfill would occur on top of the currently completed cells in Lot 11 and 12. The clay liner of the cells within Lot 11 has been breached and leachate is currently contaminating the groundwater and is leaching offsite to the south. The EMRC is implementing a strategy to control the flow of contaminated groundwater through groundwater extraction. Rectifying the leak is likely to be very difficult as its exact location is not known. It is unlikely that approval will be given to add more waste to Lot 11 without the current leak having been rectified.

Connection to the Electricity Grid

At present, further information is being sought from EOI respondents (i.e. the potential future RRF technology providers) in regards to energy outputs for the higher capacity options and technical attributes of their facilities that relate to connecting to the electricity grid. This information will be submitted to Western Power in due course for further assessment. This grid connection assessment, however, does not have a bearing on the overall placement of the RRF at the Red Hill WMF at this stage. The grid connection options are dependent on the net power export and are therefore technology dependent.

Impact of Flight Paths

Red Hill is under a flight path for aircraft approaching the Perth domestic and international airports. Westralia Airport Corporation (WAC) has set regulations that require structures within the flight paths to be under defined heights. WAC also sets gas maximum efflux velocities for facilities that have emissions from a stack. It is likely that with stack height modification (for one particular EOI respondent) all technologies could comply with the WAC regulations. In regards to efflux velocities, the likelihood is that all proponents could comply with WAC regulations for efflux velocity, at stack exit.

Lot 8 / Site E Consideration

Lot 8, currently owned by Midland Brick, 390 metres west of the Red Hill western boundary, was identified by the EMRC as a potential site (Site E) late in the development of this report. This was a result of Midland Brick declaring that Lot 8 is exhausted of clay for excavation and could potentially be acquired by the EMRC.

Whilst not being able to be investigated to the equivalent level of detail as that of the proposed sites on Red Hill WMF, an initial assessment of Site E has identified a number of benefits for the location of the RRF. The major benefits include increased separation from residences, limited impact on future landfilling operations and no impact on vegetation, existing leachate systems or current Red Hill waste management operations. Site E also does not have access or servicing issues. Potential limitations for Site E is the cost to provide a suitable foundation for the RRF, which are likely to be similar to Sites A and B1/2 and the upfront cost to acquire the site; however it is likely both of these limitations will be offset by a gain in landfill airspace at Red Hill. Another limitation is potentially the zoning of land under the local town planning scheme (regulatory). This needs to be further investigated.

Conclusions

This study has illustrated that there are a number of factors that need to be considered in the site placement of the RRF within the current Red Hill WMF footprint. Some of these factors have proven to be limitations in the satisfactory placement of the RRF for some of the proposed locations.

There is no optimal location for the RRF within the Red Hill WMF due to a number of constraints on site. There is added complexity due to the RRF having impacts on the future airspace of the landfill in the long term. However, the option of the EMRC acquiring Lot 8 from Midland Brick potentially resolves the limitations of the proposed sites within the Red Hill. **Table E5** ranks the economic, social, environmental, technical, regulatory and operational factors of each proposed site for the placement of the RRF.

Table E5: Ranking of the factors for each RRF site location

Site	Economic	Social	Environmental	Technical	Regulatory	Operational
A	Y / N	N	Y	Y	Y	Y
B1	Y / N	Y / N	Y	Y	Y	Y / N
B2	Y / N	Y / N	Y	Y	Y	Y
C	N	Y	N	N	Y	Y / N
D	N	Y	N	N	Y	Y
E	*Y*	*Y*	*Y*	*Y / N*	*Y / N*	*Y*

A qualitative assessment of the economic, social, environmental, technical, operational and regulatory attributes of each proposed locations suggests that, within the current EMRC Red Hill operations, **Site B2** is the preferred site for the location of the RRF. However, if Lot 8 / Site E became available to the EMRC, then it is an attractive option due to it resolving the issues with Site B2, namely airspace loss and proximity to residences. Before Lot 8 can be confirmed as the overall preferred site the EMRC needs to conduct further investigation into the engineering requirements for the site, based on topographical and geotechnical conditions, zoning requirements and also progress negotiations with Midland Brick in regard to the acquisition of the site.

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1 Introduction

1.1 Background

The Resource Recovery Project aims to develop an integrated waste management solution for the EMRC's Member Councils. As part of this project, the EMRC proposes to develop a Resource Recovery Facility (RRF) to process Member Council kerbside municipal solid waste (MSW). An RRF can sort and treat domestic waste collected from the kerbside (excluding comingled recyclables) to produce a valuable resource such as compost and/or energy and recyclables. The establishment of a RRF is intended to assist the EMRC in:

- Diversion of waste from landfill and extending the life expectancy of the EMRC Red Hill Waste Management Facility (WMF);
- Reducing the environmental impacts associated with landfilling, including greenhouse gas emissions and potential contamination of soil and groundwater;
- Generating a marketable product, such as compost, energy and recyclables; and
- Complying with the Waste Authority's strategies and targets for MSW as detailed in the *Draft II Waste Strategy for Western Australia* (March 2010).

The EMRC has been engaged in a process with project consultants Cardno since 2004 to develop the RRF. This process has recently included calling for and assessing Expressions of Interest (EOI) from the international marketplace and the development of a Preferred Options Report for consideration by the EMRC and Member Councils. This Preferred Options Report considered a number of strategic planning decisions including, but not limited to technology type and site selection.

Giving due consideration to the Preferred Options Report the EMRC resolved to:

- Select Red Hill WMF as the preferred site for the RRF;
- Select Anaerobic Digestion, Gasification, Pyrolysis or Combustion Technologies (with plasma technology will only be considered if it is an integral part of one of these technologies); and
- Commence the Environmental Approvals Process.

The capacity of the technology types selected (as expressed in the EOI document) will be limited to 60,000 tonnes per annum (tpa) expandable to 150,000 tpa for Anaerobic Digestion (AD) and 90,000 tpa expandable to 200,000 tpa for Energy from Waste (EfW) technologies. These capacities are based on waste projections and the potential for source separation bin collection systems.

1.2 Task 6 Requirements

EMRC requested under Task 6 of the EMRC RRF Project, that Cardno undertake an investigation into site placement of the proposed RRF at the preferred Red Hill WMF site. Cardno is also required to undertake an assessment of the changes that will be required to the existing disposal facilities on site.

At present the EMRC has shortlisted four potential sites for the RRF within the Red Hill WMF that should be further investigated. These include the:

- Current proposed location on Red Hill Farm west of the proposed Hills Spine Road in Lot 12 (Site A);
- Green waste Facility footprint in the north east corner of Lot 1 (Site B1);
- North west corner of Lot 12 (Site B2);
- Community Drop Off Waste Transfer Station within Lot 2 and intruding onto the adjoining completed putrescible landfill Cell in Lot 11 (Site C); and

- Completed putrescible landfill cell in the south west corner of Lot 11 (Site D).

For Cardno to accurately assess the preferred site location of the proposed RRF a number of aspects of the site and proposed technologies needed further investigation. These are further discussed in **Section 2** and **3**:

Given that the EMRC has nominated two sites that are partially or completely over a disused putrescible landfill cell, an assessment of the engineering requirements to safely construct the facility in such an environment was also investigated.

1.3 Report Structure

The structure of the report is as follows:

- Introduction
- Methodology
- Desktop Investigations
- Engineering Assessment
- Discussion
- Recommendations
- Conceptual Design
- References

2 Methodology

2.1 Desktop Investigations

Desktop information was gathered from a number of sources including successful Expression of Interest respondents, academia research and internet search engines. A summary of the task and references for data used is outlined in **Table 1**.

Table 1: Desktop Investigation Tasks Undertaken and References

Task	Reference
Proximity of Residences	› Landgate – Cadastre (May 2010) › NearMap Aerial Photograph – 29th May 2010 › Google Maps – Measurement Tool (May 2010) › EPA - Guidance for the Assessment of Environmental Factors. Separation Distances between Industrial and Sensitive Landuses No. 3 (2005)
RRF Building Dimensions and Footprint	› Expressions of Interest (June 2009) › Additional Information from EOI Respondents (July 2010)
RRF Efflux Velocity	› Additional Information from EOI Respondents (July 2010)
RRF Footprint Loadings	› Additional Information from EOI Respondents (July 2010)
RRF Power Inputs / Outputs	› Expressions of Interest (June 2009) › Additional Information from EOI Respondents (July 2010)
Landfill Reclamation	› Academic Papers, Global Landfill Mining Conference, Verbal Communications, Internet Search Engines
Construction upon Landfill	› Academic Papers, Verbal Communications, Internet Search Engines
Red Hill Airspace scenarios	› Volume Predictions for Red Hill Waste Management Facility prepared by EMRC (2010)
Scrap Metal Extraction	› Internal Quote Cardno Civil Engineering Department Cardno (2010)
Power Supply and Grid Connections	› Written Response from Energy Response Pty Ltd (July 2010)

The literature review of “landfill reclamation” and “construction over landfill” sought local, national and international examples.

2.2 Civil and Structural Engineering Investigations

Cardno’s Engineering Business Unit undertook a topographical, geological and economical investigation of each of the nominated potential RRF sites within the Red Hill WMF. A key outcome of these investigations was locating particular areas that would provide the most cost effective option in regards to site works required within each of the designated areas. A summary of the tasks and references utilised is outlined in **Table 2**.

Table 2: Engineering Tasks Undertaken and References

Task	Reference
Topographical	› EMRC Red Hill Site Topographical Survey (5 / 09 / 09)
Geological	› EMRC Soil Bores – Toodyay Boring (1994 and 1999)

Economical	› Rawlinson's Australian Construction Handbook Edition 27-2009 › AutoCAD and Microsoft Excel Software

A key part of the engineering assessment was the building dimensions, operational area footprint and design floor loadings of components of the RRF. As each EOI respondent has offered differing technology types and configurations, numbers varied. For the purposes of this study Cardno has selected attributes of each facility that could be considered the "highest impact scenario", namely the largest facility footprint, the largest operational footprint and the highest floor loadings. These attributes are not necessarily isolated to one particular facility, rather are a combination of all the facilities. The details provided by the respondents were also taken into account when selecting the figure used.

The data received from EOI respondents can also be considered confidential in nature and as such have not been specified in this document. Rather, ranges or maximums have been specified in this report.

