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Surat Gas Project - Hopeland EA (PL253) - EA0001401

Environmental Authority Amendment Application Report

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Contents

1. Purpose

Under Section 224 of the *Environmental Protection Act 1994* (EP Act), the holder of an environmental authority (EA) may, at any time, apply to the administering authority to amend the EA (an *amendment application*). This report has been prepared to support an application to amend the Hopeland Petroleum Lease (PL) 253 EA (EA0001401).

The purpose of this report is to provide sufficient information to enable the Department of Environment and Science (DES) to decide on the application to amend the Hopeland EA. The proposed changes are to increase the amount and type of activities authorised within this EA and to align the Hopeland EA conditions with the streamlined model conditions for petroleum.

This EA amendment application report has been developed and structured in accordance with:

- The 'Information requirements for environmental authority' listed in Appendix 4 of the Department of Environment and Heritage Protection (DEHP), now DES, Assessment Report on Arrow Energy's Surat Gas Project Environmental Impact Statement (EIS) (DEHP 2013) (hereafter 'DES Assessment Report')
- The relevant provisions of the Environmental Protection Act 1994 (EP Act) and DES Guideline Major and minor amendments (ESR/2015/1684) version 10 dated 29 September 2020 (hereafter 'DES Guideline').

This amendment application report contains technical information gathered from several sources, including documents submitted to DES during the SGP EIS process and from additional studies conducted after the approved EIS.

2. Introduction

Arrow Energy (Arrow) is an integrated coal seam gas (CSG) company that explores and develops gas fields, produces and sells CSG and generates electricity. Arrow has been developing CSG since 2000 and supplying it commercially since 2004. The company delivers almost 20 per cent of Queensland's gas supply from its five CSG fields in the Surat Basin in south-east Queensland and the Bowen Basin in central Queensland. Arrow's exploration and production tenements cover approximately 17,000 km² across Queensland and offers opportunities to support both domestic and international demand for cleaner energy.

Arrow owns and operates Braemar 2, a 450-megawatt (MW) gas-fired power station 35 km southwest of Dalby, and has interests in two others, being the Daandine Power Station (west of Dalby) and Townsville Power Station. Arrow supplies gas to the Townsville (234 MW), Daandine (33 MW), Braemar 2 (450 MW), Braemar (502 MW) and Moranbah (12 MW) power stations, as well as industrial users in Townsville and Moranbah.

A Gas Sales Agreement (GSA) between Arrow and the Shell operated QCLNG joint venture was announced in December 2017 which will see the commercialisation of most of Arrow's gas reserves in the Surat Basin through its Surat Gas Project (SGP). The collaboration between the parties relies upon the co-use of existing Arrow and QGC-operated infrastructure such as gas compression, processing and transmission infrastructure as well as water transport and treatment facilities. Utilising existing upstream infrastructure will reduce the potential for negative impacts to landholders, ecological values and to communities.

In April 2020 Arrow received a Final Investment Decision from its shareholders to begin the construction and operation of the first phase of the SGP. This important decision allows Arrow to meet the commercial and technical obligations of the GSA. PL253 is critical to the delivery of gas volumes under the GSA. Arrow is seeking this amendment to the Hopeland EA (EA0001401) as it is a critical component of the SGP FID1 and will support the expansion of Arrow's Surat Basin reserves.

Arrow's Hopeland EA currently authorises six (6) gas production wells (previously known as Hopeland Pilot), up to 20 water monitoring wells, gas and water gathering, access tracks, borrow pits, sediment ponds and the Hopeland Water Dam. In addition to these activities, Arrow is required to monitor groundwater on PL253 from existing and recently constructed water monitoring bores as part of its Groundwater Characteristics Monitoring Program (GCMP). The GCMP was developed to provide early notification of changes in groundwater flow direction and quality in relation to groundwater conditions at the former Linc Energy site (Lot 40 DY85). Section 6.3 discusses groundwater in more detail.

2.1 Proposed Amendments

The proposed amendment seeks to (see Section 3.2 for details):

- Increase the number of authorised wells from 6 to 61 (i.e. an additional 55 wells)

- Increase the intensity of gathering pipelines and access tracks as infrastructure required to support the additional 55 wells
- Increase the number of borrow pits from 1 to 6
- Change the biodiversity conditions to reflect Streamlined Model Conditions because unavoidable impacts will occur to Category B and C ESAs and their protection zones
- Change the monitoring frequency of condition Water 13(f) from 'at least biannually' to 'at least annually'.
- Remove condition Biodiversity 6 – Petroleum activities are not permitted in Category A, B or C environmentally sensitive areas
- Remove condition Biodiversity 7 – Essential petroleum activities may be undertaken in areas of pre-existing disturbance in the primary protection zones of Category B environmentally sensitive areas that are 'endangered' regional ecosystems and Category C environmentally sensitive areas other than 'nature refuges' or 'koala habitat' areas, providing those activities do not have a measurable negative impact on the adjacent environmentally sensitive area
- Add a new environmentally relevant activity (ERA) being:
- Schedule 2A – 3, which authorises a petroleum activity that is likely to have a significant impact on a category A or B environmentally sensitive area.
- Retaining those current Hopeland EA conditions that authorise previous and existing activities, and adding relevant Streamlined Model Conditions (SMC), specifically:
- Add condition Biodiversity 1 – Prior to undertaking activities that result in significant disturbance to land in areas of native vegetation, confirmation of on-the-ground biodiversity values of the native vegetation communities at that location must be undertaken by a suitably qualified person.
- Add condition Biodiversity 2 – A suitably qualified person must develop and certify a methodology so that condition (Biodiversity 1) can be complied with, and which is appropriate to confirm on-the-ground biodiversity values.
- Add condition Biodiversity 3 – For conditions (Biodiversity 4) to (Biodiversity 9), where mapped biodiversity values differ from those confirmed under conditions (Biodiversity 1) and (Biodiversity 2), petroleum activities may proceed in accordance with the conditions of the environmental authority based on the confirmed on-the-ground biodiversity value.
- Add condition Biodiversity 4 – The location of the petroleum activity(ies) must be selected in accordance with the following site planning principles:
    - maximise the use of areas of pre-existing disturbance
    - in order of preference, avoid, minimise or mitigate any impacts, including cumulative impacts, on areas of native vegetation or other areas of ecological value
    - minimise disturbance to land that may result in land degradation
    - in order of preference, avoid then minimise isolation, fragmentation, edge effects or dissection of tracts of native vegetation; and
    - in order of preference, avoid then minimise clearing of native mature trees.
- Add condition Biodiversity 5 - Linear infrastructure construction corridors must:
    - maximise co-location
    - be minimised in width to the greatest practicable extent; and

    - for linear infrastructure that is an essential petroleum activity authorised in an environmentally sensitive area or its protection zone, be no greater than 40 m in total width.
- Add condition Biodiversity 8 – Where petroleum activities are to be carried out in environmentally sensitive areas or their protection zones, the petroleum activities must be carried out in accordance with **Protecting Biodiversity Values, Table 1 – Authorised petroleum activities in environmentally sensitive areas and their protection zones**
- Add **Protecting Biodiversity Values, Table 1 – Authorised petroleum activities in environmentally sensitive areas and their protection zones** as per Streamlined Model Conditions
- Add condition Biodiversity 9 – A report must be prepared for each annual return period for all petroleum activities that involve clearing of any environmentally sensitive area or protection zone which includes:
    - Records able to demonstrate compliance with conditions (Biodiversity 4), (Biodiversity 5) and (Biodiversity 8)
    - a description of the works
    - a description of the area and its pre-disturbance values (which may include maps or photographs, but must include GPS coordinates for the works); and
    - based on the extent of environmentally sensitive areas and primary protection zones on the relevant resource authority(ies), the proportion of native vegetation cleared per environmentally sensitive area and primary protection zone, including regional ecosystem type, over the annual return period.
- Add condition Biodiversity 10 – Significant residual impacts to prescribed environmental matters are not authorised under this environment authority or the Environmental Offsets Act 2014 unless the impact(s) is specified in **Protecting biodiversity values, Table 2 – Significant residual impacts to prescribed environmental matters**
- Add condition Biodiversity 12 – An environmental offset made in accordance with the Environmental Offset Act 2014 and Queensland Offsets Policy, as amended from time to time, must be undertaken for the maximum extent of impact to each prescribed environmental matter authorised in Protecting biodiversity values, Table 2 – Significant residual impacts to prescribed environmental matters, unless a lesser extent of the impact has been approved in accordance with condition (Biodiversity 14) [for staged offsets]
- Add condition Biodiversity 13 – The significant residual impacts to a prescribed environmental matter authorised in condition (Biodiversity 10) for which an environmental offset is required by condition (Biodiversity 12) may be carried out in stages. An environmental offset can be delivered for each stage of the impacts to prescribed environmental matters.
- Add condition Biodiversity 14 – Prior to the commencement of each stage, a report completed by an appropriately qualified person, that includes an analysis of the following must be provided to the administering authority:
    - for the forthcoming stage—the estimated significant residual impacts to each prescribed environmental matter; and
    - for the previous stage, if applicable—the actual significant residual impacts to each prescribed environmental matter, to date.

- Add condition Biodiversity 15 – The report required by condition (Biodiversity 14) must be approved by the administering authority before a notice of election for the forthcoming stage, if applicable, is given to the administering authority.
- Add condition Biodiversity 16 – A notice of election for the staged environmental offset referred to in condition (Biodiversity 15), if applicable, must be provided to the administering authority no less than three months before the proposed commencement of that stage, unless a lesser timeframe has been agreed to by the administering authority.
- Add condition Biodiversity 17 - Within six months from the completion of the final stage of the project, a report completed by an appropriately qualified person, that includes the following matters must be provided to the administering authority:
    - an analysis of the actual impacts on prescribed environmental matters resulting from the final stage; and
    - if applicable, a notice of election to address any outstanding offset debits for the authorised impacts.
- Apply the same definition for ‘essential petroleum activities’ as that included in other Arrow EAs such as EPPG00972513.
- Update the definition of significantly disturbed or significant disturbance or significant disturbance to land or areas.

3. Scope of this EA amendment application

Arrow lodged an EA amendment application for the proposed full development of PL253 (i.e. 280 wells and associated infrastructure) on 6 July 2020. On 20 July 2020, the DES notified Arrow that the application was 'properly made' and that the assessment level decision was determined to be a 'major' amendment. The DES provided a further notice advising of the requirement for public notification in a substituted way (i.e. to occur after the information stage).

On 27 August 2020, the DES provided Arrow with an information request in relation to the EA amendment application. The EA amendment application and response to the Information Request was publicly notified between 18 January and 15 February 2021. Discussions with DES during the extended Decision Stage (from 17 May 2021 to 30 November 2021) established that Arrow was to pursue the full 280 well development case in two stages; with the first stage being this reduced 55 well case.

At the request of DES (meeting 1 October 2021), a summary of the changes between this 55 well development case and the document that was publicly notified for the 280 well development case is provided at the start of each chapter.

This amendment application report introduces the SGP and provides detailed information about the environmental values associated with PL253 that are the subject of the application. Section 3.1 outlines the legislative framework applicable to the SGP, Section 3.2 describes the amendments sought to the existing EA, and Section 4 describes the SGP and project activities to be undertaken on PL253. Section 5 discusses the Mandatory Application Requirements and Section 6 identifies and addresses the DES SGP EIS Assessment Report requests relevant to the scope of works for this amendment application. Section 7 describes this amendment in the context of the DES major and minor amendment thresholds.

A Coal Seam Gas (CSG) Water Management Plan (WMP) for the SGP has been developed in accordance with Section 126 of the EP Act (i.e. to address the information requirements described in the Assessment Report) and is provided as Appendix A. Appendix B has been included to address Section 126A of the EP Act. Appendices C, D, E and F provide the SGP Ecology Report, DES Streamlined Model Conditions Risk Assessment, the 2021 Groundwater Model Report and the Hopeland HHERA Report respectively.

3.1 Current Legislative Framework

Summary of change: The legislative framework is unchanged from the 280 well development case. The split of the EA amendment application into two stages is noted.

Arrow is undertaking the SGP as a petroleum activity under the *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act).

Arrow prepared a voluntary EIS and Supplementary Report to the EIS (SREIS) for the SGP under the Queensland Government *Environmental Protection Act 1994* (EP Act) and Australian Government *Environment Protection and Biodiversity Conservation Act 1999*

(EPBC Act). The EIS/SREIS received both Queensland and Australian Government approval in 2013.

The key milestones achieved during the EIS process were:

- Arrow lodged an application to prepare a voluntary EIS to DES under the EP Act on 27 January 2010
- Arrow lodged a Referral to the Australian Government under the EPBC Act on 27 January 2010
- Arrow lodged the EIS to DES and the Australian Government in March 2012
- In response to comments received on the EIS, Arrow lodged the SREIS in June 2013
- DES provided their Assessment Report on the EIS/SREIS to Arrow in October 2013, thereby completing the EIS process under Queensland legislation
- The Minister for the Environment of the Australian Government provided their conditional approval (EPBC 2010/5344) on 19 December 2013, thereby completing the EIS process under Commonwealth legislation
- The DES Assessment Report (2013) noted that the SGP EIS/SREIS adequately addressed many of the environmental impacts and risks of the project. However, Appendix 4 of the Assessment Report identified 25 requests for information required in support of an EA application
- The environmental impacts and risks associated with the activities addressed in this amendment application, and the way in which these activities will be carried out, have not materially changed since the EIS process was completed for all aspects of the environment except groundwater.
- The former Linc Energy Underground Coal Gasification (USG) operation on Lot 40 DY85 has impacted groundwater in this area. Over the past 18 months, Arrow has worked closely with DES and DoR to deliver the GCMP and build a shared understanding of the existing groundwater conditions on site. This EA application amendment report provides considerable information about existing groundwater conditions in Section 6.3.
- The Hopeland EA was issued by DES on 8 August 2018.
- The Hopeland EA was the subject of a minor amendment which was approved on 25 June 2020.
- On 7 July 2020, Arrow lodged an application to amend the Hopeland EA to include Arrow's full development case on PL253 (i.e. an additional 280 wells and associated infrastructure). The amendment application was publicly notified on 18 January 2021 and Arrow provided responses to requests for information from DES on 21 December 2020 and 29 April 2021.
- Following feedback from DES about the full development case and groundwater contamination at the former Linc site, Arrow withdrew the 2020 amendment application and will pursue the full development in two stages:
    - Stage 1: this EA amendment for the first 55 wells to support the sanctioned FID1 Gas Sales Agreement; and

- Stage 2: the remaining 225 wells that will be subject of a subsequent EA amendment application.

Under Section 224 of the EP Act, the holder of an EA may, at any time, apply to the administering authority to amend the EA (an amendment application).

Chapter 5 of the SGP EIS provided a detailed project description of the infrastructure to be developed by Arrow. The project footprint of the activities the subject of the Hopeland EA amendment application is wholly within the spatial extent of the SGP described in Section 5.1 of the EIS.

A detailed description of the socioeconomic context (Chapter 4), public consultation (Chapter 6) and existing environment (Chapters 9 to 26) accurately describe the environment, social and economic context regarding the SGP. A summary of the key impacts and cumulative impacts were provided in Chapters 27 and 28 of the EIS in relation to the general scope of the SGP in its entirety.

The development of the existing infrastructure within the Hopeland EA areas has been consistent with the proposed impact mitigation measures described in the SGP Environmental Management Plan (Volume 2, Attachment 005) and the Social Impact Management Plan (Volume 2, Attachment 006) within the SGP EIS.

One (1) new environmentally relevant activity (ERA) is proposed as part of this amendment application. The new ERA proposed to be added to this EA is **Schedule 2A – 3,** which authorises a petroleum activity that is likely to have a significant impact on a category A or B environmentally sensitive area (Category B only being relevant to this EA amendment application).

3.2 Proposed amendments

Summary of change: The proposed amendments have changed to accommodate the 55 well development case.

The proposed amendments to the existing Hopeland EA include:

- Retaining those current Hopeland EA conditions that authorise previous and existing activities.
- Amend condition General 1 – General, Table 1 – Authorised Petroleum Activities to increase the:
  - number of authorised wells from 6 to 61 (i.e. an additional 55 wells)
  - the intensity of gathering pipeline from 1.542 ha to 74 km
  - the intensity of access tracks from 8 ha to 74 km
  - Increase the number of borrow pits from 1 to 6
- Remove existing conditions Biodiversity 6 and 7.

- Add a new environmentally relevant activity (ERA) being, Schedule 2A – 3, which authorises a petroleum activity that is likely to have a significant impact on a Category A or B environmentally sensitive area.
- Add Streamlined Model Conditions (SMC), Biodiversity 1, 2, 3, 4, 5, 8, 9, 10, 12, 13, 14, 15, 16 and 17.
- Change the monitoring frequency of condition Water 13(f) from ‘at least biannually’ to ‘at least annually’.
- Apply the same definition for ‘essential petroleum activities’ as that included in other Arrow EAs such as EPPG00972513.
- Update the definition of significantly disturbed or significant disturbance or significant disturbance to land or areas.

