Chapter 14

Soils and land contamination

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Chapter 14 Soils and land contamination

The Secretary's environmental assessment requirements for the Narrabri Gas Project include a requirement to assess potential impacts on soils, such as erosion, salinity and contamination. A number of detailed assessments were undertaken in response to this requirement, including an interpretive soils report (refer to Appendix I1), contaminated land assessment (refer to Appendix I3) and concept design and assessment of reuse of the treated and amended water in irrigation (refer to Appendix G2). This chapter draws on those studies to provide an overall assessment of the potential impacts of the project on soils.

The key findings of the impact assessment in relation to soils and land contamination were:

- the soil in the project area is limited in its fertility and productive capacity
- there is no biophysical strategic agricultural land (BSAL) in the project area
- treated and / or amended water would be beneficially reused in the project area for irrigation, dust suppression, stock watering, and drilling and construction activities
- the overall risk of interacting with existing land contamination was also assessed to be low.

The limited fertility of soil in the project area is evidenced by around only seven per cent of the project area being historically cropped (OEH 2014).

A site verification certificate acknowledging the absence of BSAL in the project area was issued by the NSW Department of Planning on 1 December 2015 (refer to Appendix I2).

The key potential impact of construction activities was assessed to be potential loss of soil through water and / or wind erosion, and associated degradation of soil fertility. The degree of potential loss or degradation would be low with the implementation of drainage, erosion and sediment controls. Areas with pre-existing land contamination or sources of potential land contamination were identified. The overall risk of interacting with land contamination was also assessed to be low.

The main potential impact during operation would be the accumulation of salt in soil at the treated water irrigation area. Potential impacts of irrigation would be readily managed through:

- the use of treated water with salinity levels up to three times lower than root zone salinity levels measured during background monitoring
- appropriate site selection
- preparation of an Irrigation Management Plan
- ongoing monitoring.

All of the above are activities entirely consistent with typical irrigation management practices.

Potential spills or leaks were also considered during construction and operation but were considered readily avoided, mitigated and managed. Spills or leaks from equipment (including vehicles) would be unlikely, localised and readily controlled and remediated. Significant losses of produced water or drilling fluid were considered very unlikely given engineering controls that would form part of the project in accordance with relevant guidelines and standards. Drilling fluid would be monitored to detect losses while leak detection / monitoring systems would be in place to detect losses of produced water. The identification of loss would trigger corrective action and remediation.

The environmental significance assessment undertaken for soil and land contamination showed that implementation of mitigation and management measures and relevant design elements would be sufficient to effectively control and minimise the potential impacts of the project with regard to soils and land contamination. Residual risks associated with:

- erosion would be effectively minimised by drainage, and erosion and sediment controls
- soil salinity in areas subject to irrigation or dust suppression would be effectively minimised by standard monitoring and management, including alteration of irrigation or dust suppression regimes as required
- spills or leaks would be managed through spill awareness and response procedures.

When referring to treated and amended water in this chapter, treated water would be used for dust suppression in forested areas while amended water would be used for dust suppression in the agricultural areas to preserve or potentially improve soil quality by addition of gypsum. Only amended water would be used for irrigation activities in the agricultural areas.

14.1 Methodology

The following tasks were undertaken to describe the existing environmental values of the project area and assess the impact of the project with regard to soils and land contamination:

- undertaking a soil survey on cleared land within the project area
- preparation of a site verified interpretive soils report (refer to Appendix I1)
- verification of the project area for BSAL (refer to Appendix I2)
- preparation of a site-verified contaminated land report (refer to Appendix I3)
- preparation of an irrigation concept design (refer to Appendix G2)
- identification of the potential impacts of the project on environmental values, and development of mitigation and management measures to control those impacts.

The report contents were collectively considered and holistically applied to the proposed activities, and to the construction and operation of major facilities and gas field infrastructure under the project, in order to assess potential impacts to soils within the project area.

The soil survey was carried out to provide a detailed understanding of soil types and their limitations. The soil survey focused on the northern (predominantly agricultural) part of the project area. Soil types in forested areas were identified from prior investigations, interpretation of desktop information, and sampling sites in cleared areas within the forest. A BSAL assessment was undertaken in accordance with the *Interim Protocol for Site Verification and Mapping of Biophysical Strategic Agricultural Land* (the interim protocol; NSW Government 2013a). The adopted scale and survey effort was considered appropriate due to the low risk of BSAL occurring in the project area (refer to Section 14.2.2), the perceived complexity of soil variation, the previous BSAL work completed in the project area, and the relatively limited and diffuse surface disturbance proposed for the project.

Further details regarding field survey effort and soil landscape modelling are provided in Appendix I1.

Pre-existing land contamination or sources of potential land contamination in the project area were assessed through a review of State agency records, aerial photography and a field assessment.

Irrigation of treated and amended water was assessed through development of a conceptual design of the irrigation area and development of a water balance model. A nominal 500-hectare reference irrigation area was determined from an irrigable land survey of the project area, including a review of available literature, maps, aerial photography, geographic information and soil survey data. Discussions with local agronomists, agri-businesses and farmers were carried out to determine suitable crops to grow at the irrigation area. The water balance model was employed to simulate the operation of the irrigation area.

Potential soil impacts were identified based on the detailed assessments mentioned above, including potential for erosion in relation to soil type, potential for interaction with pre-existing land contamination, and potential for increased salinity as a result of irrigation of treated and amended water.

Potential impacts were classified in accordance with the significance assessment methodology outlined in Chapter 10. Potential impacts were therefore classified based on a combination of the magnitude of the potential impact and the sensitivity of the potentially impacted environmental value.

Detailed methodologies for the interpretive soils report (including soil survey and landscape modelling), contaminated land report and irrigation concept design are provided in Appendix I1, Appendix I3 and Appendix G2 respectively.

14.2 Existing environment

14.2.1 Soils

Mapping at 1:250,000 scale (OEH 2012a) and supplementary finer scale mapping (RPS 2013, 2013a, 2013b and 2014) was reviewed to initially determine soil types across the project area. The mapping indicated a pattern of Rudosols, Tenosols, Sodosols and Vertosols in the project area. This broad scale mapping is provided in Appendix I1.

A soil survey at an approximate field-scale of 1:75,000 was subsequently undertaken in cleared areas to refine the understanding of soil types. At a high level, the results of the soil survey aligned with the broader scale mapping, confirming the presence of Rudosols, Sodosols and Vertosols. The soil survey also identified areas of Dermosol and Chromosol.

The soil survey focused on cleared agricultural areas due to the assumed higher productive value of the soils present, and in accordance with the interim protocol (NSW Government 2013a).

The cleared areas were mostly in the northern (predominantly agricultural) part of the project area; however, cleared areas in the southern (predominantly forested) part of the project area were also surveyed to verify previous assessments (RPS 2013, 2013a, 2013b and 2014). The results of the soil survey are presented in Table 14-1 and Figure 14-1. The identified soils were a mix of Brigalow Grey Clays (including Gilgai variant and Box variant), Sandy Sodic Duplex Soils (including Acidic variant and Deep, Sandy, bleached variant), Acidic Sands (including Red variant), Recent Alluvium (including Sandy Duplex subtype, Grey-brown Clays subtype and Bohena Creek subtype), Red-brown Clays, Red-brown Earths and complex units, being combinations of multiple soil variants or subtypes.

As shown in Figure 14-1, the northern (predominantly agricultural) part of the project area is dominated by cracking clays including Brigalow Grey Clays (and subtypes), Red-brown Clays and Recent Alluvium (Grey-brown Clay subtype). Soils in the forested areas were assessed using methods described in the interim protocol (NSW Government 2013a), from which broader scale mapping (OEH 2012 and 2012a), when combined with survey effort in cleared patches of forested areas, was sufficient to indicate a pattern of Sandy Sodic Duplex soils (particularly Acidic variant and Deep, Sandy, Bleached variant), Acidic Sands and Recent Alluvium (particularly Sandy Duplex subtype and Bohena Creek subtype). The soil types identified and inferred through the soil survey were also consistent with other desktop analyses including radiometric imagery interpreted over the project area, and previous small-scale assessment of forested areas within the project area (RPS 2013, 2013a, 2013b and 2014).

