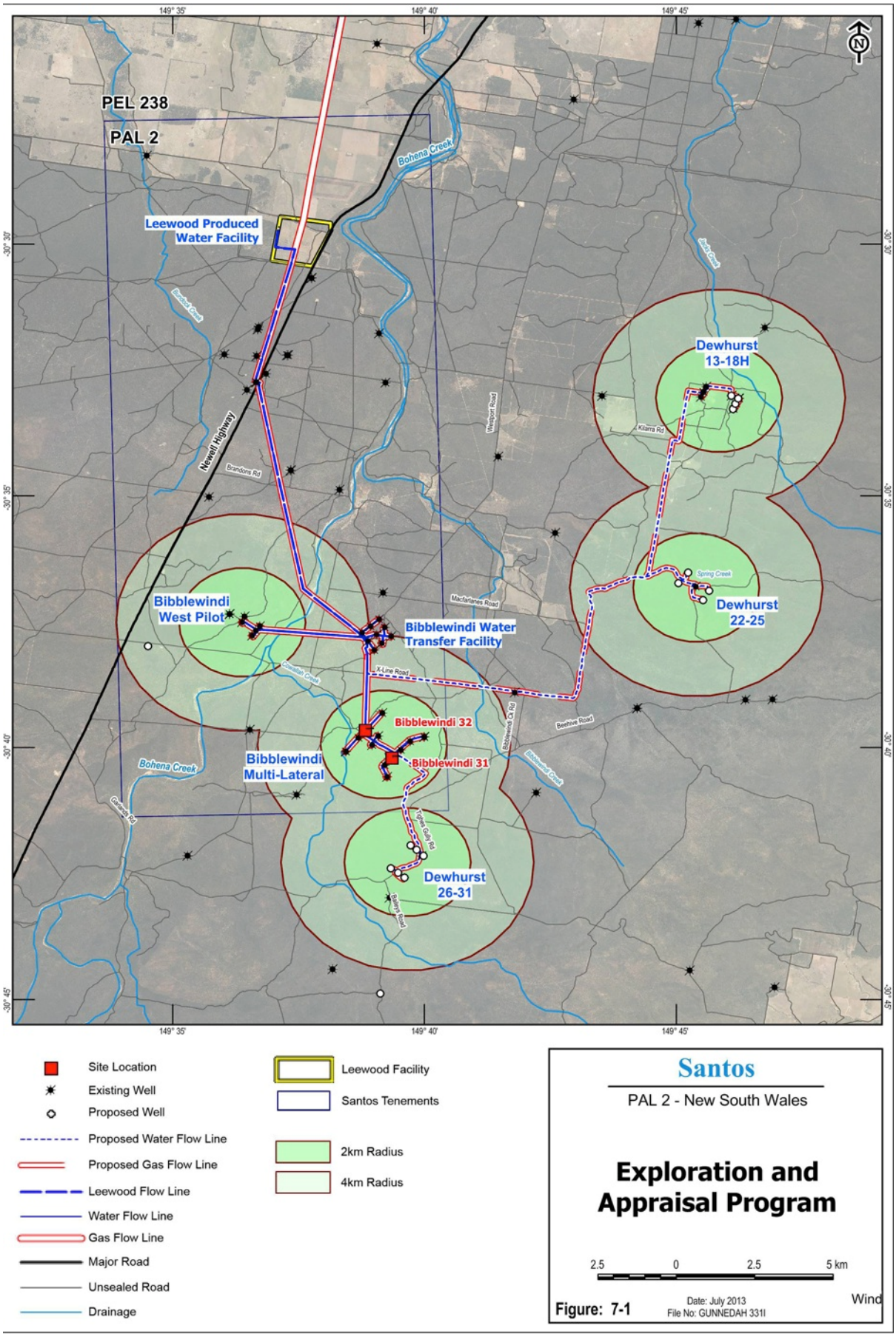

Figure 7-1 Proximity of activities within the E&A Program

PART B

8.0 Land Resources

An Agricultural Impact Statement (AIS) has been prepared in accordance with the requirements of *Guidelines for agricultural impact statements* (DP&I, 2012b) and *Guidelines for agricultural impact statements at the exploration stage (*DP&I, 2012c) and is provided in Appendix 2. The following section summarises relevant findings from the AIS.

8.1 Existing environment

The site is located within the Bibblewindi State Forest with surrounding land utilised for forestry purposes. This includes recreational activities such as bushwalking, camping and bird watching and other minor activities such as apiary uses (beekeeping) and timber harvesting. The site and its surrounds comprise of similar landscapes offering minimal land use value for intensive agricultural purposes. Figure 8-1 describes the soil type of the site.

The SRLUP identifies the site and surrounding land as having high CSG resources and underground coal exploration potential. Both CSG and coal mining are growing industries within the region with numerous existing CSG wells, and a number of existing mines are located within 100 kilometres of the site.

Extensive areas of land reserved for conservation and forestry lay in the middle of the catchment south of Narrabri. The proposed activity is not located within any conservation zone or an environmentally sensitive area of state significance, or within any mining titles as described in Figure 8-2.

8.1.1 Agriculture enterprise and resources

The Agricultural Impact Statement (AIS) identifies that the dominant land use in the Namoi catchment is sheep and cattle grazing (51 per cent). Other agricultural activities within the surrounding Narrabri LGA include wheat, cotton and other broad acre crops which are commonly grown along the alluvial floodplains in the area.

Due to the scale, diversity and productivity of agricultural enterprise within the Narrabri Shire, processing companies, research and development facilities, transport and warehousing and other service industries have been established in the Narrabri Shire (DP&I, 2012a), including:

- livestock selling centre
- farm management services
- grain and cotton processing centres
- grain and field bean merchant wholesalers
- agricultural research facilities
- crop harvesting selling centres.

The proposed activity is not located on or in the vicinity of any travelling stock routes (TSR). The nearest TSR is located 16 kilometres north of the site.

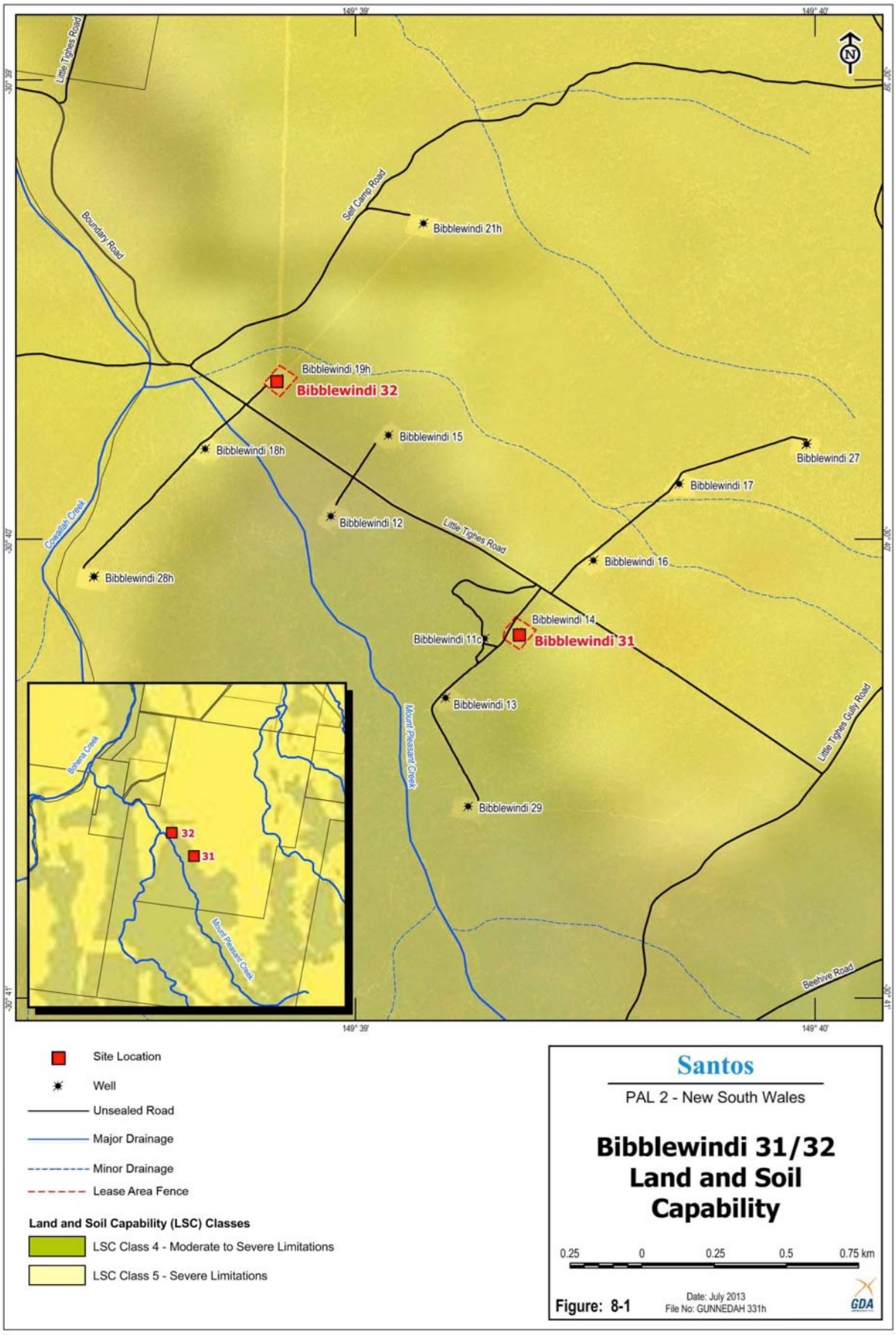

Figure 8-1 Land and soil compatibility

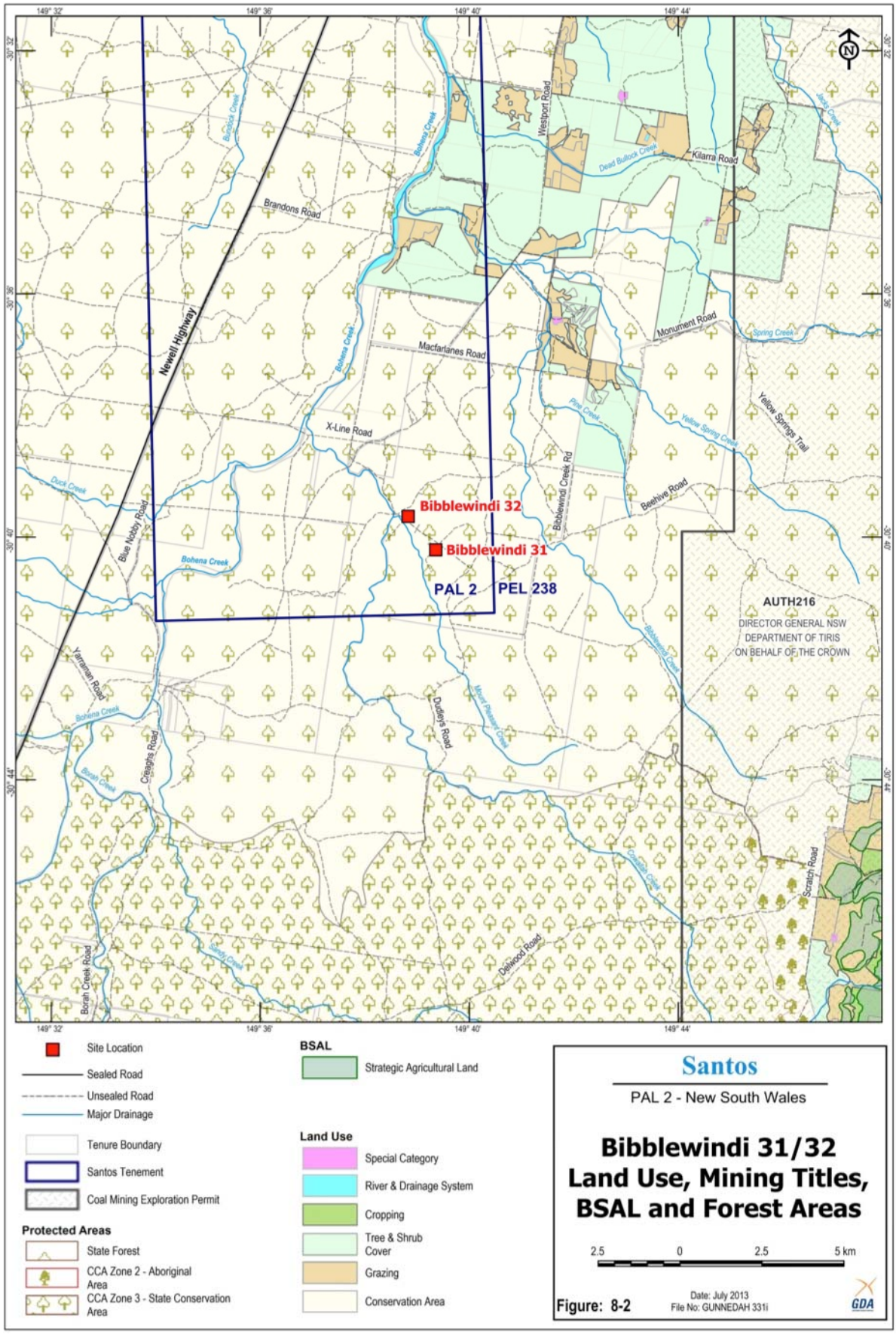

Figure 8-2 Land use, mining titles, BSAL and forest areas

8.1.2 Climate and weather

The closest operating weather station is located approximately 16 kilometres west of Boggabri (Boggabri Neotsfield – station 55273). Climate in this area is regarded as semi-arid, due to hot summers and mild winters. Average (1900 – 2013) monthly maximum temperatures range from 16.6°C (July) to 33.4°C (Jan) and maximum temperatures have not exceeded 40°C. Frost can occur in all low lying parts of the region. Frost events generally occur between June and August though can begin as early as May. Table 8.1 describes climatic conditions recorded for the region.

Average annual rainfall at Boggabri is 594.5 millimetres. Pan evaporation exceeds rainfall throughout the year, indicating the regions reliance on irrigation and soil water storage during fallows.

Table 8-1 Mean climate data

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	77.9	64.3	45.8	36	43.3	41.8	40.7	35.8	35.6	51.4	58.8	63.1
Maximum Temperature (°C)	33.4	32.5	30.2	25.9	21.1	17.4	16.6	18.6	22.4	26.2	29.7	32.4
Minimum Temperature (°C)	18.1	17.9	15.3	10.7	6.9	4.1	2.8	3.7	6.5	10.5	14	16.6
Pan Evaporation (mm)	272	217	198	133	87.1	59.7	64.4	91.8	131	184	228	273

8.1.3 Soils

The AIS provides a desktop assessment of the soils within the region and those that are likely to be present at the site. The findings of this assessment are summarised below.

The soils across the region vary depending on the local sediment source. Australian Soils Classification (ASC) mapping identify the site and much of the surrounding area as being characterised by Duplex soil (Sodosols). Separate soil profiles collected by ESG and RPS at various locations between approximately four and 7.5 kilometres from the proposed activity also found soils to be either Rudosols and Tensols or Sodosols. Sodosols are typical of those derived from the Pilliga Sandstone and are described as being highly siliceous with poor soil nutrient status, and low Plant Available Water Capacity (PAWC). Rudosols and Tenosols are also identified approximately 1.5 kilometres south-east of Bibblewindi 31 and are described as having a generally weak pedologic organisation.

In terms of erosional and sediment transport qualities, the AIS reports that areas within four to six kilometres to the north of the site were found to have slight dispersion between 0 – 0.14 metres in depth while subsoils (<0.14 metres) were found to have very high dispersion. Therefore, soils at the site are likely to be prone to erosion.

According to the *Draft Inherent Soil Fertility mapping of the New England – North West region* (OEH, 2012), the inherent soil fertility of the site is moderately low.

Soil characteristics of the site indicate moderate to severe limitations as the features of Sodosals such as low plant available water capacity, low nutrient levels and sodicity that all limit agricultural production.

The site is not expected to be contaminated. No spills or other incidents are known to have occurred during construction and previous operation of the site that may have caused contamination.

8.1.4 Land and soil capability

The soil limitations are consistent with BSAL and Land and Soil Capability Class (LSC class) mapping for the site.

SAL is highly productive land that has both unique natural resource characteristics as well as socio-economic value (DP&I, 2012a). BSAL is land with the best quality landforms, soil and water resources which are naturally capable of sustaining high levels of productivity with minimal management practices (DP&I, 2012a). A CIC is a localised concentration of interrelated productive industries based on an agricultural product that provides significant employment opportunities and contributes to the identity of the region (DP&I, 2012a).

As shown in Figure 8-2, the site is not located within land mapped as BSAL or CIC under the SRLUP. Based on the broad scale mapping provided in the SRLUP, the nearest BSAL is located approximately 15 kilometres east of the site.

In NSW, LSCs have been mapped for the New England – North West region (OEH, 2012b). The mapping is based on an eight class system with values ranging between 1 and 8 which represent a decreasing capability of the land to sustain land use. Class 1 represents land capable of sustaining most land uses including those that have a high impact on the soil (e.g. regular cultivation), whilst class 8 represents land that can only sustain very low impact land uses (e.g. nature conservation).