4. Project Description

Summary of change: This chapter is largely unchanged. A new figure showing the indicative location of the reduced 55 well development case is provided.

4.1 Overview of the SGP

Arrow Energy is expanding its coal seam gas (CSG) operations in the Surat Basin through the SGP. The project seeks to commercialise gas reserves held in Arrow's petroleum tenements. The proposed wells and associated gathering infrastructure are essential infrastructure to the SGP.

On 1 December 2017, Arrow Energy and the Shell-operated QCLNG joint venture announced a Gas Sales Agreement (GSA) to commercialise the majority of Arrow's gas reserves in the Surat Basin. The collaboration between the parties will see the use of existing QGC-operated infrastructure such as gas compression, processing and transmission infrastructure as well as water transport and treatment facilities. Improving the utilisation of the existing upstream infrastructure will reduce impacts to landholders, communities and the environment.

The nature of the delivery points for the sales gas within this commercial agreement enables Arrow to develop and commercialise its Surat tenure whilst reducing the land disturbance footprint of its SGP development beyond that approved by the Australian and Queensland government in 2013. Arrow is also progressing a Water Services Agreement for the receipt of raw water, storage, processing and re-delivery of treated water, utilising capacity made available by the Water Services provider. This similarly reduces the land disturbance footprint of the SGP development in comparison to plans presented in 2013.

The SGP project is being delivered via numerous 'batches' of workscope. Several batches have received all of the necessary regulatory approvals and landholder agreements and have either commenced the installation of infrastructure or are planned for installation in the coming months.

This section provides an overview of the SGP development for the purpose of providing context. The SGP will be a phased development over 23 PLs covering an area extending from Millmerran in the south to near Wandoan in the north. Figure 4-1 shows the location of the SGP.

The main components of the SGP development are:

- An expanded supply of gas to Arrow's existing Daandine and Tipton processing facilities and the Shell operated QCLNG joint venture processing facilities to the west of Arrow tenure
- Extended operation of Arrow's existing water treatment and storage facilities
- Approximately 2,500 new gas production wells (averaging 130 new wells per year over 20 years and with gas production for approximately 30 years)
- Approximately 2,700 km of buried low and medium pressure gas and water gathering lines

- Two field compression stations (FCS) to deliver gas to off-tenement delivery points
- Up to fourteen (14) low and medium pressure pipelines to transport gas and water from Arrow's tenure to adjacent gas sales delivery points and water services agreement receipt points
- A combination of grid power, reticulated distribution and self-generated power for local wellhead, water pumping and gas processing facility electrical supplies.

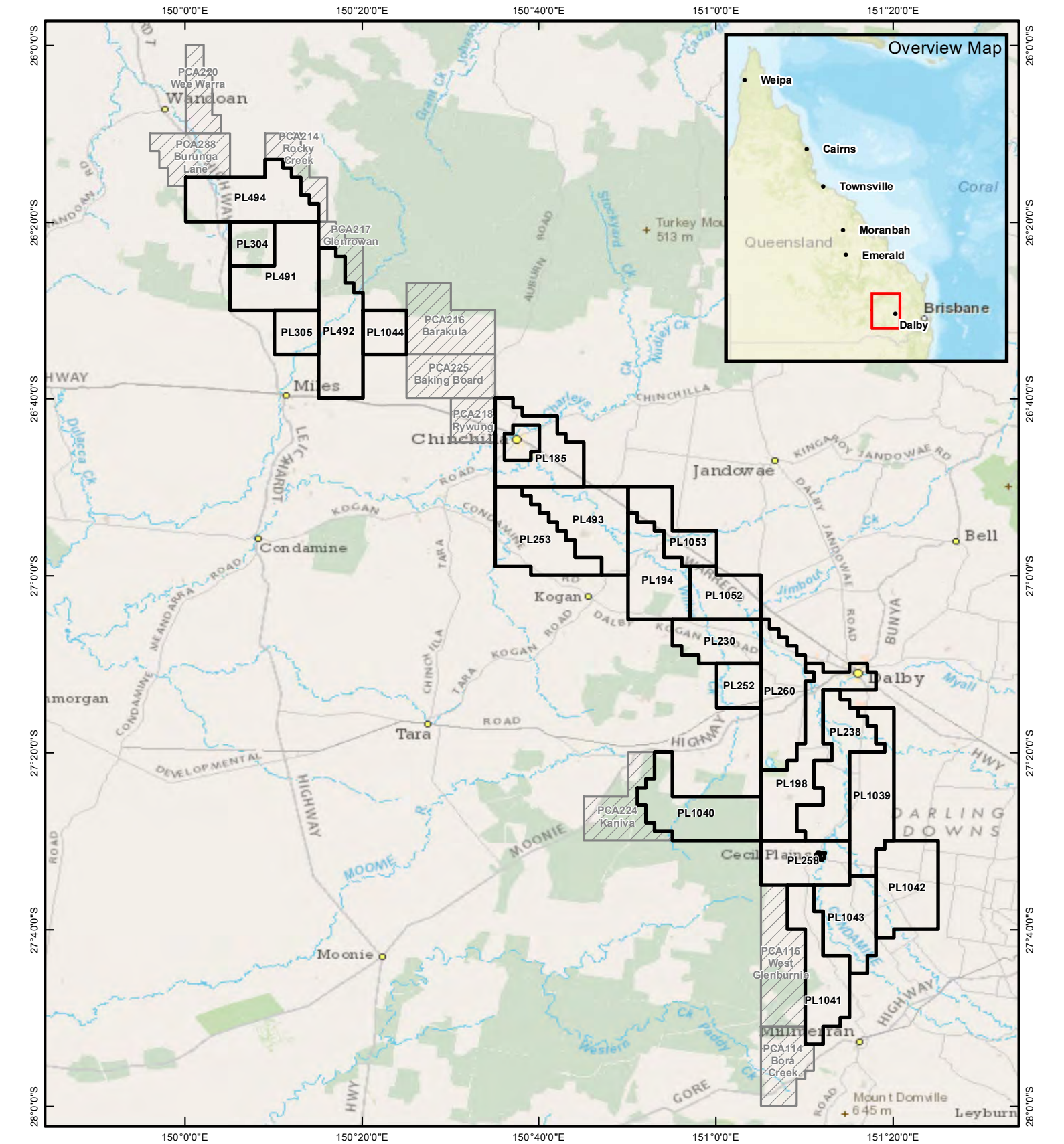

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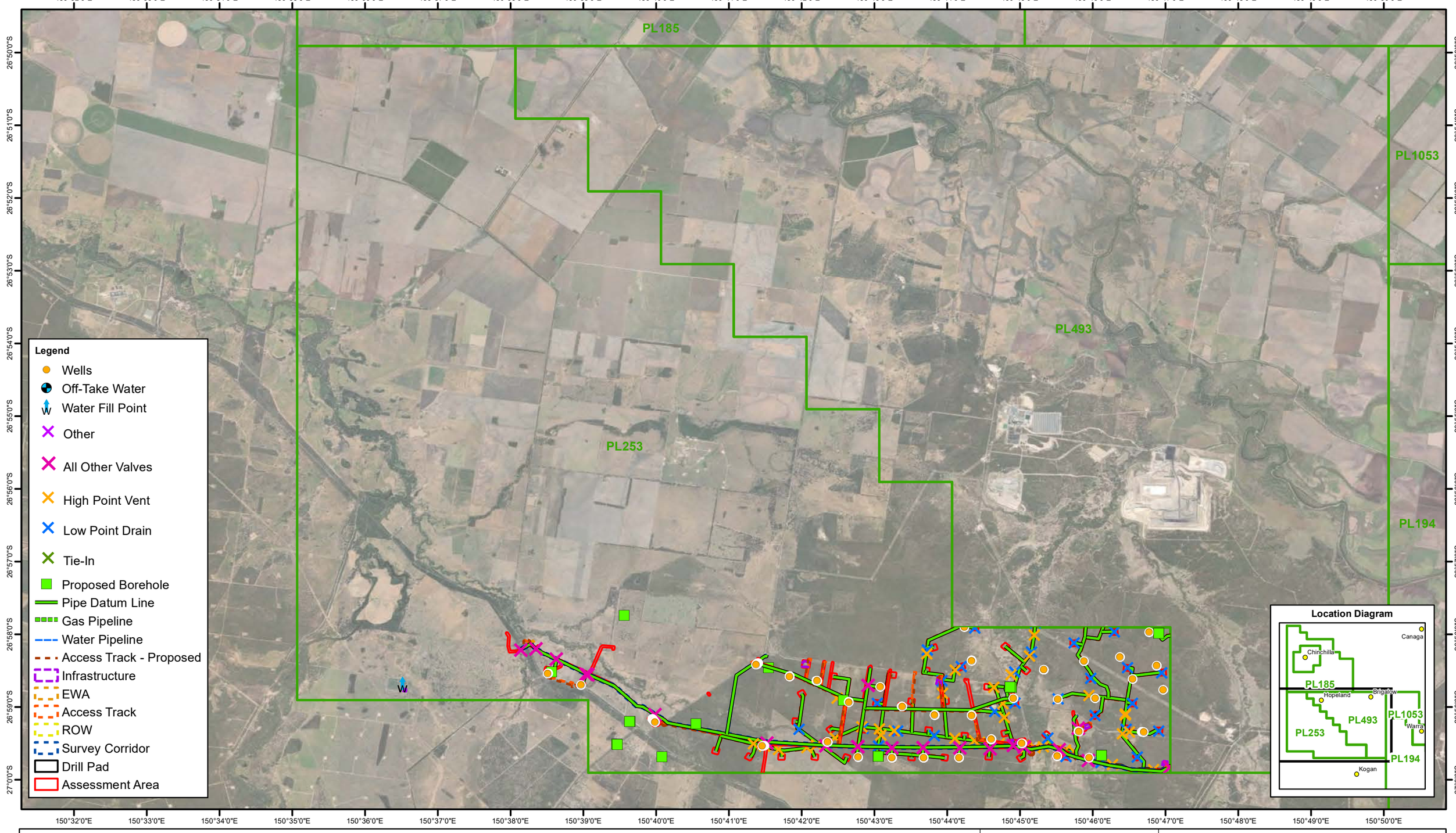
Figure 4-1 - SGP Location

4.2 Overview of the PL253 development

This Stage 1 EA amendment application seeks approval for 55 additional gas production wells on approximately 34 drilling pads located in the south-eastern corner of PL253 (see Figure 4-2).

The number of wells to be drilled per year will be refined during the Front-End Engineering Design (FEED) and maturation of the project. Having said that, the proposed field development plan (see Figure 4.2) including well and gathering locations included in this EA amendment application is appropriate to assess site specific impacts because it has been refined after a number of surface and sub-surface engineering assessments, field surveys undertaken in 2021 and reviews including the pre and post wet season ecological surveys undertaken in 2016 and 2017, data from the groundwater monitoring bore program and the Groundwater Characteristics Monitoring Program, and from discussions with landholders over the past several years including Area Wide Planning discussions with all impacted landholders during 2021.

As with all gas production wells, work overs will continue for the entirety of the project or until the gas reserves extracted by the well are depleted. Gathering lines will be installed from each well to transport the gas and water to the delivery point.



Rev	Date	Revision Description	Orig	Chkd	Eng	QA	App
1	06/10/2021	Wider extent, no labels	AW	XX	XX	AH	AH
0	05/10/2021	First issue	AW	XX	XX	AH	AH

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Kogan Creek and Kogan Road

PL253

Development Proposal

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Figure 4-2 - PL253 55 Well Field Layout

Print Date: 6/10/2021

4.3 Overview of Project Activities

The scope for development includes the following activities:

- Drilling and completion of vertical and deviated wells (see Plate 4-1)
- The vertical well pads will be sized at 100 x 100 m. However, this size will need to be increased for some well pads if located on steep gradients (i.e. >2% slope) up to a maximum area of 1.5 hectares. Three types of designs may be used; either minimal disturbance (clear and grub only) or formed (cleared and grubbed with light and/or heavy compaction of soil as required) or formed by using gravel (see Plate 4-2 for image of a pad being prepared)
- Multi well pads will be sized at 100 m x 115 m for a 2-well pad, and 100 m x 145 m for 4-well pad. However, this size will need to be increased for some multi well pads if located on steep gradients (i.e. >2% slope) up to a maximum area of 2.5 hectares. As with the vertical well, at least three types of designs will be used (i.e. minimal disturbance or the two types of formed).
- Access tracks to the well site and along some of the gathering lines will be constructed with a width of approximately 10 m. The flat to gently undulating terrain in the area suggests that approximately half of the tracks will require minimal disturbance to construct. For track construction in steeper areas, cut and fill with imported material such as gravel or road base will be required.
- Wellhead facility and infrastructure as shown in Plate 4-3 and Plate 4-4 will consist of wellhead skid, reticulated power (transformer) or gas engine generator set (genset) as shown in Plate 4-5, process safety valve, control and power cabinet and piping material.
- High-density polyethylene (HDPE) gas and water gathering lines will be installed. The gathering lines as shown in Plate 4-6 and Plate 4-7 will range from 160 mm to 1,000 mm nominal diameter and will include Low Point Drains (LPD) as shown in Plate 4-8 and High Point Vents (HPV) as shown in Plate 4-9.
- Gas-fired generators located on the well-pad is the preferred option for providing power to the wells.
- There may be a requirement for telecommunications infrastructure including buried fibre cable and telecommunications towers.

Plate 4-1 – Image of a typical Drill Rig

Plate 4-2 – Image of a pad being prepared

Plate 4-3 – Fenced well site prior to rehabilitation

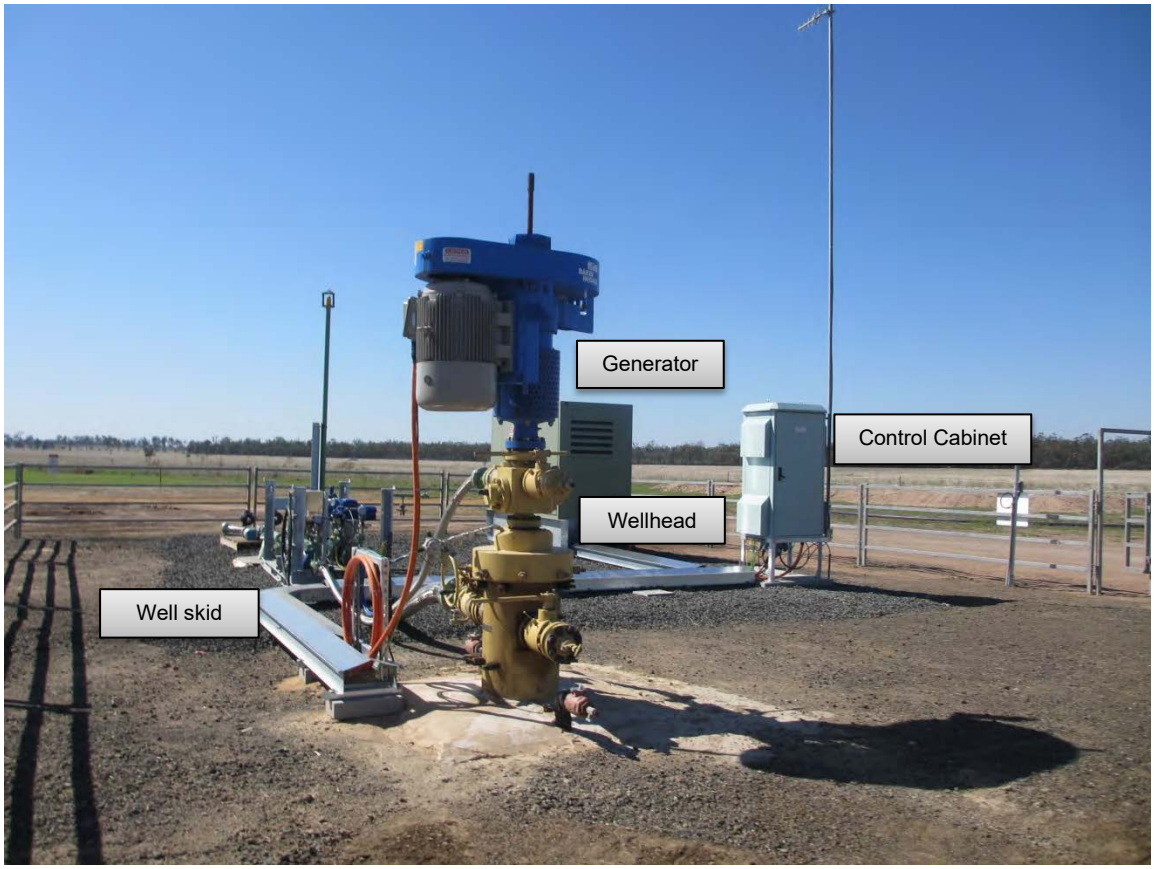


Plate 4-4 – Typical wellhead facility and infrastructure

Plate 4-5 – Image of a Wellsite Generator

Plate 4-6 – HDPE gathering being connected to the well site

Plate 4-7 – HDPE gathering being installed

Plate 4-8 - – Image of a Low Point Drain

Plate 4-9 – Image of a High Point Vent

Access tracks (new and upgrade)

Road or track access is required to all well-sites. Access tracks to the well sites will be constructed within a width of up to 10m. All weather road access will be provided to laydown yards and temporary camps. Arrow will utilise existing access roads and tracks wherever possible, however, where required, these existing tracks will be upgraded, or purpose-built access tracks will be constructed to gain access to the areas of proposed works for project vehicle and equipment. For these tracks, gravel or road base will be imported to provide a stable base for construction access and for operations where the track will remain.