As shown in Table 14-1, soils within the project area generally exhibited chemical and physical properties conducive to soil hazards, particularly erosion. All of the identified soils, except for some Brigalow Grey Clays and Recent Alluvium (Grey-brown Clay subtype), have erodible fine sand content in the topsoil. The topsoil of some clay units is also sodic and potentially dispersive. Furthermore, the majority of soils sampled exhibited potentially dispersive sodic subsoil. The subsoils of Sandy Sodic Duplex Soils and Recent Alluvium (Sandy Duplex subtype) in particular are prone to tunnel erosion and cavitation if deeply excavated or trenched when wet. Recorded values for a range of parameters including acidity, alkalinity, cation exchange capacity, salinity and sodicity at sampling sites are provided in Appendix I1.

All of the soil types identified in the project area were limited by low fertility, poor drainage and effective rooting depth. In this regard the findings of the soil survey are consistent with land and soil capability mapped by the NSW Office of Environment and Heritage (OEH 2012). The majority of the project area is mapped as Class 4, Class 5 or Class 7, meaning it contains moderately to severely limited land that is generally incapable of sustaining cropping without specialist management practices and resources. Brigalow Grey Clays and Red-brown Clays in the northern (predominantly agricultural) part of the project area are classified Class 3 and therefore capable of sustaining more productive land uses, such as cropping. Land and soil capability as it relates to land use and agriculture is discussed in Chapter 17.

Commensurate with the low risk of encountering potential, or actual, acid sulfate soils in the project area, official NSW Government mapping is limited to the NSW coastal fringe; which contain environments higher in risk of encountering these soil types. Confirmation of this low risk was verified via the *Atlas of Australian Acid Sulfate Soils* (CSIRO 2011), with the possible exception of relatively small area beneath Yarrie Lake which was mapped as having high probability. The project area excludes Yarrie Lake, including a 200 metre buffer zone. Refer to Appendix I1 for additional information.

Table 14-1 Soil survey results

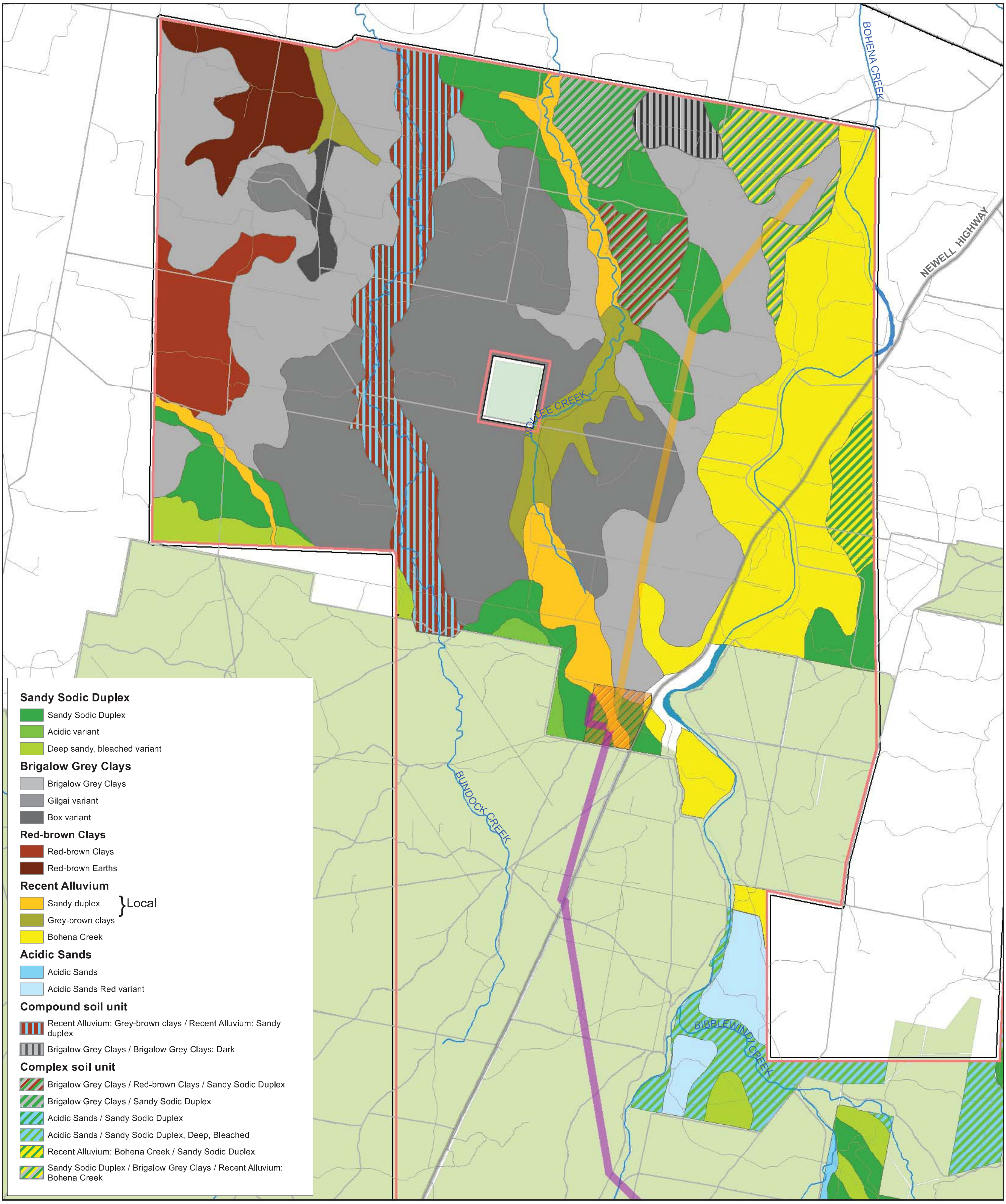
Soil group	Soil variant or subtype	Description	Characteristics	Approximate area (ha)[a]
Brigalow Grey Clays	-	Gradational grey to black cracking clays. Minor brown clays. Clays usually sandy throughout. Usually crusting surface with strong structure throughout, often with calcareous segregations in the upper or mid-B2 horizon. Lower subsoil often mottled grey and yellow. Interspersed with sub-dominant sandy texture-contrast soils.	Limited fertility Prone to water erosion in topsoil and subsoil Sodic subsoil Saline topsoil and subsoil Prone to waterlogging	7,760
	Gilgai variant	Gradational grey to grey-brown cracking clays. Often sandy clay topsoils. Generally crusting (depressions and mounds) and some self-mulching (mounds) surface with strong structure throughout, often with calcareous segregations in the upper or mid-B2 horizon. Mounds show sandiness and carbonate at surface.	Limited fertility Prone to water erosion in topsoil and subsoil Sodic topsoil and subsoil Saline topsoil and subsoil Prone to waterlogging	5,680
	Box variant	Gradational grey, cracking sandy clays. Crusting surface with strong structure throughout, often with calcareous segregations in the upper or mid-B2 horizon. Pronounced yellow and grey mottling in lower subsoil. Eroded surface with stunted, poorly structured woodland vegetation.	Low to moderately fertile topsoil Prone to water erosion in topsoil and subsoil Sodic subsoil Moderately drained	205
Sandy Sodic Duplex Soils	-	Brown to yellow and grey texture contrast soil with fine sandy loam to loamy fine sand topsoils. Strong, mottled brown, yellow, or grey sandy clay subsoils. Subsoils often dispersible and sometimes eroded. Associated with box, cypress pine, and bull oak vegetation.	Limited fertility Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil (fine sand) Sodic subsoil Imperfectly drained	6,830

Soil group	Soil variant or subtype	Description	Characteristics	Approximate area (ha)[a]
	Acidic variant	Brown to dark yellow texture contrast soil with sandy to coarse sandy loam to sandy clay loam topsoils with strong, brown, dispersible, sandy clay subsoils. Black, organic topsoil and litter layer. Associated with cypress pine, and bull oak forest.	Limited fertility Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil (fine sand) Sodic topsoil and subsoil Well drained	115
	Deep Sandy, Bleached variant	Red-brown to yellow texture contrast soil with deep, loamy fine to medium sand topsoils with conspicuously bleached A2 horizon above strong, brown, dispersible, sandy clay subsoils. Associated with box, cypress pine, and bull oak vegetation.	Limited fertility Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil (fine sand) Sodic topsoil and subsoil Moderately saline subsoil Imperfectly drained	780
Acidic Sands	-	Deep, pale brown to pale yellow sandy to coarse sandy soils with shallow organic layer, often with bleached A2 horizon, occurring as alluvium and on rises and low ridges.	Limited fertility Prone to water erosion in topsoil and subsoil Sodic subsoil Well drained	1,240
	Red variant	Deep, red-brown to pink sandy to coarse sandy soils with shallow organic layer, sometimes with paler A2 horizon, occurring as ridges with distinct slopes close to Bohena Creek.	Limited fertility Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil and subsoil (fine sand) Well drained	630