The site and surrounds have been mapped as LSC Class 4 and 5 (Figure 8-1). Lands in LSC Class 4 are described as having moderate to severe limitations and are generally not capable of sustaining high impact land uses unless using specialised land management practices with high level of knowledge, expertise, inputs, investment and technology. Lands in LSC Class 5 are described as having severe limitations and are not capable of sustaining high impact land uses except where resources allow for highly specialised land management practices to overcome limitations (e.g. high value crops).

8.1.5 Water resources

A detailed description of the groundwater resources in the area is provided in Chapter 9 and Chapter 10 describes surface water conditions.

8.2 Potential impacts

8.2.1 Land use

As the proposed activity lies within a State Forest, it will not prohibit any agricultural production within the region, and there will not be any consequent reduction in the permanent land capability of agricultural resources. Furthermore, moderate to severe limitation of the site for agricultural production and its location within the State Forest means that it is highly unlikely that the site would be used for agricultural production in the long term.

The proposed activity would be located on existing lease areas (previously cleared). As this area does not harbour trees such as the Pilliga Box, Yellow Box and Narrow Leaved Ironbark species which may be targeted by honey bees when flowering, any impact to the apiary industry would also be negligible. Similarly there would be no change to existing recreational tourism opportunities in Bibblewindi State Forest such as hiking, camping and bird watching. The presence of equipment and small stockpiles during the construction stage of the proposed activity will result in some visual clutter however this is unlikely to be noticeable other than by users of the forest in the immediate area. During operation, the well heads and related surface infrastructure may be visible from Little Tighes Road.

No existing agricultural jobs will be lost as a direct result of the proposed activity. Therefore, the proposed activities will not result in a loss of agricultural employment opportunities in the Narrabri Shire LGA.

With respect to agricultural support services within the region, there may be a minor short term increase in traffic volumes on the Newell Highway during the construction phase. Significantly, these impacts will be temporary in nature and are not expected to cause significant delay or increase risks associated with the transport of agricultural products and services. Traffic impacts are discussed further in Chapter 15.

8.2.2 Soil quality and land stability

8.2.2.1 Erosion

The proposed activity would require minor earthworks (approximately 30 square metres) on the existing well lease area as part of drilling activities to establish the cellar pit near the location of the wells and the installation of sub-surface infrastructure to connect the well to the existing gas and water gathering system. Any topsoil and spoil generated during site preparation activities will be stockpiled on site for the duration of site preparation, drilling, testing and completion activities.

The proposed disturbance to the ground surface is entirely within existing lease areas and as such the site is not considered to be sensitive to disturbance.

While the existing lease areas are relatively flat, any earthworks will increase the site's erosion potential and may result in loss of topsoil/spoil, and sedimentation of waterways. Potential impacts to surface waters are further discussed in Chapter 10.

Drilling activities will produce drilling fluid and drill cuttings. These materials are unlikely to present an erosion hazard as drilling fluid and cuttings will be contained in lined pits, surface tanks or metal bins.

Delivery trucks and personnel vehicles exiting the sites may track sediment onto Little Tighes Road. Erosion and sedimentation will be reduced through the measures identified in Section 8.4.

Potential erosion impacts are expected to be very minor and only occur during the drilling stage. Ongoing erosion impacts during operation associated with the lease areas were assessed as part of previous approvals. Sediment controls already exist at each of the lease areas as part of works for Bibblewindi 14 and 19H.

8.2.2.2 Contamination

During site establishment, construction and drilling, the proposed activity could result in soil contamination as a result of spilled or leaked chemicals (such as drilling fluid additives), fuel or oil. Spills or leaks could occur during handling, use, storage or transit of chemicals, fuels and oils. Spills or leaks may also occur during refuelling or maintenance of plant or equipment.

There is minimal risk of soil contamination occurring due to the use of drilling fluid as this will be water-based and will contain non-toxic additives. Drilling fluids and cuttings are therefore unlikely to be contaminated.

Measures to reduce the risk of contamination as a result of the proposed activity are identified in Section 8.4.

There is a risk that a line failure could occur within the gathering system that transfers lifted groundwater between the wells to the transfer tank at Bibblewindi Water Transfer Facility. Water pressure within the pipes is monitored remotely and should this occur, operation of the well will be suspended until the problem is rectified. The extent of the impact will also be small, localised and short term.

Impacts to structural integrity, land instability or subsidence are not expected.

8.2.2.3 Community use of natural resources

As the proposed activity is being undertaken on already cleared land, it will not further restrict forestry activities within the State Forest.

Natural resources required for the proposed activity include diesel for operation of plant and machinery. Quantities of fuel will not be significant. These are discussed in Section 17.

The proposed activity will not impact on existing coal mining operations. There are no known coal mines planned for the site and it is expected that the proposed activity will pose no threat to future coal mining operations.

8.2.2.4 Soil diseases

The proposed activity may contribute to the spread of soil diseases, particularly *Phytopthora.* These potential impacts will be managed through the measures identified in Section 8.4.

8.3 Cumulative impacts

The proposed activity will not contribute to the use of natural resources (particularly agricultural land) as part of the E&A Program as the proposed activity will occur within existing lease areas and utilise existing water and gas management infrastructure.

The current extent of agricultural land use within PEL 238 and PAL 2 is approximately 791,478 ha. None of the activities planned as part of the proposed E&A Program are located on agricultural land (major agricultural industries identified in PEL 238 and PAL 2 are cropping, grazing, horticulture and plantations). Although production forestry is mapped within PEL 238 and PAL 2, there is minimal exotic plantations. Rather, these areas include State forest used for timber harvesting and nature reserves (accounting for an additional 190,462 ha). Timber harvesting within the Pilliga has been reduced largely due to conservation efforts; therefore any impact on such enterprises are not considered significant.

Cumulative impacts of the E&A Program to natural resources will be negligible as the majority of agricultural land would be fully rehabilitated and available for agricultural activities following completion of exploration activities. Proposed activities will also not quarantine any Critical Industry Cluster (CIC) areas.

8.4 Mitigation measures

8.4.1 Site establishment

- Excess topsoil and subsoil generated during site preparation activities will be stockpiled on site and used as backfill following completion of drilling.
- Erosion and sediment controls will be implemented where necessary during site preparation activities, in accordance with best management practices (such as the Blue Book or IECA Guidelines). These controls will be maintained until disturbed areas of the site are stabilised.

8.4.2 Drilling

- The quantity of chemicals, fuels and oils stored on site will be minimised, where practicable.
- All additives, chemicals, fuels and oils stored on site will be kept in an appropriately secured, bunded storage shed in accordance with the relevant MSDS.
- Where there is a risk of contamination pits will be lined or material will be stored in surface tanks or metal bins.
- An MSDS register of all chemicals used or stored on site will be maintained.
- Maintenance of vehicles, plant and equipment will occur off site at an appropriately licensed facility unless deemed necessary and appropriate to conduct such maintenance on site.
- Refuelling of plant and equipment will occur in a designated, bunded area, at least 40 metres from the nearest waterway.
- Any spills or leaks will be contained and cleaned up immediately using the spill kit. Contaminated material (such as contaminated soil or absorbent materials) will be placed in a bag and removed from the site for disposal at a licensed waste facility.
- Plant and equipment will be inspected daily to ensure these are properly maintained.

8.4.3 Operation

- Ongoing management and maintenance of remaining infrastructure on site will occur, including water transfer area and well heads.
- The gathering system water pressure will be monitored. Should line failure occur between the wells to the transfer tank at Bibblewindi Water Transfer Facility, operation of the well will be suspended until the problem is rectified.

8.4.4 Post operation

The site will be rehabilitated in accordance with Section 4.5.1 of the EIS.

9.0 Groundwater

A *Groundwater Impact Technical Report* has been completed by CH2M Hill for the proposed activity. The report is provided in Appendix 3 and the assessment is summarised below.

9.1 Existing environment

9.1.1 Hydrogeological setting

The Upper Namoi and Lower Namoi Alluvium form the principal aquifers of the Namoi River Catchment. According to the relevant water sharing plans for the region, the site does not sit within any mapped Upper Namoi and Lower Namoi Alluvium.

AGE (2006) indicates that Bohena Creek is associated with an alluvial aquifer, with minor thin veneers of alluvium in some tributary creeks. The alluvium of Bohena Creek and major tributaries consist of clean, medium to coarse quartz sands which are up to about seven metres thick. The alluvial sands form elongated deposits confined to the creek alignment and have an estimated average width of about 60 metres along Bohena Creek.

The water table in the alluvium of Bohena Creek varies from surface level following periods of creek flow, to an estimated two metres below surface level during dryer periods (AGE, 2006). It is considered that groundwater in the alluvium is perched on the finer grained sedimentary deposits of the Blythesdale Group, as the water level in the deeper Pilliga Sandstone aquifer is 20 to 30 metres below ground level in the area.

Recharge of the alluvium occurs primarily from infiltration of surface water during creek flow events and to a lesser degree by direct infiltration of rainfall on the sand deposits. Groundwater flow is to the north along the creek channel, with discharge eventually to the Namoi River and/or the major alluvial aquifers associated with the river.

The main aquifers surrounding the site are associated with underlying basement rock units, and include the following:

- Southern Recharge groundwater source, under the Water Sharing Plan for the NSW GAB Groundwater Sources.
- Gunnedah-Oxley Basin MDB buried groundwater source, under the Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater Sources.
- Lachlan Fold Belt MDB buried groundwater source, under the Water Sharing Plan for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources.

The southern recharge zone of the GAB underlies the site. The GAB covers 1.7 million square kilometres and contains 8,700 million megalitres of artesian water. It consists of sedimentary sequences with layers of porous and permeable sandstones which alternate with low permeability shales, siltstones and mudstones. Aquifers of the GAB are unsuitable for irrigation use due to high levels of sodium; however, water from these aquifers is generally suitable for domestic and town water supply (GABCC, 1998).

Groundwater recharge takes place chiefly along the south and eastern fringe of the GAB. Groundwater enters the main Pilliga Sandstone aquifer directly through exposed outcrop, or at lesser rates, via overlying strata where there is potential for downward groundwater movement (DWE, 2009). The Pilliga Sandstone outcrops in the vicinity of the site, and underlies the area at a relatively shallow depth (20 to 30 metres). The Southern Recharge groundwater source, in which the site lies, is characterised by better quality groundwater than other zones of the GAB.

The Gunnedah-Oxley Basin MDB Groundwater Source covers a subcrop area of 28,600 square kilometres. It is the Permian and Triassic rocks associated with the Gunnedah Basin, and the overlying younger Jurassic and Cretaceous rocks associated with the Oxley Basin. The Gunnedah-Oxley Basin extends from the Mount Coricudgy Anticline (separating it from the Sydney Basin), the Hunter-Mooki Thrust to the east (forming the eastern boundary between the Gunnedah-Oxley Basin and the New England Fold Belt), the Lachlan Fold Belt to the west and a structural high to the north of Narrabri (NOW, 2012a).

The consolidated formations (e.g. hard rock aquifers) of the Gunnedah Basin comprise interbedded coals, sandstone and siltstones and are not considered major groundwater sources. These formations may be categorised into the following hydrogeological units (AGE, 2006):

- hydrogeologically 'tight' and hence very low yielding to essentially dry sandstone and lesser siltstone and shale that comprise the majority of the strata
- low to moderately permeable coal seams which are the prime water bearing strata within the Permian sequence.

The primary target CSG bearing formation for the proposed activity is the Bohena seam, a lower Permian coal within the Maules Creek Formation as shown in Figure 9-1.

Groundwater pressures determined from Drill Stem Tests (DSTs) during exploration by ESG indicated groundwater levels between 247 to 385 metres AHD within the Maules Creek Formation (including the Bohena Seam). All the groundwater levels derived from DST were found to be artesian and were significantly higher than groundwater levels in the alluvium (Golder, 2011). There was no coherent groundwater flow direction apparent from the DST-derived head measurements, partly due to the varied zones over which the DSTs have been conducted and also because the likely lack of discharge from the formation.

The Lachlan Fold Belt MDB Groundwater Source covers an area of 167,220 square kilometres. It consists of Cambrian to Lower Carboniferous rock successions, located deeper than the targeted CSG bearing formations. The eastern margin is truncated by the present coastline in the south and is overlapped by the Permo-Triassic succession of the Sydney Basin and its northern equivalents; the northern margin is overlaid by the Mesozoic Great Artesian Basin succession; the southern margin is truncated by the present Tasmanian coastline, and is overlaid by Permian and younger successions. The western margin is largely covered by the mainly Cainozoic Murray Basin successions (NOW, 2012b).

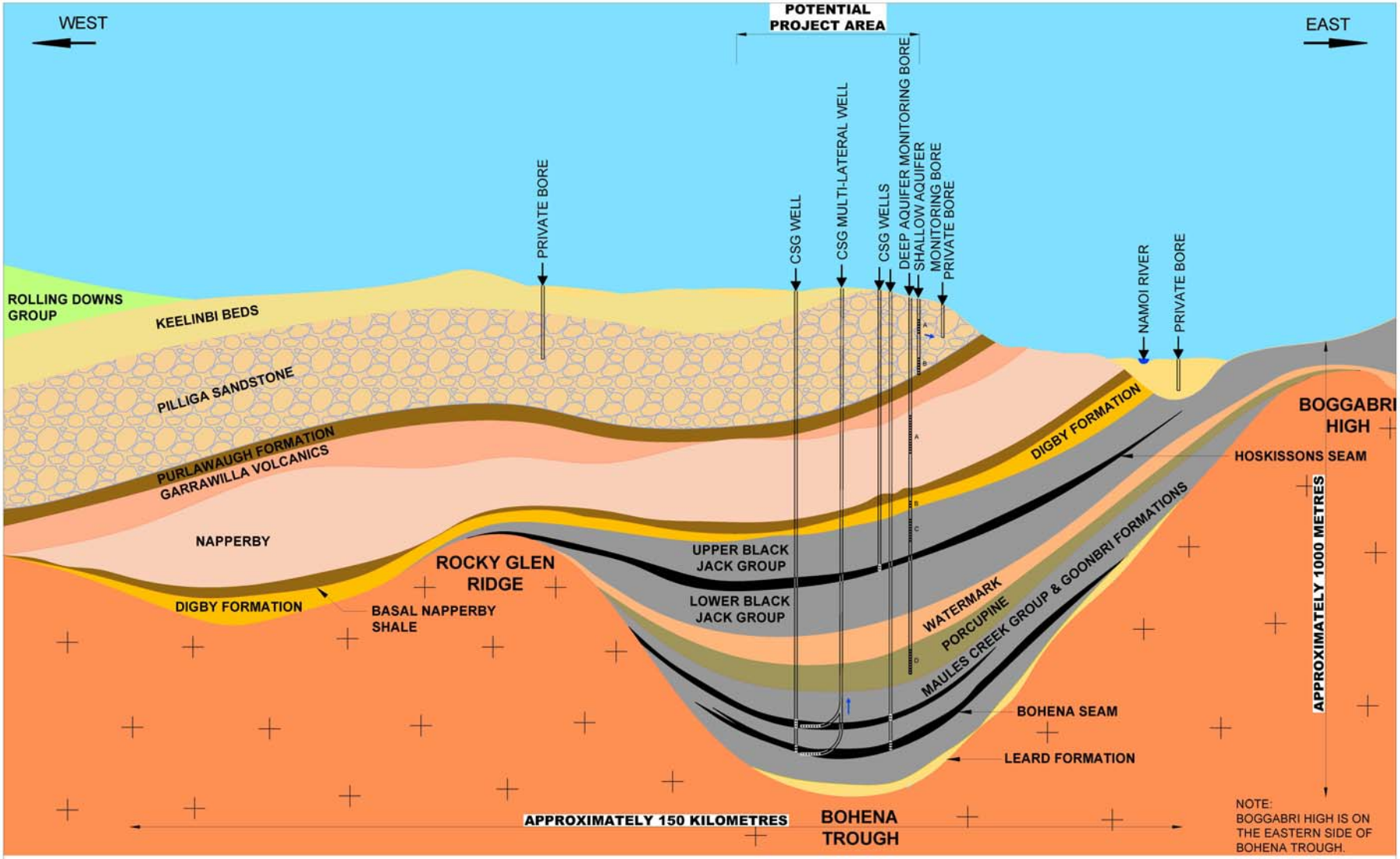

Figure 9-1 Schematic cross section through the Bohena trough (not to scale)

Source: Narrabri Groundwater Flow Model report (CH2M Hill, 2013)

9.1.2 Groundwater use

Groundwater in the Namoi River catchment supports the irrigation industry and also provides the water supply for many towns and intensive industries. There are a total of 700 groundwater license holders in the Namoi River catchment (NOW, 2011). As the Upper Namoi and Lower Namoi Alluvium form the principal aquifers of the Namoi River Catchment they are heavily used for irrigation (Schlumberger Water Services, 2012). The Namoi catchment is licensed to provide over 343,000 megalitres of groundwater entitlement per year.