2.2.1 Limitations

The information provided in this report is subject to the following limitations:

- Limited information on building equipment provided by EOI respondents. Each EOI respondent has different equipment and building layouts which will directly affect the costs;
- Limited information on the actual soil conditions under each of the proposed facility locations. Air track drill holes logs (provided by EMRC) are not sufficient to accurately estimate soil capacity (i.e. not a detailed geotechnical assessment). Drill holes are only indicative of the soil conditions;
- The drill hole logs do not cover the entire proposed facility development area. Therefore, some assumption has been made based on the available data; and
- Structural systems may significantly change should the building, equipment layout and loading provided by EOI Respondent deviate from the assumptions used in the engineering assessment.

2.3 Conceptual Designs

Conceptual designs were formulated based on the results of the desktop investigations, engineering assessment and feedback from the EMRC. Key criteria that were used in the qualitative assessment process included:

- Cost;
- Accessibility;
- Proximity to Residences;
- Visual Amenity;
- Impact on existing operations;
- Service Requirements;
- Capital and Operational Risks; and
- Westralia Airport Corporation Regulations

As the recommended location of the RRF has the potential to affect the existing operations of the Red Hill WMF, the conceptual design accounts for a number of key pieces of infrastructure on site including the weighbridge, administration building, landfill gas power plant, green waste facility and current and future landfill cells.

The current layout of the Red Hill WMF is outlined in **Map 1**.

3 Desktop Investigations

3.1 Proximity of Residences

The proximity of residences to the proposed RRF is a key consideration in the selection of a site, as there are potential environmental, health and social amenity impacts. The Environmental Protection Agency has released a document that provides guidance on buffer distances between industrial and sensitive land uses. The document is entitled:

- *Environmental Protection Agency (2005) Guidance for the Assessment of Environmental Factors - Separation Distances between Industrial and Sensitive Land Uses No. 3*

The recommended buffer distances for "composting" and "incineration" are outlined below in **Table 3**.

Table 3: Recommended buffer distances between industrial and sensitive land uses

Industry	Description of Industry	Buffer distance
Incineration	For biomedical, chemical or organic waste	500 – 1,000m depending on size
	For plastic or rubber waste	1,000m
Composting (mixed food / putrescible and vegetative food waste)	Outdoor covered windrows with continuous aeration	500m
	Enclosed windrows with odour control	250m
	In-vessel composting with odour control	150m

It must be noted that the recommended buffer distances only need to be used as a guide and that more detailed assessments should be undertaken based on local environmental conditions.

The approximate distance to residences based on the proposed location of the facilities (further detailed in **Section 4**) is outlined below in **Table 4**. This is also illustrated in **Map 2**.

Table 4: Approximate distance to sensitive land uses (residential) from the proposed location of the RRF

Site	Description	Minimum distance to closest resident	No of residences with 1km
A	Red Hill Farm Lot 12	520m	10 - 15
B1	Green waste Facility Lot 1	550m	2
B2	North-west corner Lot 12	400m	4
C	Transfer Station Lot 11 and 2	950m	3
D	South West Corner Lot 11	820m	6

The proposed Red Hill Farm location (Site A) is in close proximity to residents (520 metres minimum). This location also has the highest number of residences within 1,000 kilometre (approx 10 - 15). A number of residences will also have a direct line of sight to the facility (assuming no visual screening is provided). One residence is approximately 400 metres from Site B2; however the site is screened by existing vegetation on the residences property. The line of sight from the residence to a potential emission stack is more uncertain. The transfer station location (Site C) is the farthest away (1,000m) from residences and the line of sight to residences is well shielded due to the existing elevated landfill and surrounding vegetation.

3.2 RRF Building Dimensions and Footprints

The RRF building dimensions and footprints vary depending on the technology type and capacity of the facility. The facility dimensions selected by Cardno (based on the “high impact scenario”) for each technology type and capacity are tabulated below in **Table 5**. The operational footprint is the total area required and inclusive of the building and digester / gasifier footprint.

Table 5: Facility Dimensions Selected for Each Technology Type and Capacity

Technology	Capacity (tonnes / annum)	Building Footprint (m^2)	Digester, Gasifier or Combustion furnace Footprint (m^2)	Operational Footprint (m^2)
Anaerobic Digestion (AD)	60,000	8,200	690	35,000
	150,000	14,400	960	40,000
Gasification	90,000	4,700		9,000
	190,000	10,500		20,000
Combustion	90,000	24,400	10,000	38,000
	200,000	30,200	10,000	42,000

The 90,000 tonne per annum (tpa) gasification RRF has the lowest building (4,700m^2) and operational (9,000m^2) footprint of all of the facilities. This is followed by a 60,000 tpa AD RRF. Combustion technology (both 90,000 tpa and 200,000 tpa) generally has the largest building and operational footprints of all the technologies with a potential footprint of over 4 ha for the 200,000 tonne option. The 150,000 AD option also has a large operational footprint of 4 ha.

Digesters (AD) and gasifiers/furnaces (gasification and combustion) are important components of each technology and so impose the highest structural loadings. They undertake the biological (AD) and thermal (combustion and gasification) processes. AD has the lowest footprint (690 - 960m^2) and combustion (10,000m^2) the highest. For the purposes of this report the gasifier for gasification technology has been assumed to cover the building footprint due to the large size of the gasifier in relation to the building footprint.

The building and operational footprints (maximum 200,000 tpa combustion and minimum 90,000 tpa gasification) are illustrated in **Maps 2** and **3** respectively.

3.3 RRF Footprint Loadings

Like the RRF building and facility dimensions, floor loadings vary with the technology and specific modules selected. Generally the digesters in AD technology and gasifiers in thermal technology have the highest loadings across the facility. To maintain consistency between each technology type, a typical “general” loading (remaining components of the RRF) has been assigned across all technologies (with the exception of gasification) and specific digester and gasification loadings assigned for each technology type. The RRF footprint loadings selected by Cardno for each technology type and capacity are tabulated below in **Table 6**.

Table 6: Footprint Loadings of each RRF

Technology	Digester / Gasifier/Combustion furnace (kg/m^2)	General Loadings (kg/m^2)
Anaerobic Digestion	33,000	3,000
Gasification	3,400	3,400
Combustion	10,000	3,000

The digesters of the AD technologies exhibit the greatest loadings (33,000kg/m^2) of all the RRFs. Gasification technology exhibits the lowest with approximately 3,400kg/m^2. The general loading across all technologies is approximately 3,000 - 3,500 kg/m^2. Due to the low footprint size of gasification a loading of 3,400 kg/m^2 has been assumed for the whole facility.

3.4 RRF Service Requirements

The variable energy, water and sewerage requirements for each RRF technology have implications on the service requirements that need to be provided to service each of the options onsite. This is also the case for infrastructure in proximity to Red Hill (e.g. power lines). The following subsections detail the service requirements for each RRF technology and the capacity and ability of the Red Hill WMF (and Western Power) to provide these services.

3.4.1 Power Input and Outputs

The power input and output of each technology varies due to the different mechanisms and processes that are employed to power the plant and generate electricity.

AD technologies utilise biological processes to produces a biogas, where it is temporarily stored before being used in gas engines to produce electricity or heat. Gasification technologies convert the carbon-based materials of waste (in the presence of heat and low oxygen) to produce a syngas which is used in steam turbines to produce electricity. Combustion technologies involve the burning of carbon-based materials (in an oxygen-rich environment) to produce hot flue gas which is then used to convert water into superheated steam to generate electricity from turbines.

Whilst each of the technologies produces surplus power that requires export into the electricity grid, each technology also requires power inputs from the existing grid and LPG or natural gas to start-up and maintains the process. The range of energy inputs and outputs exhibited by the proposed RRFs are outlined in **Table 7**.

Table 7: Range of Energy Requirements and Outputs for each RRF type and capacity

Technology	Capacity (tpa)	Start-up Input (KW)	Peak Input (KW)	Output (MW)
Anaerobic Digestion	60,000	300 - 900	330 - 1,200	0.7 – 1.1
	150,000	370 – 1,400	530 – 1,800	0.7 – 1.8
Gasification	90,000	N/A	3,200	5.4
	190,000	N/A	N/A	10.8
Combustion	90,000	1,200	1,600	1.2 - 5.1
	200,000	2,000	2,600	2.4 - 10.2

The maximum peak inputs for electricity it approximately 3,200KW (gasification). The maximum start up requirements is likely to be in excess of 2,000KW for thermal technologies (based on the peak input requirements of gasification). At a minimum, approximately 300KW will be required for 60,000 tpa AD technology. The maximum output of power is from gasification (10.8MW), followed closely by combustion (10.2MW) for the 200,000 tpa options. However, these outputs have been estimated from the 60,000 tpa and 100,000 tpa capacity options presented in the EOI and will subsequently be refined by further liaison with the EOI Respondents.

LPG is also required for some technologies. Unfortunately the units for LPG volumes provide by the EOI respondents are not uniform and cannot be converted into a consistent unit. Certain AD technologies require 315 tonnes of LPG annually for start up and operational requirements. Gasification requires 6,050Nm^3/h natural gas for start up and 720Nm^3/h during peak.

3.4.2 Water and Sewerage Inputs and Outputs

Water is an important resource at the Red Hill WMF, as it is not currently connected to scheme water supply; rather rain water and bore water are required for onsite operations. As particular RRF technologies require water for the process, the servicing of water is an important consideration. The range in volumes of water that may be required for each particular technology and capacity is outlined in **Table 8**.

Table 8: Water Consumption requirements for each RRF technology type and capacity

Technology	Capacity (tpa)	Water Input (kL/annum)	Sewerage Output (m^3/annum)
Anaerobic Digestion	60,000	12,000 - 33,000	2,000 – 5,000
	100,000	19,000 – 53,000	2,000 – 7,000
Gasification	90,000	0	N/A
	190,000	0	N/A
Combustion	90,000	2,000 – 46,000	0 – 3,000
	200,000	4,000– 92,000	N/A

The volumes of water vary considerably between technologies, with the combustion technologies consuming the greatest amount of water (potentially 100,000kL with the 200,000 tpa option). Some technologies also require an avenue for the output of process water of approximately 13,500kL / annum. Stormwater or leachate is likely to be suitable for AD, whilst potable water (with treatment) will be required for combustion.

Sewerage outputs are related to the number of employees that are required on site and outputs from AD technology. The total amount of sewerage that will require processing or disposal ranges from zero in the thermal options (as it can be disposed within the process) to 7,000m^3 per annum for AD.