Soil group	Soil variant or subtype	Description	Characteristics	Approximate area (ha)[a]
Recent Alluvium	Sandy Duplex subtype	Brown to yellow-brown texture contrast soil with sandy loam to loamy sand topsoils with strong, brown, dispersible, sandy clay subsoils. Occurring in drainage lines and bottomlands, and often strongly eroded. Associated with box, cypress pine, and bull oak vegetation.	Limited fertility Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil (fine sand) Sodic subsoil Imperfectly drained	1,210
	Grey-brown Clays subtype	Gradational grey to brown, cracking clays. Crusting to massive surface with strong structure throughout, often with ferruginous or ferromanganiferous segregations in both topsoil and subsoil.	Fertile topsoil, limited fertility in subsoil Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil and subsoil (fine sand) Sodic subsoil Saline subsoil Well drained	890
	Bohena Creek subtype	Red, red-brown, yellow, to grey gradational soils of variable depth with sandy topsoils to sandy clay subsoils, often coarse sandy. Occurs on levees, cut-offs, fans, and splays associated with Bohena Creek. Variable vegetation associations.	Limited fertility Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil and subsoil (fine sand) Sodic subsoil Moderately drained	4,730
Red-brown Clays	-	Gradational brown, red-brown, and grey cracking sandy clays. Crusting surface with strong structure throughout, often with calcareous segregations in the upper or mid-B2 horizon. Sometimes include gravel in the subsoil. Interspersed with brown to red-brown texture contrast soils. Often sodic.	Limited fertility Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil Sodic subsoil Moderately drained	1,940

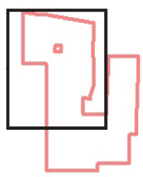
Soil group	Soil variant or subtype	Description	Characteristics	Approximate area (ha)[a]
	Red-brown Earths	Gradational, red-brown clay loams on deeply weathered substrates on level to gently undulating plains. Sandy topsoil, sometimes deep, with mottled subsoil. Brown and red-brown texture contrast soils with yellow and grey mottled subsoils. Shallow to moderately deep sandy loam topsoils, sometimes absent.	Limited fertility Prone to water erosion in topsoil and subsoil Prone to wind erosion in topsoil and subsoil (fine sand) Moderately drained	965
Brigalow Grey Clays / Red-brown Clays / Sandy Sodic Duplex Soils			-	465
Brigalow Grey Clays / Sandy Sodic Duplex Soils			-	495
Brigalow Grey Clays / Brigalow Grey Clays (Dark)			-	375
Sandy Sodic Duplex Soils / Brigalow Grey Clays / Recent Alluvium (Bohena Creek subtype)			-	780
Recent Alluvium (Grey-brown Clays subtype) / Sandy Sodic Duplex Soils			-	2,105
Recent Alluvium (Bohena Creek subtype) / Sandy Sodic Duplex Soils			-	430
Acidic Sands / Sandy Sodic Duplex Soils			-	1,980
Acidic Sands / Sandy Sodic Duplex Soils (Deep Sandy, Bleached variant)			-	1,375

[a] Excludes forested areas where field-based soil surveys were not conducted as per survey method described in NSW Government (2013a).



LEGEND

- Project area
- Leewood
- Bibblewindi
- Parks and reserves
- State forest
- Aboriginal areas
- Lakes and dams
- Watercourses
- Roads
- 100m assessment buffer
- Leewood to Wilga Park infrastructure corridor
- Bibblewindi to Leewood infrastructure corridor



0 1 2 4
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Soils on cleared land in the project area

Figure 14-1

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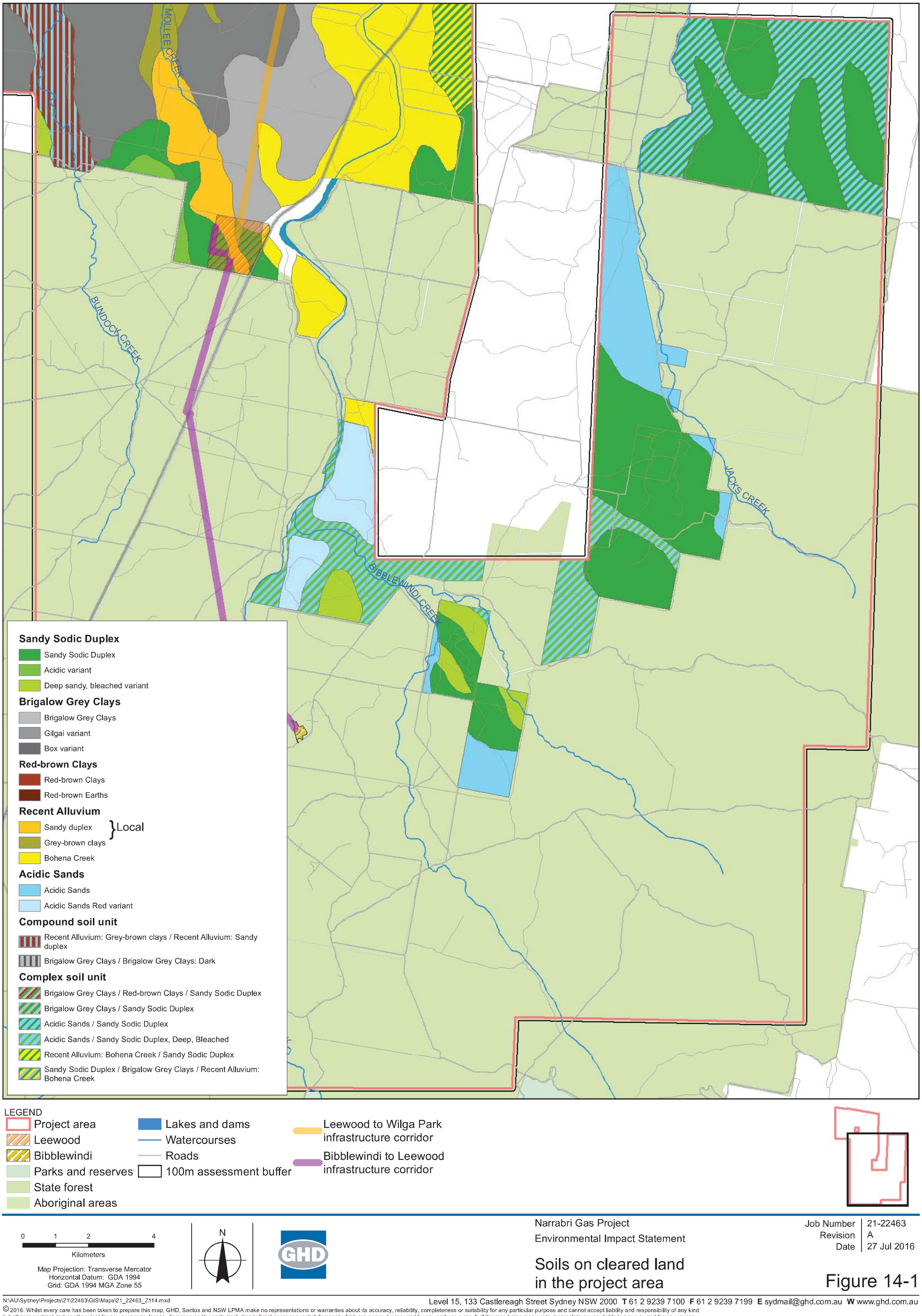
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au



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Soils on cleared land in the project area

Figure 14-1

14.2.2 Biophysical strategic agricultural land

Biophysical strategic agricultural land (BSAL) is defined by the NSW Government (2014a) as land with high quality soil and water resources capable of sustaining high levels of productivity. In NSW, it is mapped and regulated under the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*.

Potential BSAL in the project area was assessed in accordance with the interim protocol (NSW Government 2013a). The protocol defines the verification process to determine whether or not an area qualifies as BSAL.

The verification process involved a desktop review that included previous BSAL assessments as a preliminary step. The findings of the previous assessments (RPS 2013, 2013a, 2013b and 2014) were as follows:

- the northern (predominantly agricultural) part of the project area showed subsurface chemical constraints and limited soil fertility that would likely fail the BSAL assessment criteria in the interim protocol
- the southern (predominantly forested) part of the project area showed limited soil fertility, drainage and effective rooting depth that would likely fail the BSAL assessment criteria in the interim protocol.