Groundwater use in close proximity to the site is limited, due to both land use constraints arising from the site being located within the Pilliga scrub and lower yields associated with the consolidated rock units. The Maules Creek Formations (including the target Bohena seam) is not currently used for water supply due to depth, water quality and availability of good quality groundwater near the surface.

According to the Pineena database (NOW, 2010), there are five licensed groundwater bores within five kilometres of the proposed study area. Table 9-1 provides details of these registered groundwater bores. It is noted that salinity information was not provided within the database for any of the bores.

Table 9-1 Registered groundwater bores within five kilometres of the proposed activity

Bore ID	Easting	Northing	Max Depth (m)	GWMA	Authorised purpose	Water Bearing Zone (m)	Yield
GW021998	749,825	6,605,167	73.8	GAB	Oil exploration	38.7-43.5	-
						46.3-52.0	-
						56.6-69.7	1.52
GW967923	754,004	6,607,915	90.0	GAB	Industrial	65-73	-
				-	-	75-90	-
GW967935	754,134	6,609,085	93.0	GAB	Industrial (low security)	53-56	-
						65-81	-
						91-93	-
GW968789	757,680	6,609,400	84.0	GAB	Domestic/ Stock	61-84	25
GW970010	754,260	6,608,015	47.0	GAB	Test Bore	33 – 47	-

9.1.3 Groundwater Dependant Ecosystems

There are two high priority groundwater dependent ecosystems (GDEs) listed within the NOW GDE database. These are Eather Spring and Hardy's Spring, both located approximately 18 kilometres from the site. They are both located on or close to the junction of the Pilliga Sandstone and Purlawaugh Formation at outcrop.

Both springs are considered to represent recharge springs, sustained by rejection of rainfall recharge that doesn't enter the main GAB groundwater source. Recharge rejection occurs within the GAB intake beds when the rate of recharge to the shallow groundwater sources exceeds the capacity for deep drainage into the GAB intake beds, principally due to low hydraulic conductivity of Purlewaugh Formation acting as a regional seal.

9.1.4 Water quality

A water quality assessment has been undertaken that included 317 samples from 126 sources; 178 samples collected from production/exploration wells in the Gunnedah and Narrabri region and 139 samples from the Regional Bore Inventory for the Gunnedah area (Golder Associates, 2012). Groundwater samples were extracted from a number of formations including the Maules Creek (93 samples) and alluvial (11).

Overall, groundwater pH values in the E&A Program area ranged from 6.81 to 11.2. Coal seam water in the Maules Creek Formation is slightly alkaline, with a range of 7 to 9. Based on total dissolved solids (TDS) concentrations (measured at approximately 600 to 18,520 milligrams per litre), water from the coal seams can be classed as 'brackish to saline'. Alluvium and consolidated rock sources can be classed as 'fresh to brackish', with measured TDS between approximately 300 and 6000 milligrams per litre.

9.2 Assessment approach

A numerical groundwater flow model has been developed to simulate the potential cumulative impact on surface water and groundwater resources, and GDEs from the operation of the six pilot sites within the E&A program. Initial model development included:

- Data collation, literature review and gap analysis:
- Characterisation of the groundwater environment, including identification of environmental values associated with groundwater resources
- Development of the hydrogeological conceptual model (HCM)
- Development of a groundwater flow model to facilitate the assessment of the potential impacts of CSG water extraction on water resources.

The numerical groundwater model was constructed using MODFLOW-2005 and the graphical user interface (GUI) Groundwater Vistas interface V6.07 Build 18.

The model extends:

- Eastward beyond the Boggabri Ridge to the eastern side of the Namoi River
- Southward beyond the Walla Walla Ridge into the Bando Trough
- Westward to the Rocky Glen Ridge
- Northward beyond the Narrabri High and the Namoi River to the inferred location of the groundwater divide within the GAB (in accordance with groundwater level information presented in GABFLOW2000 (Welsh, 2000).

The modelling assumed that the operation of each pilot will occur for a three year period. The estimated volumes of groundwater extracted from the target seams which were applied within the modelled operation scenario are provided in Table 9-2.

Table 9-2 Estimated extraction rates for pilots

Pilot	Total Extraction (m^3)	Max Extraction (m^3/day)	Average Extraction (m^3/day)
Dewhurst 13-18 Pilot	331,121	397	302
Dewhurst 22-25 Pilot	285,140	273	260
Dewhurst 26-31 Pilot	413,801	448	378
Bibblewindi Multi-lateral Pilot	285,110	581	260
Bibblewindi West Pilot	92,940	209	85
Tintsfield 2-7 Pilot	25,162	43	23

There are no plans to use the process of hydraulic stimulation (also known as hydraulic fracturing or fracking) within the E&A Program.

Further details of the model and modelling process are provided in Appendix 3.

9.3 Potential impacts

9.3.1 Construction

Potential impacts to groundwater associated with construction may result from drilling, well installation or abandonment if not carried out correctly.

Potential impacts of drilling in mixed multi-aquifer systems include:

- creation of an artificial connection between water-bearing formations that bypasses aquitards (low permeability layers which restrict groundwater flow) or aquicludes (geological formations through which no groundwater flows) resulting in cross contamination of aquifers
- contamination of the aquifers by drilling fluids if these are lost in the formation
- groundwater discharge to the surface, which may cause flooding or impact on surface water quality depending on the discharge and receiving water qualities.

Human consumptive uses and aquatic ecosystems may be impacted from these potential risks. These risks are rated as minor and are considered unlikely to occur as wells will be designed and constructed in accordance with the *NSW Coal Seam Gas Code of Practice Well Integrity* (DTIRIS, 2012b) and over balance drilling methods will be employed.

Groundwater contamination could also occur due to spills of oil, fuels or chemicals if they are not cleaned up appropriately.

9.3.2 Operation

The assessment of potential groundwater impacts during operation was completed based on a cumulative approach, as outlined in Section 9.2. The outcome of this cumulative impact modelling is summarised in Section 9.4.5 below. The impacts of the Bibblewindi Multi-Lateral Pilot in isolation, while not modelled, can be assumed to be much lower than those predicted from this modelling.

9.4 Cumulative impacts

A detailed discussion of potential cumulative groundwater impacts, including relevant hydrographs and drawdown plots, is provided in the Groundwater Impact Technical Report. A summary of the key outcomes, in regards to the Aquifer Interference Policy (AIP) is provided below. Impacts would be confined to the NSW Murray-Darling Basin Porous Rock Groundwater Source WSP where the target seam is located. However water quality extracted from the target seam is highly brackish and unsuitable for drinking or irrigation without treatment.

9.4.1 Predicted impacts on the NSW Upper and Lower Namoi Groundwater Source WSP during operation of the pilot wells

The alluvial groundwater sources of the Upper and Lower Namoi alluvium (NSW Upper and Lower Namoi Groundwater Source WSP) are considered to be highly productive in the context of the AIP. The groundwater model predicts that there will be no decline in the water table or change in flux within these alluvial aquifers as a result of the operation of the E&A Program. This is due to the aquitard layers, including the Purlewaugh Formation, that separate the target coal seam from the alluvium.

9.4.2 Predicted impacts on the NSW GAB Groundwater Source WSP during operation of the pilot wells

The porous rock groundwater source of the GAB Surat Pilliga Sandstone (NSW GAB Groundwater Source WSP) is also considered to be a highly productive porous rock groundwater source in the context of the AIP. Groundwater modelling results indicate that there is no decline in groundwater level or change in flux within this aquifer during operation of the E&A Program. This is again due to the aquitard layers, including the Purlewaugh Formation, that separate the target coal seam from the GAB.

9.4.3 Predicted impacts on the NSW Murray-Darling Basin Porous Rock Groundwater Source WSP during operation of the pilot wells

The porous rock groundwater source of the Gunnedah Basin (GMA604) (NSW MDB Porous Rock groundwater source WSP), comprising the Triassic strata of the Digby, Napperby and Deriah formations and the Permian strata of the Black Jack Group down to and including the Maules Creek Formation, is considered within the context of the AIP to be a less productive porous rock groundwater source. These different strata are represented in the model as different layers with the CSG water extraction occurring in lowest layers. A decline in head of over 2 m within the lowest strata is indicated by the model outcomes. Given that the pilot CSG water extraction will occur within this AIP classified water source, the impact on hydraulic (pressure) head within the combined group of the three stratas and the fluxes developed within the groundwater source to meet the pilot CSG water demand are interpreted to comprise aquifer interference and will require licensing.

The zones of influence remain west of the outcrop of the Gunnedah Basin Permo-Triassic strata. Hence the registered bores within this region of the MDB Porous Rock (Gunnedah Basin GMA604) groundwater source WSP which extract from this groundwater source will not be impacted by the pilot CSG water extraction.

9.4.4 Predicted impacts on registered water supply bores

Of the five registered bores within five kilometre of the proposed activity, only one is used for stock and domestic purposes. All these bores extract water from the Pilliga Sandstone. The Pilliga Sandstone of the Surat Basin is considered the lowest (and most easterly) intake beds of the GAB. As stated above, this aquifer will not be significantly impacted by the proposed activity during either construction or operation.

There is no known registered extraction from bores in formations deeper than the Pilliga Sandstone across the E&A Program area. From the modelling result, the predicted cumulative impact on registered water supply bores across this extent will not be significant.

9.4.5 Predicted impacts on high priority Groundwater Dependant Ecosystems and related vegetation

Hardy's and Eather Spring are hydrogeologically associated with the Pilliga Sandstone. As there is no significant impact to the Pilliga Sandstone, there is expected to be no significant impact on the GDEs due to the proposed activity. Similarly, the model results indicate that there will be no significant impact on groundwater dependent terrestrial vegetation within the E&A Program area.

9.5 Mitigation measures

9.5.1 Construction

- The wells will be designed and constructed in accordance with the *NSW Coal Seam Gas Code of Practice Well Integrity* (DTIRIS, 2012b).
- Drilling and installation operations, well control, waste management and abandonment procedures for the pilot wells will be in accordance with accepted industry practices and in accordance with the processes outlined in the EIS.
- A driller that holds the relevant qualifications as defined by the NSW Office of Water will be on site during drilling of the top hole until the surface casing is set, cemented, and pressure tested. During this time, there will be 24 hour coverage by one person working the day shift and on call at site during the night. This will ensure that the appropriate knowledge of water legislation and regulation in NSW and technical skills are employed to avoid impacts to surface and groundwater sources.
- Excessive drilling fluid losses will be cured by loss circulation material (cellulose material such as sawdust or other benign naturally occurring substances, as required) to ensure most fluids return to the surface.
- Santos will make reasonable endeavours to seek permission (from landowners) to access registered groundwater bores within two kilometres of the site to undertake groundwater monitoring prior to drilling, to establish baseline conditions, and on completion of drilling, to determine if there are any impacts. Where access to bores is granted (and the bore is functioning), monitoring will include water level measurements and water quality observations in the field, and sampling for analysis by an accredited laboratory.

9.5.2 Operation

- The volume of water extracted from the pilot wells will be monitored.
- Pressure gauges will be fitted to the pilot wells, and monitored remotely through a Supervisory Control and Data Acquisition (SCADA) system. Should pressure change due to a leak, the pilot wells will be shut down immediately and the affected area investigated.
- The groundwater monitoring program will be implemented
- In line with monitoring during drilling, Santos will make reasonable endeavours to seek permission (from landowners) to continue monitoring of registered groundwater bores within two kilometres of the site to determine if there are any impacts to aquifers.
- The wells will be decommissioned as soon as they are no longer required.

9.5.3 Proposed groundwater monitoring program

The monitoring of groundwater is required to confirm the absence or onset (and magnitude) of any impact associated with CSG activities at both the deep and shallow aquifer level. Registered bore users extract water from the shallow aquifers and whilst modelling has concluded that this will not be impacted, long-term monitoring over the duration of the CSG operations is proposed.

Santos is currently implementing a comprehensive groundwater monitoring program. This program was presented and discussed with the NSW Office of Water and was approved by the OCSG on 9 July 2013.

The groundwater monitoring program proposes to include installation of shallow monitoring bores at eight locations and one deep aquifer monitoring bore over the next 12 months. The proposed location of these bores is provided in Figure 9-2, noting these are subject to change as required. A number of the monitoring locations already have relevant licences issued by the NSW Office of Water under the *Water Act 1912*.

Once installed, these monitoring bores will measure groundwater pressure and temperature within various strata and enable groundwater levels and flows to be monitored. Information will be transmitted via telemetry to a production database. The bores will not extract any groundwater beyond what is extracted during drilling and required for water quality sampling, where this occurs.

Baseline data gathered will include groundwater heads (pressures) within the hydraulically confined strata of the Gunnedah Basin and groundwater levels within these unconfined Permo-Triassic strata at or close to outcrop and subcrop. This will help to establish the baseline conditions prevailing before the commencement of any pilot trials within the wider region. The shallow monitoring bores will focus on:

- Demonstrating the baseline groundwater levels and the background flow pattern within the Pilliga Sandstone.
- Confirming the groundwater pressure in the Purlawaugh Formation.
- Verifying the confining characteristics of the Orallo formation overlying the Pilliga Sandstone.

The deep monitoring bore will focus on:

- Demonstrating the baseline groundwater pressures and the background flow patterns/existing hydraulic gradients within the hydrostratigraphic units of the Gunnedah Basin.
- Illustrating the absence or otherwise of vertical hydraulic continuity within the Gunnedah Basin strata.
- Enabling elaboration of the migration of groundwater depressurisation both laterally in the target seam and vertically above and below the target seam, following the commencement of CSG water extraction.

The proposed location of the monitoring network has been arranged to maximise the acquisition of beneficial data which can:

- Inform the absence or otherwise of potential impact to the regional GAB aquifers.
- Act as sentinel monitoring locations between the Narrabri Gas Field Area and groundwater abstractions in the Gunnedah Basin domain.
- Yield essential hydrogeological data comprising additional stratigraphic data, remote head and field testing data and cores for laboratory testing of hydraulic parameters.

9.5.4 Licensing

Under s60I of the WMA, a WAL is required to take water in the course of carrying out a mining activity. During its operation, the Bibblewindi Multi-Lateral Pilot is expected to extract a maximum of approximately 285 megalitres of groundwater over three years from the Gunnedah-Oxley Basin MDB groundwater source under the NSW MDB Porous Rock Groundwater Source WSP. Santos has been granted a ‘certificate of right to apply for an access licence’ of 600 unit shares from within the Gunnedah-Oxley Basin MDB groundwater source by the NSW Office of Water. An application for a WAL of 600ML per annum for this water source (one unit share is currently equal to one megalitre of water) has been made. Santos also currently holds a 20 unit share aquifer access licence entitlement for this same groundwater source. Santos has submitted an application for a Water Supply Works Approval for the Bibblewindi Multi-Lateral Pilot.

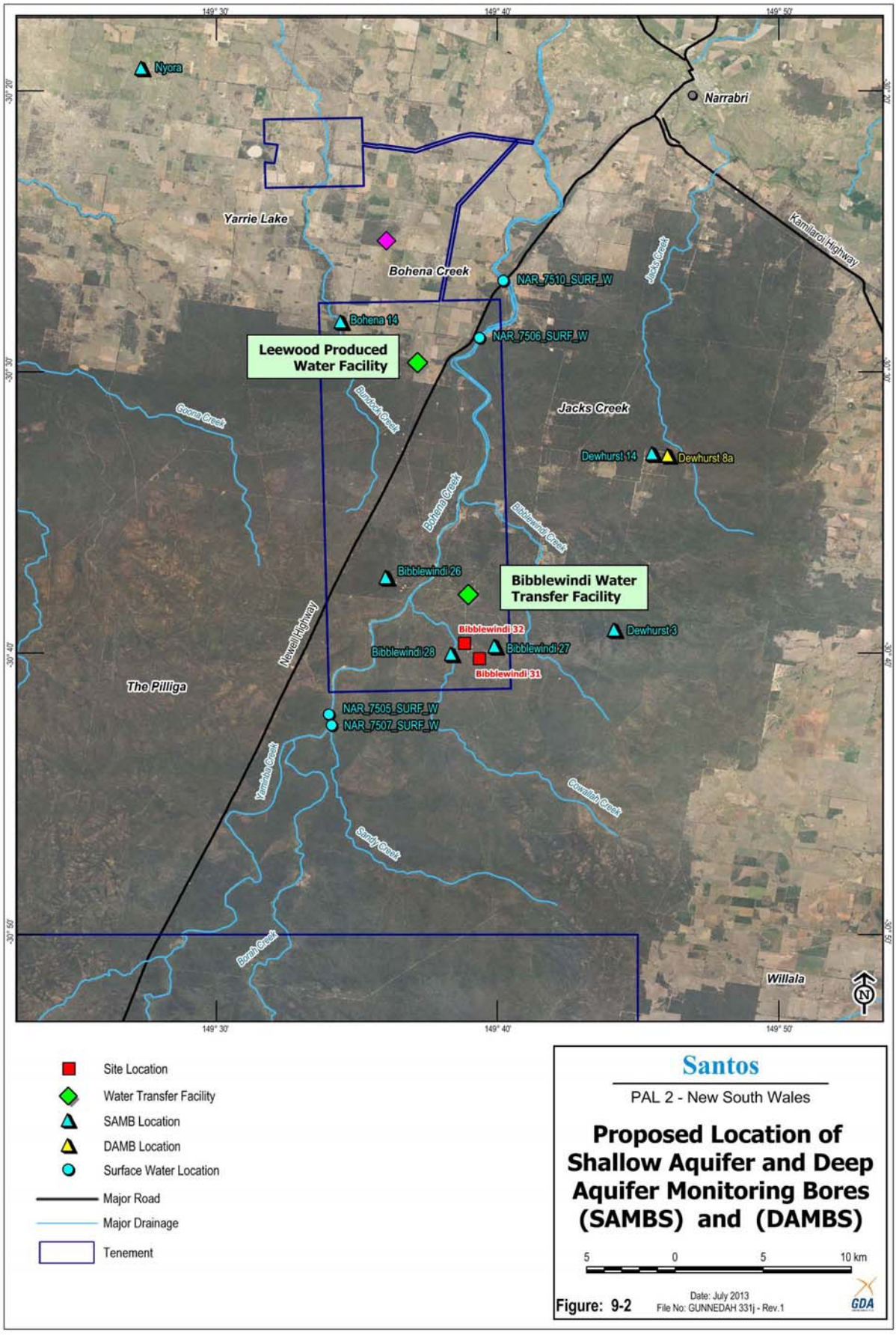

Figure 9-2 Proposed locations of shallow aquifer and deep aquifer monitoring bores

10.0 Surface water

10.1 Existing Environment

10.1.1 Surface water catchment

The site is located within the Namoi River catchment which covers an area of approximately 42,000 square kilometres stretching from Woolbrook in the east to Walgett in the west. The catchment is bounded by the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south and the Nandewar Ranges and Mount Kaputar to the north. Major tributaries of the Namoi River include Coxs Creek and the Mooki, Peel, Cockburn, Manilla and Macdonald rivers, all of which join the Namoi River upstream of Boggabri with Pian, Narrabri, Baradine and Bohena Creeks joining below Boggabri (NCMA, 2013).