3.5 Power Supply and Grid Connections

The Red Hill WMF is in close proximity to two high voltage power lines. A 22kV power line runs along the northern boundary (which is currently accessed by Landfill Gas and Power) and a 132kV power line runs along the southern boundary. This provides the EMRC with two options for energy import / export.

The capacity of these lines and the cost to connect is currently uncertain and requires further investigation (which is currently being undertaken by Energy Response in conjunction with Western Power). At this stage, the lower output power AD facilities with less than 2 MVA would be the least costly, whilst the high energy output for the thermal facilities, especially the high capacity facilities would have the highest costs. The cost to connect to the lower voltage power line would also be less expensive than the high voltage.

At present, further information is being sought from EOI respondents in regards to energy outputs for the higher capacity options and technical attributes of their facilities that relate to connecting to the grid. This information will be submitted to Western Power in due course for further assessment. This grid connection assessment, however, does not have a bearing on the overall placement of the RRF.

3.6 Landfill Reclamation

The reclamation of landfill (or landfill mining) has been undertaken in various parts of the world over the past 50 years. The technique was introduced in Israel in 1953 as a method of improving soil quality in orchards. However, more recently it has been pursued to extract resources for recycling and reuse, such as metals, organics and cover material. Machinery that is typically utilised includes excavators and screeners. Magnetic separators and eddy current separators can isolate ferrous metals and aluminium respectively, whilst the screens can separate organics and soil (to an extent).

Advantages of landfill reclamation, in the context of this project, will include the following:

- Reclamation of resources / generation of revenue to offset some of the costs;
- Possible mitigation of an existing contamination source (Site D);
- Reclaimed soil for cover;
- Land value of the landfill area is reclaimed for other uses;
- Sites are not visible from residences; and
- Possible retainment of landfill airspace capacity on the remainder of the site.

The literature review undertaken revealed that energy recovery by the thermal treatment of excavated fractions with sufficient calorific value is feasible. Excavated fractions which still contain a high content of organics can also be moisturised in anaerobic digesters and could generate biogas for energy. This is a potential future option for the EMRC.

Disadvantage of landfill reclamation, in the context of this project, can include the following:

- Managing hazardous materials;
- Poor quality of recovered materials;
- Controlling release of methane and odours;
- Fire and explosion risk
- Controlling subsidence and collapse;
- Increased wear on excavation equipment;
- Occupation Health and Safety; and
- Increased engineering risks in developing the sites to be suitable for the RRF

There are a number of local, national and international examples of landfill reclamation. These are summarised in **Table 9**.

Table 9: Examples of Landfill Reclamation

Jurisdiction	Landfill Facility	Comments
Local (Metropolitan)	Shenton Park	Urban Reclamation
	Herdsman	Urban Reclamation
	Fremantle	Urban Reclamation
Local (Rural)	Cunderdin	Extending Landfill Life Expectancy
	Bruce Rock	Extending Landfill Life Expectancy
	Merredin	6,000 tonnes. Oil and Asbestos located. Not value for money. Cost approx $37,000, Made a return of $10,000 (Metal - $100 / tonne). Depends on Metal

		Prices. Now currently $150 / tonne. $200 / tonne at height of boom. Mostly overburden recovered.
National (N.S.W)	Blue Mountains	Expansion of Landfill Capacity (mining and new cells). Currently undergoing community consultation, desktop and field Investigations. Looking to commence in mid 2011. Mining 100,000 – 200,000m^3. Costing between $25-100 tonne (mining and construction of new cells)
International (U.S.A)	Naples Landfill, Florida	Reduce liability and recover soil
	Edinburg Landfill, New York	Alternative to landfill closure
	Frey Farm, Pennsylvania	Waste to Energy recovery and increase landfill capacity
International (E.U)	Germany, England, Italy, Sweden	

Site-specific conditions will determine whether or not landfill mining and reclamation is feasible. Conditions include: waste composition, history of operating procedures, extent of degradation of waste, types of markets and uses for recovered materials. Methane and odours can be reduced if the existing landfill is subject to aerobic conditions prior to excavation (through trenching or air injection), however this could increase the risk of fire or explosion without sufficient management measures.

3.6.1 Contaminated Sites and Regulatory Approval

A review of the Red Hill WMF Licence (6833/10) suggests there are no conditions or statements that would disallow a disused landfill cell from being excavated. It is likely that a works approvals would also not be required as is could be considered that the excavation would be part of normal landfilling operations at the site. However, it would be prudent for the EMRC to inform the relevant regulatory authorities (i.e. Department of Environment and Conservation) of any activities prior to commencement and prepare a management plan to mitigate the risk or fire, noise, dust and odour impacts.

The existing disused landfill can be considered a contaminated site; however the disturbance on the disused landfill would not have any implications under the Contaminated Sites Act 2003.

3.6.2 Waste Composition of Lot 11

The completed landfill cell under consideration for the RRF site placement is approximately 30 years old and was not operated by the EMRC. The cell was operated by the City of Bayswater prior to the facility being taken over by the EMRC. Therefore, it is difficult to know the composition of the waste disposed, however it can be assumed that 30 years ago the majority of waste was kerbside and drop off MSW and is broadly similar to today's waste.

The volume of materials that will require excavation, an estimate of the cost to excavate and expected revenue is further discussed in **Section 4**.

3.7 Construction over Landfill

Due to the mixed compositional nature of waste and the breakdown of organics through natural degradation, the construction of a structure upon a landfill has a number of engineering difficulties. Any subsidence under a structure can compromise the structural integrity of the building and could cause collapse. Even small subsidence could cause serious operation difficulties for the RRF technologies. However, modern engineering techniques can mitigate such risks and provide a suitable environment for construction. When undertaking an expensive project such as the RRF, the basic consideration is whether the risks associated with the landfill redevelopment outweigh the benefits attained. Some advantages and disadvantages with undertaking this technique are outlined below.

Advantages of construction over landfill, in the context of this project, can include the following:

- Land value of landfill area is reclaimed for other uses;
- Sites C and D are not visible from residences; and
- Possible retainment of landfill airspace capacity on the remainder of the site

Disadvantages of construction over landfill, in the context of this project, can include the following:

- Engineering Costs;
- Ongoing monitoring costs;
- Uncertainty in waste composition;
- Subsidence Risk (non piled areas);
- Road maintenance;
- Liability concerns;
- Risk of breaching the landfill cell liner;
- Foundation Support; and
- Methane Generation

Engineering techniques usually employed to enable construction over landfill involve slab, piles and dynamic compaction. The piles support the structure via drilling through the waste and into the natural earth below which exhibit load bearing capacity. The concrete slab then provides support across the entire facility (supported by the piles). Care would be required if the construction of underground utilities (e.g. electricity) is necessary due to settlement and the potential for the utilities becoming vectors for methane gas into structures. Greater detail in regards to the proposed solution developed by Cardno is discussed in **Section 4.2**.

Landfills generate significant quantities of methane (post closure) through the degradation of organic material by micro-organisms in anaerobic conditions. Methane is considered non-toxic; however it is highly flammable, odourless and is an asphyxiate if it displaces oxygen in an enclosed space. Whilst modern landfills (such as the Red Hill WMF) have landfill gas capture systems that collect a portion of the methane for electricity generation, not all of the gas can be captured and is progressively released into the atmosphere.

Due to the ongoing methane emissions after landfill closure, management measures are required if a populated structure is in close proximity or is constructed over a disused landfill. A number of techniques have been utilised worldwide to prevent methane seepage into buildings. These include:

- Natural air ventilation (300 - 500mm gap beneath the structure);
- Passive methane system including vent layer plus liquid boot spray-applied membrane and methane piping extraction system through the roof;
- Trenching prior to construction;
- Sealants; and.
- Air injection/air curtain systems to move methane away from structures

A passive gas methane membrane and extraction system is estimated to cost $2.50 – $6.00 per sq foot in the United States 2007. This is equivalent to $30 – $80 / m^2 in Australia today. Methane gas monitoring alarms are also available for installation.

There are a number of international examples of buildings being constructed over landfill. No examples of construction over landfill could be located in Australia. International examples are summarised in **Table 10**.

Table 10: International examples of construction over landfill

Country	New Facility	Comments
United States	Lakeside Marketplace (2006)	$51 million facility. Old landfill turned into Retail shopping centre. Methane membrane and piping system. Pilings and slab for support.
	Walkers Brook Retail Complex (2005)	$85 million facility. 36,000m^2 building. Pilings and methane gas extraction system with flare.
United Kingdom	Mullen Mor Housing (2008)	Old landfill used for residential housing
	Newbury Retail Park (2005)	$7 million facility. 3,600m^2 steel frame brick clad building built over landfill. Encapsulated with clay with piled foundations.
	Manchester Retail Park (2003)	$45 million facility. Landfill over 40 year old and 14 metre deep. Vibro compaction, deep dynamic compaction, driven cast piling engineering utilised.

The examples located were predominantly commercial retail complexes with relatively low loadings capacities. No industrial facilities (including RRFs) being constructed over landfills could be located.

3.8 Flight Path Considerations

Westralian Airports Corporation (WAC) has undertaken an assessment under the Airports (Protection of Airspace) Regulations and has concluded that the Red Hill WMF is beneath the Protected Airspace of Perth Airport Runway 24 Approach. This has implications on the allowable height of buildings, stacks and the efflux velocity of gases from the RRF. **Table 11** details the heights of the buildings and stacks.

Table 11: Maximum Heights of each RRF technology in metres and metres AHD at each site.

			Height Building (mAHD) including stack			
Technology	**Height Building (m)**	**Height Stack (m)**	**Site A**	**Site B1/2**	**Site C**	**Site D**
Anaerobic Digestion	15	10	300	315	293	297
Gasification	23	40	325	340	323	324
Combustion	40	80	365	380	358	362

AD has the lowest building height (15 metres) and stack height (10 metres for biogas flare) of the proposed RRF technologies. Combustion has the highest building height (40 metres) and stack height (up to 80 metres).

Regulations set by the WAC stipulate maximum heights of buildings that are allowable within the Perth Airport's flight path approach. The following statement was received by the EMRC on the 20th July 2010.