The interim protocol defines a 12-step verification process to verify BSAL in the field. According to the interim protocol, if an area does not pass any of the 12-steps in this process, the area is deemed to not be BSAL.

The BSAL survey and site verification report (GHD 2015) undertaken for the project area were completed to inform the 12-step site verification process under the interim protocol. The site verification report (GHD 2015) detailing the findings of the BSAL work was provided to the NSW Office of Environment and Heritage in November 2015. A site verification certificate confirming the absence of BSAL in the project area was issued by the NSW Department of Planning and Environment on 1 December 2015 (refer to Appendix I2).

14.2.3 Land contamination

State agency records relevant to land contamination are administered by the NSW Environment Protection Authority and include the record of regulatory notices issued under the *Contaminated Land Management Act 1997* and the record of pollution incidents under the *Protection of the Environment Operations Act 1997*. A search of the record in the project area found one notice.

A regulatory notice was issued to Cargill Processing Limited for the disposal of vegetable oil wastes on Lot 181 on DP 628398 (a liquid disposal pond owned by Cargill Processing Limited). The notice was revoked following remediation works in 2008. The site is no longer considered to present a significant risk of harm to human health or the environment.

In addition, there are a number of known pollution incidents and two Pollution Studies and Reduction Programs associated with the petroleum activities in the project area. These are summarised below and further information is provided in Appendix I3.

In June 2011 approximately 10,000 litres of untreated produced water was released from the Bibblewindi water treatment plant that was not reported to the regulator by Eastern Star Gas who previously owned and operated the water treatment plant. The spill resulted in an area of around 3.4 hectares of vegetation die back adjacent to the water treatment plant. After acquiring Eastern Star Gas in November 2011, Santos discovered evidence of the release from the Bibblewindi facility and other reporting failures and notified the regulator.

In December 2011 Santos temporarily shut down all operations in the area including the treatment plant and the treated produced water discharge to Bohena Creek. The treatment plant was subsequently decommissioned and removed and the water stored at the facility was transferred to the Leewood Water Management Facility.

Santos publicly released a report on incidents at the Bibblewindi Water Treatment Facility in February 2012. The report included the results of soil testing undertaken around the Bibblewindi Water treatment plant. The results did not represent a health or ecological risk with the exception of salts. The salts were responsible for the area of vegetation die back adjacent to the Bibblewindi plant and were present in the soil due to the spill.

The EPA found that water in the affected groundwater system was ‘barely moving’, resulting in no danger to stock or crops in the area (NSW EPA 2014a). The area affected by the spill is being progressively rehabilitated.

In July 2012 Eastern Star Gas was issued two penalty infringement notices (PINs) under section 120 of the Protection of Environment Operations Act 1997 for pollution incidents which occurred in the months of March and November 2010 at the Bibblewindi Water Treatment Facility for discharging water from the treatment plant containing high levels of salt into Bohena Creek.

The EPA also issued a Formal Warning to Santos for a discharge event in December 2011 that contained elevated levels of ammonia. The EPA stated that it did not believe that environmental harm resulted from this event.

In June 2013 Santos NSW Pty Ltd was prosecuted under the *Petroleum (Onshore) Act 1991* for the previous reporting failures during Eastern Star Gas’ operations. Santos NSW Pty Ltd entered guilty pleas for Eastern Star Gas' failure to report the spill in June 2011 and for lodging three reports by Eastern Star Gas that contained inaccuracies about the quality of treated water being discharged from the treatment plant. Santos NSW was fined $52,500.

In 2013 elevated levels of total dissolved solids and slightly elevated levels of other elements (arsenic, barium, strontium and uranium) were detected during groundwater sampling at the Bibblewindi water treatment facility. Santos reported these results to the EPA and a conceptual site model was subsequently prepared for the site which indicated that a leak from Pond 3 at the facility had occurred. The lateral extent of groundwater impacts was confined to a discrete area immediately adjacent to the leak and generally found to decrease with depth. The investigations indicated that site conditions posed no risk to human health or the environment.

On 1 May 2014 the EPA issued an Environment Protection Licence (EPL) for gas operations around Narrabri. The EPL included a Pollution Studies and Reduction Program (PRP) for the Bibblewindi Water Management Facility. The PRP required the removal of all liquid from the pond by the end of 2014 and further information in relation to the leak and groundwater monitoring at the site. The pond was emptied in October 2014 with the water transferred to the Leewood Water Management Facility. The EPA was satisfied with the completion of the PRP and removed it from the licence, whilst extensive groundwater monitoring continues at the site in accordance with the EPL requirements.

The other Pollution Studies and Reduction Program previously required under the EPL relates to the Tintsfield produced water storage ponds which are located on Santos owned land adjacent to Wilga Park Power Station. In May 2013 Santos reported to the EPA that routine water quality monitoring of the groundwater surrounding the Tintsfield Water Management Facility had shown elevated levels of dissolved metals in bores around the site.

Investigation by the EPA found that most of the elevated metals, including uranium, occurred naturally in soils at the site. The investigation did not identify factors indicating risk to private bores. A Clean Up Notice was issued in July 2014 which required Tintsfield Pond 2 to be emptied and for a report to be provided to the EPA on the volume transferred.

Approximately 44.5 megalitres of produced water was removed from Pond 2 in September 2014 and inspections of the pond by a third party determined that the liner, welds and seams were intact The EPA subsequently amended the EPL in August 2015 to include a Pollution Studies and Reduction Program that required further groundwater data and a summary of changes to be provided, together with a report on whether additional groundwater monitoring piezometers were required. This report was prepared and submitted in September 2015.

Subsequent groundwater investigations, including data from the additional nested monitoring bore installed, identified that a persistent groundwater mound is centred around a recharge zone several hundred metres east (hydraulically up gradient) from the Tintsfield ponds.

The EPA concurred with the investigation findings and indicated its satisfaction that the requirements of the PRP were met. The PRP has been removed from the licence. Monitoring at the additional installed nested monitoring bore continues to occur in accordance with the EPL.

In addition, a Liner Integrity Monitoring Program is in place for the Tintsfield Water Management Facility. This involves operating the two Tintsfield ponds in a duty and standby mode, whereby once a pond has been emptied, an annual inspection of the liner is undertaken and a report is to be provided to the EPA. The report will include details on the operation of the pond during the reporting period and the findings of the liner inspection.

The areas affected by the above notices and incidents are shown in Figure 14-2. The risk of a recurrence of these types of incidents going forward has been significantly reduced through the design, construction and operation of new infrastructure, changes to operational procedures and ongoing monitoring.

The recently constructed Leewood Water Management Facility now contains the majority of the produced water and brine associated with the Narrabri operations. The Leewood facility includes two double lined ponds with leak detection equipment installed. The facility meets the requirements of the NSW Government's Code of Practice *Produced Water Management, Storage and Transfer* (NSW Department of Industry, Skills and Regional Development 2015c).

Small volumes of produced water are also stored at the Tintsfield Water Management Facility which now operates under a Liner Integrity Management Program, as outlined above.