Given the dominant use of the land in the Namoi catchment as grazing and both dryland and irrigated cropping (refer Chapter 8); surface water quality within the catchment is likely to be influenced by agricultural runoff, spray drift, and vapour transport (NCMA, 2013).

The subject site is located within the Bohena sub-catchment of the Namoi River catchment. The sub-catchment covers an area of approximately 830 square kilometres south of Narrabri and is the northern extension of the Borah sub-catchment. The Bohena sub-catchment is drained by Bohena, Cowallah and Bibblewindi creeks (NCMA, 2013). Issues within the sub-catchment include soil erosion, biodiversity conservation, water quality and riparian management.

The Bohena sub-catchment forms the Bohena Creek Water Source under the *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources* (NOW, 2012c) A search of the NSW Office of Water's website indicated that there are currently no records of any Water Access Licences under the *Water Management Act 2000* within this water source.

Bohena Creek and its tributaries are ephemeral watercourses that do not form significant topographical features within the landscape. They generally flow for short periods following significant rainfall or prolonged wet periods (WRM, 2006). Baseflow in these creeks are insignificant. Bohena Creek remains dry for extended periods between runoff events, sometimes for periods in excess of 12 months (WRM, 2006). It contributes little inflow to the Namoi under normal conditions; however during protracted wet conditions, significant flood inflows to the Namoi can be generated. Sedimentation in the catchment has resulted in extensive sand deposits in Bohena Creek and its tributaries. Due to the ephemeral nature of Bohena Creek, it can be inferred that the extensive sand deposits are caused by intense rainfall events that mobilise and rework sediment.

The Namoi Water Quality Project 2002-2007 (Mawhinney, 2011) incorporated a surface water monitoring station on Bohena Creek at the Newell Highway, downstream of the confluence with Bibblewindi Creek (station number 419905). The frequency of sampling throughout the program's five year life was once a month, however over the course of the five year monitoring period, a total of only five samples were collected at this site, always following heavy rainfall in the catchment area. This reflects the ephemeral nature of the watercourses in this area. Details of the water quality measured at this sampling location on Bohena Creek are provided in Table 10-1.

Table 10-1 Water quality measured on Bohena Creek (station number 419905) from 2002–2007

Parameter	Minimum	25th per centile	Median	75th per centile	Maximum
EC (µS/cm)	148	184	185	192	327
Turbidity (NTU)	17	57	76	82	130
Total Phosphorus (mg/L)	0.061	0.063	0.073	0.099	0.107
Total Nitrogen (mg/L)	0.52	0.57	0.62	0.78	0.91

10.1.2 Site drainage and local surface water sources

Figure 10-1 shows local drainage lines within the vicinity of the proposed activity. The existing pilot wells are located in the vicinity of Cowallah Creek and Mount Pleasant Creek, as well as unnamed tributaries of Mount Pleasant Creek and Bohena Creek as summarised in Table 10-2. All of these watercourses are ephemeral.

Table 10-2 Proximity to drainage lines and creeks

Water course	Stream order	Distance from Bibblewindi 14 lease area (km)	Distance from Bibblewindi 19H lease area (km)
Unnamed tributary of Cowallah Creek	2nd	0.58	0.125
Mount Pleasant Creek	3rd	0.5	0.225
Cowallah Creek	4th	1.5	0.45
Bohena Creek	5th	5.2	4

The closest watercourse to Bibblewindi 32 is an unnamed tributary of Mount Pleasant Creek located approximately 50 metres north east of the lease area (refer to Plate 10-1). The closest watercourse to Bibblewindi 31 is Mount Pleasant Creek, a tributary of Cowallah Creek, located approximately 500 metres to the west. Cowallah Creek flows into Bohena Creek approximately four kilometres downstream from the site.

Plate 10-1 An unnamed ephemeral creek 50 metres north west of Bibblewindi 32

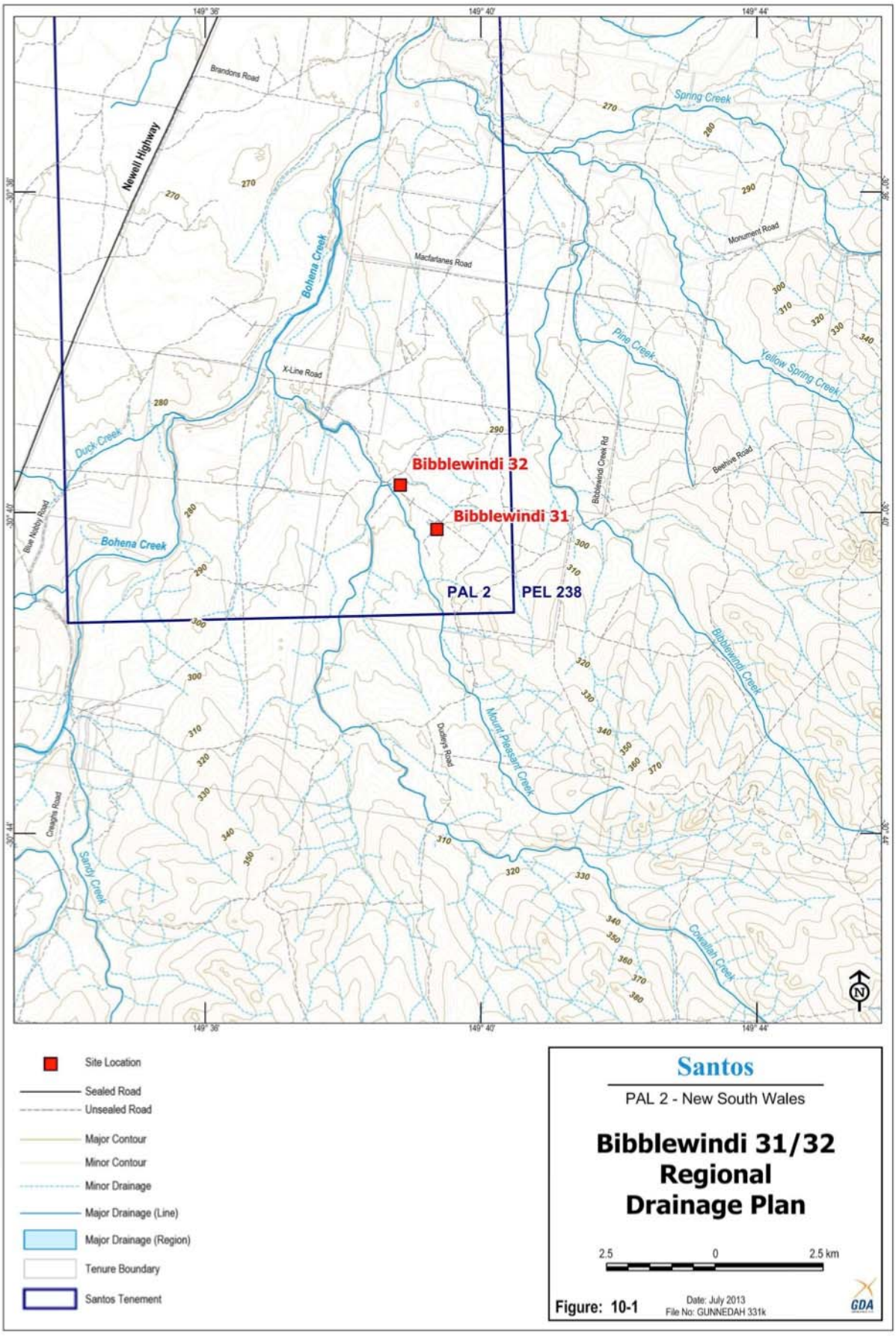

Figure 10-1 Regional drainage plan

According to a stream order classification assessment undertaken as part of the Ecological Assessment (Appendix 4), Bohena Creek is considered to be a fifth order watercourse (as defined under the *Water Management Act 2000*, using the Strahler System) which exhibits generally good landscape condition. Cowallah Creek is a relatively undisturbed fourth order watercourse, while Mount Pleasant Creek and the unnamed tributary of Cowallah Creek are third and second order watercourses, respectively. Stream Order was determined for the watercourses based on drainage lines captured from orthophotos at 1:50,000 and 1:25,000 scale.

The location of the proposed activity is within the Pilliga Outwash landscape unit as described in Lampert and Short (2004). An aggradational landscape of low lying, undulating alluvial sediments, the outwash is traversed by a number of south to northwest trending drainage lines, many being abandoned paleochannels. Most sediment within the watercourses of this landscape is derived from upstream Pilliga Sandstone plateaus or as a result of reworking of the broad outwash plain.

According to Lampert and Short (2004), Bohena Creek is representative of the 'low sinuosity, sand' river style. This river style does not retain surface water between flows. The channel will go through phases of incision, expansion and lateral migration and then recover through bench formation. Overbank flows, which occur every one to two years, activate flood channels, dissipating flow energy onto the floodplains.

Lambert and Short (2004) summarise the geomorphic units of the low sinuosity, sand river style as a single, laterally unconfined and relatively active channel set within a slightly undulating, wide and continuous floodplain. The channel bed is a relatively featureless, mobile sand sheet with scattered gravels, while the banks are composed of fine sands with some silt and organic matter.

The unnamed tributary of Cowallah Creek is characterised by a small, tightly sinuous ephemeral channel system that flows into Cowallah Creek. The tributary is two to three metres wide, with gentle banks characterised by sandy soils. Deposition was apparent and there was little evidence of active erosion during a site visit in November 2012. The banks are relatively stable and despite above average rainfall in the area, there was limited erosion observed in the channel.

The tributary does not appear to be connected with the local groundwater system. Water levels in the tributary are more likely to be affected by water backing-up the tributary, when water levels in Cowallah and Bohena Creeks are high, then by runoff flows within the tributary catchment. Only large catchment flows would activate erosion in this creek line and mobilise sediments.

There are a number of floodplains declared under the *Water Act* 1912 located nearby but not on the site. The closest is the Namoi River: Carroll to Boggabri floodplain, located approximately 37 kilometres to the east.

The site is not located within a drinking water catchment however surface water would filter to groundwater which is potentially used for drinking water in the surrounding areas.

10.1.3 Values of receiving waters

Water Quality and River Flow Objectives have been defined for uncontrolled streams within the Namoi catchment (DECCW, 2006). The relevant objectives and how the proposed activity will achieve these objectives are outlined in Table 10-3. The key indicators and trigger values provided as guideline levels within the Water Quality Objectives for the Namoi catchment are adopted from the Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 guidelines or *Australian Drinking Water Guidelines* (NHMRC and NRMMC 2011).

Table 10-3 Relevant water quality and river flow objectives for the site

Objective	Description of objective	How the proposed activity will meet objective
Water Quality Objectives		
Aquatic ecosystems	Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	The site will be managed to ensure that no water used for drilling and operation is discharged to drainage lines and that existing salinity, turbidity and pH levels of surface waters are maintained.
Visual amenity	Aesthetic qualities of waters	The site will be managed to ensure that no water, oil/fuel or debris is discharged to drainage lines. The proposed activity is unlikely to introduce aquatic pests or weeds. Vehicle cleaning procedures will ensure that other weed species are not introduced to watercourses.
Livestock water supply	Protecting water quality to maximise the production of healthy livestock	Due to its ephemeral nature, surface water in the vicinity of the site is not used to supply livestock water. The Groundwater Impact Technical Report (Appendix 3) determined that the aquifers which may be used for livestock water supply would not be impacted upon by the proposed activity. The wells will be constructed in accordance with industry standards and will isolate aquifers.
Irrigation water supply	Protecting the quality of waters applied to crops and pasture	Due to its ephemeral nature, surface water in the vicinity of the site is not used to supply irrigation water. The Groundwater Impact Technical Report (Appendix 3) determined that the aquifers which may be used for irrigation water supply would not be impacted upon by the proposed activity. The wells will be constructed in accordance with industry standards and will isolate aquifers.
Homestead water supply	Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing	Due to its ephemeral nature, surface water in the vicinity of the site is not used to supply water for homesteads. The Groundwater Impact Technical Report (Appendix 3) determined that the aquifers which may be used for domestic water supply would not be impacted upon by the proposed activity. The wells will be constructed in accordance with industry standards and will isolate aquifers.
Drinking water – Disinfection only, or Drinking water – Clarification and Disinfection, or Drinking water – Groundwater	Refers to the quality of drinking water drawn from the raw surface and groundwater sources before any treatment	The proposed activity does not involve the drawing of potential drinking water from raw surface or groundwater sources.

Objective	Description of objective	How the proposed activity will meet objective
River Flow Objectives		
Protect pools in dry times	Protect natural water levels in pools of creeks and rivers and wetlands during periods of no flows	The proposed activity will not involve extraction from any surface waters.
Protect natural low flows	Protect natural low flows	The proposed activity will not involve extraction from any surface watercourses.
Protect important rises in water levels	Protect or restore a proportion of moderate flows ('freshes') and high flows	The proposed activity will not involve extraction from any surface watercourses.
Maintain wetland and floodplain inundation	Maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems	The proposed activity will not involve any additional disturbance beyond previously approved works.
Manage groundwater for ecosystems	Maintain groundwater within natural levels and variability, critical to surface flows and ecosystems	The Groundwater Impact Technical Report (Appendix 3) determined that the aquifers which may feed groundwater dependent ecosystems and baseflows would not be impacted upon by the proposed activity. The wells will be constructed in accordance with industry standards and will be isolated from intercepting aquifers.

10.1.4 Santos surface water monitoring program

Surface water monitoring is important in predicting and measuring the potential impact of CSG activities within the Namoi catchment. To enable this, the baseline water quality characteristics of the catchment must be understood, against which change can be measured and monitored.

URS has designed and implemented a baseline surface water sampling plan for Santos within the Narrabri Region, incorporating PAL 2. The sampling program commenced in February 2012, with approximately 30 locations considered to be 'regular' sites throughout the monitoring program period to date. Due to the ephemeral nature of tributaries within the Namoi catchment, including Bohena Creek, some locations are only able to be monitored periodically. The closest relevant regular monitoring points to the Bibblewindi Multi-Lateral Pilot are described in Table 10-4 and shown on Figure 9-2.

Table 10-4 Regular surface water monitoring locations

Monitoring ID	Site description	Easting	Northing	Number of samples (Feb 2012 – Jun 2013)	Distance from the site (km)
NAR_7505_SURF_W	Bohena Creek upstream of Bibblewindi site	745875	6600481	2	9
NAR_7506_SURF_W	Bohena Creek off Newell Hwy picnic area	755014	6625004	11	20
NAR_7507_SURF_W	Garlands Dam	746022	6599750	16	10
NAR_7510_SURF_W	Bohena Creek crossing, Newell Hwy	756470	6628742	11	24

Six locations were also monitored on an *ad hoc* basis, at the request of Santos. This monitoring is generally undertaken to quantify potential environmental impacts observed in the field, and/or to capture additional data during wet weather events. Most of the locations are situated on ephemeral tributaries which are known to flow only in prolonged wet periods, and are therefore not considered to be viable for long-term baseline monitoring on a regular basis. The closest additional monitoring points to the Bibblewindi Multi-Lateral Pilot are described in Table 10-5.