"At the locations shown in your correspondence the heights above ground level may not be acceptable to Perth Airport. The maximum allowable height for structures on the site should not exceed 368 metres AHD. This structure height must also include the provision of aerials, antenna, lightning arrestors or fixtures to be installed on the building or structure either now or in the future"

The only technology that exceeds 368 metres is combustion at Site B1/2. This is a result of the high stack height of 80 metres being used for the assessment. However, other EOI Respondent combustion technologies have reported that the stack height could be as low as 35 metres, which would comply with the regulations.

Another consideration is the efflux velocity of the gas exiting the stacks. The release of emissions, via the stack, can cause air disturbance and this has implications on aircraft overhead. WAC has stipulated that

"*The level of air turbulence for turbulence caused by an emission from a stack or vent is upward vertical velocity of 4.3 metres per second at the point of emission.*"

The height of 4.3m/s efflux velocity, at the stack exit, for AD (flare) was not available from the respondents. The height of 4.3m/s efflux velocity, at the stack exit, for gasification and combustion ranged between 50 metres and 100 metres respectively, however this needs to be clarified with EOI respondents. Modification of the emission system that is the stack diameter and/or stack height should enable the respondents to comply with the regulations.

4 Engineering Assessment

As discussed previously, a number of factors need to be taken into consideration when undertaking an engineering assessment of a particular site, including, among others, topography, soil bearing capacity, and management measures to provide the required environment for construction. This section details these factors, management measures and cost implications of locating the RRF at the four proposed sites at the Red Hill WMF.

4.1 Red Hill Characteristics

The Red Hill WMF is located upon the Darling Range approximately 25 kilometres north-east of Perth. The 315 ha (Landgate 2010) site comprises of six lots (Lot 1, 2, 11, 12, 82 and 501) that span the boundary between the townships of Red Hill and Gidgegannup. The facility has been in operation since 1981. Operations on site include Class III (Putrescible) landfill, Class IV (Hazardous) landfill, green waste processing, landfill gas extraction and power generation, community waste transfer station, soil remediation, weighbridge, administration and education centre

The current operational footprint is outlined in **Map 1**.

4.1.1 Topography

As the site is located upon the Darling Range and is utilised for landfill, topography of the site is naturally undulating with some considerable height differentials in areas that have been land filled or used for overburden stockpiles. A summary of contour differences for each Lot is outlined below in **Table 12**.

Table 12: Topography of the Red Hill WMF

Lot Number	Lowest (m)	Highest (m)
1	270	302
2	267	303
11	251	286
12	**241**	**304**

The highest point of the site is approximately 304 metres in Lot 12. The lowest point of the site is 241 metres, also in Lot 12, demonstrating the undulating and in some cases steep grades of the site. **Map 3** provides a visual representation of the topography.

4.1.2 Geology

The geology of the site is predominantly made up of two soil types. These include "granites" and "gravel" (DMP 2006). Granites are characterised by fine to coarse-grained, occasionally porphyritic rocks of granite, granodiorite and adamellite composition. Gravels are yellow-brown to reddish brown, loose, fine to coarse, ferruginous pisolites, poorly sorted; variable amounts of sand and silt in matrix, minor recementation; colluvial origin. The granites or gravels soils are distributed unevenly throughout the site. Soil borings have been undertaken by the EMRC over certain proportions of the Red Hill WMF. Generally the soil profile is as follows. Gravel (0 - 0.5m), Lateritic Caprock (0.5 - 1.5m), Sand (1.5 – 2m), Clays (2m - 10m), Granite Bedrock (10m+).

The completed, clay lined, landfill area in Lot 11 is approximately 30 years old and covers approximately two thirds of the Lot and ranges from 10 to 15 metres depth, depending on the contours of the site. The base of the landfill has a 1% gradient, which allows leachate to flow towards two leachate ponds north and south of the landfill.

4.1.3 Past and Future Operations

As outlined in **Section 4.1**, the Red Hill WMF has been utilised for landfilling since 1981. Past, present and future (ready for waste acceptance) landfill areas are outlined in **Map 1**. Due to the ongoing requirement for landfill and economic return to the EMRC, it is envisaged that the majority of the site will be utilised for landfill over time. Future landfill cell locations have not been finalised beyond the recently constructed cell in Lot 12. The EMRC has assessed future landfilling scenarios for the site as an input to this study. These scenarios are further discussed in **Section 4.4**.

4.2 Engineering Considerations

The topographical and geological characteristics of each proposed RRF site influence the engineering requirements, and therefore cost, of locating a facility over a particular location on the Red Hill WMF site. Engineering considerations for the placement of a RRF are outlined below. As Site B2 has been considered late in the process, the engineering requirements have not been undertaken. For the purposes of this report it can be assumed that the engineering requirements are similar to Site B1.

4.2.1 Excavation and Filling

The RRF will require a level ground for construction. As the site is undulating and the RRF facilities are of a considerable size, excavation and/or filling will be necessary for each of the proposed RRF sites. When selecting a particular site within each of the four proposed “areas”, consideration was made to the flattest areas available to minimise civil engineering costs.

As components of the RRF technologies can have high structural loadings, excavation has been minimised where possible for sites A and B1/2 due to the high bearing capacity of the lateritic soil in the upper soil profile (rather than clay). Lateritic soil stockpiles on site will be used for fill in these areas where necessary. In regards to sites C and D (over the disused landfill) excavation of waste and placement of fill to create a level ground was assumed.

Site A and B2 do not require excavation due to the preference to retain the soil profile and import fill. Cardno assumed that Site B1 also does not require excavation; however this will need to be reconsidered at a more detailed design stage to determine if the removal of the clay hardstand used for the green waste facility is desirable. Site C also requires little excavation (1,300m^3 – 5,000m^3) due to the existing waste transfer station footprint. Site D requires the greatest amount of excavation with approximately 4,000m^3 – 42,000m^3 depending on the technology selected. Site A requires the least amount of imported fill (4,000m^3 – 5,000m^3). Sites B1 (assuming the hardstand is retained), B2, C and D all require significant amounts of fill ranging from 5,000m^3 – 66,000m^3.

4.2.2 Piling

Due to the geotechnical characteristics of general refuse in landfill including limited bearing capacity and subsidence due to microbial breakdown of organics in the waste, piling (with pre-drilling) will be required to maintain stability of the RRF structure. The piles require consideration of vertical and lateral pile capacity of the building and the waste in the landfill and also the depth to suitable underlying soil with appropriate bearing capacity.

As discussed in **Section 3.3**, particular components of RRF technologies have high structural loadings. These include the digesters in AD technology and gasifiers or furnaces in gasification and combustion technologies. The bearing loads for the AD digesters selected for this study have very high loadings of approximately 33 tonnes / m^2. This is higher than the bearing capacity of the natural soils within the Red Hill WMF (150 kPa). Therefore, pilings may be required (depending on the AD technology eventually selected) for AD technology regardless of the location onsite. Piling would only be required under the digester and not the remaining building footprint. The bearing capacity of the earth within the Red Hill WMF will be sufficient for the loadings of thermal technologies for Sites A and B1/2.

Piling depth for facilities over the landfill will need to be approximately 20 metres (to granite bedrock), whilst piling depth for the AD digesters over earth will need to be approximately 10 metres (to granite bedrock). Site C is unique in that the digesters and gasifiers or combustion furnaces for each technology can be placed on solid ground in the location of the existing WTS therefore only requiring 10 metre piles for the AD digesters. The remainder of the facility footprints and operational footprints can be located partially over both the WTS (no piling) and over the disused landfill (requiring piling) so reducing costs.

4.2.3 Concrete Slab Foundations

Like the requirement for pilings, the thickness of concrete slab foundations for the RRF will be dependent on the loading of the RRF components and building and whether or not piling is utilised. The range of concrete thicknesses assumed for this study is between 200mm and 300mm. A summary of the concrete thickness for each site and technology is outlined below in **Table 13**.

Table 13: Concrete Slab Thickness assumed for each Site and Technology

	Anaerobic Digestion	Gasification	Combustion
Site A	250mm (digester) 200mm (support building)	200mm (gasifier and support building)	300mm (furnace), 200mm (support building)
Site B1/2	250mm (digester) 200mm (support building)	200mm (gasifier and support building)	300mm (furnace), 200mm (support building)
Site C	250mm (digester support building and general)	<u>90K</u> 200mm (gasifier, support building and general) <u>200K</u> 200mm (gasifier, support building) 250mm (general)	300mm (furnace) 250mm (support building and general)
Site D	250mm (digester support building and general)	250mm (digester support building and general)	250mm (furnace support building and general)

Combustion requires the thickest concrete slab (300mm) for the furnace over sites A, B1/2 and C. Whilst the loading capacity of the digesters is higher than the thermal gasifiers, the required thickness of concrete under the AD digesters (250mm) is reduced due to the use of piles (as discussed in **Section 4.2.2**). A 200mm concrete slab is utilised for the support building across all the technologies for sites A and B1/2 where no piling is required. Due to the nature of the soil profiles in Site C and D, the concrete slab thickness varies between 200mm and 300mm depending on loadings and the use of piling.

Particular concrete foundation requirements and cost are further discussed in **Section 4.3**.

4.2.4 Methane Extraction System

Feedback from the EMRC and literature investigated, suggests that the completed landfill cell in Lot 11 (the location of sites C and D) is still producing methane from the biological breakdown of waste. Due to the health considerations outlined in **Section 3.7**, a methane extraction system (in addition to that already constructed by Landfill Gas and Power) will be required. The system proposed includes an impervious membrane (sealing the building) and plastic piping system that captures methane under the building and vents (or flares) it into the atmosphere, thus diverting methane away from the building.

Particular methane extraction system requirements and costs are further discussed in **Section 4.3**

4.3 Engineering Cost Estimates

The engineering cost estimates for each site and technology are outlined below. Sites A and B1/2 do not require abnormal foundations and building slabs, so the costs of these elements are accommodated within the current cost estimates for the RRF. Sites C and D require piling and slab designs related to construction over the landfill. The current cost estimates for the RRF do not make allowance for the associated extra cost. For comparative purposes, the engineering costs for all sites have been estimated to a common base of building slab and with suitable support areas.