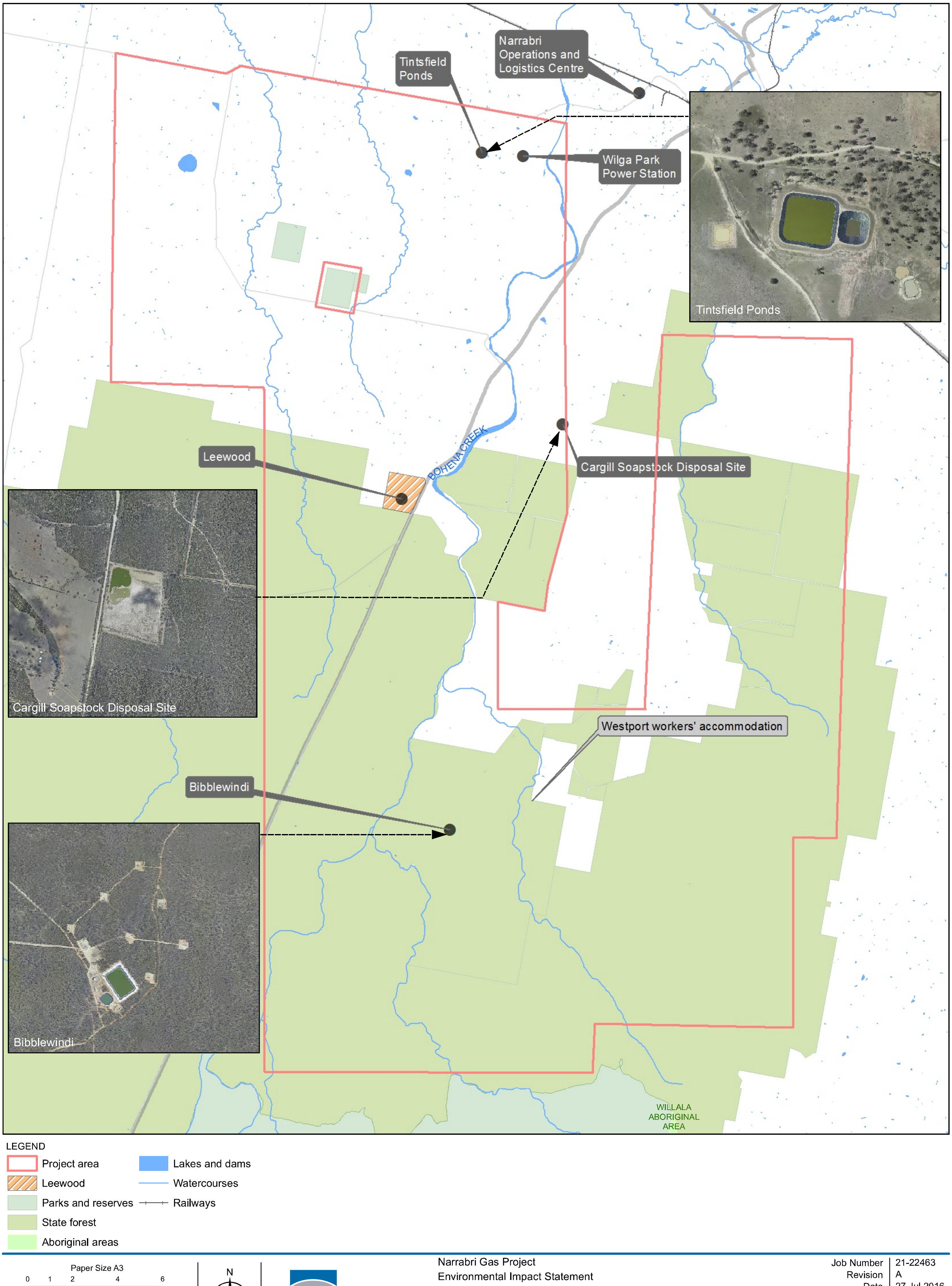
These changes, together with the extensive infrastructure and groundwater monitoring undertaken across the activities and the implementation of Santos systems for infrastructure operation and environmental management, minimises the risk of potential pollution incidents.

In addition, emergency preparedness with the use of Trigger Action and Response Plans and a project specific Pollution Incident Response Management Plan, would further lower the risk. Refer to Section 14.4.2 for additional design and mitigation measures to lower the risk likelihood.

In addition to State records, evidence of potential land contamination in the project area was assessed through a review of current and historical aerial photography and other documentation relating to the land. Significant developments or sources of potential land contamination were not apparent in aerial photographs of the project area (taken in 1956–1961, 1980–1983, 1994, 2009–2014). Agricultural development appears to have begun from around 1994, as evident from land clearing and the appearance of residences and dams.

A field assessment identified the following additional sources of potential land contamination, which may occur sparsely throughout the project area:

- agricultural operations (potential pesticide residues, chemical and fuel storage and soil stockpiles), mainly in the northern part of the project area—private properties were not accessed, though agricultural operations were observed from public roads
- illegal dumping (fibre cement, rubber tyres, corroded drums and car bodies), evidence of which was observed in State forest and at various locations from the Newell Highway
- possible minor fuel spills, evidence of which was observed in State forest and thought to be associated with former logging activities
- quarry pits and material stockpiles of unknown origin, which were observed in State forest and at various locations along the Newell Highway.



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Regulatory notices, pollution incidents and sources of potential land contamination in the project area

Figure 14-2

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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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14.3 Potential impacts – construction

Construction of the project has the potential to affect soils as a result of clearing, topsoil stripping and stockpiling, soil compaction and erosion. Construction would also involve the storage and handling of fuels and chemicals with the potential to leak or spill into soil.

These activities would occur variously through the construction of facilities at including Leewood, Bibblewindi, the Bibblewindi to Leewood infrastructure corridor and other corridors as well as field development activities such as construction of access tracks, gas and water gathering lines and well pads. Construction of the project is discussed in further detail in Chapter 6.

Potential impacts of the construction of the project are discussed further in Section 14.3.1 with regard to soil disturbance, Section 14.3.2 with regard to pre-existing land contamination, Section 14.3.3 with regard to leaks and spills and Section 14.3.4 with regard to dust suppression. These activities and their potential impacts would be readily controlled with the implementation of measures discussed in Section 14.6.

14.3.1 Soil disturbance

As described in Section 14.2.1, the project area contains a range of soil types that would be encountered during construction, including:

- construction activities at Leewood would be carried out in areas mapped as Brigalow Grey Clays, Sandy Sodic Duplex Soils and Recent Alluvium (Bohena Creek subtype)
- construction activities at Bibblewindi and the Bibblewindi to Leewood infrastructure corridor would occur within forested areas and would therefore be expected to encounter Sandy Sodic Duplex Soils, Acidic Sands and / or Recent Alluvium
- construction activities at the Leewood to Wilga Park underground power line and the gas field would cross a broad range of soil types (refer to Section 14.2.1)
- construction of other ancillary infrastructure would largely occur within forested areas and would therefore be expected to encounter Sandy Sodic Duplex Soils, Acidic Sands and / or Recent Alluvium.

Clearing and levelling, if improperly managed, has the potential to aggravate erosion within cleared and excavated areas. Exposed soils at construction sites could cause erosion from runoff and / or wind. The exposure of soil at one time would be minimised by the progressive nature of construction and / or the use of covers like industrial matting or polymers at well pads. The area of disturbance across the gas field would be minimised through co-location of access tracks and gas and water gathering lines, where viable. Excavation for site levelling would generally be relatively shallow, meaning exposure of subsoils to water flow or infiltration would be minimised.

Deeper excavations would be necessary for construction of produced water / brine ponds at Leewood, to a lesser extent refurbishment and recommissioning of water management infrastructure at Bibblewindi, trenching for gas and water gathering lines and/or underground services, and temporary pits for drill cuttings at well pads. These deeper excavations could lead to tunnel erosion or cavitation, particularly where excavation intersects the potentially dispersive subsoils, such as those predicted to occur in the Sandy Sodic Duplex Soils or Recent Alluvium.

Significant subsoil erosion by water would require the occurrence of heavy rainfall and / or overland flow. The risk of impact would be lessened by the progressive nature of construction and the temporary timeframe in which the excavations would be exposed, in particular:

- produced water / brine ponds would be bunded and double lined, preventing the ingress of overland flow and rainfall respectively
- trenches would be excavated and backfilled progressively as underground services or gas and water gathering are installed
- temporary drill cutting pits would be open and utilised between about 10 and 30 days, being the approximate duration of drilling.

Stockpiling of soils for extended durations, if improperly managed, could lead to degradation of fertility, in addition to losses from erosion and sedimentation. The use of unsuitable or degraded soil in rehabilitation would have implications for plant establishment, exacerbation of topsoil and subsoil erosion, and post rehabilitation land use. As such, a range of measures would be implemented that would minimise erosion and maintain soil fertility over time (refer to Section 14.6).

Soils underlying construction sites would be subject to compaction and a degradation of soil structure, potentially inhibiting plant re-establishment at a later date. As such, soil structure may need to be ameliorated as necessary during progressive rehabilitation and decommissioning (refer to Section 14.5).

It is proposed that drill cuttings would be beneficially re-used on well pads using a mix, turn, bury strategy. The application of surplus drill cuttings at well pads would be carried out with regard to the volume and characteristics of the drill cuttings, the characteristics of the receiving soil, and the volume and nutrient requirements of growth media. A balance of these factors would be required to ensure successful rehabilitation of well pads. Drill cuttings that are inappropriate for beneficial reuse would be classified and transported off site and disposed at an appropriately licensed waste management facility.

Overall, soils disturbed during the construction of the project would be managed through standard topsoil / subsoil stripping, stockpiling and amelioration practices (such as the application of gypsum to sodic soils) and the implementation of erosion and sedimentation control measures. The mitigation and management of potential impacts during the construction are detailed in Section 14.6.

Interaction with acid sulfate soils is considered very unlikely as the project area is hundreds of kilometres from coastal areas where these soils tend to occur, and there is a 200 metre exclusion zone around Yarrie Lake.