Where new access tracks are required, they will be located with consideration of ESAs, landholder and road owner (e.g. Transport and Main Roads or Western Downs Regional Council / Toowoomba Regional Council) requirements; and will preferentially be aligned to the shortest distance between well pad and existing road and/or with the proposed well gathering lines to minimise the project's area of ground disturbance.

Enhancements to the road infrastructure will be negotiated between Arrow, the relevant local authority and the relevant state authority as necessary.

Wells and Pads

It is proposed to drill 55 new wells on approximately 34 pads under this EA. To drill the wells, a drill rig/s will operate 24 hours a day, seven (7) days a week in the initial phase of drilling.

These wells will be constructed to enable water and gas production from the deeper coal seams of the Walloon Coal Measures. The depth of wells will range from approximately 200 m to 800 m, with an average depth of approximately 450-500 m. There will be a mix of single well pads and multi well pads, comprising:

- Three (3) pads with four (4) wells
- 12 pads with two (2) wells
- 19 pads with one (1) well.

The wells are designed for a 30-year life. No hydraulic fracturing activities are proposed in any of the development areas as per condition 4 of Arrow's approval under the EPBC Act (EPBC 2010/5344).

Depending on the well depth, it will take up to one week to drill each well however drilling activities can take longer if circumstances determine, for example, wet weather or operational issues. The top section of each well between the targeted coal seam and the surface will be cased and cemented through the non-gas producing strata to prevent cross-contamination between groundwater aquifers. As this work will occur in advance of constructing the gathering lines, these initial wells will be 'suspended' and then completed (i.e., addition of the in-well pump) later, closer to commissioning and subsequent production.

The size of well pads is determined by several factors, including:

- The number of wells
- The type of wells
- The type and manoeuvrability of drill rigs

- The terrain which determines whether cut and fill earthworks are required
- Whether the area is cleared or supports vegetation
- The existing land use
- The equipment stored temporarily on the pad
- The area required for offices, light vehicle parking, equipment and supplies deliveries
- The required separation distance between wells and the area required to complete drilling operations safely.

The sizes of the well pads can be managed so that the maximum level of overall disturbance is consistent with the existing EA intensity of impact - 1 ha per single well pad, 1.5 ha per multi-well pad. Many of the additional wells required in this application will, as detailed above, be drilled on multi-well pads, with a consequent improvement in overall disturbance efficiency.

Where practicable, well sites are located on the fringes of farming land, in corners of paddocks, areas of land unsuitable for farming, near access tracks, right of ways (RoWs), easements, road reserves, or in areas that minimise the impact on farming and ESAs. All well locations would be determined following consultation with the landholder to ensure that impacts to their operations and lifestyle are minimised as much as possible.

When developing a well pad, the area is cleared (if not already cleared by agricultural activities), topsoil stripped and stockpiled, and the pad foundations laid and levelled to provide a stable platform for the drilling rig. For minimal disturbance well pads the topsoil will be left in place. Site preparation works will be carried out using earthmoving equipment such as graders, excavators and bulldozers. Where the subgrade material is deemed to be inadequate and unsuitable for heavy vehicle access or where all weather access is required, consideration shall be given to:

- Amendment of soil (e.g., using additives and / or dynamic compaction)
- Use of technologies (e.g. rig mats, tracked vehicles, roll-out sheets). Typically, these technologies are utilised and reused to support each activity
- Clear, grub and remove unsuitable material and replace with more suitable material such as gravel.

During the development of some wells, and dependent on the terrain, topography and vegetated state of the site, additional area will be required to be disturbed (i.e. above the 1 ha (single) or 1.5 ha (multi) EA authorised threshold) to facilitate plant and equipment access. Drill rigs require a flat pad (< 2% slope to effectively operate the fluid systems), and therefore on steep or undulating sites, areas may need cut and fill earthwork batters to provide these. Similarly, these sites may require additional area for the additional diversion drainage and erosion and sediment controls. For heavily vegetated sites more area may be required for stockpiling of cleared vegetation and to providing adequate clearance limits for firebreaks.

In these circumstances and consistent with other EAs issued for the SGP, the maximum area for a single-well pad will be 1.5 ha and for a multi-well pad will be 2.5 ha. For this

reason, Arrow seeks the same definition of essential petroleum activities as those applied to other SGP EAs.

When well pads are being drilled, completed or worked-over, they may have appropriate storage of a capacity <1 ML for drilling fluids. Drill by-products, such as cuttings, will be collected for either on-site spreading, mix/bury/cover, or off-site disposal, while the liquids will be recycled and reused as drilling fluids where practical.

Any well sites that are prone to flooding will be designed with careful consideration of the potential impact of overland flow during rainfall and flood conditions.

Once all wells on a pad are installed, the footprint of the pad will be stabilised outside the infrastructure footprints to meet EA, landholder and progressive rehabilitation requirements.

The Arrow 'standard' well site will be used for the project and will include the wellhead metering skid, vent, control cabinet and generator. The standard wellhead metering skid provides the following functionality:

- Connection of the well to the gas / water gathering network
- Overpressure protection of the gas / water gathering network
- Control of gas flow under turndown conditions
- Metering of gas and water for control, surveillance and reporting.

Work over of wells will continue for the life of the project. The frequency of work overs will generally be every 2 years for the first two work overs and then every 3 years thereafter. A work over is the process of performing major maintenance or remedial treatments on a gas well. In many cases, a work over implies the removal and replacement of the production tubing string and is done by a specific work over rig.

Gathering (water and gas)

An additional ~74 km of gathering will be constructed under this EA amendment. The function of the gas and water gathering systems is to convey gas from the well systems to a centralised facility (e.g., CGPF, FCS, pond or dam). The current gathering network design is notional and subject to change as the project matures. However, whenever practical the water gathering network would follow the path of the gas gathering system.

Where practicable, gathering infrastructure, fibre optic cables and power cables will be installed in a common RoW. The RoW width for the co-located facilities will be up to 50 m.

Generally, the gathering network will be installed by conventional trenching using a trenching machine. Where the gathering network is required to be installed beneath existing roads or infrastructure, trenchless technologies such as horizontal directional drilling (HDD) may be used.

Conventional trenching involves an open trench. The depth and width of the trench is dependent on that required to install, inspect or maintain piping, conduits or cables. After the pipeline installation is completed, the trench is backfilled with soil, compacted equivalent to surrounding soils, reinstated in the same order it was removed and the topsoil spread across the surface.

The installation of gathering networks on IFL will be undertaken with minimal disturbance of cultivated regions. This only impacts a small area of the proposed development the subject of this application. To achieve this, existing land profiles will be re-established, mixing of soil layers will be avoided and current levels of compaction retained. Reference will also be made to the *Regional Planning Interests Act 2014* (RPI Act) and approvals would be obtained as required.

An example of gathering being laid using the trenching method is shown in Plate 4-10 and an example of backfilling of the trench is shown in Plate 4-11.

Plate 4-10 – Image of pipeline being installed by trench method

Plate 4-11 – Backfilling pipeline trench

Power

Power to the wells will be provided by several methods depending on the power requirements and proximity to existing electricity infrastructure. Power to individual vertical wells will typically be provided by a gas-fired generator installed on the well pad.

Where reticulated power is installed, it will be distributed to the site from a High Voltage (HV) supply for both single-well and multi-well pad arrangements. Solar power may be considered for equipment with low power consumption (e.g., high point vents or low point drains) in remote locations where reticulated power is not available.

Wherever possible, power infrastructure will be co-located with gas and water gathering lines and adjacent existing roads or access tracks. Additionally, and where practicable, power lines will be installed with other infrastructure in a common RoW.

High Point Vents

High Point Vents (HPVs) will be constructed along the water gathering network to catch and remove gas accumulating in the gathering system and to maintain the hydraulic performance of the lines.

HPVs are usually vented to the atmosphere; however, some may have sufficient pressure to send the gas to the gas gathering system. The required location of HPVs is dependent on the topography of each trunkline and will be determined as the gathering network is refined. The number of HPVs is subject to preliminary studies and optimally most of the accumulated gas will be released in the first one or two HPVs from each well site.

The design criterion for HPVs is:

- Minimise physical footprints above ground
- Atmospheric vents on water lines are to be used in rural locations only, preferably away from landholder properties
- Not Normally Manned
- Automated operation.

Low Point Drains

Low Point Drains (LPDs) will be constructed to manage liquid accumulation in the gas gathering system. A LPD consists of an oversized tee piece on the pipeline to catch liquid and transfer it to the water line. There is also a surface pump with power. The design criterion for LPDs is:

- Environmental – eliminate discharge of CSG water to grade
- Health, Safety, Regulatory Compliance
- Stakeholder and land access – minimising surface impacts, land use and footprints
- The location of LPD pad and associated infrastructure will be carefully selected with consideration to factors such as terrain slope, ground disturbance, proximity to water courses, flood levels during wet seasons, and the presence of rock
- Not Normally Manned
- Automated operation.

Valves

Above ground valves are required on connecting pipelines to allow sections of pipeline to be isolated, with an operational footprint of 2 m by 2 m. Valves will be located adjacent existing access tracks and/or fence lines to minimise the impact on landholder activities.

Short Term Accommodation

There may be a need to establish small, short-term, temporary accommodation to support the early establishment of works (e.g., construction of water supply pipelines, communications, borrow pits, access roads).

Due to the location of PL253, the following options are being investigated to provide accommodation for the workforce:

- Hotels, motels and third-party accommodation in and around Miles and Chinchilla
- Small mobile construction camps dedicated for the project. If such camps are >21 EP, an amendment to this EA will be submitted to address the Environmentally Relevant Activity number 63.

Mobile Camps

To support the construction and drilling crews on site, mobile camps may be required. These self-contained camps will be sized appropriately for the workforce and will generally provide accommodation, kitchen facilities, communications, mobile sewage treatment facilities, bunded fuel storage areas, and waste collection and segregation facilities. Power supply will be via diesel generators and potable water will be supplied by tankers.

Any temporary camps situated on the areas subject to this amendment application will be small and the water supply demand or sewage discharge will not be greater than 21 EP. The selection of sites will consider the following objectives:

- No clearing of remnant vegetation
- Not to be located within 100 m of a watercourse
- An assessment of flood mapping will be undertaken to ensure camp sites or pipe storage areas are not exposed to flooding risk
- Documented evidence that camp sites and pipe storage areas have received cultural heritage clearance
- Restoration of site to equivalent surrounding condition.

There is one mobile drill rig camp proposed to be located on PL253 on an area of approximately 0.3 ha.

Water Supply

Water will be required for short term construction activities and ongoing use for drilling, dust suppression (minor), potable water supply to mobile camps and for hydrostatic testing of pipelines. Water will either be:

- Obtained from an off-site commercial water service supplier
- Obtained from the nearby Hopeland dam
- Trucked from Miles, Chinchilla or other nearby locations such as CSG water ponds
- Reused treated effluent and / or CSG water from production wells.

Borrow Pits / Quarries

Quarry materials are required throughout the life of the project. The initial use will be for short-term construction of roadworks, hardstands and concrete works. Borrow pits and /or quarries will be the source of material such as foundation aggregate for the construction of well pads and access tracks. For the purposes of this amendment application, the material will be sourced from either authorised quarries or on-site borrow pits.

Any borrow pits will be preferentially situated on previously cleared areas and the volume of material extracted will be <5,000 t per annum. The specific volume of material and the relevant sources will be determined as the project is refined. At present it is proposed to

include 5 new borrow pits as part of this amendment application. Should this premise change, an amendment to this EA will be lodged.

Telecommunications

Telecommunications will include mobile (wireless) communications for mobile phones and two-way voice communications (e.g., hand-held radios and vehicle mounted radios). Several communications towers will be installed for Arrow's proposed FCS, laydown yard and within the operating well field. It is likely that some of the towers will be located on other PLs and therefore subject to other Arrow EAs; however, provision within the definitions of this EA is sought to allow for a tower on PL253 as there is one proposed to be located on PL253 on a one hectare pad.

A fibre optic system backbone will be installed to connect the telecommunications towers for data transmission for a range of purposes (e.g., a Supervisory Control and Data Acquisition (SCADA) system). It is planned this will be installed at the same time as the gathering lines and in the same right of way.

Logistics

To support the project's logistical requirements, the existing Dalby depot will be expanded to house additional materials and supplies. It is envisaged that either a centralised laydown area will be constructed in a suitable location or several smaller laydown areas will be established across the field development area. Irrespective of the option chosen, the laydown areas will be located to avoid impacts on matters of state environmental significance (e.g., ESAs) and will be constructed and operated in accordance with the conditions of the EA. Currently, there are three proposed laydowns to be located on PL253, each one to be situated on one hectare sites.

Concrete Batching Plants

No concrete batching plants will be required in the areas the subject of this amendment application.

4.4 General Description of Environment

Summary of change: This section is largely unchanged. A few minor amendments have occurred to tailor the description to reflect the environment in the south-eastern corner of PL253 rather than the full extent of the environment relevant to all of PL253.

Stakeholders

For this amendment application, stakeholders are individuals or organisations who are directly or indirectly affected by the project. These include landowners of properties on which Arrow proposes to undertake activities; communities; traditional owners; local, state, and national government departments; policy makers; advocacy groups and NGOs who have an interest in the project.

Identification of stakeholders assists the engagement process by:

- Designing effective and relevant consultation and communication activities
- Preparing for and managing emerging issues
- Tailoring project key messages to relevant stakeholder groups and individuals.

Stakeholder analysis subsequently determines key stakeholder risks and inter-relationships, their potential involvement and impact, and stakeholder issues/exceptions at specific stages of the project.

Table 4-1 identifies the stakeholders that have already been identified for the SGP project area. This list will continue to grow as stakeholder engagement continues.

Table 4-1 – Stakeholders

Stakeholder	Location/Committees
Landholders requiring Conduct and Compensation Agreements (CCAs) (the number and exact timing for securing landholder agreements will be determined as the field development plan is refined)	PL253
Broad community members	Wandoan, Miles, Chinchilla, Dalby, Cecil Plains

Stakeholder	Location/Committees
Traditional Owner Groups • Western Downs Unclaimed Area Native Title Group o Barunggam o Bigambul o Cobble Cobble o Emon o Jarowair o Iman o Kambuwal o Mandandanji o Northern Gomeroi o Western Wakka Wakka o Yarowair	Surat Basin
• Western Downs Regional Council • Toowoomba Regional Council • State Member for Condamine • State Member for Callide • State Member for Southern Downs • State Member for Warrego • Federal Member for Groom • Federal Member for Maranoa • Office of Premier • Minister for Environment (State) • Minister for Natural Resources and Mines (State) • Minister for Resources (Federal) • Minister for Environment (Federal) • Department of Environment & Energy (Federal) • Department of Environment and Science • Department of Natural Resources, Mines and Energy • Gas Fields Commission **Industry** (engagement managed through Project Team) • Powerlink • Ergon Energy • Stanwell • Queensland Rail/Aurizon/ARTC • APA Group • Alinta Energy	• Arrow Intensively Farmed Land (AIFL) Committee • Arrow Surat Community Reference Group (ASCRG) including: o AgForce o Central Downs Irrigators o Basin Sustainability Alliance • QRC • APPEA • Media

Public consultation on the SGP project has been and will continue to be extensive. During the SGP EIS (refer Chapter 6 of the SGP EIS for details), consultation was held with:

- 12 State Government departments
- Four (4) government-owned corporations
- All registered property owners within the entire development area
- All leaseholders of properties within the entire development area that made themselves known through participation in consultation activities
- The communities of Dalby, Cecil Plains, Chinchilla, Goondiwindi, Miles, Millmerran and Wandoan

- Six (6) indigenous groups
- 11 local industry and business associations
- Eight (8) agricultural associations
- 18 environmental groups / associations
- 12 community / interest groups
- 29 schools
- Print (7), radio (5) and television (2) media.

Following the SGP EIS, consultation with many of the above listed groups has continued, with particular attention provided to the relevant government agencies, landowners, leaseholders, indigenous groups and the communities of Wandoan, Miles, Chinchilla, Dalby and Cecil Plains.