4.3.1 Unit Rates Utilised

The cost unit rates assumed for each of the engineering elements are outlined below in **Table 14**:

Table 14: Assumed Unit Rates

Description	Task	Unit Price per/m^3	Unit Price (each)
Excavation of Landfill	Remove and Stockpile (inclusive of other management measures)	$20	
	Screening	$5.50	
	Remove and Dispose (inc trucking)	$6.80	
	Place, Compact and Airspace Consumed	$53	
	TOTAL	**$85 / m^3**	
Backfilling	Clean Fill	$6.80 / m^3	
Piling	10 metres		$3,610
	20 metres		$7,220
Concrete	Grade 32MPa	$262.50 /m^3	
Methane Extraction System	Membrane and piping extraction system (not required if waste removed to liner)	$80 / m^2	

As no excavation is required for Sites A and B1 (assuming the green waste areas clay pad does not need removal) and B2 only excavation of the landfill is required for sites C and D.

4.3.2 Engineering Cost Summary

The engineering cost summary for each technology (and capacity) for each proposed RRF site is outlined below in **Table 15**.

Table 15: Engineering cost summary for each site and technology ($)

	60,000 tpa AD	150,000 tpa AD	90,000 tpa Gasification	90,000 tpa Combustion	200,000 tpa Gasification	200,000 tpa Combustion
A	$980,000	$1,600,000	$560,000	$2,700,000	$1,300,000	$3,100,000
B1/2	$1,200,000	$1,800,000	$620,000	$2,900,000	$1,400,000	$3,500,000
C	$9,700,000	$11,100,000	$2,000,000	$11,100,000	$5,300,000	$12,300,000
D	$14,200,00	$16,300,000	$4,500,000	$16,600,000	$6,700,000	$18,500,000

Site A has the lowest site engineering costs overall, ranging between $560,000 - $3,100,000, followed closely by Site B1/2 ($60,000 - $400,000 cost increase). Due to Sites C and D being partially or completely over landfill, the engineering costs are significantly higher ($2,000,000 - $18,500,000).

Gasification has the lowest site costs due to the technology exhibiting a relatively small footprint and loadings. AD and combustion exhibit similar (yet high) costs due to the large footprints, piling for AD digesters and thick concrete slab (300mm) for the combustion furnace.

4.4 Airspace Value Estimates

As the proposed RRF sites are to be located in areas that are envisaged to be utilised for possible further landfilling in the future, the value of the estimated loss of landfilling airspace has been estimated. As a final development plan for the Red Hill WMF has not yet been adopted, a number of potential development scenarios have been prepared by the EMRC for the Red Hill WMF. To assess the impact of the RRF on Red Hill WMF, the scenarios have been developed, exclusive and inclusive of the RRF. These scenarios are summarised below in **Table 16**.

Table 16: Landfill and RRF Site Placement Scenarios

Scenario	Landfill Lots	Green waste	Transfer Station	RRF	Height
1	1, 2, 11 and 12	N	N	N	360
1a	1, 2, 11 and 12	N	N	N	340
2	1, 2 and 12	N	Y / N	Y / N	360
3	1, 2, and 12	Y / N	Y	Y	340
3a (north west Lot 12)	1, 2,11 and 12	Y / N	Y	Y	340
4	1, 2, 11, and 12	Y / N	N	Y	340
5	12	N/A	N/A	N	335

Note: N means the facility has not been included in the scenario; Y means that the facility has been included in the scenario; and Y/N means it is may not be possible to include the facility in the scenario.

360m AHD is approaching the 368mAHD limit set by WAC and may have regulatory implications during cell capping and revegetation

The proposed Hill Spine Road and required buffer to residences will prevent the landfill expanding further east.

Some of the development scenarios make no provision for retaining the transfer station and the current green waste processing area. Alternative transfer stations could be provided for the public at other locations away from Red Hill WMF, such as in Hazelmere and Gidgegannup. These would be in addition to the current facilities within the Shires of Mundaring and Kalamunda. The green waste processing area could potentially be accommodated in the vicinity of the RRF site if green waste processing continues to be undertaken.

When estimating the total airspace loss for each RRF footprint, the EMRC did not just consider the airspace loss above the facility, but the total airspace loss when taking into account the impact on the overall engineered contours of the site. A summary of the total airspace loss for each technology and the remaining capacity is outlined in **Table 17**. These estimates and their viability are further discussed in **Section 5**.

Table 17: Total airspace loss (m^3) for each RRF capacity option for each proposed site.

	60K AD	150K AD	90K Gasification	90K Combustion	200K Gasification	200K Combustion
A	3,430,000 m^3	3,760,000 m^3	1,530,000 m^3	3,760,000 m^3	2,720,000 m^3	3,900,000 m^3
B1	3,722,000 – 8,006,000 m^3					
B2	1,788,000 m^3					
C	3,722,000 – 4,284,000 m^3					
D	3,722,000 – 4,284,000 m^3					

Note: Technology options were only assessed by the EMRC for Site A. Site B1/2 is based on a worst case scenario of 200K combustion plant.

Site B1, C and D provide a best - worst range due to multiple scenarios having an impact on airspace loss

Siting the RRF at Sites B1, C and D has the potential to have the highest airspace volume implications. Site B1 is located at the maximum AHD and this affects the overall engineering and maximum airspace capacity of the landfill. Site B1 has the highest airspace loss of all sites of 8 million m^3. Sites C and D could also have high losses of approximately 4.2 million m^3. The large ranges in total airspace loss depend on the comparative scenario. The high airspace losses for the sites are based on the assumption that it would be possible to place additional waste over Lot 11 (which is currently experiencing leachate leaking issues).

Sites A and B2 with smaller footprint facilities (e.g. 60,000 tpa AD and 90,000 tpa gasification) have the lowest implications on airspace capacity due to the facility being located at the edge of the landfill area. Site B2 potentially has the lowest airspace loss of all sites of 1.78 million m^3 with a 4 ha (combustion) site under a particular scenario.

Placing the RRF in the north-west corner of Lot 12 (scenario 3a) when compared to the current green waste area (scenario 3) has a maximum 6.22 million m^3 airspace saving.

As the loss of airspace is directly correlated with the cost, there are obvious implications for the EMRC. The cost of the airspace loss for each site option is outlined in **Table 18**.

Table 18: Value of airspace loss for each RRF option for the proposed sites (based on $25/m3).

	60K AD	150K AD	90K Gasification	90K Combustion	200K Gasification	200K Combustion
A	$85,700,000	$94,100,000	$38,200,000	$93,900,000	$68,100,000	$97,500,000
B1	$92,500,000 - 200,150,000					
B2	$44,700,000					
C	$92,500,000 - 107,100,000					
D	$92,500,000 - 107,100,000					

Note: The costs for Sites B1, B2, C and D are based on a 200K combustion facility.

Sites B1 and C / D have considerable cost implications, whilst Site A and B2 has the least. The difference in airspace cost is approximately $60 million depending on the technology and capacity for Site A.

4.5 Value of Airspace saved by RRF Operations

Whilst the placement of the RRF has implications on the available airspace at the Red Hill WMF, the RRF offsets this to an extent by reducing the amount of waste requiring landfill. **Table 19** summarises the potential airspace saving over a 20 year period for each RRF technology and capacity.

Table 19: Airspace Retention from Implementation of RRF Technology

	Capacity	Diversion	Tonnes (annual)	Tonnes (20 years)	Cubic Metres (20 years)	Airspace Cost Saving
AD	60,000	90%	54,000	1,080,000	900,000	$22,500,000
AD	150,000	70%	105,000	2,100,000	1,750,000	$43,750,000
Gasification	90,000	90%	81,000	1,620,000	1,350,000	$33,750,000
Combustion	90,000	90%	81,000	1,620,000	1,350,000	$33,750,000
Gasification	200,000	90%	180,000	3,600,000	3,000,000	$75,000,000
Combustion	200,000	90%	180,000	3,600,000	3,000,000	$75,000,000

The large thermal technologies, diverting the highest amount of waste will have the greatest airspace cost saving of approximately $75,000,000.

5 Discussion

There is no optimal location for the RRF at the Red Hill WMF due to a number of constraints on site. There is added complexity due to the RRF having impacts on the potential future airspace of the landfill in the long term. This requires finding a balance between envisaged landfilling operations on site, the necessity to move towards resource recovery, reducing engineering costs, having access to services to operate the RRF and minimising the social impacts on the surrounding community. This section outlines the advantages and disadvantages of each proposed site based on economic, social, technical, environmental, operational and regulatory criteria.

5.1 Economic

Economic considerations for the placement of the RRF include civil / structural engineering costs, the future loss of potential airspace and availability of utility services for the sites.

As discussed in **Section 4.3**, Site A would require the least amount of structural and civil engineering costs, followed closely by Site B1/2. The cost estimates for site development for Sites C and D are higher than Sites A and B1/2 and need to be interpreted giving consideration to the unknown issues such as the composition of the disused landfill and existing soil conditions. The higher costs limit the desirability of these sites of host the RRF. The distance to services (i.e. powerlines, water supply access) varies between the sites; however, the cost differences relative to other costs are not significant. Therefore, the key remaining economic factor for determining the preferred site location is the impact on landfill airspace. The value of the airspace at the Red Hill WMF will become increasingly important as existing landfills in close proximity to the Perth metropolitan area become exhausted.

The completed landfill cells in Lot 11 are leaking leachate due to an apparent breach of the clay liner. The EMRC is required to take measures to contain the leachate on the site as the leachate has contaminated groundwater within the adjoining John Forrest National Park to the south in the past. It is undesirable to add more landfill to Lot 11 while this leak continues. It is also unlikely that approval will be given from the DEC for this to occur. If this is the case, landfill scenarios 1, 1a, 4 and 6 will not be feasible. For the purpose of this study, it has been assumed that these scenarios are not feasible.

As Sites C and D both lose high amounts of airspace and incur high engineering costs these sites should not be considered any further. Based on these conclusions, the remaining operational scenarios (2, 3, 3a and 5) are left for consideration together with Sites A and B1/2.

Scenarios 2, 3, 3a and 5 have similarities in that they do not involve additional landfilling in Lot 11 on top of existing landfill cells. Scenario 2 includes maximising landfilling within Lots 2, 1 and 12 while retaining the WTS on the western boundary of Lot 2. Scenario 3 is similar to scenario 2; however the current green waste processing facility is retained. Scenario 3a the green waste area / RRF area is pushed further north. Scenario 5 assumes that additional landfilling over the existing cells in Lots 1 and 2 will not occur and that landfilling in Lot 12 will be maximised.