14.3.2 Leaks and spills

Fuel and chemicals at Leewood, Bibblewindi and Westport workers' accommodation has the potential to leak or spill if inappropriately stored or handled. Fuel and chemicals stored would include diesel, hydraulic fluids and water treatment products. Storage facilities would be designed and operated under the applicable Australian standards and protocols. Design controls would include bunding to constrain the movement of liquids in the event of a spill or leak. It is considered that the implementation of the appropriate standards and protocols would be sufficient to adequately avoid, mitigate and manage spills or leaks.

The operation and maintenance of equipment, including vehicles, during field development could result in leaks or spills. Equipment, including vehicles, would be maintained in good working order, so these spills would be unlikely. Leaks or spills, if they did occur, would typically be localised and readily controlled and remediated. As such, leaks or spills would be adequately avoided, mitigated and managed with the implementation of the measures defined in Section 14.6.

Losses of drilling fluid into the soil profile is very unlikely due to the drilling methodology and engineering and operational controls that would be implemented. Drilling would comply with the *Code of Practice for Coal Seam Gas: Well Integrity* (DTIRIS 2012) which sets out the design, construction and maintenance requirements for gas wells to ensure the safe and environmentally sound production of gas.

Under the conventional overbalanced drilling fluid system that would be used for the project, the pressure of the column of drilling fluid is equal to, or greater than, the pressure of the various downhole formations through which they are drilled. This prevents influx of water or gas into the well bore whilst drilling. Surface drilling occurs to allow a steel pipe, called a conductor, to be cemented into the ground generally to 10 to 20 metres below the surface. This isolates loose or unconsolidated rock near the surface and prevents any impacts to the surface soils during the rest of the drilling process and the ongoing operation of the well. Well integrity will be monitored throughout the life of the well in accordance with the requirements of the Code of Practice.

14.3.3 Dust suppression

Water for dust suppression at construction sites would be sourced from existing, previously approved water treatment facilities at Leewood and / or licensed water bores. If improperly managed, the application of water for dust suppression has the potential to cause erosion, waterlogging, and the accumulation of contaminants (mainly salt). The application and subsequent evaporation of water over time has the potential to result in salt accumulation, particularly on compacted surfaces where drainage is impeded. The salt may then be mobilised by rainfall and deposited outside the disturbed areas.

The potential impacts of dust suppression would be minimised due to the quality of water used and the nature of the activities. The salinity of the treated and / or amended water used for dust suppression (in forested and agricultural areas respectively) would be relatively low and in the order of salinity measurements found in groundwater bores and used in regional irrigation (Parsons Brinckerhoff 2011; refer to Chapter 7).

The quantity of water applied would be restricted to that required to control dust and would only be applied in dry conditions, minimising the potential for waterlogging or ponding. Water would be applied to disturbed and non-productive areas such as construction sites or access tracks, and/or well pads under construction. These areas would typically be levelled and / or compacted, thereby preventing deep drainage. Accumulated salt mobilised by rainfall would be subject to dilution. The salt would likely be collected in drainage structures present on site, such as sediment basins on well pads or spoon drains along forest roads. Once deposited, residual salt would be subject to ongoing leaching during rainfall. As such, salts mobilised from dust suppression areas are not expected to be significant in quantity or extent.

Visual inspection would be undertaken to check for ponding or runoff, to ensure that the quantity of water applied is restricted to that required to control dust. Application rates and frequency would be decided based on the observed conditions. Mitigation and management are discussed further in Section 14.6.

14.3.4 Sewage effluent

Sewage generated by the construction workforce will be managed using packaged wastewater treatment plants at Leewood, Bibblewindi and Westport worker’s accommodation whilst portable ablution facilities for the storage of sewage will be used at construction sites (e.g. during drilling). Packaged wastewater treatment plants, which are extensively utilised in both municipal and project related settings, employ an aerobic process to treat sewage, generating treated effluent that can be released to land and a residual sludge that is held within storage tanks that are periodically emptied for disposal to an appropriate facility.

A 200-person capacity packaged wastewater treatment plant would be installed at Bibblewindi and a 400-person capacity packaged treatment plant would be installed at Leewood. The Westport workers’ accommodation has existing approval for 64-person sewage facilities and this would be upgraded to cater for a total of 200 people. The wastewater treatment plants will be designed to Australian Standards and treated effluent would be disposed of to a dedicated on-site disposal area by subsurface infiltration or adsorption trenches, irrigation or similar, in line with all regulatory requirements.

Sewage effluent management infrastructure would be sited, designed and operated as determined through a site selection and a sewage effluent management plan and ongoing monitoring. This approach would ensure sewage effluent was managed in a sustainable manner.

14.3.5 Land contamination

Construction of the project has potential to interact with pre-existing land contamination or sources of potential land contamination (refer to Section 14.2.3). However, the risk of interaction is low, because:

- identified sources of potential land contamination are sparsely distributed through the project area
- existing water management infrastructure at Leewood is not subject to pollution incidents or regulatory notices identified in Section 14.2.3, while previous clearing and ongoing operations at Leewood would have identified pre-existing land contamination or sources of potential contamination
- construction activities at Bibblewindi have the potential to interact with prior pollution incidents recorded at Bibblewindi water treatment facility. However, remediation works in the affected area are ongoing and it is not considered that construction at Bibblewindi would interfere with these works
- previous clearing and construction activities at the Bibblewindi to Leewood infrastructure corridor and Leewood to Wilga Park underground power line would have identified pre-existing land contamination or sources of potential land contamination
- flexibility in the location of gas field infrastructure would enable the avoidance of existing land contamination or sources of potential land contamination, including the liquid disposal pond owned by Cargill Processing Limited (refer to Section 14.2.3)
- previous clearing and construction activities at Westport workers' accommodation would have identified pre-existing land contamination or sources of potential land contamination.

14.4 Potential impacts – operation

14.4.1 Soil disturbance

The operation of the project would involve limited and occasional disturbance of soil for maintenance purposes. This disturbance would primarily occur within the footprint previously disturbed during construction. As such, potential impacts during operation would be less significant than during construction (refer to Section 14.3).

The operation of the project is not anticipated to lead to interaction with pre-existing land contamination or sources of potential land contamination.

Disturbed areas would have the potential to cause erosion and sediment laden runoff during heavy rainfall. Disturbed areas at Leewood would be minimised by the re-establishment of ground cover and the application of gravel in the flare exclusion zone and high-traffic exposed areas.

Similarly, the area of disturbance at Bibblewindi would be minimised due to the application of gravel in the flare exclusion zone and high-traffic exposed areas.

The existing Bibblewindi to Leewood infrastructure corridor would be widened for the project, however partial rehabilitation of the corridor following the completion of construction would minimise the potential for erosion and runoff.

The Leewood to Wilga Park underground power line would be buried within an existing corridor, and is therefore not expected to cause erosion.

Exposed areas in the gas field would be minimised by partial rehabilitation of well pads, which would occur at the completion of construction. Partial rehabilitation would reduce the right of way for access tracks and gas and water gathering from an average of 10 metres to five metres, and reduce well pad areas from approximately one hectare in size to around one-quarter of a hectare. Erosion would be further minimised at access tracks by using gravel for all-weather access.

The operation of road and intersection upgrades would not directly disturb soils, although exposed areas would cause erosion from runoff. Drainage, erosion and sediment controls would be incorporated into the design of the road upgrades and, as a result, impacts would be minimal and unlikely to differ significantly from those caused by the roads and intersections in their existing state.

The operation of Westport workers' accommodation would not directly disturb soils, although exposed areas could cause erosion from runoff. Drainage, erosion and sediment controls would be incorporated into the design of infrastructure to avoid impacts.

The treated water managed release pipeline from Leewood to Bohena Creek would be buried and would therefore not disturb soils or aggravate soil hazards during its operation.

Soils underlying operational sites would be subject to compaction, degrading soil structure and potentially inhibiting plant re-establishment at a later date. As such, soil structure would be ameliorated as necessary during progressive rehabilitation and decommissioning (refer to Section 14.5).

Overall, soil impacts during the operation of the project are anticipated to be minor. Drainage, erosion and sediment controls would be incorporated into the design of the project to avoid impacts. Impacts would be further managed through erosion and sedimentation control measures outlined in Section 14.6.

14.4.2 Leaks and spills

The operation of water management infrastructure at Leewood, Bibblewindi, the Bibblewindi to Leewood infrastructure corridor and the water gathering lines in the gas field has the potential to result in leaks or spills of produced water, including the potential for the mobilisation of naturally occurring material in the soil.