Arrow has an extensive and ongoing community engagement program. The following outlines the recent consultation and future consultation relevant to PL253 and this EA amendment:

- Project announcement: on 1 December 2017 Arrow and the Shell-operated QCLNG joint venture announced a Gas Sales Agreement (GSA) to commercialise most of Arrow's gas reserves in the Surat Basin. The collaboration between the parties will see the use of existing QGC-operated infrastructure such as gas compression, processing and transmission infrastructure as well as water transport and treatment facilities. Utilising the existing upstream infrastructure will reduce impacts to landholders and to communities.
- In 2010, Arrow established the Arrow Surat Community Reference Group (ASCRG) and the Arrow Intensively Farmed Land Committee (AIFLC) to directly address community and agricultural issues associated with Arrows operations and the SGP development. Since that time, the committees have met on a regularly basis.
- Government: Arrow meets with the Queensland Government Department of Environment and Science (DES) monthly and the Department of Resources (DoR) on a fortnightly basis to provide project updates. These meetings have commenced and will continue throughout the life of the SGP.
- Arrow has been meeting with DES and DoR on a six weekly basis to work through the implementation of the GCMP and share knowledge regarding Lot 40 DY85. Arrow also holds regular engagements with the Australian Government Department of the Agriculture, Water and the Environment (DAWE) with regards to the biodiversity and water plans required for the SGP. We also engage closely with relevant local government authorities and elected officials across the three tiers of government.
- Indigenous stakeholders: the traditional owners of relevance to PL253 are the Western Downs Unclaimed Area Native Title Group. Arrow has an existing Indigenous Land Use Agreement (ILUA) and accompanying Cultural Heritage Protocol with this group. As per the ILUA, Arrow meets with the Group's Committee on a regular basis and engages Western Downs' field crews to undertake pre-clearance surveys in areas of proposed disturbance.

- Community engagements: Since 2010, Arrow have undertaken over 60 Community Information sessions across the region, including Dalby, Chinchilla, Miles, Cecil Plains and Toowoomba. In 2020, the Community Information Sessions were held online, which enabled stakeholders from beyond the local region to also participate. Since 2021, face to face community engagements have resumed.
- Area Wide Planning (AWP): Arrow has established its AWP program that enables landholders and neighbours to contribute to Arrows local development planning, resulting in minimised impacts to farming operations and infrastructure. This includes hosting shed meetings with groups of landholders to discuss development plans, discuss specific issues relating to the area and incorporate mitigation measures early in the planning process. AWP in the region of the full development case for PL253 started with landholders in May 2020. Specific to this Stage 1 EA amendment application, AWP started with landholders in this region in January 2021.
- Conduct and Compensation Agreements (CCAs): following Area Wide Planning, specific landholder, and where relevant leaseholder, agreements are formalised in CCAs. As per the P&G Act, these agreements or similar landholder consent must be reached prior to any construction activities occurring on the landholder's property. This process has commenced and will continue throughout the SGP as the project development footprint expands. As noted above, landholder engagement in the area the subject of this EA amendment started in January 2021 and CCAs will be presented to landholders once the amended EA and PL are granted.

Sensitive Places

Most sensitive places across PL253 are private residential dwellings. The final locations of infrastructure would consider the proximity to these dwellings and potential impact to occupants as described in the Area Wide Planning and CCA process noted previously.

Potential impacts on other sensitive places has been taken into consideration when siting infrastructure. In terms of the field development plan, the only sensitive receptors within 1,000 m of proposed infrastructure are residential dwellings. This separation distance is relevant to the noise generated by drill rigs (see Section 6.5 for details).

Environmentally Sensitive Areas (ESAs)

ESAs (i.e. Category A, B and C areas) as defined in Schedule 12, Part 1, of the *Environmental Protection Regulation 2008* are also particularly relevant to, and considered in, Arrow's infrastructure planning activities.

As identified in Section 5.3, petroleum activities will be undertaken in Category B ESAs and their protection zones and Category C ESAs and their protection zones.

Environment

<u>Bioregion</u>

All activities proposed in this amendment application will occur in the Brigalow Belt Bioregion (Bioregion Number 11), entirely within the Inglewood Sandstones (11.32) Sub-Bioregion.

Bioregion 11 experiences a subtropical, sub-humid climatic zone, with a marked wet summer and moderately dry winter.

Regional Ecosystems

In general, the land is dominated by cleared grazing land, agricultural activities, open woodlands and patches of remnant vegetation (eucalypt woodlands and Brigalow). The activities to be undertaken for this amendment application have been preferentially located on cleared lands. Where this is not possible the location of infrastructure has been chosen to minimise impacts to the environment and to agricultural and grazing activities. Table 4.1 identifies the Regional Ecosystems (REs) which are present within the development area. All these REs have been ground-verified by suitably qualified ecologists.

Table 4.1 List of REs present across the development area

RE	Short Description	Vegetation Management Status	Biodiversity Status
11.3.14	*Eucalyptus* spp., *Angophora* spp., *Callitris* spp. woodland on alluvial plains	LC	NCAP
11.3.25	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage	LC	OC
11.4.3	*Acacia harpophylla* and/or *Casuarina cristata* shrubby open forest on Cainozoic clay plains	E	E
11.5.1	*Eucalyptus crebra* and/or *E. populnea*, *Callitris glaucophylla*, *Angophora leiocarpa*, *Allocasuarina luehmannii* woodland on Cainozoic sand plains and/or remnant surfaces	LC	NCAP
11.5.1a	*Eucalyptus crebra* and/or *E. populnea*, *Callitris glaucophylla, Angophora leiocarpa, Allocasuarina luehmannii* woodland on Cainozoic sand plains and/or remnant surfaces	LC	NCAP
11.5.20	*Eucalyptus moluccana* and/or *E. microcarpa* and/or *E. woollsiana* +/- *E. crebra* woodland on Cainozoic sand plains	LC	NCAP
11.7.7	*Eucalyptus fibrosa* subsp. *nubila* +/- *Corymbia* spp. +/- *Eucalyptus* spp. woodland on Cainozoic lateritic duricrust	LC	NCAP

Terrain

The terrain is generally flat to gently undulating plains with some gently undulating rises. In some areas there are steep hills. The project area is generally between 300 m to 350 m above sea level.

Soil Descriptions

A review of the dominant soil order mapping shows that the dominant soils across the development area are Vertosols and Sodosols. More specifically, there are four land zone categories across the PL253 development area as per the Land Zones of Queensland (Wilson and Taylor, 2012). These categories are as follows:

Land Zone 3

Recent Quaternary alluvial systems, including closed depressions, paleo-estuarine deposits currently under freshwater influence, inland lakes and associated wave-built lunettes. Excludes colluvial deposits such as talus slopes and pediments. Includes a diverse range of soils, predominantly Vertosols and Sodosols; also with Dermosols, Kurosols, Chromosols, Kandosols, Tenosols, Rudosols and Hydrosols; and Organosols in high rainfall areas.

Land Zone 4

Tertiary-early Quaternary clay deposits, usually forming level to gently undulating plains not related to recent Quaternary alluvial systems. Excludes clay plains formed *in-situ* on bedrock. Mainly Vertosols with Gilgai microrelief but includes thin sandy or loamy surfaced Sodosols and Chromosols with the same paleo-clay subsoil deposits.

Land Zone 5

Tertiary-early Quaternary extensive, uniform near level or gently undulating plains with sandy or loamy soils. Includes dissected remnants of these surfaces. Also includes plains with sandy or loamy soils of uncertain origin, and plateau remnants with moderate to deep soils usually overlying duricrust. Excludes recent Quaternary alluvial systems (land zone 3), exposed duricrust (land zone 7), and soils derived from underlying bedrock (land zones 8 to 12). Soils are usually Tenosols and Kandosols, also minor deep sandy surfaced Sodosols and Chromosols. There may be a duricrust at depth.

Land Zone 7

Cainozoic duricrusts formed on a variety of rock types, usually forming mesas or scarps. Includes exposed ferruginous, siliceous or mottled horizons and associated talus and colluvium, and remnants of these features, for example low stony rises on downs. Soils are usually shallow Rudosols and Tenosols, with minor Sodosols and Chromosols on associated pediments, and shallow Kandosols on plateau margins and larger mesas.

Further information about soils and soil management are provided in Section 6.10.

Watercourses

PL253 located in the Balonne River and Condamine River catchments of the Condamine-Culgoa Basin. These rivers are major tributaries of the Murray-Darling Basin (see Section 15.3.1 of the EIS for details).

The Condamine River flows southeast to northwest, approximately 4-5 km outside of the boundary of PL253. It ultimately joins the Balonne River, and these rivers form the northern headwaters of the Murray-Darling River system.

Wetlands

The nearest major wetlands to the development area are Lake Broadwater approximately 50 km to the south-east from the boundary of PL253 and Longswamp which is approximately 30 km from the boundary also in a south-east direction. Lake Broadwater is situated on PL260 and Longswamp is located on PL198, 238 and 260 which are all existing Arrow tenures and therefore outside the subject area of this amendment application. There is also a much smaller wetland located within PL253 (RE 11.3.27f). However, this wetland is not located within the development area the subject of this amendment application.

Springs

Great Artesian Basin springs in the SGP development area are located between 50 km and 300 km to the north and northwest of Wandoan (SGP EIS Appendix G). This amendment application is for PL253 located approximately 100 km south of Wandoan so therefore outside the area of any GAB springs. There is one non-spring groundwater dependent ecosystem (i.e., a spring fed from a shallow perched aquifer) and this is discussed in Section 6.3 of this application report.

Groundwater Systems

The Condamine Alluvium aquifer is a groundwater supply generally suitable for agricultural uses but is not the dominant groundwater system on PL253. Rather, PL253 is underlain by the Springbok Sandstone, Walloon Coal Measures and Hutton Sandstone (see Section 6.3 for details).

Floodplains

The watercourses within the Condamine-Culgoa Basin are dominated by low gradients and therefore characterised by low-energy conditions (SGP EIS Section 15.3.2). The Condamine River is largely a continuous flowing river that distributes flood flows into such watercourses as Wilkie Creek during large flood events. However, given the location and low-energy conditions of the system and the infrequency of overbank events, there is low potential for this to occur.

The Moonie Basin is generally flat, with low-relief hills bordering floodplains. Most of these floodplain and lowland areas have been cleared for grazing and cropping practices. Vegetation clearance, construction of weirs and dams, and extraction of water for irrigation has greatly altered the hydrology of the Condamine, Balonne, and Moonie Rivers. Arrow flood modelling indicates that at scenarios up to and including 1,000-year flood events that the development area is not impacted by floodwaters.

5. Mandatory Application Requirements

Summary of change: This chapter is largely unchanged. Tables 5.1 and 5.2 have changed to reflect the 55 well development case,

5.1 Requirements for amendment application

Pursuant to section 226 and 226A of the EP Act, the following sections address the requirements for an amendment application.

Be made to the administering authority

This EA amendment application has been made to DES, which is the administering authority.

Be in the approved form

Arrow has applied for this EA amendment via DES's online Connect system. This report is provided as supporting information to the application.

Be accompanied by the fee prescribed under a regulation

Arrow has elected to pay the fee by credit card on the online DES Connect system.

Describe the proposed amendment

This site-specific amendment application seeks to make the following changes to the existing Hopeland EA.

Arrow propose changes to condition **General 1 – General, Table 1 – Authorised Petroleum Activities** as detailed in Table 5.1 (~~strikethrough~~ = deletions' red = additions).

Table 5.1 Proposed changes to condition General 1 – General, Table 1 – Authorised Petroleum Activities

Petroleum activities and infrastructure	Scale	
	Intensity	Maximum
Wells Hopeland 5, Hopeland 5T, Hopeland 6, Hopeland 7, Hopeland 8, Hopeland 9	1 ha per single well site 1.5 ha per multi-well site	~~6~~ 61 (6 existing)
Existing water monitoring wells Shallow Hopeland 11, Hopeland 12, Hopeland 13, Hopeland 14, Hopeland 16 Deep Hopeland 17	0.03 ha for shallow monitoring bores 1 ha for deep monitoring bores	6
Additional water monitoring wells	0.03 ha for shallow monitoring bores 1 ha for deep monitoring bores	14
Gathering pipeline	~~1.542 ha~~ 74 km	N/A
Access Tracks	~~8 ha~~ 74 km	N/A
Hopeland Water Dam (regulated structure)	21 ha	1 dam

Arrow also propose to add a new environmentally relevant activity (ERA) being **Schedule 2A – 3**, which authorises a petroleum activity that is likely to have a significant impact on a category A or B environmentally sensitive area (ESA). However, note that no Category A ESA will be disturbed.

Arrow proposes to remove or add the following conditions in accordance with the Streamlined Model Conditions (SMCs):

- Add condition Biodiversity 1 – Prior to undertaking activities that result in significant disturbance to land in areas of native vegetation, confirmation of on-the-ground biodiversity values of the native vegetation communities at that location must be undertaken by a suitably qualified person.
- Add condition Biodiversity 2 – A suitably qualified person must develop and certify a methodology so that condition (Biodiversity 1) can be complied with, and which is appropriate to confirm on-the-ground biodiversity values.
- Add condition Biodiversity 3 – For conditions (Biodiversity 4) to (Biodiversity 9), where mapped biodiversity values differ from those confirmed under conditions (Biodiversity 1) and (Biodiversity 2), petroleum activities may proceed in accordance with the conditions of the environmental authority based on the confirmed on-the-ground biodiversity value.
- Add condition Biodiversity 4 – The location of the petroleum activity(ies) must be selected in accordance with the following site planning principles:

  - Maximise the use of areas of pre-existing disturbance
  - In order of preference, avoid, minimise or mitigate any impacts, including cumulative impacts, on areas of native vegetation or other areas of ecological value
  - Minimise disturbance to land that may result in land degradation
  - In order of preference, avoid then minimise isolation, fragmentation, edge effects or dissection of tracts of native vegetation; and
  - In order of preference, avoid then minimise clearing of native mature trees.
- Add condition Biodiversity 5 - Linear infrastructure construction corridors must:
  - Maximise co-location
  - Be minimised in width to the greatest practicable extent; and
  - For linear infrastructure that is an essential petroleum activity authorised in an environmentally sensitive area or its protection zone, be no greater than 40 m in total width.
- Remove condition Biodiversity 6 – Petroleum activities are not permitted in Category A, B or C environmentally sensitive areas
- Remove condition Biodiversity 7 – Essential petroleum activities may be undertaken in areas of pre-existing disturbance in the primary protection zones of Category B environmentally sensitive areas that are 'endangered' regional ecosystems and Category C environmentally sensitive areas other than 'nature refuges' or 'koala habitat' areas, providing those activities do not have a measurable negative impact on the adjacent environmentally sensitive area
- Add condition Biodiversity 8 – Where petroleum activities are to be carried out in environmentally sensitive areas or their protection zones, the petroleum activities must be carried out in accordance with Protecting Biodiversity Values, Table 1 – Authorised petroleum activities in environmentally sensitive areas and their protection zones as detailed in Table 5.2.
- Add Protecting Biodiversity Values, Table 1 – Authorised petroleum activities in environmentally sensitive areas and their protection zones as per Streamlined Model Conditions
- Add condition Biodiversity 9 – A report must be prepared for each annual return period for all petroleum activities that involve clearing of any environmentally sensitive area or protection zone which includes:
  - Records able to demonstrate compliance with conditions (Biodiversity 4), (Biodiversity 5) and (Biodiversity 8)
  - A description of the works
  - A description of the area and its pre-disturbance values (which may include maps or photographs, but must include GPS coordinates for the works); and
  - Based on the extent of environmentally sensitive areas and primary protection zones on the relevant resource authority(ies), the proportion of native vegetation

cleared per environmentally sensitive area and primary protection zone, including regional ecosystem type, over the annual return period.