As the final landform in the eastern half of the landfill cells in Lot 12 is similar for each of scenarios 2, 3, 3a and 5, the RRF located at Site A has a similar impact on these scenarios. Site A is located on the eastern edge of the proposed landfill area in Lot 12, immediately to the west of the proposed Hills Spine Road.

The EMRC has estimated that loss of airspace for Site A with the landfilling scenarios as are shown in **Table 20.**

Table 20: Total Airspace Loss for Site A under scenarios 2, 3, 3a and 5

Scenario	Total Airspace Lost (m^3)
2	1,500,000 – 3,900,000
3, 3a and 5	1,200,000 – 3,000,000

If Site B1, located on or near the current green waste processing area, was adopted, then the loss of future airspace has been estimated by the EMRC to be shown in **Table 21**.

Table 21: Total Airspace Loss for Site B1 under scenarios 2, 3, 3a and 5

Scenario	Total Airspace Lost (m^3)
2 and 3a	7,400,000
3 and 5	Nil

If Site B2, located in the north-west corner of Lot 12, was adopted, then the loss of future airspace has been estimated by the EMRC to be shown in **Table 22**.

Table 22: Total Airspace Loss for Site B2 under scenarios 2, 3, 3a and 5

Scenario	Total Airspace Lost (m^3)
2, 3 and 5	1,790,000
3a	Nil

The loss of future airspace for Site B1 would be significantly greater (up to 8,000,000m^3) if scenarios 1, 1a, 4 and 6 were acceptable. This is due to the ability to achieve a higher finished surface level over the landfill areas due to the larger footprint.

If Site B1 was adopted for the RRF, it would be possible for the EMRC to decide subsequently if it was to adopt landfill scenarios 2, 3, 3a or 5. The available future landfill airspace with these scenarios is shown in **Table 23**.

Table 23: Total Available Airspace for Sites A, B1 and B2

Scenario	Available future airspace for Site A (m^3)	Available future airspace for Site B1 (m^3)	Available future airspace for Site B2 (m^3)
2	26,700,000 – 29,100,000	23,200,000	28,800,000
3	20,200,000 – 22,000,000	23,200,000	21,400,000
3a	26,400,000 – 28,200,000	25,700,000	29,500,000
5	11,200,000 – 13,000,000	14,200,000	12,400,000

The above analysis illustrates that there are advantage and disadvantages of locating the RRF at particular sites under different scenarios. Sites A and B2 are preferred for scenario 2. Site B1 is preferred for scenarios 3 and 5. This is largely due to the assumption that the green waste facility must remain in its current position, when it could potentially be located at an alternate location on sight with appropriate topography. The greatest available future airspace, overall, is potentially Site B2 with approximately 29.5 million cubic metres of available airspace.

Preferred Economic Option: Site A or Site B2

5.2 Social

The social impacts under consideration for the placement of the RRF include proximity to residences, modification of the amenity value of the site and landfill excavation requirements. Amenity value is particularly related to the height of the landfill or RRF infrastructure including stack (for thermal technologies) in addition to noise and odour. There are particular sensitivities in proximity to the Red Hill site due to it being in a rural "hills" setting and limited commercial or industrial facilities being in the vicinity of the site (with the exception of the extraction industries).

Due to the existing topography of the site, Site C and D can be considered the best sites for amenity as they are screened from view from residents surrounding the Red Hill site and are farthest away from residents. However, as significant excavation requirements are required to achieve structural stability there could be the potential for odour impacts if not properly managed.

Site A is exposed on the cleared farm and is close to multiple residents (520 metres minimum). Site B1 is also in close proximity to a single resident (550 metres) to the north; however it is screened naturally by vegetation to the north and east. Site B2 is in closest proximity to a residence (400 metres) and could also be screened by vegetation.

Preferred Social Option: Site C or Site D.

If sites C and D are not acceptable, then Site B1 is preferred over Site A.

5.3 Environmental

As the site is an active landfill and is predominantly cleared of vegetation, the environmental value of the site has been diminished over time. No remnant vegetation will need to be cleared for any of the proposed sites. The potential environmental impacts of excavating or filling Lot 11 (Site C and D) is difficult to determine without further field analysis, however it is likely that odour, leachate, dust and explosive risk could be issues if a RRF was constructed or further landfilling was undertaken.

The close proximity of Sites A and B1/2 to residents may also have implications in respects to required buffers for thermal technologies (based on the recommended buffer distances stipulated by the EPA), however this will be further investigated through odour, noise and air emission modelling through the Environmental Approvals process.

Preferred Environmental Option: Site A or Site B1/2

5.4 Technical

As discussed earlier, placing the RRF over a disused putrescible landfill has a number of technical challenges due to structural stability, methane production, unknown landfill composition and requirements to excavate (landfill mine) a proportion of the landfill. Whilst technically possible to undertake the remediation and engineering works required placing the RRF at Site C or D it would be extremely risky and would not be cost effective. If the EMRC were to choose the route of construction of the RRF over the landfill it would be considered world leading as no examples of high load bearing industrial facilities have been identified during this study.

Sites A and B1/2 have some site work requirements that would be necessary due to the undulating nature of the site, however the engineering procedures could be considered routine in the construction industry.

Preferred Technical Option: Site A or Site B1/2

5.5 Operational

There is some uncertainty as to the future operational characteristics of Red Hill. The realignment of Toodyay Road / Perth to Adelaide Highway, the introduction of the proposed Hills Spine Road, the potential for the waste transfer station being located offsite in Hazelmere and / or Gidgegannup, the future need for the Class IV cell and the various landfilling scenarios proposed all need to be taken into consideration. If the status quo is assumed in the short term, all proposed sites have no issue with accessibility. Existing sealed road networks can service Sites B1/2 and C, whilst new sealed roads would be required for Sites A and D.

The proposed scenarios have implications on the services that the Red Hill WMF can provide. With the exception of scenario 3 and 5, the scenarios do not allocate space for the waste transfer station, green waste facility and / or the RRF.

As Site B1 is currently the location of the existing green waste facility, this will have an effect on current green waste operations, however due to the large size of the current green waste footprint (greater than 4 hectares), it is possible that the RRF and green waste facility could be integrated, especially if 3 bin AD technology was selected and the City of Bayswater current green waste was diverted to the RRF.

The placement of the RRF at Site C would result on the loss of the current waste transfer station. Sites A, B2 and D provide the possibility of retaining all existing infrastructure and are accessible.

Preferred Operational Option: Site A, B2 or D

5.6 Regulatory

Red Hill is in a flight path for aircraft entering the Perth domestic and international airports. Westralia Airport Corporation (WAC) has set regulations that require structures to be less than 368 metres in these flight paths. WAC also sets maximum efflux velocities for facilities that have emissions from a stack. WAC has concern with some of the heights and efflux velocities nominated by the EMRC. The maximum heights have subsequently been refined by Cardno under the engineering assessment utilising AutoCAD to accurately determine contour lines and a “worse case” building height and stack height scenario. Site B1/2 has the highest elevation on site and this could potentially have issues for thermal technology with a stack height of 80 metres, however a thermal plant with a reduced stack height (nominated by other EOI respondents) would comply under the regulations. It is likely that stack height for the particular respondent with a stack height of 80 metres could be modified to achieve the WAC requirements. In regards to efflux velocities, the likelihood is that all proponents could comply with WAC regulations for efflux velocity, at stack exit.

The EMRC should also consider the impact the final finished surface of the landfill surface under each of the scenarios. The maximum height is 360 metres under scenarios 1, 2 and 6 and is reasonably close to the maximum height of 368 metres stated by WAC flight path regulations.

Preferred Regulatory Option: All Sites

6 Consideration of Lot 8 (Midland Brick site)

6.1 Introduction

Communications between the EMRC and Midland Brick in the past have suggested that the clay excavation areas on Lots 8, 9 and 10 could potentially be acquired by the EMRC when the targeted clay has been exhausted. A recent meeting between Midland Brick and the EMRC confirms that the target clay in Lot 8 has become exhausted and Midland Brick is willing to commence negotiating terms of the transfer of ownership. This presents the opportunity for the EMRC to acquire the site and add an additional RRF location option. Due to this additional option (Site E) only recently coming into consideration, it has not been incorporated into earlier sections of the report. This section presents information in regards to the attributes of Site E including proximity to residences, engineering, airspace value, flight path considerations and access. It also presents a summary of the economic, social, environmental, technical, operational and regulatory impacts.

6.2 Lot 8 Description

Lot 8 is currently owned by Midland Brick and is located approximately 350 metres from the western boundary of Lot 11 (owned by the EMRC). Lots 9 and 10, also owned by Midland Brick are located between Lot 8 and 11. The site has been completely cleared of vegetation for clay extraction purposes. A figure of Lots 8, 9 and 10 in relation to the Red Hill WMF and Site E is presented in **Map 4**. The past use of Lot 8 was for the extraction of clay for use in brick manufacture at Midland Bricks operations in Middle Swan. At present Lot 8 varies considerably in topography (251m – 278m AHD) due to excavations across the site.

6.3 Proximity to Sensitive Landuses

For the purposes of this assessment Site E has been assumed to be located in the most southern portion of Lot. Based on the largest combustion building footprint size, the closest residence is approximately 1,200 metres south-east. This residence is also the closest to Sites C and D. An amphitheatre, currently being constructed, is located approximately 970 metres to the west of Lot 8. Overall Site E is the farthest from any sensitive land uses of all the proposed RRF site location options.

6.4 Engineering Considerations

As noted above, Site E has been nominated as a potential site late in the site selection process. Due to time limitations, a detailed engineering assessment has not been undertaken; however it can be assumed that due to a number of the steep gradients of the Lot, caused by excavations, larger footprint technologies will require substantial recontouring, when compared to Sites A and B1/2. Structural engineering requirements, such as piling and the concrete slab, are likely to be similar to Sites A and B1/2. As the lateritic gravel profile has been removed from the surface soil profile, exposing the underlying clay, a thicker slab may also be required. These structural engineering costs are therefore likely to be of a similar magnitude to those of Sites A and B1/2.