Table 10-5 Additional surface water monitoring locations

Monitoring ID	Site description	Easting	Northing	Number of samples (Feb 2012 – Jun 2013)	Distance from the site
NAR_7500_SURF_W	Tributary upstream of Bibblewindi WTF	754865	6604386	1	0.6
NAR_7501_SURF_W	Tributary downstream of Bibblewindi WTF	753042	6608471	1	4
NAR_7522_SURF_W	Bohena Creek downstream of confluence with Cowallah Creek	751182	6608728	1	5
NAR_7539_SURF_W	Bohena Creek upstream of confluence with Bibblewindi Creek	752086	6609903	1	5

Sampling is undertaken in accordance with the requirements of AS/NZS 566.6:1998, *Guidance on sampling of rivers and streams.*

In situ measurements for physico-chemical parameters are obtained at each monitoring location using a water quality meter. The following *in situ* parameters are recorded:

- pH
- Dissolved Oxygen (DO)
- Electrical conductivity
- Total Dissolved Solids (TDS)
- Water temperature.

Surface water samples are obtained using the grab sampling technique, a sample methodology set out in AS/NZS 5667.1:1998 and 5667.6.1998, and with consideration of ANZECC Guidelines and Water Quality Objectives in NSW. A suite of analysis is undertaken by a National Association of Testing Authorities (NATA) accredited laboratory.

Reporting is undertaken monthly following completion of the laboratory analysis and an annual characteristic report is currently being completed. As part of this report, the frequency and locality of the sampling is being reviewed based on the results to date. It is anticipated that surface water sampling will continue for the life of the CSG program to meet requirements of future regulation and environmental assessment.

Summaries of the data collected to date are provided in Table 10-6 and Table 10-7 for the regular and additional monitoring locations, respectively.

Table 10-6 Regular surface water monitoring locations – data summary

Parameter	NAR_7505_SURF_W			NAR_7506_SURF_W			NAR_7507_SURF_W			NAR_7510_SURF_W		
	Min	Med	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
EC (µS/cm)	147	N/A	512	118	180.5	224	80	118	202	117	204.5	301
TDS (mg/L)	N/A	586	N/A	87	132.5	172	112	156	410	124	152	210
DO (mg/L)	7.58	N/A	9.38	4.29	7.5	9.47	4.76	6.94	12.79	5.7	7.16	8.4
Dissolved Organic Carbon (mg/L)	15	N/A	36	9	10.5	18	4	15	19	14	17	20
PAH (mg/L)	<0.0155	N/A	<0.0155	<0.0155	<0.0155	<0.0155	<0.0155	<0.0155	<0.0155	<0.0155	<0.0155	<0.0155
pH	7.12	N/A	8.03	6.71	7.36	7.69	7.38	7.54	8.25	6.9	7.39	7.57
Total N (µg/L)	700	N/A	1300	400	600	1100	400	1000	2000	800	1000	1100
Total P (mg/L)	0.11	N/A	0.17	0.02	0.04	0.2	0.01	0.06	0.18	0.01	0.09	0.15
Sum of BTEX (µg/L)	<1	N/A	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Turbidity (ntu)	109	N/A	165	2.5	18.6	101	18.1	44.1	83.6	13.1	38.5	167

Table 10-7 Additional surface water monitoring locations – data summary

Parameter	NAR_7500_SURF_W	NAR_7501_SURF_W	NAR_7522_SURF_W	NAR_7539_SURF_W
EC (µS/cm)	124	272	448	435
TDS (mg/L)	-	177	290	284
DO (mg/L)	5.5	2.64	7.17	7
Dissolved Organic Carbon (mg/L)	21	79	9	8
Polycyclic Aromatic Hydrocarbons (mg/L)	<0.0155	<0.0155	<0.0155	<0.0155
pH	7.02	7.55	7.9	7.97
Total N (µg/L)	1100	5200	500	500
Total P (mg/L)	0.11	0.76	0.1	0.08
Sum of BTEX (µg/L)	<1	<1	<1	<1
Turbidity (ntu)	203	709	37.2	36.5

10.2 Potential impacts

Potential surface water impacts are greatest during construction and drilling. During operation, potential surface water impacts would be limited to those associated with leakages from the gathering system.

10.2.1 Surface Water Flow Regimes

The proposed activity will not result in any change to the existing approved disturbed areas during construction or operation. Some minor redirection of flow already occurs as a result of sediment controls and drainage bunding on the existing Bibblewindi 14 and 19H lease areas.

Changes to the area, volume or flow of the surrounding surface watercourses, including Cowallah Creek and Mount Pleasant Creek, are unlikely to occur particularly during drilling as activities would not be undertaken during prolonged wet periods.

10.2.2 Surface Water Quality

Potential impacts of the proposed activity on surface water quality include the uncontrolled runoff during construction activities and/or release of contaminants, including leakage of produced water during operation.

Drilling fluids will be captured in tanks where it will be re-used or taken to the FTF. It is unlikely that drilling fluid will be spilled as all tanks will be fitted with high low sensors to detect levels.

Some fluids could be spilt as a result of tank failure, during the drilling process, or during transit to and from the site. This could result in pollution of drainage lines or watercourses with sediment and other contaminants, but this is considered unlikely given current over balance drilling techniques, the sensors fitted to tanks and the use of licensed waste transport operators. The proposed activity will only require small volumes of fluids to be transported to and from the site with the potential for spills and/or leaks being minor and likely to remain localised. In the event of an incident, appropriate measures to contain and remediate areas of impact will be initiated.

There is potential for chemicals, fuels or oils used or stored on site to leak or spill and enter drainage lines, including Cowallah Creek or Mount Pleasant Creek, and degrade local water quality. Pollutants or wastewater could also be discharged to these watercourses during general site activities such as vehicle washing or dust suppression. Litter from personnel on site may enter watercourses and degrade water quality. Surface runoff and gross pollutants will be captured through site bunding along the lease area.

During operation the groundwater lifted from the coal seam will need to be stored temporarily and disposed of in accordance with the proposed water management strategy, outlined in Section 10.3. An uncontrolled discharge to the environment could occur due a leak onsite at the lease areas or within the gathering system network. If this were to occur, there could be localised impacts to surface water. Due to the regular monitoring and inspection protocols that will be implemented, the extent of the impact will be minor, localised and short term.

Santos would operate the site in accordance with the requirements of an EPL.

10.2.3 Local surface water resources and users

There are no existing permanent surface water features, and hence resources, in the vicinity of the site. Water for the drilling and onsite requirements will be sourced from town water or a producing well, rather than a natural/local surface water body.

Due to the ephemeral nature of the creeks within the Bohena Creek catchment, there are currently no Water Access Licences issued within this water source. Therefore there are no registered surface water users that will affected by the proposed activity.

10.2.4 Flooding

The proposed activity will not result in any change to the existing disturbed areas. Therefore, there will be no additional impact to the extent, frequency or duration of flooding as a result of the proposed activity.

In addition, the site is not located within a designated floodplain and the proposed activity is unlikely to significantly affect the distribution or flow of floodwaters.

For these reasons a detailed flood impact assessment was not considered necessary as part of this EIS. There is still potential that sediment, contaminants or gross pollutants may be released into watercourses as a result of localised flooding and inundation of the site during construction although given the scale of the activity, this is likely to be minor.

10.3 Cumulative impacts

Due to the staggered implementation of the construction phase across the E&A Program and the distances between sites, cumulative impacts to surface water are considered to be negligible.

During operation, the water management strategy proposed as part of the E&A program includes a number of measures to reduce any impacts to surface water as a result of a spill or leak. This includes:

- Remote monitoring, sensors and pressure gauges at all well heads and along key infrastructure nodes
- Balance tanks to manage the volume and pressure of water
- The ability to remotely shut in wells at the well head if any leaks are detected
- A leak collection system at the Leewood Produced Water Facility
- Double lining of ponds at the Leewood Produced Water Facility
- Water level monitoring of ponds

No produced water from the Bibblewindi Multi Lateral Pilot will be transferred to the existing ponds at the Bibblewindi Water Transfer Facility.

Similar to construction, cumulative impacts to surface water during operation are considered to be negligible as any leakages that may occur will be localised and short term given the leakage detection and automated shutdown systems proposed.

10.4 Mitigation measures

The erosion and sediment control measures identified in Section 8.4 will minimise impacts to surface water and the site will be rehabilitated in accordance with Section 4.5 of the EIS. The following additional measures will be implemented:

10.4.1 Construction

- Water will not be extracted from nearby watercourses, including Cowallah Creek or Mount Pleasant Creek.
- The existing diversion bund will be maintained on the up-slope side of the lease areas to divert clean water around the work area.
- Drilling fluids will be contained in surface tanks which will be regularly inspected and maintained.
- Water that drains to the cellar pit will be circulated with the drilling fluid throughout the drilling process.
- Should any formation fluid rise through the well, it will be captured in the waste fluid tank and will be removed to a licensed waste facility that is able to accept liquid waste for disposal or treatment.
- Drilling fluids will be transported to and from the site by an appropriately licensed contractor.
- Fuel and lubricants will be stored on site only when necessary and maintained off site whenever possible.
- Wastewater generated through general site activities will be removed by an appropriately licensed contractor for disposal at a licensed facility or treated to an appropriate quality prior to discharging.
- All areas storing or handling fuel, fuel using equipment, and chemicals will be bunded in accordance with Australian Standard 1940–2004; The Storage and Handling of Flammable and Combustible Liquids or other relevant guidelines.
- Weather forecast will be monitored and in the event that prolonged, severe wet weather of flooding is predicted, works will cease and plant, machinery and any chemicals will be secured and bunded.
- A minimum freeboard of 300 millimetres will be maintained for any tanks or pits containing liquid waste.

10.4.2 Operation

- The surface infrastructure at the lease areas will be regularly inspected.
- The surface water monitoring program will be implemented

10.4.3 Licensing

As no water is proposed to be extracted from any surface water within the Bohena Creek water source during construction or operation, no water access licence under the *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources (NOW, 2012c)* is required.

11.0 Biodiversity

An *Ecological Assessment* has been completed by RPS for the proposed activity (Appendix 4). The assessment included:

- database searches, including the EPBC Act Protected Matters Search Tool and Atlas of NSW Wildlife, for threatened species, populations and ecological communities within 10 kilometres of the site
- review of relevant photos and maps, including aerial photography and National Vegetation Information Systems mapping within the vicinity of the site
- a field survey by a qualified ecologist on 27 November 2012

For the ecological assessment the site refers to the two lease areas (Bibblewindi 14 and Bibblewindi 19H), the access tracks to the lease areas and a 20 metre buffer around each.

11.1 Existing environment

11.1.1 Vegetation

Only one vegetation community occurs within the immediate vicinity of the site, namely *Ironbark Shrubby Woodlands of the Pilliga area, Brigalow Belt South*.

The canopy of this community is generally 15 to 19 metres high, with a patchy to moderate 15 to 50 per cent projected foliage cover (PFC). It is dominated by Narrow-leaved Ironbark (*Eucalyptus crebra*).

A shrub layer of variable height (0.1 to 1.7 metres) occurs, with coverage of 80 to 95 per cent. It is dominated by *Acacia caroleae* (Wattle) and, to a lesser extent, *Acacia spectabilis* (Mudgee Wattle), *Callistemon linearis* (Narrow-leaved Bottlebrush) and *Cassinia arcuata* (Sifton Bush).

Ground cover also exhibits coverage of 80 to 95 per cent, with variable heights between 0.1 to 0.8 metres. It is dominated by *Dianella revoluta* (Blue Flax-lily), *Lomandra filiformis* (Wattle Mat-rush), *Aristida ramosa* (Purple Wire Grass), *Eragrostis brownii*, *Aristida vagans* (Threeawn Speargrass) and *Cheilanthes sieberi* (Mulga Fern).

This community adjoins the existing cleared lease areas and access tracks and is in poor to moderate condition. The majority of the native vegetation is of a young age, which limits the resources that the community can produce and hence the fauna species it can support.

The existing lease areas are largely devoid of flora species. During the site inspection, the lease areas exhibited some evidence of natural regeneration. The regeneration was still in its infancy and was dominated by native grasses (*Panicum effusum* and *Eragrostis brownii*). Some juvenile shrubs (*Dodonea viscosa*) were starting to encroach into the lease areas.

11.1.2 Listed ecological communities

11.1.2.1 Threatened Ecological Communities under the EPBC Act

Five Threatened Ecological Communities (TEC) listed under the EPBC Act were identified as potentially occurring within 10 kilometres of the site by the EPBC Protected Matters Search Tool. These are:

- Coolibah – Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions.
- Grey Box (*Eucalyptus microcarpa*) grassy woodlands and derived native grasslands of south-eastern Australia.
- Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland.
- Weeping Myall Woodlands.
- White Box – Yellow Box – Blakely's Red Gum grassy woodland and derived native grassland.

No TECs listed under the EPBC Act occur within the site or the immediate surrounding area.

11.1.2.2 Endangered Ecological Communities under the TSC Act

Seven Endangered Ecological Communities (EEC) listed under the TSC Act were identified as potentially occurring within 10 kilometres of the site, based on known or predicted communities occurring within the Namoi catchment (NSW Atlas of Wildlife Search). These are:

- Carex Sedgeland of the New England Tableland, Nandewar, Brigalow Belt South and NSW North Coast Bioregions.
- Coolibah-Black Box Woodland of the Darling Riverine Plains and the Brigalow Belt South bioregions.
- Fuzzy Box Woodland on alluvial Soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions.
- Inland Grey Box Woodland in the Riverina; NSW South Western Slopes; Cobar Peneplain; Nandewar and Brigalow Belt South Bioregions.
- Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South Western Slopes bioregions.
- Native Vegetation on Cracking Clay Soils of the Liverpool Plains.
- White Box – Yellow Box – Blakely's Red Gum Woodland.

No EECs listed under the TSC Act occur at the site or within the 10 kilometre surrounding area.

11.1.3 Flora

11.1.3.1 Threatened species

Threatened species database searches indicate10 threatened flora species listed under the EPBC Act and/or TSC Act were identified within the surrounding 10 kilometres of the site. These species, their threat status and their likelihood to occur at the site are identified in Table 11-1. Likelihood to occur assessments were undertaken based on a number of factors including habitat preferences, recent field investigations, background data and local technical knowledge.

Table 11-1 Threatened flora species within 10 kilometres of the site

Species	Listing[1]		Identified during field survey	Likelihood to occur within the siite[2]
	TSC Act	EPBC Act		
Bertya opponens	V	V	No	Possible
Diuris tricolor	V	-	No	Possible
Monotaxis macrophylla (Large-leafed Monotaxis)	E	-	No	Possible
Philotheca ericifolia	-	V	No	Possible
Polygala linariifolia (Native Milkwort)	E	-	No	Possible
Pomaderris queenslandica (Scant Pomaderris)	E	-	No	Unlikely
Pterostylis cobarensis (Cobar Greenhood Orchid)	V	V	No	Possible
Pultenaea setulosa	-	V	No	Unlikely
Rulingia procumbens	V	V	No	Possible
Tylophora linearis	V	E	No	Possible

[1]E = endangered, V = vulnerable
[2]Likely to occur at and within 10 kilometres of the site

11.1.3.2 Species recorded at the site

A total of 25 flora species were identified during the field survey, none of which are EPBC and/or TSC Act-listed species. No regionally significant flora was identified. The field survey included the site and the 10 kilometres surrounding the site.

A list of the flora species recorded is provided in the Ecological Assessment.

11.1.3.3 Weeds

No introduced species of flora were identified during the field survey.

11.1.4 Fauna

11.1.4.1 Threatened species

Sixteen threatened fauna species listed under the EPBC Act and 32 threatened species listed under the TSC Act were identified as potentially occurring at the site or within the immediate ten kilometres surrounding the site. The likelihood of occurrence of these species was assessed, based on broad habitat type within the surveyed area, as well as species distribution.

Table 11-2 outlines the threatened fauna species that have potential to occur, based on the likelihood assessment. For many species, the immediate surrounding area provides sub-optimal habitat that may provide foraging resources only. No unique habitat occurs on the site itself.