- Add condition Biodiversity 10 – Significant residual impacts to prescribed environmental matters are not authorised under this environment authority or the Environmental Offsets Act 2014 unless the impact(s) is specified in **Protecting biodiversity values, Table 2 – Significant residual impacts to prescribed environmental matters.**

Table 5.2 Proposed additions to Schedule D, Protecting biodiversity values, Table 3 – Significant residual impacts to prescribed environmental matters

Prescribed Environmental Matter	Location of impact	Maximum extent of impact
REGULATED VEGETATION		
Endangered regional ecosystem		
Of concern regional ecosystem (not within an urban area)		
Regional ecosystems (not within an urban area) within the defined distance from the defining banks of a relevant watercourse on the vegetation management watercourse map		
Essential habitat (not in an urban area) for vulnerable wildlife		
CONNECTIVITY AREAS		
Connectivity area that is a regional ecosystem (not in an urban area)		
WETLANDS AND WATERCOURSES		
PROTECTED WILDLIFE HABITAT		
An area shown as a high risk area on the flora survey trigger map that contains plants that are endangered or vulnerable wildlife		
Habitat for an animal that is vulnerable wildlife		
Habitat for an animal that is endangered wildlife		
Habitat for an animal that is special least concern wildlife		

- Add condition Biodiversity 12 – An environmental offset made in accordance with the Environmental Offset Act 2014 and Queensland Offsets Policy, as amended from time to time, must be undertaken for the maximum extent of impact to each prescribed

environmental matter authorised in Protecting biodiversity values, Table 2 – Significant residual impacts to prescribed environmental matters, unless a lesser extent of the impact has been approved in accordance with condition (Biodiversity 14) [for staged offsets]

- Add condition Biodiversity 13 – The significant residual impacts to a prescribed environmental matter authorised in condition (Biodiversity 10) for which an environmental offset is required by condition (Biodiversity 12) may be carried out in stages. An environmental offset can be delivered for each stage of the impacts to prescribed environmental matters.
- Add condition Biodiversity 14 – Prior to the commencement of each stage, a report completed by an appropriately qualified person, that includes an analysis of the following must be provided to the administering authority:
    - For the forthcoming stage—the estimated significant residual impacts to each prescribed environmental matter; and
    - For the previous stage, if applicable—the actual significant residual impacts to each prescribed environmental matter, to date.
- Add condition Biodiversity 15 – The report required by condition (Biodiversity 14) must be approved by the administering authority before a notice of election for the forthcoming stage, if applicable, is given to the administering authority.
- Add condition Biodiversity 16 – A notice of election for the staged environmental offset referred to in condition (Biodiversity 15), if applicable, must be provided to the administering authority no less than three months before the proposed commencement of that stage, unless a lesser timeframe has been agreed to by the administering authority.
- Add condition Biodiversity 17 - Within six months from the completion of the final stage of the project, a report completed by an appropriately qualified person, that includes the following matters must be provided to the administering authority:
    - An analysis of the actual impacts on prescribed environmental matters resulting from the final stage; and
    - If applicable, a notice of election to address any outstanding offset debits for the authorised impacts.
- Change the monitoring frequency of condition Water 13(f) from ‘at least biannually’ to ‘at least annually’
- Amending the definition of Essential Petroleum Activities
- Increasing the maximum size for a well pad in defined circumstances
- Adding communication towers to the definition of Essential Petroleum Activities
- Amending the night-time noise conditions for drilling activities to be consistent with the World Health Organisation’s Guidelines for Community Noise and other Arrow EAs.

Describe the land that will be affected by the proposed amendment

This EA amendment application is relevant to PL253, a 21,300-ha area of land approximately 10 km south of Chinchilla and 4.6 km north of Kogan. The surrounding area has two primary uses and two secondary uses. These are:

- Agricultural use (primary use)
- Cattle grazing (primary use)
- Infrastructure (secondary use)
- Gas exploration and production (secondary use).

PL253 is comprised of 71 sub-blocks as detailed in Table 5.3. The sub-blocks relevant to this revised EA amendment application for the 55 well development case are shown in bold in Table 5.3.

Table 5.3 Block and Sub-block configuration for PL253

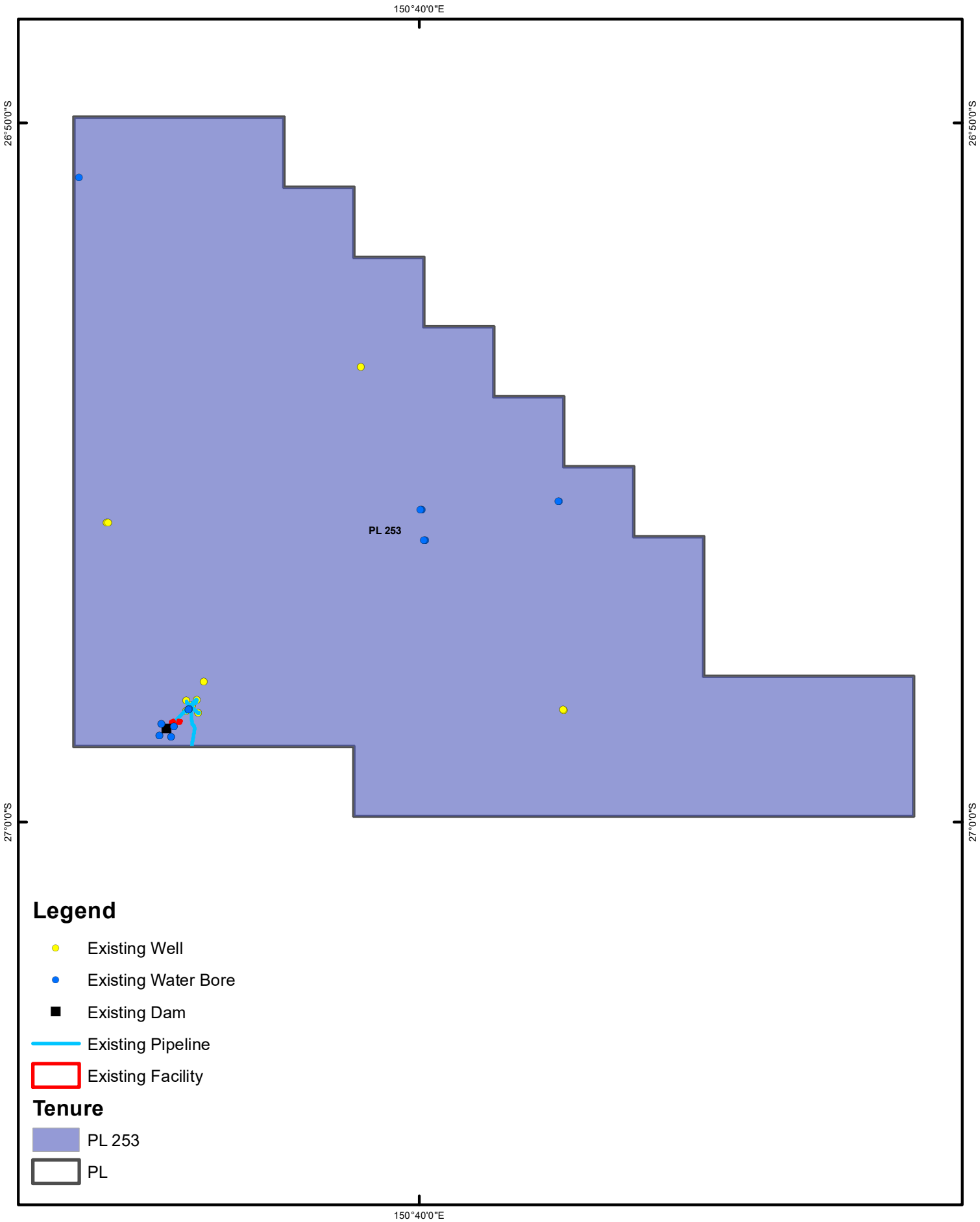
Petroleum Authority	Block Description	Sub-blocks
PL253	BRIS2456	a, b, c, f, g, h, j, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z
	BRIS2457	q, v, w
	BRIS2528	a, b, c, d, e, f, g, h, j, k, l, m, n, o, p, q, r, **s, t, u, z**
	BRIS2529	a, b, c, f, g, h, j, l, m, n, o, **p, q, r, s, t, u, v, w, x, y, z**
	BRIS2530	**l, m, n, q, r, s, v, w, x**

A map of the Petroleum Tenement is shown in Figure 5-1. The map shows the boundary of PL253 and existing infrastructure including plugged and abandoned wells. The existing Hopeland infrastructure is located on Lot 2 on DY94 and Lot 34 on DY94. There are no State Forests, timber reserves or unallocated State land within the area of this amendment application.

Resource authorities within the area of this application are presented in Table 5-4.

Table 5.4 Overlapping tenures on PL253

Resource Authority	Authority Holder
MDL335	CS Energy (Aberdare Collieries Pty Ltd)
EPQ14	Carbon Energy (Operations) Pty Ltd
PSL2026	Australia Pacific LNG CSG Transmissions Pty Ltd



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Source:
Arrow Energy Limited, Geosciences Australia
Dept. Envir. and Resource Mgmt.

N

Coordinate System: GCS GDA 1994

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km

Existing Infrastructure
PL 253
Hopelands

arrow energy
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Figure 5-1 - PL253 Infrastructure

Existing infrastructure

Wells

Six (6) appraisal wells are now production wells and six (6) water-monitoring bores have been installed on PL253, as listed in Table 5-3. The appraisal wells were converted (administratively) to production wells following the grant of PL253. More recently, 8 water monitoring bores were installed as part of the Groundwater Characteristics Monitoring Program (GCMP) discussed in Section 6.3.

Table 5.5 Hopeland CSG and water monitoring wells

Well name	Type	Coordinates	Depth m	Spud Date
Hopeland 5T	Production Well	-26.9722, 150.6126	735.95	20-Oct-2012
Hopeland 5	Production Well	-26.9721, 150.6127	421.40	09-Nov-2012
Hopeland 6	Production Well	-26.9711, 150.6113	642.68	20-Nov-2012
Hopeland 7	Production Well	-26.9709, 150.6138	633.00	07-Dec-2012
Hopeland 8	Production Well	-26.9739, 150.6141	631.78	02-Jan-2013
Hopeland 9	Production Well	-26.9736, 150.6113	623.10	12-Jan-2013
Hopeland 17	Water Monitoring	-26.9732, 150.6118	1223.16	08-Feb-2013
Hopeland 16	Water Monitoring	-26.973, 150.6119	49.60	10-Sep-2013
Hopeland 11	Water Monitoring	-26.9765, 150.6053	11.50	17-Oct-2013
Hopeland 12	Water Monitoring	-26.9771, 150.6083	10.30	17-Oct-2013
Hopeland 14	Water Monitoring	-26.9793, 150.6048	7.70	17-Oct-2013
Hopeland 13	Water Monitoring	-26.9797, 150.6077	10.0	18-Oct-2013
Hopeland 20	GCMP Monitoring Bores	-26.9235, 150.6999	124.55	23-Nov-2019
Hopeland 21	GCMP Monitoring Bores	-26.9235, 150.6998	225.43	12-Nov-2019
Hopeland 22	GCMP Monitoring Bores	-26.9327, 150.6682	105.5	28-Dec-2019
Hopeland 23	GCMP Monitoring Bores	-26.9327, 150.6681	150.0	26-Dec-2019
Hopeland 24	GCMP Monitoring Bores	-26.9327, 150.6679	266.43	19-Dec-2019
Hopeland 25	GCMP Monitoring Bores	-26.9255, 150.6674	101.0	16-Dec-2019
Hopeland 26	GCMP Monitoring Bores	-26.9255, 150.6672	140.43	14-Dec-2019
Hopeland 27	GCMP Monitoring Bores	-26.9254, 150.6671	256.43	7-Dec-2019
Hopeland 29	Surat Make Good	-26.8462, 150.5857	655.43	28-Nov-2019

Associated Infrastructure

Associated infrastructure that exists on PL253 and forms part of this amendment application is stated in Table 5.6.

Table 5.6 PL253 associated infrastructure

Type	Dimensions
Gathering Pipeline	1028 m x 15 m (~1.6 ha)
Raw Water Pipeline	1452m x 15 m (~2.2 ha)
Hopeland Pilot Dam	200 ML (Regulated), (~9 ha)
Sediment Pond	~0.5 ha
Borrow Pit	~0.5 ha
Access Tracks	3246.59 m x 12 m (~4 ha)
Pipeline (PPL2030)	~2ha
Total Existing Disturbance	**~19.8 ha**

The existing gas-gathering pipeline is linked to a common flare facility located central to the CSG wells (-26.972150, 150.612636). The flare facility is for potential (rare) upset conditions following the connection of the existing gathering network to the Hopeland Pilot Pipeline constructed under PPL2030 and EA0001025. The existing water-gathering network discharges to the Hopeland Dam.

The dam (-26.977646, 150.606565) is an aggregation dam for holding CSG water which was previously fed by six appraisal wells, and which are now production wells. The water was transferred to the dam along raw water gathering. The following sensitive receptors are located within proximity to the regulated dam on PL253.

Table 5.7 Sensitive receptors nearby the regulated dam on PL253

Nearest Sensitive Receptor	Distance
Residential dwelling	>2,500 m
Watercourse	235 m
Wetland	>2,500 m

The specification of the regulated dam on PL253 are:

- The maximum surface area (ha): ~9 ha
- The maximum volume of dam (m³): 200,000 m³
- Maximum depth of dam (m): 6.45 m.

Terminated Infrastructure

There are six (6) plugged and abandoned wells on PL253 as summarised in Table 5-8. The location of these is shown on Figure 5-1.

Table 5.8 Plugged and abandoned wells

Well name	Type	Coordinates	Depth m	Spud Date
Hopeland 1	Exploration	-26.9287, 150.5926	210.7	12-Jun-2011
Hopeland 1A	Exploration	-26.9287, 150.5924	643.4	01-Sep-2011
Hopeland 2	Exploration	-26.8915, 150.6529	575.2	23-Aug-2012
Hopeland 3	Exploration	-26.9733, 150.7012	243.7	16-Sep-2011
Hopeland 3A	Exploration	-26.9733, 150.7011	563.7	20-Nov-2011
Owen-1	Appraisal	-26.9665, 150.6154	581.5	17-Sep-2001

All wells have been plugged and abandoned in accordance with the applicable edition of Code of Practice for the construction and abandonment of coal seam gas wells and associated bores in Queensland.

Describe any development permits in effect under the Planning Act for the carrying out of the relevant activity for the authority.

Arrow does not have any development permits in effect under the *Planning Act 2016* for the carrying out of the relevant activities for the authority.

State whether each relevant activity will, if the amendment is made, comply with any eligibility criteria for the activity

This is not relevant to Arrow's application as the application is a site-specific amendment application.

If the application states that each relevant activity will, if the amendment is made, comply with any eligibility criteria for the activity-include a declaration that the statement is correct.

This is not relevant to Arrow's application as the application is a site-specific amendment application.

State whether the application seeks to change a condition identified in the authority as a standard condition.

The application does not seek to change a standard condition.

If the application relates to a new relevant resource tenure for the authority that is an exploration permit or GHG permit – state whether the applicant seeks an amended environmental authority that is subject to the standard conditions for the relevant activity or authority, to the extent it relates to the permit.

This is not relevant as this application relates to the existing PL253 and does not seek to include any new resource authorities.

Describe environmental values affected by proposed amendment

While this application proposes amendments to the existing Hopeland (PL253) EA, the proposed activities associated with the amendment were assessed in the SGP EIS. Section 6 of this EA amendment application provides relevant information from the EIS Assessment Report for each proposed activity.

Biological Environment

Table 5-9 lists the Queensland government mapped Matters of State Environmental Significance (MSES) for the development area on PL253 and identifies (green) those MSES that were verified as present on PL253 during surveys.

Table 5.9 MSES likely or known to be present on PL253

MSES	Area (ha)	Proportion of Tenure (%)
1a Protected Areas- estates	0	0
1b Protected Areas- nature refuges	0	0
2 State Marine Parks- highly protected zones	0	0
3 Fish habitat areas (A and B areas)	0	0
4 Strategic Environmental Areas (SEA)	0	0
5 High Ecological Significance wetlands on the map of Referable Wetlands	0	0
6a High Ecological Value (HEV) wetlands	0	0
6b High Ecological Value (HEV) waterways	0	0

7a Threatened (endangered or vulnerable) wildlife	10.65	0.05
7b Special least concern animals	7.69	0.04
7c i Koala habitat area - core (SEQ)	0	0
7c ii Koala habitat area - locally refined (SEQ)	0	0
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	0.7	0.003
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	3.5	0.02
8c Regulated Vegetation - Category R (GBR riverine regrowth)	0	0
8d Regulated Vegetation - Essential habitat	27.4	0.13
8e Regulated Vegetation - intersecting a watercourse	6.26	0.03
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	0	0
9a Legally secured offset areas- offset register areas	0	0
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0	0

The biodiversity values of the PL253 tenure were ground-verified by suitably qualified ecologists and were found to be different to those mapped by the Queensland government. The biodiversity assessment of the footprint identified remnant and regrowth patches of vegetation consistent with Regional Ecosystems (REs) 11.3.14, 11.3.25, 11.4.3, 11.5.1, 11.5.1a, 11.5.20 and 11.7.7. The infrastructure intersects a large, contiguous patch of RE 11.5.1 in the south-east corner of PL253. A patch of regrowth Brigalow (*Acacia harpophylla*, >15 years) consistent with RE 11.4.3 and the *A. harpophylla* dominant and co-dominant Threatened Ecological Community (TEC) was identified during initial surveys for this project. Several mapped watercourses also intersect the project area.

Based on the above assessment of vegetation communities, there is ground-verified core habitat present for the endangered (NC Act) Grey Snake (Hemiaspis damelii), the vulnerable (NC Act) Glossy Black Cockatoo (Calyptorhynchus lathami), Painted Honeyeater (Grantiella picta), Koala (Phascolarctos cinereus), Greater Glider (Petauroides volans), Eastern Long-eared Bat (Nyctophilus corbeni), Common Death Adder (Acanthophis antarcticus), Dunmall's Snake (Furina dunmalli), and Pale Imperial Hairstreak (Jalmenus eubulus).