6.5 Airspace Value

Locating the RRF in Lot 8 (the western portion of the existing Midland Brick quarry), provides the opportunity to maximise the future airspace capacity of the Red Hill WMF, assuming that the remainder of the Midland Brick site is used for landfilling. The EMRC estimates that approximately 40.4 million m^3 is available across the Red Hill and Midland Bricks sites (assuming Lot 11 is also reused). Excluding Lot 8 from this total has not been calculated, however would not be significant when compared to the scenarios outlined in **Section 4.4**. Site E will allow the EMRC greater flexibility in how it operates the current landfill and locates future landfill cells.

6.6 Regulatory

As outlined in **Section 6.2**, the topography of Lot 8 varies between 251 and 278 metres. This is well below the maximum building height of 368 metres nominated by WAC as the allowable upper limit. Whilst it would be prudent to confirm with WAC the height limit for Site E, it is unlikely locating the RRF with Lot 8 would have any implication on aircraft approaching the airport.

6.7 Access and Servicing

Site E is in close proximity to the existing power lines located on the northern and southern boundary of Lot 8; however access to water will need to be further investigated by the EMRC. Lot 8 has the benefit of heavy haulage access from Toodyay Road due to the existing extraction operations. It would be possible to provide the RRF with a separate access to that for the current Red Hill WMF operations

6.8 Summary

Whilst not investigated to the extent of Sites A - D, Site E has been found to have a number of benefits for the location of the RRF. The major benefits include increased proximity from residences (social), limited impact on future landfilling operations (economic), no impact on vegetation or existing leachate systems (environmental), or current operations (operational). Site E also does not have access or servicing issues. Some potential limitations for Site E include the cost to provide a suitable foundation for the RRF (technical) and the upfront cost to acquire the site, however it is likely these limitations can be overcome will be offset by a gain in landfill airspace at Red Hill. Another limitation is potentially the zoning of land under the local town planning scheme. This needs to be further investigated.

7 Conclusion

This study has illustrated that there are a number of factors that need to be considered when locating the RRF within the current Red Hill WMF footprint. Some of these factors have been found to place limitations on the satisfactory placement of the RRF.

An assessment of the economic, social, environmental, technical, operational and regulatory attributes of each proposed locations suggests that within the EMRC Red Hill operations Site B2 (north-east corner of Lot 12) is the preferred site for the location of the RRF. Whilst Site B2 has some limitations in regards to loss of future airspace and proximity to a residence it is considered the best site overall within the current Red Hill footprint.

The study has also found advantages with the option of locating the RRF on the western portion of the adjoining Midland Brick site (Site E), located to the west of the Red Hill WMF current operations. If this site (Lot 8) is considered, then it becomes an attractive option due to it resolving some of the issues with Site B2, namely airspace loss and proximity to residences. Before Lot 8 can be confirmed as the overall preferred site, the EMRC needs to progress negotiations with Midland Brick in regard to the acquisition of the site and conduct further investigation into the engineering requirements for the site.

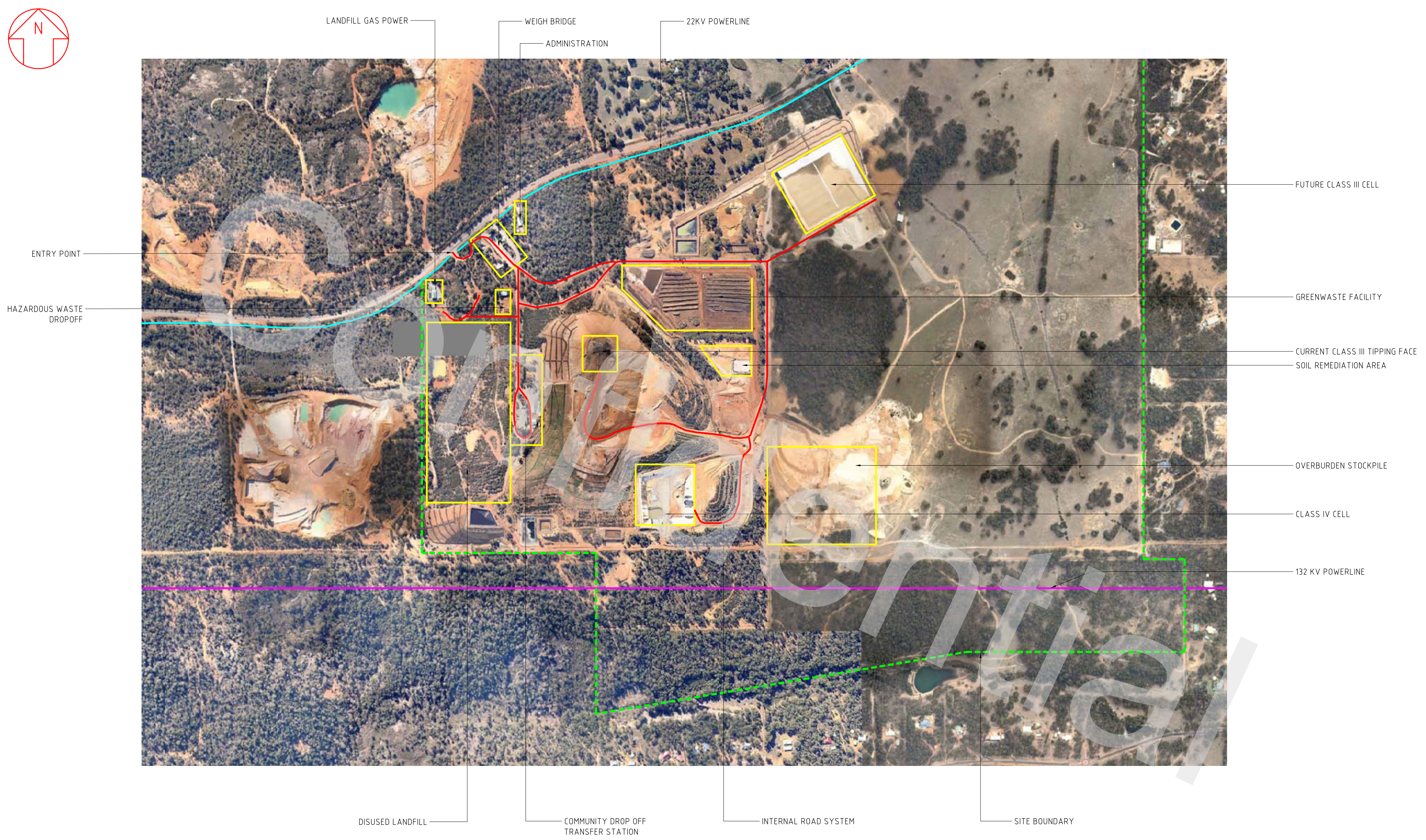
Map 1: Current Operations at Red Hill

Map 2: Building Footprints and Distance to Residences

Map 3: Operational Footprints and Topography

Map 4: Building Footprints and Distance to Residences (including Site E – Midland Brick)

Maps



Rev	Date	Description	Drn	Chk	Dsgn	D.Chk	App	Drawing No	Reference Drawings
A	18.05.10	ISSUED FOR REVIEW						-	-

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Drawn: RJJ Date: 18.05.10
Checked / Date
Designed / Date
Design Checked / Date
Approved / Date

Client: EMRC

Title: RESOURCE RECOVERY FACILITY
SITE PLACEMENT STUDY
MAP 1
CURRENT OPERATIONS

Units: MILLIMETRES UNO
Scale: 1:2500
Size: A1
Drawing Number: 1111-057-010101
Revision: A

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XREF's: 2008-01-053 - Red Hill Drilling Map
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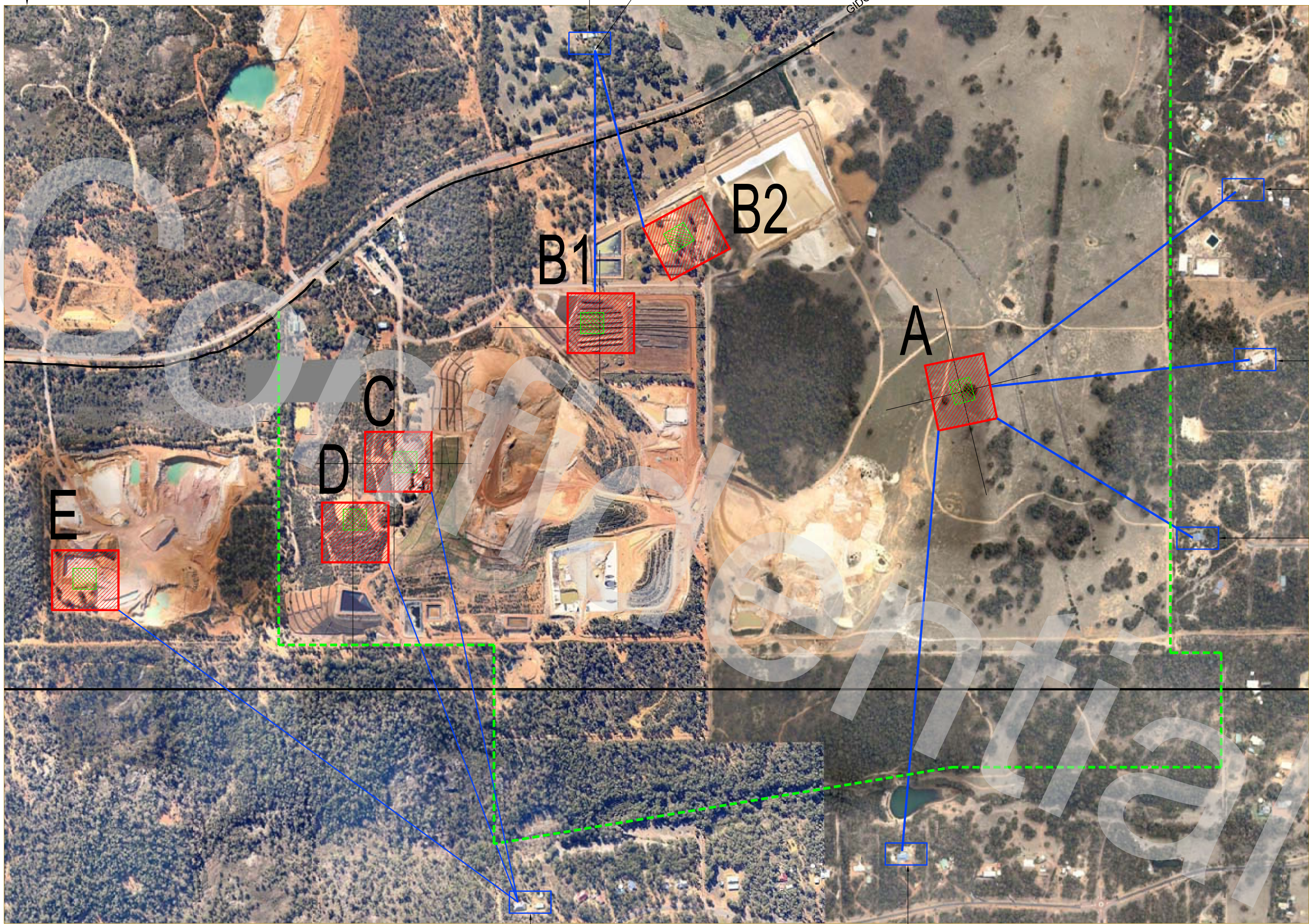
DATE PLOTTED: 05 August 2010 - 9:18am BY: ben.tasker