Table 11-2 Threatened fauna species with potential to occur at the site and the immediate 10 kilometres surrounding the site

Species	Listing[1]		Identified during field survey	Likelihood to occur at site[2]
	TSC Act	EPBC Act		
Anthochaera Phrygia (Regent Honeyeater)	CE	E	No	Possible
Calyptorhynchis lathami (Glossy Black Cockatoo)	V	-	No	Likely
Chthonicola sagittata (Speckled Warbler)	V	-	No	Likely
Climacteris picumnus victoriae (Brown Treecreeper)	V	-	No	Likely
Daphoenositta chrysoptera (Varied Sittella)	V	-	No	Possible
Glossopsitta pusilla (Little Lorikeet)	V	-	No	Likely
Lathamus discolour (Swift Parrot)	E	E	No	Possible
Leipoa Ocellata (Malleefowl)	-	V	No	Possible
Lophoictinia isura (Square-tailed Kite)	V	-	No	Possible
Melanodryas cucullata cucullata (Hooded Robin)	V	-	No	Possible
Neophema pulchella (Turquoise Parrot)	V	-	No	Likely
Ninox connivens (Barking Owl)	V	-	No	Likely
Polytelis swainsonii (Superb Parrot)	V	V	No	Possible
Pomatostomus temporalis temporalis (Grey-crowned Babbler)	V	-	No	Likely
Stagonopleura guttata (Diamond Firetail)	V	-	No	Possible
Tyto novaehollandiae (Masked Owl)	V	-	No	Possible
Hieraaetus morphnoides (Little Eagle)	V	-	No	Possible
Cercartetus nanus (Eastern Pygmy-possum)	V	-	No	Possible
Chalinolobus dwyeri (Large-eared Pied Bat)	V	V	No	Possible
Chalinolobus picatus (Little Pied Bat)	V	-	No	Possible
Nyctophilus corbeni (South-eastern Long-eared Bat)	V	V	No	Possible
Petaurus norfolcensis (Squirrel Glider)	V	-	No	Possible
Macropus dorsalis (Black-striped Wallaby)	E	-	No	Possible
Phascolarctos cinereus (Koala)	V	V	No	Possible
Pseudomys pilligaensis (Pilliga Mouse)	V	V	No	Possible
Saccolaimus flaviventris (Yellow-bellied Sheathtail-bat)	V	-	No	Possible
Vespadelus troughtoni (Eastern Cave Bat)	V	V	No	Possible

[1]CE = critically endangered, E = endangered, V = vulnerable
[2]Likely to occur at and within 10 kilometres of the site

11.1.4.2 Species recorded during surveys

A total of nine common native avifauna species were identified during the field survey, none of which are EPBC and/or TSC Act-listed species.

A list of the avifauna species recorded is provided in the Ecological Assessment (Appendix 4).

11.1.4.3 Migratory species

The EPBC Protected Matters Search Tool indicated that 11 migratory species listed under the EPBC Act were identified as potentially occurring within a ten kilometre radius of the site. An assessment of likelihood of occurrence was completed for each species, based on habitat preference and known species distribution. The assessment confirmed that five species have the possibility of occurring:

- *Anthochaera phrygia* (Regent Honeyeater)
- *Leipoa ocellata* (Malleefowl)
- *Hirundapus caudacutus* (White-throated Needletail)
- *Apus pacificus* (Fork-tailed Swift)
- *Merops ornatus* (Rainbow Bee-eater)

No migratory species were observed during the field survey.

11.1.4.4 Introduced species

No introduced species were recorded during the field survey. A number of pest species have been recorded opportunistically within the broader Pilliga forest including the Red Fox (*Vulpes vulpe*s), Goat (*Capra hircus*), Rabbit (*Oryctolagus cuniculus*), Brown Hare (*Lepus europaeus*), Cat (*Felis catus*) and Pig (*Sus scrofa*).

11.1.4.5 Habitat values

As the existing lease areas and access tracks are cleared they offer potential basking habitat for reptiles and, consequently, foraging habitat for some birds. However, they are generally of limited value to fauna species, due to the lack of habitat resources.

The surrounding vegetation contains open forest dominated by *Eucalyptus crebra* (Narrow-leaved Ironbark). The vegetation is primarily regrowth with many canopy trees being of a relatively young age. The canopy is fragmented, possibly as a result of selective logging practices. As a result of the maturity of the canopy, no hollow-bearing trees were observed during the field survey. Hollows are an important habitat attribute for a number of fauna species. The understorey also exhibits signs of regeneration after fire disturbance and some areas are almost completely dominated by *Acacia spectabilis*. This vegetation type may still provide habitats such as high, mid and low canopy, shrub and groundlayer vegetation. Other habitat attributes such as leaf litter, fallen timber, small exposed rocks and exposed soil/sand are also present.

11.1.5 Aquatic ecology

11.1.5.1 Riparian and aquatic vegetation

According to Namoi CMA (2010), four riparian vegetation communities occur in nearby creeks surrounding the site. These include:

- Blakely's Red Gum riparian woodland – located predominantly along Cowallah and Bohena Creek. A small patch also exists along the unnamed tributary of Cowallah Creek, upstream of Bibblewindi 32.
- Rough-barked Apple – Blakely's Red Gum riparian grassy woodlands – associated with the ephemeral drainage lines along Cowallah Creek and extends out to the border of Mount Pleasant Creek.
- Ironbark shrubby woodlands – associated with the unnamed tributary of Cowallah Creek nearby to Bibblewindi 31. This community is not considered a riparian vegetation community.
- Ironbark – Brown Bloodwood – Black Cypress Pine heathy woodlands, Brigalow Belt – associated with the ephemeral drainage lines. This community is not considered a riparian vegetation community.

Riparian vegetation, dominated by sparse grasses and graminoids such as *Juncus sp*., occurs as a narrow strip (approximately two metres wide) along the unnamed tributary of Cowallah Creek. Trees are present, but these are generally set back from the channel and are unlikely to create a source of woody debris in the short term. The tree canopy overhangs areas along the unnamed tributary line and thus would provide a source of detritus and food for some aquatic fauna.

No aquatic vegetation was identified at the site.

The Office of Environment and Heritage (OEH) (2006) wetland mapping identified no wetlands within a ten kilometre radius of the site.

11.1.5.2 Aquatic habitat values

Aquatic habitat is in poor to moderate condition. The cover of instream habitat (e.g. small and large woody debris, tree roots and aquatic vegetation) is limited, while was no evidence of log-jams along the unnamed tributary of Cowallah Creek (approximately 125 metres northeast of the Bibblewindi 19H lease area).

Due to a lack of suitable habitat (absence of slow flowing deep waters), the unnamed tributary is unlikely to support listed rare and threatened species such as the Murray Cod (*Maccullochella peelii peelii*). While Mount Pleasant and Cowallah Creek were not surveyed, they are also considered unlikely to contain suitable habitat for Murray Cod due to their ephemeral nature. No suitable habitat for turtles was identified.

Under prolonged wet conditions these creeks are likely to be characterised by shallow pools and runs with poor instream-diversity. The ephemeral nature of these creeks is more likely to support common fish species during migration and breeding, and potentially provide feeding areas for some aquatic fauna.

While these ephemeral waterways are small, they are an important component of ecological function, potentially providing breeding and habitat resources for species such as frogs and reptiles. They also provide for fauna movement throughout the broader landscape.

11.1.5.3 Waterway Classification

The stream order of the water courses in the vicinity of the site is provided in Section 10.1. The Strahler System provides a measure of system complexity and therefore the potential for fish habitat to be present. Third order streams and above are considered likely to display valuable fish habitat, and hence could support viable fish populations.

Although some exceptions apply, stream order can also correspond with the waterway classification, with Class 4 waterways generally being first and second order streams (and some third order streams), while Class 3 will generally be third order streams. Class 1 and 2 will be third order or above streams.

The stream order and waterway classification of the water courses in the vicinity of the site are provided in Table 11-3.

Table 11-3 Stream order and waterway classification of nearby water courses

Water course	Stream order	Waterway classification	Key fish habitat	Distance from Bibblewindi 14 lease area (km)	Distance from Bibblewindi 19H lease area (km)
Unnamed tributary of Cowallah Creek	2nd	Class 4	-	0.58	0.125
Mount Pleasant Creek	3rd	Class 3	Likely	0.5	0.225
Cowallah Creek	4th	Class 3	Likely	1.5	0.45
Bohena Creek	5th	Class 2	Likely	5.2	4
Source NSW Department of Primary Industries (2007) Key Fish Habitat mapping					

Applying the general correlation between stream order and waterway classification, the major creek systems identified include:

- Class 4 (unlikely fish habitat) – unnamed ephemeral drainage line.
- Class 3 (minimal fish habitat) – Mount Pleasant Creek.
- Class 3 (minimal fish habitat) – Cowallah Creek.
- Class 2 (moderate fish habitat) – Bohena Creek.

According to the Waterway Classification system outlined in Fairfull and Witheridge (2003), Mount Pleasant Creek, Cowallah Creek and the tributary of Cowallah Creek provide either unlikely or minimal fish habitat. Bohena Creek is considered to contain moderate fish habitat.

11.2 Assessment approach

The database searches undertaken as part of the Ecological Assessment identified threatened vegetation communities and flora and fauna species, as well as migratory fauna species, that have been recorded or that are considered likely to occur within 10 kilometres of the site. The probability of individual threatened species and vegetation community occurring within the site and surrounding 20 metre buffer was determined as being either unlikely, possible, likely or known, based on a range of criteria.

Once the likelihood to occur was determined, the likely level of impacts as a result of the proposed activity was considered for each species or community. They were assessed separately, based on their likelihood of occurrence, while recognising other parameters such as home range, habitat use, connectivity, as well as the scope of the proposed activity. Based on the outcome of the assessment, a decision was made as to whether further assessment was required.

11.3 Potential impacts

11.3.1 Vegetation clearing

The proposed activity has been designed to avoid any works being undertaken within the adjacent Ironbark Shrubby Woodland. No vegetation clearing outside of the lease area will occur as a result of the proposed activity. As such the proposed activity will not have an impact on the Bibblewindi State Forest, including impacts on conservation and recreational values. Some minor clearing of grasses may occur within the lease area in the immediate area surrounding the well. This is to remove any potential ignition sources during drilling.

11.3.2 Terrestrial impacts

Minimal short-term impacts are associated with the proposed activity, during both construction and operational activities. The primary potential impacts are indirect, as the proposed activity will be carried out within existing disturbance areas. Considerations of specific potential impacts are outlined in Table 11-4.

Table 11-4 Potential terrestrial impacts

Area of concern/impact	Overview
Impacts on threatened species and communities (under the TSC Act)	Section 5A of the EP&A Act lists seven factors (the 7-part test) that must be taken into account in the determination of the significance of potential impacts of proposed activities on 'threatened species, populations or ecological communities (or their habitats)' listed under the TSC Act. A generalised application of the 7-part test concluded that the proposed activity is not likely to have a significant effect on the seven threatened ecological communities, seven threatened flora and 26 threatened fauna species listed under the TSC Act that are considered to have the potential to occur within the site and surrounding 20m buffer. There is potential for indirect impacts during both the construction and operational phases of the proposed activity, in particular potential fauna strike associated with increased vehicle movements. However, provided the mitigation measures in Section 11.5 are implemented, there will be no direct or indirect impacts upon threatened species or their habitats as a result of the proposed activity. Therefore a Species Impact Statement (SIS) is not considered necessary for any of the threatened species, populations or ecological communities.
Impacts on threatened species and communities (under the EPBC Act)	No threatened Ecological Communities are present within the site and immediate surrounding areas. Five threatened flora and nine threatened fauna species listed under the EPBC Act are considered to have the potential to occur within the site and immediate surrounding area however these are considered to not be directly or indirectly impacted on as a result of the proposed activity including proposed mitigation measures. Five migratory species listed under the EPBC Act are considered to have the potential to occur within the site and immediate surrounding area however no species is likely to be directly or indirectly impacted upon as a result of the proposed activity including proposed mitigation measures.
Impacts on Bibblewindi State Forest	The proposed activity has been designed to avoid additional vegetation clearance. Provided the mitigation measures in Section 11.5 are adhered to, there will be no direct or indirect impacts upon the Bibblewindi State Forest. Furthermore, rehabilitation works will incorporate species native to the Forest.
Loss of fauna habitat	The proposed activity has been designed to avoid any works being undertaken within the remnant of Ironbark Shrubby Woodland, which offers potential habitat to a diversity of fauna species. No fauna habitat features located within the Ironbark Shrubby Woodland, such as hollow-bearing trees, will require removal as part of the proposed activity. No 'potential' koala habitat, as defined by SEPP 44, will be removed as part of the proposed activity – nor does any occur within close proximity to the site and immediate surrounding area.
Habitat fragmentation	As the proposed activity will be carried out within an area previously cleared and will not involve any further clearing, the existing vegetation surrounding the site will not be fragmented by the proposed activity.

Area of concern/impact	Overview
Introduction and spread of weeds	The proposed activity has the potential to create favourable conditions for the introduction and spread of weed species within the site through the movement of traffic to the site. However, provided the mitigation measures in Section 11.5 are adhered to, it is unlikely that this will occur as a result of the proposed activity.
Disruption of breeding cycle, roosting and sheltering behaviour	Given the poor habitat values within the site, it is considered unlikely that the proposed activity will impact upon the breeding cycle, roosting, sheltering and foraging behaviour of fauna species.
Noise, dust and light	The proposed activity may result in short-term increased noise and dust pollution as well as an increase in light, which has the potential to temporarily disrupt foraging and roosting behaviour of some native fauna species. However, the lack of intact overstorey vegetation lessens the potential impact, as few sensitive species are likely to occur within the site and 10 km surrounds.

11.3.3 Aquatic impacts

The proposed activity does not require any new creek diversions, crossings, access tracks or upgrades; therefore there will be no direct impact on identified watercourses. In addition, no riparian vegetation (and hence habitat) along identified watercourses will be cleared.

There are no proposed discharges to any watercourses during operation and therefore impact to water quality, flows or increases in bank and channel erosion are not anticipated for any watercourses in the immediate vicinity or downstream. As previously stated in Section 10.2, the potential exists for the leakage of produced water to occur during operation and enter waterways.

11.3.4 Key threatening process

The EPBC Act and TSC Act provide for the identification and listing of key threatening processes (KTPs). KTPs are defined as a threatening process 'if it threatens or may threaten the survival, abundance, or evolutionary development of a native species or ecological community' (SEWPaC, 2012).

KTPs under the EPBC Act and TSC Act that are relevant to the proposed activities are discussed in Table 11-5.

Table 11-5 Summary of key threatening processes

Key threatening process	Relevance to proposed activities
EPBC Act/TSC Act	
Competition and land degradation by feral European Rabbits	Rabbits were not observed within the site but are considered likely to occur. However, it is not anticipated that the proposed activity will increase opportunities for increase to the Rabbit population.
Competition and land degradation by unmanaged goats	Goats were not observed during the survey, but are considered likely to occur. However, it is not anticipated that the proposed activities will increase opportunities for increase to the goat population. Mitigation measures may be required at the completion of the project to ensure rehabilitation activities are not disturbed by unmanaged goats.
Dieback caused by the root-rot fungus (*Phytophthora cinnamomi)*	There exists the potential for the importation of this pathogen on unclean vehicles and plant machinery.
Land clearance/removal of native vegetation	No clearing or removal of native vegetation is required.
Predation by European Red Fox	European Red Fox were not observed, but are considered likely to occur. It is considered unlikely that the proposed activity will result in increased predation by European Red Fox, as no additional clearing is proposed,

Key threatening process	Relevance to proposed activities
Predation by feral cats	Feral cats were not observed, but are considered likely to occur. If waste is not managed on site, there is the potential for an increase in the feral cat population.
Predation, habitat degradation, competition and disease transmission by feral pigs	Feral pigs were not observed, but are considered likely to occur. It is considered unlikely that the proposed activity will result in increased predation, habitat degradation, competition or disease transmission.
TSC Act	
High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition	The proposed activity will not result in high frequency fires. Fire prevention strategies are outlined in Chapter 17.
Removal of dead wood and dead trees	No removal of dead wood or dead trees is required.
Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands	No works are proposed to occur within any streams or wetlands. The proposed works will not alter the natural regimes of any rivers, streams and their floodplains and wetlands.
Predation and hybridisation by feral dogs, (*Canis lupus familiaris*)	Feral dogs were not observed, but are considered likely to occur at the site.
Loss of hollow-bearing trees	No loss of hollow-bearing trees will occur as a result of the proposed activity.
Invasion of native plant communities by exotic perennial grasses	There exists the potential for the invasion of native woodland and grassland communities by exotic perennial grass species, transferred via vehicles and site machinery.

11.3.5 Groundwater dependent ecosystems

Stygofauna communities (fauna that live in groundwater) may exist within aquifers and thus can also be classed as a GDE (Serov *et al.,* 2012). Slight changes in groundwater attributes (quality or quantity) may result in changes to the population assemblage.

Stygofauna are known to occur within the Namoi River alluvial aquifer. This aquifer does not underlie the site, but is a potential source of colonisation for stygofauna. Thin sedimentary aquifers associated with Bohena, Cowallah and Bibblewindi Creeks extend south into the Pilliga and are potentially suitable habitat for stygofauna. It is possible that communities may be present in permanently saturated parts of these aquifers, especially if they have an occasional hydrological connection to the larger Namoi alluvium.

Stygofauna may also be present in the shallower GAB sandstone aquifers present on-site, such as the Pilliga Sandstone. For these to be suitable for stygofauna, they would have to be fractured or weathered enough to allow stygofauna movement and a sufficient flux of water and organic matter. The suitability of these rock aquifers as stygofauna habitat diminishes with depth from the surface.