The likelihood of leaks or spills of produced water are considered low given the design and operational engineering controls and extensive management and monitoring systems that would form part of the project. These include:

- the produced water and brine storages at the Leewood Water Management Facility include double lined ponds that have leak detection equipment installed. The ponds meet the requirements of the *Exploration Code of Practice: Produced Water Management, Storage and Transfer* (NSW Department of Industry, Skills and Regional Development 2015c)
- continuous pressure monitoring of produced water pipelines for indications of a leak. Water pressures at well heads and within water gathering lines is low
- programmed inspections and maintenance of plant and equipment
- all facilities would be designed and operated under the applicable Australian safety standard and protocols
- operations in accordance with the requirements of the Environment Protection Licence and a Produced Water Management Plan
- the ability to remotely operate and shut in wells if required.

In the unlikely event that a spill or leak did occur the risk of human health and the environment is negligible. Design and engineering controls along with monitoring systems would enable leaks to be detected and rectified quickly. Additionally, there is a low risk that bores would be affected as these generally take from sources that are over 50 metres below perched or shallow water bodies that could be impacted by a spill. In addition, the presence of relatively impermeable geological units in addition to perched water bodies having very low transmissivity further minimises the risk.

Fuel and chemicals at Leewood, Bibblewindi and Westport workers' accommodation has the potential to leak or spill if inappropriately stored or handled. Fuel and chemicals stored would include those used in the operation of the water treatment plant, the gas processing and compression facilities and the power generation facility. The volume of fuel required to be stored during operation would generally be lower than that required during construction. Chemicals will be stored and handled in accordance with relevant Australian Standards including AS1940-2004 including *AS 1940-2004 The storage and handling of flammable and combustible liquids*.

Design controls would include bunding to contain liquids in the event of a spill or leak.

The operation and maintenance of equipment, including vehicles, during operation of the gas field could result leaks or spills. Equipment, including vehicles, would be maintained in good working order minimising the risk of leaks. Vehicle refuelling would occur with suitable containment measures in place for volumes of more than 50 litres and will not be undertaken within 40 metres of a watercourse.

Maintenance requirements would be carried out in accordance with operational procedures that would minimise the potential for spills or leaks to occur. Bunding, drip trays and other preventative measures would be utilised as necessary and spill kits would be in place as appropriate. As such, leaks or spills would be adequately avoided, mitigated and managed. It is considered that the implementation of these standards and protocols would be sufficient to adequately avoid, mitigate and manage spills or leaks.

14.4.3 Irrigation activities

Produced water would be treated and amended at the water treatment facility at Leewood. The beneficial reuse options for the treated and amended water assessed in this chapter, being irrigation, construction including drilling and dust suppression, are depicted in Figure 14-3. The options include the irrigation of crops. If improperly managed, the application of treated water to land has the potential to cause erosion, waterlogging, degradation of soil structure and the accumulation of salts.

The *Environmental guidelines: Use of effluent by irrigation* (DEC 2004) establishes an approach to the siting, design and operation of irrigation areas to avoid environmental impacts in accordance with statutory requirements under the *Protection of the Environment Operations Act 1997*. As stated in the guidelines (DEC 2004), all irrigation involves the application of water containing salt. This salt is typically prevented from accumulating in the soil profile by the downward flow of water, which may originate as rainfall or the irrigated water itself. Plant uptake also contributes to the removal of salt from the soil profile.

The removal of salt from produced water would be a key function of the water treatment facility at Leewood. Salt loads would be significantly reduced during multiple stages of the water treatment process including reverse osmosis, thermal evaporation, brine crystallisation and chlorination for ammonia removal, dechlorination, and pH adjustment. Treated water to be used for irrigation would be further amended to improve its suitability and beneficial reuse properties.

Amendment of the treated water would follow by adding calcium in the form of gypsum to adjust the sodium adsorption ratio. This is a typical agricultural practice regularly undertaken by the irrigation industry to manage soil conditions. It is noted that the addition of calcium sulphate salts as gypsum would nominally increase the salinity of the treated water—this process is a soil ameliorant that would improve soil structure for cropping and drainage purposes. The quality of the resulting treated and amended water would be consistent with the short term irrigation water quality framework within the ANZECC/ARMCANZ (2000) water quality guidelines. The treatment of produced water is described in Chapter 7.

The salinity of the amended water used for irrigation would be relatively low and in the order of salinity measurements found in groundwater bores and used in regional irrigation (Parsons Brinckerhoff 2011; refer to Chapter 7). The amended water would therefore be suitable for irrigation, even for moderately sensitive crops as defined in *Environmental guidelines: Use of effluent by irrigation* (DEC 2004). The target electrical conductivity (an indicator of salinity) of water applied to crops would be around 566 microsiemens per centimetre. For context, root zone soil sampling at reference sites indicated an average electrical conductivity of 2,550 microsiemens per centimetre (refer Appendix G2).

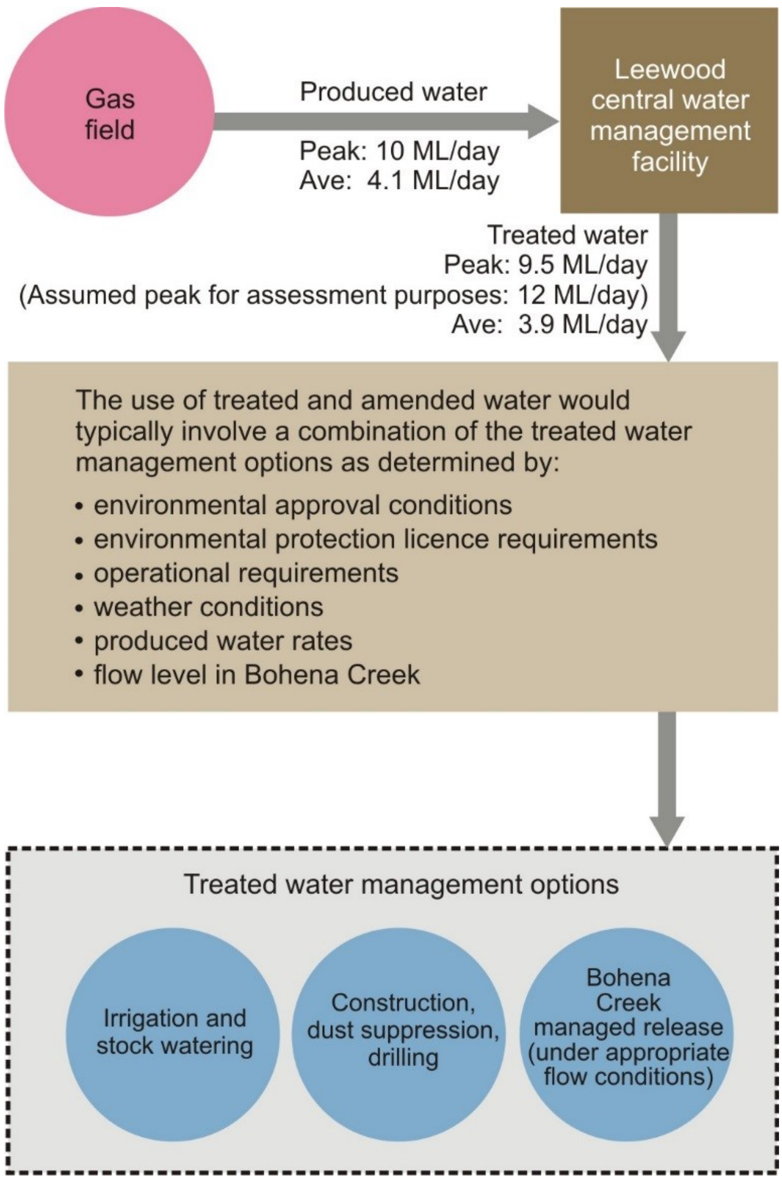

Figure 14-3 Treated water management options

The volume irrigation achieved would depend on the supply of produced water from the project, the demand for irrigation and the type of crop to be irrigated. The supply of produced water is expected to peak at around 10 megalitres per day but average around 4 megalitres per day over the life of the project.

Lucerne is expected to be a preferred crop for produced water irrigation and requires an irrigation rate of around 750 millimetres per year. At this rate, the irrigation would result in salt deposition of about 1.75 tonnes per hectare per year. The dispersive characteristics of soils in the region mean the application of some types of salt can improve soil structure. About half of the deposited salts would likely be calcium sulfate (gypsum), which would improve soil by reducing its dispersivity.