N

90K GASIFICATION - 4700m²

200K - COMBUSTION - 30200m²



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XREF's: 2000-01-053 - Red Hill Drilling Map; 2000-01-106 - Red Hill Existing Conditions Base Sheet

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Rev	Date	Description	Drn	Chk	Dsgn	D.Chk	App	Drawing No	Reference Drawings
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Date	18.05.10
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Design Checked	
Approved	
Client	EMRC
Title	RESOURCE RECOVERY FACILITY SITE PLACEMENT STUDY MAP 4 BUILDING FOOTPRINTS/RESIDENTS
Units	MILLIMETRES UNO
Scale	1:2500
Size	A1
Drawing Number	1111-057-010102
Revision	A

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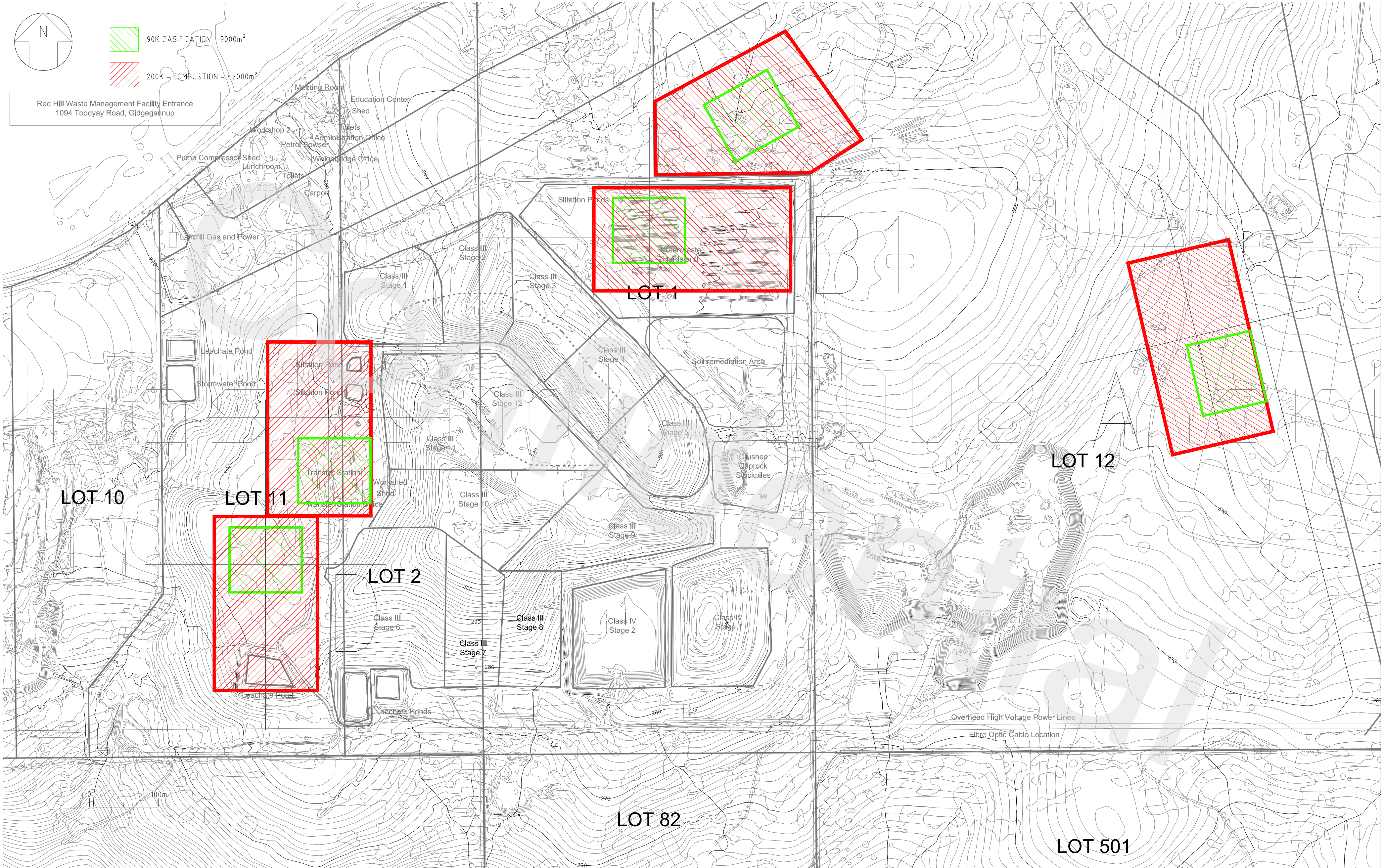

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Drawing No	Reference Drawings
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Drawn	RJJ
Date	18.05.10
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Design Checked	
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Client	EMRC
Title	RESOURCE RECOVERY FACILITY SITE PLACEMENT STUDY OPERATIONAL FOOTPRINT AND TOPOGRAPHY MAP 3
Units	MILLIMETRES UNO
Scale	1:2500
Size	A1
Drawing Number	1111-057-010103
Revision	A

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DATE PLOTTED: 02 November 2010 - 3:32pm BY : macalister.walton

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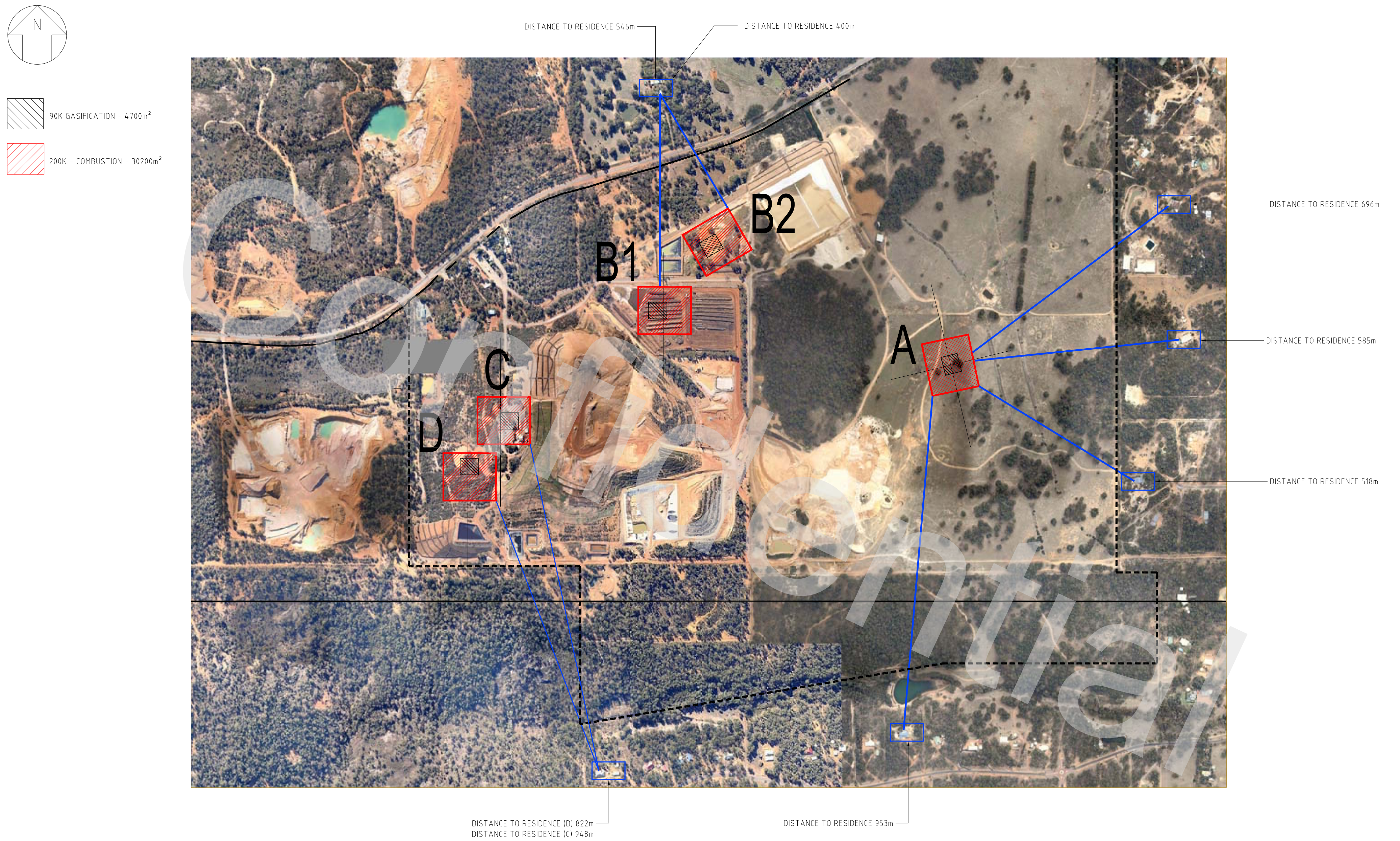

Rev	Date	Description	Drn	Chk	Dsgn	D.Chk	App	Drawing No	Reference Drawings
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Checked — Date
Designed — Date
Design Checked — Date
Approved — Date

Client: EMRC

Title: RESOURCE RECOVERY FACILITY
SITE PLACEMENT STUDY
MAP 2
BUILDING FOOTPRINTS/RESIDENTS

Units: MILLIMETRES UNO — Scale: 1:2500 — Size: A1
Drawing Number: 1111-057-010102 — Revision: A

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DATE PLOTTED: 04 November 2010 - 8:43am BY : macalister.walton

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