The deeper target coal seam aquifers are unlikely to contain stygofauna as:

- the space available for movement is reduced significantly with increasing depth
- there is an overall decline in water quality.

The proposed activity potentially poses the following threats to stygofauna:

- Penetrating suitable habitat during drilling and the subsequent draining of the aquifer or contamination through trans-boundary flow between aquifers
- Depressurisation of underlying aquifers causing a change in the physical structure of stygofauna habitat that may result in drainage or contamination from more saline water.

Neither of the proposed wells require drilling through alluvial aquifers, significantly reducing the potential for impact to stygofauna.

Provided drilling, operation and closure activities are undertaken in accordance with the relevant guidelines and legislation, the proposed CSG drilling and extraction activities are unlikely to pose a significant threat to any known or likely stygofauna habitat.

In addition, as it is considered feasible that stygofauna populations may exist in the region, additional sampling will be undertaken to investigate presence or absence of stygofauna populations within PEL 238 and PAL 2.

11.3.6 Indirect impacts

The proposed activity has the potential to indirectly impact on flora and fauna including aquatic habitat. Potential indirect impacts include fauna strikes associated with increased vehicle movements, an increase in noise, dust and light impacts at the site and impacts to water resulting from spills or leaks and sediment laden runoff.

The potential for indirect impacts to flora and fauna as a result of the proposed activity are considered low given the exiting environment and the potential for flora and fauna to occur at the site. Provided mitigation measures for the proposed activity are adhered to , there will be no indirect impacts upon any TSC Act listed threatened species or their habitats as a result of the proposed activity during both construction and operation.

11.4 Cumulative impacts

As no vegetation clearing or disturbance is to be undertaken as part of the proposed activity, ecologically-related cumulative impacts are considered not to occur. A study on the cumulative effects of the E&A Program on biodiversity within PEL 238 and PAL 2 has been undertaken and is detailed in EcoLogical (2013).

The cumulative impact as a result of the proposed program and existing exploration and appraisal activities to vegetation within the PEL 238 and PAL 2 equates to the loss of:

- 237.36 ha which represents a loss of approximately 0.5% of consolidated vegetation within the E&A Program area and 0.045% of all vegetation within PEL 238 and PAL 2.
- Between 26.3 and 237.1 ha of potential foraging habitat (depending on species) for threatened fauna species which represents a loss of between 0.01% and 0.17% of the available breeding habitat available within PEL 238/PAL 2
- Between 12.3 and 159.9 ha of potential breeding habitat (depending on species) for threatened fauna species which represents a loss of between 0.05% and 0.11% of the available breeding habitat available within the PEL 238/PAL 2

Fragmentation of habitat as a result of the proposed program and existing exploration and appraisal activities is considered unlikely to adversely affect any EPBC or TSC Act listed species, with only one of the twenty-five potential movement pathways for the Pilliga Mouse affected by long-term impacts. The remaining threatened and migratory fauna are highly mobile and can traverse large distances across modified and cleared landscapes. Fragmentation is unlikely to significantly affect any threatened flora species as the proposed program and existing exploration and appraisal activities are unlikely to split contiguous habitat into two or more distinct patches with pollination and dispersal mechanisms able to continue largely unimpeded.

Given the relatively small extent of clearing as a proportion of available habitat (both within the study area and the Namoi CMA region), minimisation of fragmentation impacts by locating linear infrastructure (flow lines) along existing tracks wherever possible, and measures proposed to avoid, minimise and mitigate impacts, the proposed program and existing exploration and appraisal activities are not expected to significantly fragment or reduce the availability of habitat in a way which will adversely affect EPBC or TSC Act listed species.

Based on the above, the cumulative impact of the proposed E&A Program combined with existing exploration and appraisal activities is considered unlikely to have a significant impact as there is unlikely to be a long term decrease in population sizes, significant fragmentation or adverse disturbance to breeding cycles or critical habitat.

11.5 Mitigation measures

The following measures will be implemented during both construction and operation:

- The site boundary will be clearly demarcated to ensure that plant and vehicles keep within the approved area of disturbance
- The site will be rehabilitated in accordance with Section 4.5 of the EIS
- Construction and operational vehicles/plant will only travel on the designated access tracks. Site speed limits will be imposed to reduce the potential of fauna strike and to reduce dust generation.
- Weed management measures will be undertaken.
- Weed monitoring will occur throughout all phases of the proposed activity. Weed removal will be carried out as necessary.

12.0 Air Quality

Wilkinson Murray has completed an Air Quality Impact Assessment for the proposed activity. It is provided in Appendix 5 and summarised below.

12.1 Existing environment

Regional air quality is likely influenced by mining activities, grazing, land clearing and soil preparation, sowing and harvesting of crops, vehicle and heavy machinery movements, bushfires, burn-offs and other residential activities.

12.1.1 Sensitive receptors

The nearest sensitive receptor is over seven kilometres from the site as shown in Table 3-2.

12.1.2 Air quality assessment criteria

Air quality criteria are targets set to protect the general health and amenity of the community in relation to air quality. The criteria that are relevant to the proposed activity are taken from the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (NSW DEC, 2005).

The air quality targets for the relevant criteria pollutants relate to the total pollutant burden in the air and not just the pollutants from the proposed activity. Therefore consideration of background pollutant levels is required when using these targets to assess potential impacts. Table 12-1 shows the impact criteria relevant to the proposed activity.

Table 12-1 NSW EPA air quality impact assessment criteria

Pollutant	Averaging Period	Impact	Criterion
Total suspended particulates (TSP)	Annual	Total	90 µm/m^3
Particulate matter > 10 µm(PM_{10})	Annual	Total	30 µm/m^3
	24-hour	Incremental	50 µm/m^3
Deposited dust (DD)	Annual	Total	2 g/m^2/month
	Annual	Incremental	4 g/m^2/month
Nitrogen dioxide (NO_2)	1-hour	Total	246 µm/m^3
	Annual	Total	62 µm/m^3
Carbon monoxide (CO)	15-minute	Total	100 mg/m^3
	1-hour	Total	30 mg/m^3
	8-hour	Total	10 mg/m^3

12.1.3 Particulate matter

Suitable particulate matter monitoring data was not available to quantify the existing ambient levels at the site. Therefore the nearest location with available data (Tamworth NSW EPA monitoring site, 132 kilometres from the proposed activity) was utilised to provide an approximation of air quality.

Due to the presence of human activity, including residential areas, traffic, major highways and industry, the data from the Tamworth monitoring location is conservative as it is likely to overestimate the likely levels of air pollutants at the site.

A summary of the annual average PM_{10} monitoring data collected during 2010-2012 at the Tamworth monitoring site is presented in Table 12-2. The monitoring data shows that the annual average PM_{10} concentrations at this monitoring site are below the 30µg/m³ criterion.

Table 12-2 Summary of Annual PM_{10} Concentrations from Tamworth NSW EPA Monitoring Site (µg/m³)

Year	PM_{10} Concentration
2010	12.0
2011	13.1
2012	15.9

There are no readily available site specific total suspended particulates (TSP) and deposited dust (DD) monitoring data for the proposed activity. The Tamworth NSW EPA monitoring site does not measure these components; however estimates of the background levels for the site are required to assess the impacts as per the NSW EPA criteria.

Estimates of the annual average background TSP concentrations were determined from a relationship with measured PM_{10} concentrations. Based on an annual average PM_{10} concentration of 15.9 µg/m³, an annual average TSP concentration of 39.7µg/m³ was estimated.

Estimates of the annual average dust deposition levels were determined from a relationship with the estimated TSP concentration. This relationship indicates a background annual average dust deposition of 1.8 g/m²/month for the area surrounding the proposed activity.

12.1.4 Nitrogen dioxide

Similar to particulate matter, suitable nitrogen dioxide (NO_2) monitoring data was not available to quantify the existing ambient levels at the site. Background ambient NO_2 data obtained from the Muswellbrook NSW EPA monitoring site (215 kilometres from the proposed activity) is the closest suitable site. Due to the presence of human activity, including residential areas, traffic, major highways and industry, data from the Muswellbrook monitoring location is likely to be conservative as it is likely to overestimate the likely levels of air pollutants at the site.

The maximum daily 1-hour average NO_2 concentrations from the Muswellbrook NSW EPA monitoring site from November 2011 to July 2013, indicates that there were no exceedances of the NSW EPA 1-hour average goal of 246µg/m³ during this period. The data indicates that levels of NO_2 are relatively low compared to the criterion level and show a seasonal fluctuation.

12.1.5 Carbon monoxide

The NSW EPA monitoring sites at Tamworth and Muswellbrook do not record ambient concentrations of carbon monoxide (CO). Combustion activities are the cause of CO emissions and spatially there is very little such activity in the vicinity of the site apart from power generation, motor vehicles and wood heaters. Therefore, ambient concentrations of CO are expected to be low.

NSW EPA air quality targets for CO are set at higher concentration levels than the NO_2 targets. Based on the NO_2 monitoring data which are low compared to the targets, and consideration of the typical mix of ambient pollutant levels, it can be assumed that ambient levels of CO would similarly also be well below the air quality targets.

12.2 Assessment approach

12.2.1 Emission estimation

12.2.1.1 Construction

Dust emission estimates from construction works have been made using emission factors developed both locally and by the US EPA. Appendix 5.

Table 12-3 presents the estimated TSP emissions for the construction works associated with the proposed activity. Further details regarding the emissions estimation techniques applied to estimate the TSP emissions are provided in Appendix 5.

Table 12-3 Estimated emissions for construction works

Activity	TSP emissions (kg/year)
Travel to site	12,774
Travel between Bibblewindi 31 and Bibblewindi 32	1,401
Excavating material	16
Drilling	5
Wind erosion of exposed areas	6,912
Total	**21,108**

12.2.1.2 Operation of the flare

During operation, some small amounts of gas may be flared at the Bibblewindi Water Transfer Facility if gas cannot be consumed at Wilga Park Power Station. Modelling of air emissions associated with the occasional use of the flare has been undertaken based on the flare exhaust flow rate and estimated stack concentrations (Table 12-4).

Table 12-4 Stack parameters and estimated emissions for flare

Parameter	Value	Units
Stack height	6.1	m
Stack diameter	0.206	m
Exit velocity	5.49	m/s
Exit temperature	750	°C
Peak gas flow rate	20.56	Am^3/s
Peak gas flow rate	5.49	Nm^3/s
NO_2 emission rate	0.027	g/s
CO emission rate	0.023	g/s

12.2.1.3 NO_X to NO_2 conversions

The NO_X to NO_2 conversion was estimated using a method outlined in the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (NSW DEC, 2005) and developed by Janssen *et al.* (1988).

It was determined that the predicted maximum NO_2 impacts were recorded approximately 0.43 kilometres from the source during summer. Based on this distance, the ratio of NO_2 to NO_x at nearby receptors due to the flare operations was calculated to be three per cent.

12.2.2 Modelling methodology

The AUSPLUME dispersion model in conjunction with a TAPM generated meteorological data file provided predictions of the ground level concentrations of pollutants based on the emission estimation provided in Section 12.2.1.

Sources for modelled during the construction scenario were modelled as volume sources, while source during the operation scenario were modelled as point sources.

Modelling has been undertaken for a full year to account for seasonality variables.

12.3 Potential impacts

12.3.1 Construction

Dust created during construction will have the greatest impact on air quality. Other emissions would occur from the exhaust of plant equipment required for drilling. These emissions are generally considered to be too low to generate any significant pollutant concentrations in the vicinity of the site and have not been assessed further.

Table 12-5 presents the predicted incremental and total impacts at each of the sensitive receptor locations (shown in Figure 3-7) for PM_{10} as an indicator of dust levels.

Table 12-5 Predicted incremental and total concentrations at sensitive receptors – construction for PM_{10}

Resident ID	Distance from site (km)	24-hr Average ($\mu g/m^3$)	Annual average proposed activity ($\mu g/m^3$)	Total impact ($\mu g/m^3$)[1]
NSW EPA Criteria		**50**	**30**	**30**
RR1	8.3	0.15	0.02	17.73
RR2	9.2	0.26	0.05	17.77
RR3	9.5	0.08	0.01	17.71
RR4	8.2	0.08	0.01	17.71
RR5	7.5	0.09	0.01	17.71

Notes
[1]Based on 2012 data measured at the Tamworth NSW EPA monitoring site

At all sensitive receptors PM_{10} is well below acceptable levels. When combined with estimated background data (noting that these are conservative as they are measured within a residential area in Tamworth) the predicted levels are also well below annual average criteria. Further, the impact on the nearby sensitive receptors is likely to be lower than predicted due to the vegetation between the site and receptors. Studies have shown that significant vegetation barriers can reduce dust emissions by up to 30% (Warren, 1973). The modelling completed for this assessment has not taken into account any mitigation from the vegetation buffer.

When averaged across a year, in accordance with the criteria, PM_{10}, TSP and dust deposition at any sensitive receptor is also well below accepted criteria and in most cases would be negligible.

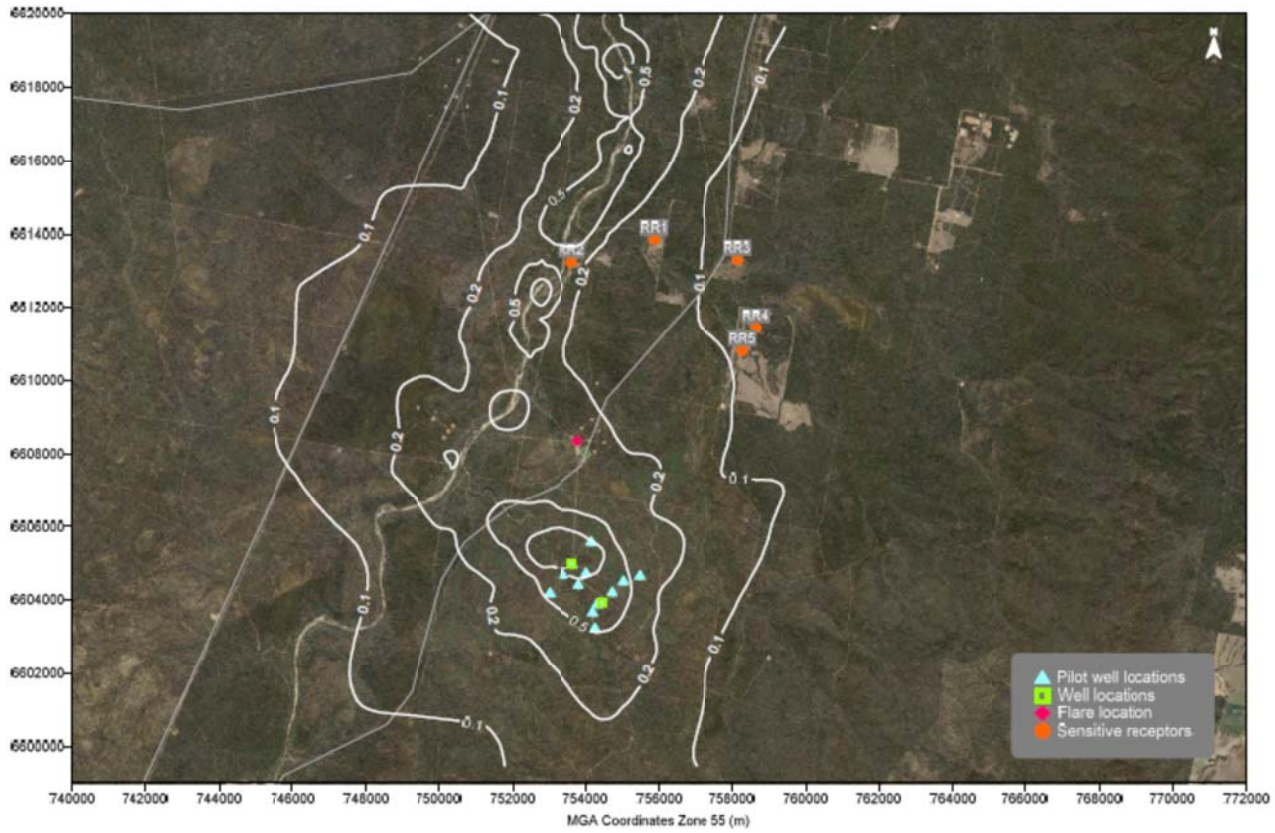

Figure 12-1 Predicted maximum 24-hour average incremental PM_{10} concentrations (µg/m^3)

12.3.2 Operation

Emissions of carbon monoxide (CO) and nitrogen dioxide (NO_2) can be expected from the combustion and flaring of intermittent gas during operation. In addition to CO and NO_2 formation, a small amount of PM_{10} may be generated from the combustion operation however this is considered to be negligible and has not been assessed further.

Table 12-6 presents the predicted incremental NO_2 and CO impacts at the surrounding sensitive receptors when the flare is in operation. At all sensitive receptors this is well below acceptable levels.