The Painted Honeyeater, Koala, Greater Glider, Eastern Long-eared Bat and Dunmall's Snake are also Matters of National Environmental Significance (MNES) listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). There is also potential habitat for the special least concern (NC Act) Short-beaked Echidna (Tachyglossus aculeatus) present within PL253.

Provide the details of any emissions likely to be generated by each relevant activity

The proposed amendment does not change any of the emissions generated by the relevant activities covered under the existing Hopeland EA. The primary air quality emission relevant to this EA amendment application is particulate matter (i.e., dust) generated by construction activities. Further detailed information about emissions is discussed in Section 6.7.

Describe environmental risks and likely magnitude of impacts of the proposed amendment

Environmental risks and likely magnitude of impacts is discussed in detail in Section 6 of this report. Arrow acknowledges the previous operations on the former UCG site located on Lot

40 DY85 of PL253 and the potential risk associated with groundwater at this location. This is discussed further in Section 6.3. The following provides a discussion of risks other than that to groundwater associated with Lot 40 DY85.

The proposed increase in wells and associated gathering infrastructure increases risk to the biological environment during construction when clearing activities may be required outside of the dedicated project areas. To minimise risk and the magnitude of impact, site activities will be planned for minimum disturbance wherever possible and clearing boundaries will be clearly marked on construction maps and at site. As discussed above, several conservation significant fauna species may be present and therefore the avoid, minimise then mitigate hierarchy will be applied. The mitigation measures provided within the Surat Gas Project EPBC-approved Species Impact Management Plan will also be implemented and will benefit both Matters of National Environmental Significance (MNES) and Matters of State Environmental Significance (MSES) (https://www.arrowenergy.com.au/environment/environmental-management-plans-and-reports).

The Grey snake (*Hemiaspis damelii*) is particularly at risk from construction due to their habit of living within soil cracks. This species will be specifically managed using spotter-catcher and spotlighting surveys as required.

Mitigation measures employed to address other risks such as the use of water trucks for dust suppression, or the planned rehabilitation works for the prevention of off-site land and soil impacts are also effective for the treatment of risks to visual amenity, which with mitigation is considered a low risk.

Describe management practices associated with the proposed amendment

The management practices are described in Section 6 for each of the relevant matters within this application.

Describe how the land the subject of the application will be rehabilitated after each relevant activity ceases

Arrow will rehabilitate disturbed areas of PL253 in accordance with the relevant EA conditions as follows:

- Restoration - the pipeline RoW and laydown areas will be re-profiled with drainage lines re-established, topsoil reinstated and the area stabilised. Stabilisation will include planting vegetative groundcover that is not a declared pest species. This will be done once construction activities have been completed.
- Decommissioning - at the end of the project infrastructure life, or when it is no longer required, infrastructure will be decommissioned by removal of surface facilities from the site. Subsurface infrastructure such as pipelines will generally remain in situ. Any contaminated soils will be remediated or removed and disposed of at a licensed disposal facility.
- Final rehabilitation – (where required, i.e., alternative arrangements may be agreed with the landholder), topography, re-profiling and revegetation of the site will be undertaken to return disturbed land to as near as possible to its pre-disturbance state or agreed land

use. The final rehabilitation will be determined in conjunction with the landowner and to meet the EA requirements.

Further detailed information about rehabilitation is provided in Section 6.10 of this report.

Describe the proposed measures for minimising and managing waste generated by each relevant activity

Arrow will continue to ensure that the proposed measures for minimising and managing waste generated by activities will be in accordance with the relevant EA conditions. Detailed information about waste management is provided in Section 6.6 of this report.

Provide any details of any site management plan that relates to the land the subject of the application

No site management plans relate to the land the subject of this application.

Include any other document relating to the application prescribed under a regulation

There are no other documents relating to the application prescribed under a regulation.

5.2 Requirements for site-specific applications – CSG activities

Pursuant to section 126(1) of the EP Act, a site-specific application must also address the information provided in the following sections.

The quantity of CSG water the applicant reasonably expects will be generated in connection with carrying out each relevant CSG activity

Figure 5-2 presents the CSG water production forecast for the development the subject of this application. The forecast indicates that approximately 9.4 GL of water will be produced from the proposed development the subject of this application, over its operating lifetime. Water production from this development area will likely commence at the start of 2025. Appendix A provides the complete SGP CSG Water Management Plan.

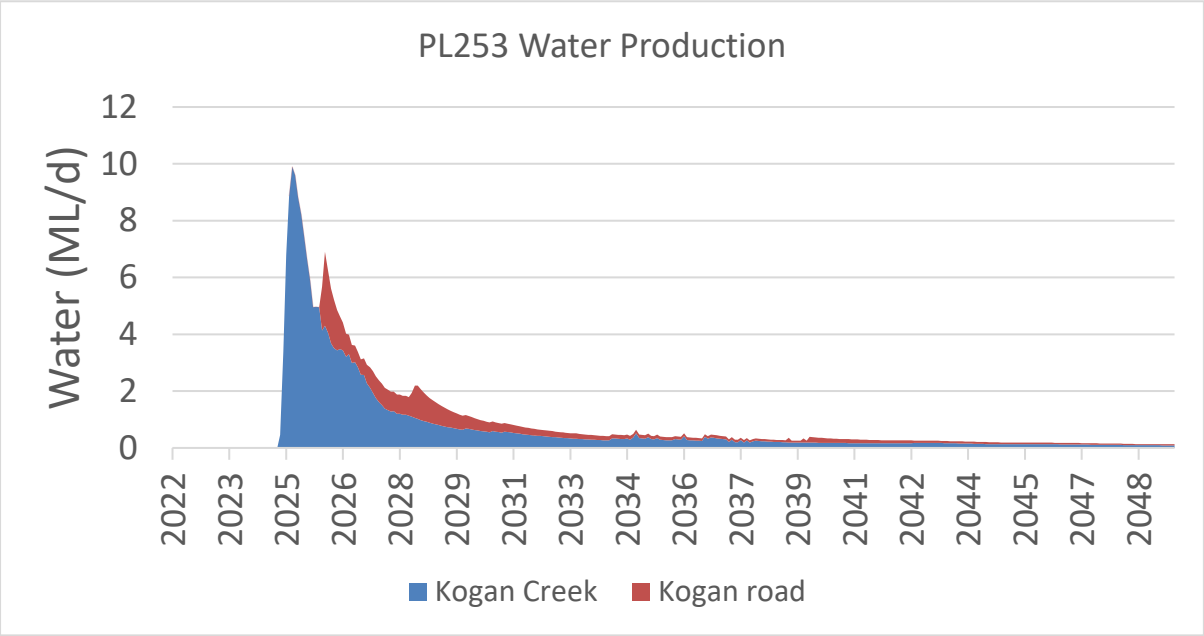

Figure 5-2 – Water Production across the development area

The flow rate at which the applicant reasonably expects the water will be generated

Figure 5-2 indicates that water production will begin in early 2025, with a peak flow rate of approximately 9.9 ML/day achieved by mid-year 2025. Water production will reduce quite quickly from this peak by 2026 and then continue to reduce through to 2049.

The quality of water, including changes in the water quality the applicant reasonably expects will happen while each relevant CSG activity is carried out

The SGP targets the Walloon Coal Measures, which typically has brackish water quality, with the following characteristics:

- pH of about 7.77 to 8.7
- Salinity (electrical conductivity - EC) in the range of 12,500 to 14,500 µS/cm (i.e., brackish)
- Suspended solids that typically settle out over time
- Trace metals and low concentrations of nutrients.

Section 6.3 presents a summary of expected water quality for wells across the SGP development area.

The proposed management of the water including, for example, the use, treatment, storage or disposal of the water

Section 3.3, Section 3.4, Section 3.5 and Section 4 of the CSG Water Management Plan (Appendix A) detail the proposed management strategies, options and infrastructure networks for the project. Water produced from PL253 will be delivered to the QGC operated Kenya Water Treatment Plant (WTP) where it will be treated. Treated water will be piped back to Arrows tenures and provided to third parties for beneficial reuse. Supply will primarily

be for irrigation, but water may also be supplied for other authorised beneficial uses (e.g., stock intensive). Supply of water for beneficial use will address Arrow's commitment to offset its impact to the Condamine Alluvium.

SGP water management will comprise the following (see Figure 5-3):

1. CSG production wells and associated water gathering system
2. Water transfer pipeline(s)
3. Aggregation dam(s)
4. Water Treatment Plants (WTP)
5. Treated water dam(s) and associated beneficial use offtakes
6. Brine dam(s).

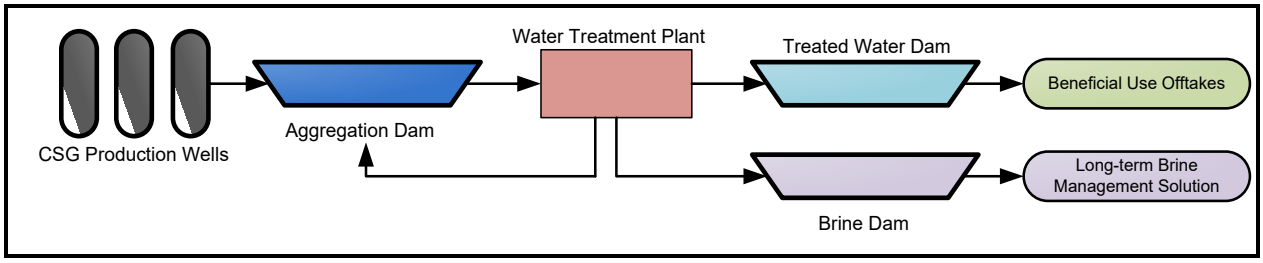

Figure 5-3 Conceptual Diagram of CSG Water Management

The measurable criteria (the management criteria) against which the applicant will monitor and assess the effectiveness of the management of the water

Arrow has defined measurable criteria for the SGP in accordance with Section 126 (1) of the EP Act 1994. To ensure criteria are targeted towards those CSG water management activities and elements that require the greatest control, they have been developed from the outcomes of the risk assessment described in Section 5 of the CSG Water Management Plan (Appendix A).

Table 5-8 presents the measurable criteria required to satisfy the requirements of the EP Act. The criteria will be re-evaluated as required.

Table 5.10 Measurable criteria for SGP

Management Component	Objectives	Environmental Value Protected	Controls	Measurable Criteria
Transmission of CSG water via pipelines	Effective containment of water throughout transmission activities from well to beneficial use / disposal.	Surface and groundwater quality. Soil quality (including structural and chemical properties).	Regular monitoring and maintenance in accordance with asset integrity and maintenance plan. Process safety in design and controls.	No reportable unplanned releases of CSG water.

Management Component	Objectives	Environmental Value Protected	Controls	Measurable Criteria
Storage of CSG water in regulated dams	Effective containment of CSG water in dams. Regulated dams operated and maintained in accordance with approvals.	Surface and groundwater quality. Soil quality (including structural and chemical properties).	Annual dam integrity inspections. Groundwater monitoring program. Scheduled maintenance of infrastructure and facilities. Dam operating plans. Water balance modelling to develop operating philosophy and strategy.	Water level below DSA at Nov-1.[1] No breaches of MRL. Annual inspections completed. No unplanned releases.
Beneficial Use	Maximise beneficial use of CSG water. Ensure that supplied beneficial use water is in accordance with approvals.	Surface and groundwater quality. Soil quality (including structural and chemical properties).	Regular monitoring of the qualities and quantities of water suppled for beneficial use. Scheduled maintenance of infrastructure and facilities. CSG Water and Salt Management Strategy.	Water supply agreements in place. Water quality for beneficial use meets approval conditions.
Management of salt and brine	Management of salt in accordance with the regulatory framework.	Land use capability, having regard to economic considerations. Surface and ground water quality. Soil quality (including structural and chemical properties).	Continual assessment of feasible options for beneficial use and/or disposal of salt in accordance with the CSG Water Management Policy 2012. Containment of salt and brine in fit for purpose storage infrastructure operated and maintained in accordance with approvals.	Water level below DSA at Nov 1. No breaches of MRL. Annual inspections completed. No reportable unplanned releases.

The action proposed to be taken if any of the management criteria are not complied with, to ensure the criteria will be able to be complied within the future

Should any of the Measurable Criteria in Table 5.8 not be met, the following response procedures will be implemented:

- Where relevant, reporting of the incident in line with DES requirements
- Evaluation of the underlying cause of the criteria not being met

[1] If the dam is a regulated structure as per the failure to contain overtopping scenario in the *Queensland Department of Environment and Heritage Protection, Manual for Assessing Consequence Categories and Hydraulic Performance of Structures,* DES, Queensland, Australia (ESR/2016/1933).

- Review relevant procedures, protocols and management plans and make changes where required
- Implementation of corrective actions to address underlying cause. This, for example, could include:
    - engineering solutions
    - amendments to operating procedures
    - change to management process.
- Where relevant, conduct incident investigation in accordance with Arrow policy.

5.3 Prescribed Environmentally Relevant Activities and Notifiable Activities

Activities that would be prescribed environmentally relevant activities (ERA's) (i.e., in Schedule 2 of the EP Reg) if they were not being conducted as part of a petroleum activity (e.g., chemical storage, hydrocarbon gas refining, gas producing, electricity generation, fuel burning, regulated waste storage, regulated waste treatment, waste disposal, waste transfer station operation, sewage treatment).

Section 2 of the SGP EIS identified eleven (11) Schedule 2 prescribed ERA's relevant to the SGP project, only three ERAs are relevant to the activities that are the subject of this EA amendment application. Table 5-9 discusses the relevance of the 11 EIS ERA's and this amendment application.

Table 5.11 ERAs relevant to PL253

Prescribed ERAs as per SGP EIS	Description	Relevant to this EA amendment application	Comment
Level 1 chapter 5A activity	Relates to a petroleum activity that is likely to have a significant impact on a category A or B environmentally sensitive area.	Yes	The current field development plan for PL253 includes approximately 5 ha of ground disturbance within a category B ESA. As such, this triggers the following: ***Schedule 2A – 3 a petroleum activity that is likely to have a significant impact on a category A or B environmentally sensitive area***
Level 1 chapter 5A activity	A petroleum activity carried out on a site containing a high-hazard dam or a significant hazard dam.	Yes	Whilst this amendment application is not requesting the construction of any high hazard or significant hazard dams, there is an existing regulated dam on PL253 known as the Hopeland Dam.

Prescribed ERAs as per SGP EIS	Description	Relevant to this EA amendment application	Comment
			This dam is operational and as such, this triggers the following: ***Schedule 2A – 6 a petroleum activity carried out on a site containing a high hazard dam or a significant hazard dam***
ERA 8 – chemical storage	500 m³ or more of chemicals of class C1 or C2 combustible liquids under AS 1940 (Standards Australia, 2004a) or dangerous goods class 3.	No	This amendment application is not requesting to store more than 500 m^3 of such chemicals
ERA 14 – electricity generation	Electricity generation (the relevant activity) consists of generating electricity by using gas at a rated capacity of 10 megawatt (MW) electrical or more.	No	This amendment application is not requesting electricity generation at the scale of this ERA
ERA 15 – fuel burning	Fuel burning (the relevant activity) consists of using fuel-burning equipment that is capable of burning at least 500 kg of fuel in an hour.	No	This amendment application is not requesting fuel burning activity at the scale of this ERA
ERA 56 - regulated waste storage	Regulated waste storage (the relevant activity) consists of operating a facility for receiving and storing regulated waste for more than 24 hours.	Yes	CSG water is currently being stored at one regulated dam located on PL253 known as the Hopeland Dam. No other regulated dams are to be constructed on PL253. Whilst ERA 56 is no longer in the Environmental Protection Regulation and is no longer used, ERA 62 is the relevant ERA for the Hopeland Dam for the storage and disposal of produced water. Specifically, ERA 62(1)(c) relates to a category 2 regulated waste.
ERA 58 –	Regulated waste treatment (the relevant	No	The temporary storage and treatment of CSG water is

Prescribed ERAs as per SGP EIS	Description	Relevant to this EA amendment application	Comment
regulated waste treatment	activity) consists of operating a facility for receiving and treating regulated waste or contaminated soil to render the waste or soil non-hazardous or less hazardous.		authorised under PPL2034 and EA0001540 and is not an activity which will be undertaken on PL253.
ERA 43 – concrete batching	Concrete batching (the relevant activity) consists of producing 200 t or more of concrete or concrete products in a year, by mixing cement with sand, rock, aggregate or other similar materials.	No	No concrete batching plants at the scale of this ERA will be constructed on PL253
ERA 60 – waste disposal	Operating a facility for disposing of regulated waste; more than 200,000 t.	No	This amendment application is not requesting to operate a waste disposal facility at the scale of this ERA
ERA 63 – sewage treatment	Operating 1 or more sewage treatment works at a site that has a total daily peak design capacity of more than 21 EPs.	No	No sewage facilities with a total peak design capacity of more than 21 EP are required on the PL253
ERA 64 – water treatment	Water treatment (the relevant activity) consists of carrying out any of the following activities in a way that allows waste, whether treated or untreated, to be released into the environment: a. Desalinating 0.5 ML or more of water in a day. b. Treating 10 ML or more of raw water in a day. c. Carrying out advanced treatment of 5 ML or more of water in a day.	No	This amendment application is not requesting water treatment at the scale of this ERA

Notifiable activities (Schedule 3 of the EP Act) carried out on the site (e.g., coal gas works, petroleum product or oil storage, landfill, disposing of waste, waste storage, treatment or disposal at a place other than where it was generated).