The area to be irrigated with treated and amended water would be sited, designed and operated as determined through site selection, an Irrigation Management Plan and ongoing monitoring typical of irrigation schemes. It is considered that this approach would avoid environmental harm and maintain the receiving soil in a stable and productive state.

Consistent with typical irrigation practices, the operation of the irrigation area would be such that treated water would be applied at a rate where potential accumulation and leaching of salts would be in equilibrium, resulting in a relatively stable level of soil salinity at or near baseline conditions. For example, additional treated water could be applied under appropriate conditions (low evapotranspiration) to promote leaching of salts from the soil. Given that slope would be a key consideration in the selection of the treated water irrigation area, runoff from the irrigation area would be negligible and readily controlled.

The irrigation of treated water would be undertaken in accordance with an Irrigation Management Plan that would seek to ensure:

- the structure, stability and productive capacity of the soils are maintained
- minimisation of erosion
- effective stormwater runoff controls.

Irrigation would also include a program of monitoring, with the irrigation schedule being adjusted as needed to address to maintain the soil in a stable, productive state.

14.4.4 Dust suppression

The management options for the disposal of treated water also include the application of the water to land for the purpose of dust suppression. The relationship of dust suppression and other beneficial reuse options is depicted in Figure 14-3.

If improperly managed, the application of water for dust suppression has the potential to cause erosion, waterlogging and accumulation of contaminants (mainly salt). The application and subsequent evaporation of water over time has the potential to result in salt accumulation—particularly on compacted surfaces where drainage is impeded. The salt may then be mobilised by rainfall and deposited outside of the disturbed areas.

The potential impacts of dust suppression would be minimised due to the quality of water used and the nature of the activities. The quantity of water applied would be restricted to that required to control dust and would only be applied in dry conditions, minimising the potential for waterlogging or ponding. Water would be applied to disturbed and non-productive areas such as construction sites or access tracks, and / or well pads under construction. These areas would typically be levelled and / or compacted, thereby preventing deep drainage. Accumulated salt mobilised by rainfall would be subject to dilution. The salt would likely be collected in drainage structures on site, such as sediment basins on well pads or spoon drains along forest roads. Salt mobilised further from the site would likely be subject to further dilution. Once deposited, residual salt would be subject to ongoing leaching during rainfall.

Dust suppression would be carried out on roads and access tracks using treated or amended water as appropriate. Treated water would be used in forested areas while amended water would be used in the agricultural areas to preserve or potentially improve soil quality by addition of gypsum.

The water balance for the project indicates that between one and two megalitres of water could be required per day for the purpose of dust suppression, equating to around five kilograms of salt each day over a nominal one kilometre stretch of road or access track where dust suppression activities are undertaken. This deposition would typically be flushed by rainfall and reassimilated into the environment.

Dust suppression activities would be actively monitored to ensure water application rates are appropriate to observed conditions and prevent ponding or runoff.

14.4.5 Sewage effluent

The facilities discussed in Section 14.3.4 will accommodate sewage generated by construction staff, and as such, they will continue to be utilised throughout operations, albeit at a reduced scale.

14.5 Potential impacts – decommissioning

Decommissioning would involve the removal of aboveground infrastructure, with below-ground infrastructure left *in situ*. As such, decommissioning of the project would have limited potential to directly disturb soils through excavation. The removal of surface infrastructure would result in the exposure of soils and potentially cause erosion through runoff. As final rehabilitation would follow decommissioning, it is not anticipated that significant or persistent impacts on soil would result.

Soils underlying decommissioning sites would be subject to compaction, degrading soil structure and potentially inhibiting plant re-establishment at a later date. As such, soil structure would be ameliorated as necessary during decommissioning.

It is not considered that the decommissioning of the project would lead to interaction with pre-existing land contamination, additional to that encountered during construction.

14.6 Significance assessment

A range of mitigation and management measures proposed to control potential impacts of the project with regard to soils and land contamination. Table 14-2 demonstrates the effectiveness of these mitigation measures in reducing the level of environmental risk posed by the project.

In addition to the listed measures, erosion, sedimentation and contamination risk during the operation of the project would be further managed and mitigated by elements of the project developed in detailed design. These elements would typically include stormwater drainage, sediment traps, vegetated areas, diversion berms, scour protection, double lined produced water / brine ponds and chemical storage bunds.

Table 14-2 Environmental significance assessment

Potential impact	Phase	Pre-mitigated significance			Mitigation and management measures	Residual significance		
		Sensitivity	Magnitude	Significance		Sensitivity	Magnitude	Significance
Erosion and sedimentation	Construction	Moderate	Moderate	Moderate	Erosion and sediment controls for the project will be implemented based *on Managing Urban Stormwater – Soils and Construction Vol. 1* (Blue Book – Landcom 2004).	Moderate	Low	Low
	Operation	Moderate	Low	Low		Moderate	Low	Low
	Decommissioning	Moderate	Low	Low		Moderate	Low	Low
Soil stockpiling leading to degradation of soil fertility	Construction	Moderate	Moderate	Moderate	Rehabilitation of impacted areas will occur in accordance with the Rehabilitation Strategy (refer to Appendix V).	Moderate	Low	Low
	Operation	Moderate	Moderate	Moderate		Moderate	Low	Low
	Decommissioning	Moderate	Moderate	Moderate		Moderate	Low	Low
Soil compaction inhibiting rehabilitation	Construction	Moderate	Moderate	Moderate	Rehabilitation of impacted areas will occur in accordance with the Rehabilitation Strategy (refer to Appendix V).	Moderate	Low	Low
	Operation	NA	NA	NA		NA	NA	NA
	Decommissioning	NA	NA	NA		NA	NA	NA
Interaction with pre-existing land contamination leading to mobilisation of contaminants	Construction	Moderate	Low	Low	If previously unidentified land contamination or sources of potential land contamination are encountered the landholder will be notified and the contamination will be avoided as far as practicable.	Moderate	Low	Low
	Operation	Low	Low	Negligible		Low	Low	Negligible
	Decommissioning	Low	Low	Negligible		Low	Low	Negligible
Leaks or spills leading to land contamination	Construction	Moderate	Low	Low	Chemicals will be stored and handled in accordance with relevant Australian Standards, including *AS 1940-2004 The storage and handling of flammable and combustible liquids*. Refuelling will occur with suitable containment when volumes greater than 50 litres are involved and not within 40 metres of a watercourse. Irrigation of treated water will be undertaken in accordance with an irrigation framework, included under the Produced Water Management Plan.	Moderate	Low	Low
	Operation	Moderate	Low	Low		Moderate	Low	Low
	Decommissioning	Moderate	Low	Low		Moderate	Low	Low

Potential impact	Phase	Pre-mitigated significance			Mitigation and management measures	Residual significance		
Irrigation leading to erosion, waterlogging, degraded soil structure or the accumulation of contaminants	Construction	Moderate	Low	Low	Irrigation of treated water will be undertaken in accordance with an irrigation framework, included under the Produced Water Management Plan.	Moderate	Low	Low
	Operation	Moderate	Low	Low		Moderate	Low	Low
Dust suppression leading to degraded soil structure or the accumulation of contaminants	Construction	Moderate	Low	Low	Only treated, amended or bore water will be used for dust suppression and rehabilitation.	Moderate	Low	Low
	Operation	Moderate	Low	Low		Moderate	Low	Low
	Decommissioning	Moderate	Low	Low		Moderate	Low	Low

NA: Not applicable during this project phase. Compaction would occur during construction.

14.7 Conclusion

The implementation of mitigation and management measures and relevant design elements would be sufficient to effectively control and minimise the potential impacts of the project with regard to soils and land contamination. As such, the significance of the residual impacts presented by the project would generally be low (refer to Table 14-3).

Table 14-3 Soils and land contamination significance of residual impacts

Potential impact	Construction	Operation	Decommissioning
Erosion and sedimentation	Low	Low	Low
Soil stockpiling leading to degradation of soil fertility	Low	Low	Low
Soil compaction inhibiting rehabilitation	Low	NA	NA
Interaction with pre-existing land contamination leading to mobilisation of contaminants	Low	Negligible	Negligible
Leaks or spills leading to land contamination	Low	Low	Low
Irrigation leading to erosion, waterlogging, degraded soil structure or the accumulation of contaminants	Low	Low	NA
Dust suppression leading to degraded soil structure or the accumulation of contaminants	Low	Low	Low

NA: Not applicable during this project phase.