Table 12-6 Predicted incremental concentrations at sensitive receptors – operation

Resident ID	Distance from the site (km)	NO_2 (µg/m^3)		CO (µg/m^3)	
		1-hr Average	15-min Average	1-hr Average	8-hr Average
NSW EPA Criteria		246	100	30	10
RR1	8.3	0.00594	0.00022	0.00017	0.00011
RR2	9.2	0.00741	0.00027	0.00021	0.00014
RR3	9.5	0.00617	0.00023	0.00017	0.00011
RR4	8.2	0.00827	0.00030	0.00023	0.00015
RR5	7.5	0.00836	0.00031	0.00023	0.00015

With the addition of the maximum 1-hour background NO_2 levels measured at Muswellbrook during November 2011 to July 2013 (86.48 µg/m³), the total predicted impact still does not exceed the NSW EPA criteria.

Site specific CO monitoring was not undertaken as part of this assessment. However, comparison of the predicted incremental CO concentrations with the NSW EPA criteria for CO shows that the contribution of the proposed activity would be significantly below the criteria. It is considered highly unlikely that existing background levels of CO would be approaching the criteria levels. Therefore the maximum CO impacts due to the proposed flare operation should not exceed the NSW EPA criteria in the vicinity of the site.

12.4 Cumulative impacts

In the vicinity of the proposed activity there are potentially other sources of NO_2 and CO emissions originating from on-site plant equipment, site vehicles, small generators and other flaring operations. These sources are unlikely to generate significant amounts of NO_2 and CO and would be located away from the nearby sensitive receptors to allow sufficient dilution.

Other flares proposed as part of the E&A Program would similarly generate low levels of NO_2 and CO concentrations and combined with the large spacing between the flares, any cumulative impact would be negligible.

12.5 Mitigation measures

The following mitigation measures will be implemented throughout the duration of proposed activity:

- Dust will be suppressed as required by spraying water along the access tracks and lease areas
- Site speed limits will be imposed to minimise dust generated by vehicle movements
- Vehicles, plant and equipment will be regularly maintained to ensure they are in good operating condition
- Vehicles, plant and machinery will be turned off when not in use rather than left idling
- Rehabilitation works, including landform establishment, will occur within six months of abandonment.

13.0 Greenhouse Gases

13.1 Existing environment

Greenhouse gases (GHGs) are gases that absorb infrared radiation (heat) in the atmosphere. They occur naturally and are critical to maintaining the Earth's surface at liveable temperatures. When anthropogenic activities increase the concentrations of these gases this effect is accelerated, leading to the 'enhanced greenhouse effect'. It is the results of this enhanced greenhouse effect that are identified as 'climate change'.

Based on the current scientific consensus from the 2007 Intergovernmental Panel on Climate Change, there is a high degree of confidence that our current climate is changing due to human activities, with this rate of change likely to intensify into the future.

It is therefore important to consider, on balance, the GHG contributions and benefits of significant projects.

13.2 Assessment approach

In accordance with the *GHG Protocol Corporate Standard* (WBCSD and WRI, 2004), Scope 1 GHG emissions have been defined as direct emissions of GHGs (expressed as carbon dioxide equivalent) which are owned and/or controlled by Santos in relation to the proposed activity. Relevant inclusions are:

- Extracted gas consumed in the flare (when in use)
- Extracted gas vented (both fugitively and directly)
- Fuel use on site for power generation
- Fuel use on site for plant and equipment (including civil works and drill rigs)
- Vegetation clearing.

Scope 2 emissions cover those GHGs resulting from the purchase of energy (electricity or steam) originating from outside the proposed activity boundary. No scope 2 emissions are relevant to the proposed activity.

Scope 3 emissions have been defined as those indirect emissions which are a consequence of the proposed activity, but are not under the control, influence or authority of Santos. These emissions will form the scope 1 emissions of other organisations, so are considered separately and with discretion to avoid 'double counting' of the emissions profile.

The potential inclusions for Scope 3 emissions are extensive and often beyond quantification. For the EIS the inclusions have been limited with respect to the scale of the proposed activity and the available information, as consistent with the GHG Protocol methodology. Specific inclusions are:

- Use of sold products and services (CSG to the Wilga Park Power Station)
- Lifecycle emissions of materials and fuels where this information is consistent and readily in the public domain (such as the Infrastructure Sustainability Council of Australia (ISCA) materials calculator).

Emissions have been profiled over the construction and operation phases of the proposed activity, presented as both phase and annual totals as appropriate. Emissions intensity (relative to production) is also included.

13.2.1 Calculation methodology

The Greenhouse Gas Protocol outlines that a GHG inventory should be completed with regard to the following principles:

- Relevance
- Completeness
- Consistency
- Transparency
- Accuracy.

In the absence of relevant local data, emission factors for calculation have been sourced from the National Greenhouse Accounts (NGA) Factors (DCCEE 2012), with some supplementary inputs taken from the *American Petroleum Institute Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry* (the API Compendium) (URS 2009). The relevant emission factors applied in estimates are provided in Table 13-1.

Table 13-1 Relevant greenhouse gas emission factors

Emission source	Energy content		CO_2	CH_4	N_2O	Total	NGA Factors Reference
Emission factor (kg CO_2^e/GJ)							
CSG combustion	0.0377	GJ/m^3	51.1	0.2	0.03	51.33	Table 2; Page 13
Diesel combustion – Stationary Energy	38.6	GJ/kL	69.2	0.1	0.2	69.5	Table 3; Page 15
Diesel combustion – Transport	38.6	GJ/kL	69.2	0.2	0.5	69.9	Table 4; Page 17
Diesel combustion –Scope 3	38.6	GJ/kL	-	-	-	5.3	Table 39; Page 70
Emission factor (t CO_2^e /t gas flared)							
CSG flaring (exploration)			2.8	0.7	0.03	3.53	Table 8; Page 13
Emission factor (t CO_2^e /gas throughput)							
CSG leakage (production)			-	1.2×10^{-3}	-	0.0012	S 2.4.2.6; Page 29
Emission factor (t CO_2^e /km pipeline)							
CSG leakage (transmission)			0.02	8.7	-	8.72	Table 15; Page 30
Emission factor (t CO_2^e /drilling day)							
Water-based mud degassing			-	5.47	-	5.47	Converted from Table 5-17 API Compendium (@ 83.85% CH4)

13.3 Potential impacts

13.3.1 Scope 1 Emission Quantification

The bulk of scope 1 emissions from the proposed activity are expected to be derived from the use of diesel fuel for drilling and site operations, and the use of captured gas for minor on-site power generation.

The augmentation of the existing Bibblewindi gathering system will allow delivery of the bulk of the collected gas to Narrabri Power's Wilga Park Power Station. As this delivery involves a transfer of custody of the gas, emissions generated by the combustion of the fuel for power generation are not considered within Santos' direct emission scope.

Flaring will not be a regular source of GHG. It is estimated (based on existing operations data) that under the proposed operating regime whereby the gas is consumed at WPPS (subject to approval) less than five per cent of the produced CSG from Bibblewindi 31/32 will be flared. Flaring will always be undertaken in preference to venting when it is possible and safe to do so.

Flaring of gas will result in a net reduction of the GHG emissions when compared to venting. When the gas is flared methane is consumed in the process resulting in a significantly lower emission than from direct release to the atmosphere (as methane is recognised as having 21 times the global warming potential (GWP) of carbon dioxide). Consistent with Santos' Climate Change Policy, venting and flaring will only be employed where there is no feasible alternative. Such situations may include:

- disposing of air and any produced CSG (when air drilling)
- production testing the well
- drill stem testing
- in an emergency well control situation.

Minor amounts of gas may be emitted to the atmosphere as fugitive emissions during well development and operation, as well as from the gas gathering pipeline network and associated equipment. To assist in quantifying the extent of CSG fugitive emissions across the E&A Program, a monitoring program, including baseline monitoring, will be implemented. The monitoring program will be conducted in the general area of the E&A Program to monitor any changes in methane levels as an indicator of fugitive emissions during operation.

Venting and flaring rates, durations and volumes can vary significantly and depend on drilling technology, the number of gas zones and the distance between the zones. Santos intends to drill the wells using water based drilling fluids to minimise venting and flaring requirements during this phase. These emissions are therefore expected to be incidental however have been included in the estimate for completeness.

Forecasting suggests approximately 10 per cent of the captured gas will be used for electricity generation at the drill sites, avoiding the need to use more emissions intensive fuels (such as diesel) for this purpose.

Exhaust emissions from site-based vehicle movements, plant and machinery are based on initial traffic model inputs and information for the drill rigs. For the purpose of this assessment delivery of dedicated plant and equipment between Santos sites has been assumed to be a Scope 1 contribution.

As the site is completely within existing cleared/prepared areas, no clearing of vegetation is anticipated to be accounted in this GHG assessment.

Table 13-2 provides a summary of quantified Scope 1 emissions.

Table 13-2 Scope 1 greenhouse gas emissions profile

Component	Tonnes/CO_2^e/well	Tonnes/CO_2^e/year
	Construction Phase (2 wells)	Operation Phase[1] (14 wells)
Estimated total	568	10,046
Notes [1]Based on 4.5 + 0.25 million standard cubic feet per day (MMSCF/day)		

Based on the above operational emissions, the GHG intensity of the produced CSG is estimated to be approximately 5.5 kg CO_2^e/GJ.

13.3.2 Scope 2 Emission Quantification

Scope 2 (indirect GHG) emissions will not occur as there will be no purchases of electricity from the grid. What electricity is used on site will be generated from captured fuel gas, so is accounted for in the Scope 1 inventory.

13.3.3 Scope 3 Emission Quantification

The Scope 3 profile in Table 13-3 below excludes any Scope 3 components which cannot be reliably or predicably forecast, in line with the GHG Protocol.

The primary ongoing Scope 3 emission for the project is the consumption of the gas transmitted to the Wilga Park Power Station. Existing operations data suggests approximately 90 per cent of the available gas will be able to be provided to the facility.

Lifecycle emissions associated with the purchase of concrete, steel and HDPE pipe have been calculated using the ISCA materials calculator.

The emissions associated with the production of diesel for the drill rig and other on-site equipment has also been considered.

Table 13-3 Scope 3 greenhouse gas emissions profile

Component	Tonnes/CO_2^e/well	Tonnes/CO_2^e/year
	Construction Phase (2 wells)	Operation Phase (14 wells)
Estimated total	34	84,867

While the use of the extracted gas in the Wilga Park Power Station is the dominant operations Scope 3 emissions source, it should be noted that this fuel (per GJ) has a significantly lower emissions profile than more traditional energy sources such as coal (with an emissions intensity of 88.43 kg CO_2^e/GJ, compared to 51.33 kg CO_2^e/GJ for CSG). In this scenario this substitution would equate to an annual emissions reduction in the order of 68,500 tonnes of GHG by supporting an additional 20 MW of additional lower-emission generation capacity. The additional Bibblewindi 31 and 32 wells facilitate around 1.2 MW of this contribution.

13.3.4 Potential risks associated with greenhouse gas emissions

The primary risk associated with GHG emissions are their potential contribution to NSW and Australian GHG profiles.

Australia's GHG Inventory for 2011 (the most current data available at the time of writing) is provided in Table 13-4. The table shows the maximum expected emissions for the Scope 1 GHG emissions during operation phase of the proposed activity over a 12 month period. The potential GHG contribution of the

proposed activity to Australia's existing GHG profile is extremely minor, being less than 0.002 per cent and 0.007 per cent of the National and State emissions profiles respectively.

Based on these results the risk of the proposed activity to the local and national climate is considered very minor. The magnitude of emissions is not of a scale to indicate any directly attributable and measurable impacts on climate.

Table 13-4 Australian and NSW emission profiles

	GHG Emissions (Tonnes CO_2^e)
Australian Emissions (2011)	563,140,390
NSW Emissions (2011)	158,991,280
Maximum Estimated Proposed Activity Emissions (operations phase)	10,046

13.4 Cumulative impacts

Emission estimates for the operation of the E&A Program place the GHG profile at between 200 and 220 kT of CO_2^e annually (including flaring and onsite power generation). The Bibblewindi Multi-Lateral Pilot contributes in the region of five per cent of this total based on the proposed operating regime of the gas being predominantly consumed at WPPS.

13.5 Mitigation measures

13.5.1 Construction

The following measures will be carried out during construction to minimise the potential impacts associated with the Scope 1 GHG emissions from the proposed activity:

- Energy efficient equipment and processes will be used where possible.
- Water based drilling fluid will be used.
- Appropriate monitoring of emissions and consumables will be undertaken for legislative reporting requirements (such as to inform NGERS calculations).

13.5.2 Operation

On balance, the proposed activity provides significant GHG mitigation potential through the supply of CSG for power generation, which represents a 40 per cent emissions saving (per GJ) over more traditional large-scale energy sources such as coal.

In addition, the following measures will be carried out during operation to minimise the potential impacts associated with the scope 1 GHG emissions from the proposed activity:

- Regular monitoring and maintenance of equipment and pipes will occur to identify any leaks to minimise fugitive emissions.
- A fugitive emissions monitoring program will be implemented in the E&A Program area.
- Appropriate monitoring of emissions and consumables will be undertaken for legislative reporting requirements (such as to inform NGERS calculations).

13.6 Climate Change Policy

Climate change is a long-term issue, requiring urgent but informed action to stabilise atmospheric greenhouse gas concentrations. As a global stakeholder in the energy business, Santos recognises its social and environmental responsibility to pursue strategies that address the issue of climate change.

Santos is committed to working with government, industry and the community to address climate change with specific focus on addressing energy efficiency, adaptation strategies, the transition to lower emission technologies and reporting transparency.

Santos' Climate Change Policy outlines the organisations approach to climate change and realisation of the vision to 'lower the carbon intensity of its products'. The policy identifies the following commitments:

- continue to reduce the carbon intensity of Santos' products by focusing on energy efficiency, technology development and by embedding a carbon price in all activities
- use energy more efficiently by identifying opportunities to implement energy efficiency projects and report their progress
- examine the commercial development of low emission technologies, including storage solutions, which will contribute towards long-term emission reduction targets
- pursue no flaring or venting of associated gas, unless there are no feasible alternatives
- continue to publicly disclose Santos' greenhouse emissions profile and carefully examine forecast emissions
- understand, manage and monitor climate change risk and develop appropriate adaptation strategies for our business
- assist governments and engage with other stakeholders on the design of effective and equitable climate change regulations and policy
- inform employees about its commitment to climate change and ensure climate change initiatives continue to be implemented
- report progress against these commitments to the Board.

13.6.1 Emissions reporting

Santos has publicly reported its GHG emissions since 2004 with independent assurance provided annually, and as a result has established comprehensive governance processes which will ensure that the emissions associated with the proposed activity will be accurately reported under the *National Greenhouse and Energy Reporting Act 2007* (Cth) (NGER Act). Santos' governance system includes:

- annual independent assurance of GHG emissions
- regular audits in relation to implementation of the Environmental, Health and Safety Management System (EHSMS)
- risk-based internal audits are administered to ascertain conformance with, and effectiveness of the EHSMS Standards
- monitoring and review of energy efficiency opportunities
- other audits of compliance with internal policies and procedures related to GHG reduction through the internal audit program.

14.0 Noise

An assessment of the potential noise impacts was prepared to consider the construction and operational noise associated with the proposed activity. This chapter provides a summary of the Noise Assessment, provided in Appendix 6.

14.1 Existing environment

The nearest residences to the site are shown in Figure 3-7. The nearest residence (Receiver 5) is more than 7.5 kilometres north of the site, with four other residences (Receivers 1-4) located further north of Receiver 5.

Long-term unattended noise monitoring was conducted at two locations (Figure 14-1) to establish the existing noise environment:

- At the nearest sensitive receiver (ML1) between 14 November 2012 and 26 November 2012
- Within the forest (ML2) between 14 November 2012 and 15 November 2012

Results of the noise monitoring compared to rating background levels (RBLs) is provided in Table 14-1.

Table 14-1 Background noise levels for day, evening and night time periods at Receiver 5

Location	Rating background levels – LA_{90}			Ambient Noise levels – LA_{eq}		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
ML1	32	33	35	47	56	54
ML2	28	33	16	42	43	36

14.2 Assessment approach

The Noise Assessment was undertaken with reference to the relevant guidance documents:

- NSW Industrial Noise Policy (INP) (EPA, 1999a)
- Interim Construction Noise Guideline (ICNG) (DECC, 2009)
- Environmental Criteria for Road Traffic Noise (EPA, 1999b).

Noise modeling has been undertaken using SoundPLAN v7.0 and the prediction methodologies *ISO 9613-2 Acoustics-Attenuation of sound during propagation outdoors-Part 2: General method of calculation* (for 'neutral' conditions) and CONCAWE (for 'worst-case' conditions) with calculated sound power levels from field measurements taken in accordance with *AS1217.7-1985 Acoustics-Determination of sound power levels of noise sources* and ISO 3744:1994 *Acoustics-Determination of sound power levels of noise sources using sound pressure-Engineering method in an essentially free field over a reflecting plane* to derive sound power values for the activities. The calculations are made with an estimated uncertainty of ±3 dB(A) at 1000 metres. The sound levels calculated in this report are cross-checked with measured levels at 50 metres and with a variation of approximately 1 dB(A) this allows confidence in the prediction methodology and assumptions.