There will be no notifiable activities undertaken within PL253 and there are no notifiable activity addressing CSG development generally. However, activities associated with construction and operation, such as sewage treatment facilities, petroleum and chemical storage, are notifiable activities under the EP Act if they occur above defined thresholds. With regards to land being used for a notifiable activity:

- Fuels, such as diesel, will generally be stored at drilling and construction sites but may also be stored on operational sites as a primary or alternative fuel supply for generators. Petroleum may be stored in above ground tanks; however, volumes will be less than the threshold volumes for Notifiable Activity No. 29 (Petroleum product or oil storage -storing petroleum or oil in class 3 in packaging groups 1 and 2 of more than 2,500 litre capacity; packaging group 3 more than 5,000 litres capacity; and class C1 or C2 combustible liquids of more than 25,000 litres capacity).
- Chemicals used in the treatment of coal seam gas (e.g., triethylene glycol) and coal seam gas water will not be used on PL253. These will be stored and used at operational facility sites in other areas of the SGP development. Chemicals which may be stored on PL253 for other activities will be at volumes less than the threshold volumes for Notifiable Activity No. 7 (Chemical storage—storing more than 10 t of chemicals).
- Mobile sewage treatment plants are proposed to be used on PL253 to support the construction workforce. The mobile sewage treatment facilities will not have a design capacity that triggers Notifiable Activity No. 37 (Waste storage, treatment or disposal - storing, treating, reprocessing or disposing of regulated waste more than the equivalent of 50,000 persons).

To avoid contamination from the activities undertaken as part of this EA amendment application, the following will be implemented:

- Inspect the locations of ground disturbing activities for the presence of contamination prior to the commencement of works
- Avoid disturbance in areas of contamination
- Stop works if disturbance of contaminated soil or groundwater is encountered during project activities
- If contaminated land is disturbed:
    - act immediately to protect human health and safety of site workers, public and the environment
    - isolate areas containing contaminated soil / groundwater, where possible
    - undertake an assessment by a suitably qualified contaminated land specialist
    - remediate or manage in accordance with Queensland Government legislation and guidelines.

The SGP EIS addressed the environmental risks posed by a regulated dam as follows:

- Detailed requirements for the design, construction, operation and safety of regulated dams (Section 4.9 of the Strategic Environmental Management Plan - Surat Gas Project) including the management measures for dams across all project-related activities as shown in Table 5.12.
- The development of a groundwater monitoring program based on a risk assessment to detect any impacts from seepage from any regulated dam (Section 4.5.3 of the Strategic Environmental Management Plan - Surat Gas Project).

Table 5.12 Management of regulated dams

Element or issue	• Impacts on land use relative to the footprint of the dam. • Hazard to people if the dam overtops or fails. • Impacts from salinity through leakage of untreated coal seam gas water or of brine. • Loss of habitat relative to the footprint of the dam. • Diminished surface and groundwater quality if the dam overtops or fails.
Environmental and social objectives	• To ensure no uncontrolled release or leakage occurs and that coal seam • gas water and brine in regulated dams is appropriately managed.
Performance criteria	• Operated and maintained in accordance with the certified design plan.
Implementation strategy for planning and design	• Consider local biological, groundwater and surface water conditions when identifying sites for coal seam gas water dams and brine dams. [EIS Commitment Number - C124] • Design coal seam gas water dams in accordance with relevant legislation, standards and guidelines. [C154] • Subject each dam to separate approvals by the regulating authority. Each approval will require the incorporation of general and specific controls to avoid, mitigate or manage threats associated with flooding. [C206] • Use an independent, suitably qualified, third party to certify that dams meet the dam design plan. [C209] • Have in place a system for the collection and proper disposal of any contaminants that move beyond the bounds of the containment system of brine dams. [C210] • Design and size dams to account for predicted flood conditions. [C211]
Implementation strategy for construction	• Develop the construction, design and monitoring requirements for new dams (either raw water, treated water or brine dams) and determine the hazard category of the dam in accordance with the requirements of the most recent version of Manual for assessing hazard categories and hydraulic performance of dams (EHP, 2012b). • Construct the dams under the supervision of a suitably qualified and experienced person in accordance with the relevant DERM schedule of conditions relating to dam design, construction, inspection and mandatory reporting requirements. [C141] • Line banks of dam with an impervious lining. [C213]

	• Design dams to have an egress (escape point) for wildlife. [C214]
Implementation strategy for operations	• Establish overflow and operational controls in accordance with the dam operating plan. [C215] • Inspect and maintain dam integrity. [C216]
Implementation strategy for decommissioning	• Implement a decommissioning and rehabilitation plan in accordance with the dam design plan. [C074]
Inspection and monitoring	• Implement the dam operating plan. [C207] • Routinely monitor water quality in dams. [C009] • Monitor dam levels. [C528] • Have a suitably qualified person routinely monitor the integrity and • available storage of dams. [C532]
Auditing	• Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this Strategic EMP.
Reporting	• Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this Strategic EMP.
Corrective action	• Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

The measures described in Table 5.12 are being implemented at the Hopeland dam site.

In accordance with Section 4.4.1.1 of the CSG Water and Salt Management Strategy attached to the EIS, Arrow maintains a Regulated Dam Register that contains information including, but not limited to:

- Dam name, location and date of entry into Register
- Description of dam purpose and contents
- Hazard category
- Details of composition and construction of any liner
- Dimensions and surface area
- Maximum operational volume
- Design Storage Allowance at Nov 1st each year
- Mandatory Reporting Level
- Date construction certified
- Name and qualifications of certifier
- Dates on which dam was inspected for structural and operational adequacy
- Date on which annual inspection report was provided to administering authority.

In accordance with Section 4.4.1.2 of the CSG Water and Salt Management Strategy, each dam is operated under a Dam Operating Plan which includes:

- Dam details
- Operating guidelines
- Inspections checklists
- Regulatory reporting requirements
- Surface water monitoring programs.

In accordance with Section 4.4.1.3 of the CSG Water and Salt Management Strategy, an annual audit is undertaken to ensure that dams are assessed as structurally sound and compliant with current performance standards. During the audit process, dams are assessed for the following:

- Hazard category in accordance with the most recent version of DES's Manual for Assessing Hazard Categories and Hydraulic Performance of Dams
- Condition and adequacy for dam safety
- Its structural, geotechnical and hydraulic performance against the criteria contained in the design plan.

If the structural integrity of any dam is identified to be deficient, a management plan will be developed defining safe operating parameters and any remediation requirements. All new dams will be designed and constructed by a suitably qualified and experienced person in accordance with the hazard assessment and hydraulic performance standards prescribed by DES (Manual for Assessing Hazard Categories and Hydraulic Performance of Dams) and with Arrow's standard specification for the construction of regulated dams for the CSG industry.

In accordance with Section 4.4.1.4 of the CSG Water and Salt Management Strategy, a Decommissioning and Rehabilitation Management Plan will be developed as part of the initial dam design plan for approval by DES. The plan is specific to the project and is established based on the timeframes for construction, operation and decommissioning of each facility. At the end of the life of a dam:

- All liquid and solid material must be removed from the dam prior to rehabilitation
- Where used, artificial liners must be removed and transported to a regulated waste facility for disposal
- Brine must be evaporated, and the solid salts must be removed from the dam for:
    - Appropriate disposal to a regulated waste disposal facility designed for that purpose
    - Further treatment
    - Use as an input into another production process.

5.4 DES streamlined model conditions for petroleum activities

DES in partnership with the Australian Petroleum Production and Exploration Association (APPEA) and industry representatives have developed streamlined model conditions for production activities ('streamlined conditions') for the petroleum industry.

Streamlined Model Conditions (SMCs) can be incorporated into an EA where the applicant declares, or demonstrates through material in their application, that the risks of the proposed activities are consistent with the risk assessment for petroleum activities that was undertaken at the inception of the SMCs. Appendix D provides risk assessment for petroleum activities to be undertaken on PL253.

The current Hopeland EA contains some of the SMCs; however, this amendment application seeks to increase the scale of activities permitted under the EA and as such, it is considered necessary to include several additional SMCs in the Hopeland EA. Arrow is confident in its declaration that the risks associated with the activities proposed in this amendment application are consistent with the risk assessment for petroleum activities presented at Appendix D.

6. Addressing the EA information requirements (including description of environmental values affected by proposed amendment)

Summary of change: This chapter is largely unchanged. The following changes have been made between this 55 well development case and the full 280 well development case EA amendment applications:

- Section 6.2: the scale/intensity of disturbance to ecological values
- Section 6.3: the groundwater modelling of the Stage1 development case and the resulting no change from baseline groundwater conditions at the former Linc site
- Section 6.4: the reduced number of noise sensitive receptors.

This section provides relevant information from the DES EIS Assessment Report (Section 6.1) and includes a description of environmental values affected by proposed amendment. Responses to each DES request are provided in Sections 6.2 to 6.10.

6.1 DES SGP EIS Assessment Report information requests

Table 6-1 lists the 25 areas where additional information would be required in support of an EA application (as identified in the DES Assessment Report) and notes whether the request is relevant to this amendment application.

Table 6.1 DES SGP EIS Assessment Report Information Requests

Request Number	DES Request Description	Relevant to the EA	Arrow Response
1	Location of major infrastructure, such as gas compression plants, water treatments plants and accommodation camps, and the potential impacts of these locations on environmental values.	No	Arrow proposes to construct two new FCSs (Girrawheen FCS) and Lynwood FCS) as part of the SGP. These facilities are to be constructed under the authority of separate EAs. There are no plans to construct major accommodation camps or water treatment plants on PL253.
2	Site selection of infrastructure in consideration of: • Impacts of disturbance on ESAs • Impacts of power distribution infrastructure on Category C ESAs (State forests) • Impacts of wells and gathering networks on terrestrial ecology (animal habitat and breeding places, protected plants) • Application of the avoid, minimise, mitigate hierarchy for proposed disturbance • Identification, through ground-verification where possible, of regional ecosystems to be disturbed • Identification of proposed disturbance to areas of high ecological significance	Yes	Section 6.2 of this report discusses how the petroleum activities addressed in this amendment application will be in consideration of the listed factors.

Request Number	DES Request Description	Relevant to the EA	Arrow Response
	including those protected under the NC Act, EPBC Act and wetlands.		
3	Site-specific CSG water management options including details of proposed beneficial use schemes or releases of watercourses.	No	This amendment application does not seek approval for CSG water releases to watercourses (hereafter discharge). However, the CSG water that will be brought to the surface by the production wells will be used (e.g., for dust suppression, foundation compaction) where possible and in accordance with the EA conditions. Once in production, all water extracted from PL253 will be delivered to QGC's Jammat FCS before being sent for treatment at the QGC operated Kenya Water Treatment Plant (WTP) To promote beneficial use of the treated water, Arrow proposes to construct a pipeline from the Kenya WTP back onto Arrow tenure Management of the brine that results from the treatment of the produced CSG water (including brine storage, crystallisation and salt disposal) will be the responsibility of Arrow. Brine pond/s will be constructed adjacent to the Kenya WTP and these structures are authorised under the existing PPL2034 and EA0001540.
4	Site-specific details of the groundwater monitoring program including: • Locations of monitoring wells, including those proposed as leak detection bores around dams • Frequency of monitoring	Yes	Section 6.3 of this report discusses the groundwater monitoring program in relation to the petroleum activities addressed in this amendment application and as per the conditions of Arrow's Surat Gas Expansion Project approval (EPBC 2010/5344).

Request Number	DES Request Description	Relevant to the EA	Arrow Response
	• Quality parameters of concern that should be monitored.		
5	Consideration of residual impacts on State Significant Biodiversity Values under the Queensland Biodiversity Offsets Policy and potential provision of offsets.	Yes	Section 6.2 of this report discusses offsets in relation to the petroleum activities addressed in this amendment application.
6	Site-specific noise and vibration assessment for each proposed infrastructure location.	Yes	Section 6.4 of this report discusses noise and vibration in relation to the petroleum activities addressed in this amendment application.
7	Details of the proposed management of sewage	Yes	Section 6.5 of this report discusses sewage management in relation to the petroleum activities addressed in this amendment application.
8	Details of the management practices proposed to prevent and minimise environmental harm caused by uncontrolled release of waste	Yes	Section 6.5 of this report discusses waste management in relation to the petroleum activities addressed in this amendment application.
9	Site-specific air quality assessment for each proposed infrastructure location that describes point source and fugitive emissions.	Yes	Section 6.6 of this report discusses air quality in relation to the petroleum activities addressed in this amendment application.
10	Consideration of bioaccumulation of chemicals in the environment from discharges of hydrotest water, sewage, CSG water and runoff	Yes	Section 6.5 of this report discusses the potential for bioaccumulation of chemicals in relation to the petroleum activities addressed in this amendment application.

Request Number	DES Request Description	Relevant to the EA	Arrow Response
11	Description of the minimisation and management of any waste generated by the activities, including details of the proposed reuse of soils, drill cutting, hydrostatic test water and waste or washout liquids.	Yes	Section 6.5 of this report discuss minimising waste including reuse of soils, drill cutting and hydrostatic test water in relation to the petroleum activities addressed in this amendment application.
12	Generation and management of hydrostatic test water including quantity, source, quality and additives, storage and disposal.	Yes	Hydrostatic testing will occur during the testing and installation of the gas and CSG water gathering lines. Section 6.5 of this report discusses the generation and management of hydrostatic test water in relation to the petroleum activities addressed in this amendment application.
13	Details of the proposed ERAs to be included in the project.	Yes	Two new ERAs are being applied for as part of this amendment application and have been described earlier (see Section 5.3 for details).
14	Details of the proposed notifiable activities to be included in the project.	Yes	Section 5.3 of this report also discusses notifiable activities in relation to the petroleum activities addressed in this amendment application.
15	Specification of the existing and proposed infrastructure to allow DES to consider the scale and intensity of the project.	Yes	Section 5.1 of this report discusses the existing infrastructure on PL253, and Sections 5.1 and 7 describe the proposed infrastructure relevant to the petroleum activities addressed in this amendment application.
16	Details of CSG water management infrastructure including identification of	Yes	Appendix A of this amendment application provides a SGP CSG Water Management Plan. Details regarding the existing Hopeland Dam have been provided in Section 5.1. This amendment application does not seek approval for any new

Request Number	DES Request Description	Relevant to the EA	Arrow Response
	beneficial use infrastructure for both CSG water and salt/brine.		CSG water management infrastructure. All water extracted from PL253 will be transported off tenure via pipelines to QGC's Jammat FCS. Water transported off tenure will be treated and returned to Arrow. Arrow infrastructure used to transport raw water and treated water will be the subject of separate EAs. For further information regarding brine see Section 5.2.
17	Details of a greenhouse gas management strategy including potential impacts of the project on state and national GHG inventories, best practice methods for minimisation of GHG emissions and commitments to continuous improvement of GHG emissions.	Yes	Section 6.7 of this report discusses the greenhouse gas management strategy relevant to the petroleum activities addressed in this amendment application.
18	Details of existing contaminated land parcels on the Environmental Management or Contaminated Land Registers, and identification of the notifiable activities and locations that will require listing on these registers.	Yes	Section 6.8 of this report discusses contaminated land parcels relevant to the areas addressed in this amendment application, and Section 5.3 discusses notifiable activities.
19	Details of land management strategies including soil and topsoil handling and management, and erosion and sediment control measures.	Yes	Section 6.9 of this report discusses the land management strategies relevant to the petroleum activities addressed in this amendment application.

Request Number	DES Request Description	Relevant to the EA	Arrow Response
20	Identification of sensitive receptors and potential impacts on sensitive receptors including land, water, air, noise, waste and visual amenity.	Yes	Section 6.2 to 6.6 of this report summarises the potential impacts to sensitive receptors relevant to the petroleum activities addressed in this amendment application.
21	Identification of flood plains and site selection of infrastructure regarding minimisation of the impacts of flooding.	Yes	Section 6.2 of this report discusses flooding relevant to the petroleum activities addressed in this amendment application.
22	Details of discharges/releases of water including: • Exact location of release point with description including environmental values of the release point and reasoning for site selection based on risk assessment of impacts to environmental values • Source of release water including quantity and quality • Proposed monitoring program including parameters, frequency and locations with program review procedures to ascertain effectiveness of the program.	No	This amendment application does not seek approval for CSG water discharge.
23	Consideration of impacts on groundwater dependent ecosystems within the project footprint.	Yes	Section 6.3 of this report discusses groundwater dependent ecosystems within the project footprint relevant to the petroleum activities addressed in this amendment application.
24	Details of site-specific groundwater environmental values, potential impacts on groundwater environmental values and	Yes	Section 6.3 of this report discusses site-specific groundwater environmental values, potential impacts on groundwater environmental values and mitigation measures relevant to the

Request Number	DES Request Description	Relevant to the EA	Arrow Response
	mitigation measures including groundwater monitoring programs for all major infrastructures.		petroleum activities addressed in this amendment application. However, this amendment application does not seek approval for CSG water management infrastructure. All water extracted from PL253 will be transported off tenure via pipelines to the existing QGC Jammat FCS.
25	Details of rehabilitation plan including: • Rehabilitation hierarchy for post-rehabilitation outcome/land use • Rehabilitation methods including site preparation and revegetation activities • Rehabilitation goals including establishing final land use in consultation with landholders and DES, identifying analogue sites to measure rehabilitation success, indicators of rehabilitation success • Monitoring program • Progressive rehabilitation and timeframes for commencement of rehabilitation activities.	Yes	Section 6.10 of this report discusses rehabilitation planning relevant to the petroleum activities addressed in this amendment application.

6.2 Locating infrastructure to avoid and minimise impacts

Management hierarchy

Coal Seam Gas developments apply an iterative process in terms of locating wells and gathering lines. This is required because there are several competing constraints when it comes to locating the infrastructure on the surface. These constraints include ecological values, landholder preferences, geological features, topographic features, noise impacts and flooding, existing infrastructure, and access tracks. Planning and management of surface activities and ground disturbance is undertaken utilising a set of hierarchical management principles used to avoid, minimise, and mitigate impacts to ecological values. These principles are:

- **Avoid**: Arrow's first preference is to avoid environmental values such as ESAs, Prescribed Environmental Matters (PEMs) and areas of high ecological significance including those protected under the Nature Conservation Act 1992 and EPBC Act
- **Minimise**: where other competing constraints or the scale / location of ESAs and PEMs dictate that avoidance is not possible (e.g., where there are long linear strips of Brigalow that need to be crossed or large areas of suitable habitat for wide ranging fauna species), Arrow will preferentially locate infrastructure in a manner that minimises the impact to these values (e.g., cross the Brigalow at the narrowest or most degraded part or where practicable on the edge of suitable habitat for listed species so as not to bisect good quality habitat)
- **Mitigate**: implement mitigation measures to further minimise the direct and indirect impacts on ecological values
- **Remediate and rehabilitate**: actively remediate and rehabilitate impacted areas to promote and maintain long term recovery
- **Offset**: Arrow will offset unavoidable significant residual impacts to PEMs as per the EA conditions and the Queensland Environmental Offsets Policy.

Application of the management hierarchy

The following steps are already embedded in Arrow's process and will be undertaken to implement the above-mentioned management hierarchy for the activities the subject of this EA amendment application:

- Pre-clearance surveys
- Final Layout Approval
- On-site management and reporting
- Annual reporting.

Pre-clearance surveys

Arrow has already completed ecological surveys within the areas of proposed activities. However, additional pre-clearance surveys will be undertaken when the SGP activities proceed through the detailed design and planning phase. At this point in time, a field inspection of the specified disturbance footprint will be undertaken by a suitably qualified ecologist. The pre-clearance survey will confirm the presence, absence and extent of environmental values and these will be mapped in the field via GIS. The results of this step will be recorded within Geocortex (Arrow's GIS based mapping system) and the Arrow Access and Approvals System (Arrow's data compilation software used by the Access and Approvals Team).

Final layout Approval

Following the pre-clearance surveys, a Final Layout Approval (FLA) meeting will be held with the project engineers, planners, ecologists, land liaison officer and an archaeologist. The purpose of this meeting is for each specialist to discuss the proposed location of the infrastructure and the opportunities and constraints based on the findings of their field assessment.

It is at this meeting where the ecologist will be reiterating Arrow's management hierarchy for ESAs/PEMs and aiming to avoid and minimise impacts to these values. The outcome of the FLA meeting is an agreed location for the surface infrastructure after taking into consideration each competing constraint. The results of this step will be recorded within the Arrow Access and Approvals database.

On-site management and reporting

Where the FLA meeting has identified that impacts to PEMs are unavoidable, the following will be undertaken so that the actual area cleared will be surveyed to quantify the impacts:

- Record GPS coordinates of the boundary of the PEM in relation to the proposed clearing boundaries and ensure the limits of the area to be cleared are clearly marked on the ground (e.g., high visibility flagging tape, hazard netting or similar).
- Complete a Habitat Quality Assessment as per the Queensland Government Department of Environment and Science's Guide to determining terrestrial habitat quality – Methods for assessing habitat quality under the Queensland Environmental Offsets Policy, Version 1.3 (2020).
- Ensure a fauna spotter-catcher is present during clearing. The spotter-catcher will be suitably qualified. The number of fauna spotter-catchers on site at the time of clearing will depend on the number of machines being used at any given time.
- Record the coordinates and total area of PEMs to be cleared.

Annual reporting

The field data collected above will be provided to the Arrow Environment Team at the completion of site disturbance activities and tracked monthly against the approved PEM maximum disturbance limits provided within the Hopeland EA conditions.

Mitigation measures and commitments to avoid and minimise impacts

Table 6.2 Description of mitigation measures / commitments for activities the subject of this amendment application

Mitigation	Commitment	Intended outcome
Pre-construction clearance surveys / minimise clearing	• Minimise the disturbance footprint and vegetation clearing • Use existing roads and tracks, where practicable • Avoid unnecessary impervious surface coverings and reduce land footprint and vegetation clearing when designing facilities • Reduce the width of construction ROW within areas of sensitivity to the greatest extent practicable without compromising the safety of workers • Conduct preconstruction clearance surveys to identify any additional areas that may need to be avoided • Conduct preconstruction clearance surveys and include as a minimum: o Vegetation mapping at a scale suitable for site- specific planning o Identification of habitats and listed species o Identification of site-specific sensitive areas that require avoidance or buffer areas	• To identify opportunities where the residual impacts to PEMs can be further reduced
Construction activities as per plan (no-go areas)	• Ensure construction activities do not extend beyond the work site boundaries • Mark site boundaries clearly for site-specific sensitive areas that require avoidance • Demarcate buffers and inform workers and machinery operators of buffer locations when working within the vicinity of national- and state-listed species, communities and areas identified for avoidance • When clearing vegetation, seek to avoid creating gaps in stands or patches and to avoid isolating parcels of remnant vegetation from more continuous tracts • Retain habitat trees, where practicable • Construct production wells, gathering lines and access tracks within cleared areas, where practicable, with the aim of avoiding sensitive areas • Avoid damaging standing trees not identified for removal. Limit the scraping of standing tree trunks and breaking of limbs by equipment as far as practicable	• To ensure that no unplanned impacts occur on PEMs because of construction activities
Clear Communication	• Inform relevant workers, including contract plant and machinery operators of the location of significant remnant vegetation and buffers and use qualified personnel to guide clearing activities • Prohibit disturbance or harassment of wildlife and the unauthorised collection of flora and forest products	• To ensure that no unplanned impacts occur on PEMs because of

Mitigation	Commitment	Intended outcome
		construction activities
Fauna spotter catcher	• Assess trees prior to felling for potential nesting hollows. If identified, fell trees in the presence of a suitably qualified fauna spotter-catcher (FSC) and roll them so that the hollows are facing upwards, allowing fauna to escape • Identify key koala trees (Eucalyptus tereticornis and Eucalyptus populnea), and visually inspect prior to clearing to ensure that they are free of koalas. If koalas are located, the tree should be retained until the animals have moved on, typically overnight • Use appropriately trained personnel or a FSC to capture injured wildlife, where possible. If further action is required, consult with a qualified vet to determine appropriate action • The FSC will be present during clearing. The number of FSCs on site at the time of clearing will depend on the number of machines being used at any given time • Checks for fauna species breeding places will be undertaken immediately prior to commencing vegetation clearing • Potential breeding places will be clearly marked in the field with spray paint, coloured flagging tape (unless not permitted by landowners, e.g., some cattle properties), or by other suitable methods	• To ensure that no unplanned impacts occur on listed threatened species
Reduce project traffic speed	• Implement speed limits on project-controlled roads to reduce the potential for vehicle collisions with wildlife • Confine project traffic to designated roads and access tracks, where practicable	• To ensure that no unplanned impacts occur on ground-dwelling fauna species
Weed control	• Inspect work sites and access routes for notifiable weeds and pest plants and animals prior to accessing the site • Wash down vehicles and equipment that have potentially been in contact with weeds before entering new work sites • Advise all relevant personnel of the location and extent of weed infestations in the vicinity of the work areas and the risks involved in moving from one site or property to another • Identify declared weeds [as per the Land Access Code 2016] during the preconstruction clearance survey	• To avoid reduction in the condition of PEMs and listed threatened species habitat

Scale and location of disturbance

The SGP EIS and SREIS (Arrow Energy 2012, 2013) identified the general locations, disturbance areas and environmental values relevant to the life of the project. This section provides more specific and current information relevant to the activities proposed under the Hopeland EA.

An indicative location for the proposed works that are the subject of this EA amendment application is shown on Figure 4-1 and approximate disturbance areas within ESAs are as follows (note that these areas will be revised as the management hierarchy steps discussed above are implemented):

- Footprint within an ESA (Cat A) = 0 ha
- Footprint within an ESA (Cat B) = 0 ha
- Footprint within an ESA (Cat C) = 55 ha.

Table 6.3 provides the breakdown of maximum disturbance areas to each PEM listed in the DES Streamlined Model Conditions (SMCs).

The actual area of construction within PL253 tenure has been selected to have minimal environmental impact where possible. The significant residual impacts to prescribed environmental matters are presented in Table 6-3.

It is noted that Table 6-3 has been developed in recognition of the EPBC approval for the SGP EIS (EPBC 2010/5344) and Tables 1 and 2 of that approval whereby maximum disturbance areas for Matters of National Environmental Significance MNES) have been prescribed and will be offset via the approved EPBC Offset Strategy.

Table 6-3 - Significant residual impacts to prescribed environmental matters

Prescribed environmental matter	Location of impact	Maximum extent of impact
REGULATED VEGETATION		
Endangered regional ecosystem	NA	0 ha
Of concern regional ecosystem		
RE 11.3.4	PL253	0.5 ha
Regional ecosystems (not within an urban area) that intersect a wetland on the vegetation management wetlands map	NA	0 ha
Regional ecosystems (not within an urban area) within the defined distance from the defining banks of a relevant watercourse on the vegetation management watercourse map	NA	NA

Prescribed environmental matter	Location of impact	Maximum extent of impact
RE 11.3.4	PL253	1.0
RE 11.3.25	PL253	1.0
RE 11.5.1	PL253	7.0
RE 11.5.20	PL253	0.5
RE 11.7.7	PL253	1.0
Essential habitat (not in an urban area) for endangered wildlife		
Hemiaspis damelii (Grey Snake)	PL253	1 ha
Essential habitat (not in an urban area) for vulnerable wildlife		
Jalmenus eubulus (Pale Imperial Hairstreak)	PL253	4 ha
Phascolarctos cinereus (Koala)	PL253	10 ha
Connectivity area that is a regional ecosystem (not in urban area)	PL253	8 ha
A wetland in a wetland protection area shown on the Map of referable wetlands (HES wetlands in GBR)	NA	NA
A wetland of high ecological significance shown on the Map of referable wetlands	NA	NA
Designated precinct in a strategic environmental area	NA	NA
An area shown as a high-risk area on the flora survey trigger map that contains plants that are endangered or vulnerable wildlife	PL253	2 ha
An area not shown as a high-risk area on the flora survey trigger map that contains plants that are endangered or vulnerable wildlife	NA	NA

Prescribed environmental matter	Location of impact	Maximum extent of impact
A non-juvenile koala habitat tree located in an area shown as a bushland habitat, high value rehabilitation habitat or medium value rehabilitation habitat in the 'Map of Assessable Development Area Koala Habitat Values'	NA	NA
Habitat for an animal that is endangered wildlife		
Hemiaspis damelii (Grey Snake)	PL253	6 ha
Habitat for an animal that is vulnerable wildlife		
Acanthophis antarcticus (Common Death Adder)	PL253	125 ha
Furina dunmalli (Dunmall's Snake)	PL253	117 ha
Nyctophilus corbeni (Southern Long-eared Bat)	PL253	68 ha
Petauroides volans (Greater Glider)	PL253	2 ha
Calyptorhynchus lathami (Glossy Black Cockatoo)	PL253	3 ha
Jalmenus eubulus (Pale Imperial Hairstreak)	PL253	5 ha
Habitat for an animal that is special least concern wildlife		
Tachyglossus aculeatus (Echidna)	PL253	50 ha
National park	NA	NA
Regional park	NA	NA
Nature refuge	NA	NA
Conservation park zone	NA	NA
Marine national park zone	NA	NA
Preservation zone	NA	NA
Other zones	NA	NA

Prescribed environmental matter	Location of impact	Maximum extent of impact
A declared fish habitat area	NA	NA
Fish passage (not in an urban area)	PL253	4 ha
Marine plant (not in an urban area)	NA	NA
Legally secured offset area	NA	NA

6.3 Groundwater

6.3.1 Overview of environmental values

An assessment of groundwater environmental values was undertaken as part of the SGP EIS and SREIS. These, together with further studies and sampling since the EIS was approved, have provided Arrow a comprehensive understanding of groundwater in the area the subject of this EA amendment application as a result of:

- Groundwater Characterisation Management Program activities:
    - The sampling undertaken at the following groundwater monitoring sites:
        - 11 existing bores on Lot 40 DY85 (i.e. the former Linc Energy site), with monitoring data from 2018 provided by DES
        - 5 landholder bores on properties within the vicinity of Lot 40 DY85
        - 8 monitoring bores completed by Arrow in 2020 on three properties at specific locations within approximately 100m of Lot 40 DY85.
    - Groundwater modelling, using available and Arrow collected data, undertaken by third party suitable qualified experts. Arrow has completed three prior models of the EA area using firstly the OGIA UWIR model and subsequently a refined local scale model. The key elements of the current model, which includes hydraulic groundwater movement predictions, are presented in this chapter and detailed in Appendix E.
- Groundwater modelling of the area conducted by the Office of Groundwater Impact Assessment (OGIA) to inform their Underground Water Impact Report (UWIR). This model is typically reviewed annually and updated every three years. The UWIR assesses the potential impacts on groundwater from CSG extraction in the Surat Basin Cumulative Management Area (CMA) taking into account all existing and proposed CSG projects.
- Groundwater monitoring undertaken as part of the UWIR water monitoring strategy at the Hopeland Pilot site and on adjacent tenures.
- Development of a Water Monitoring and Management Plan for the SGP, including desktop review and field assessment of potential groundwater dependent ecosystems (GDEs).
- Baseline and bore assessment (47 and 15 respectively) of landholder bores conducted by Arrow within PL253.
- Geological, seismic and pilot production data collected by Arrow.

The studies above have established that limited environmental values for groundwater are present in the Hopeland area. A full description of groundwater environmental values is presented in Appendix E. The limited environmental values for groundwater in the area are:

- There is one spring in the area (the Orana spring), which is a spring with a local alluvial source aquifer and is not linked to the Great Artesian Basin formations and therefore not subject to impact from resource development in the Walloon subgroup. The depth to groundwater indicates that it has some limited environmental value with regards to

intermittently supporting terrestrial groundwater dependent ecosystems from Cenozoic sediments.

- The findings of the EIS / SREIS indicates that groundwater has no identified environmental value with regards to cultural heritage significance.

- There is some groundwater extraction for livestock watering and crop spraying from the Springbok Sandstone, Walloon Coal Measures, and Hutton Sandstone. The most accessible aquifers to landholders in this area (i.e. the Springbok Sandstone and coal seams in the Walloon Coal Measures) are brackish (6,500 – 22,000 µS/cm and ~2,500 – 5,500 µS/cm respectively) and not suitable for drinking (drinking water is typically below 2,000 µS/cm). Treatment to drinking water quality due to the salinity would simultaneously remove potential contaminants of concern and hence there would not be a potential impact to human health through this potential pathway. Therefore, groundwater in the area has farming value to those landholders that can access it.
- However, the OGIA UWIR identifies the area will be within the immediately affected area (IAA) and long term affected area (LAA) for both the Springbok Sandstone and the Walloon subgroup. Therefore landholder bores where groundwater levels are or potentially will be affected by CSG activities triggers a requirement on proponents to enter 'make good' agreements with these landholders. Where it is determined from the bore assessment conducted as part of the 'make good' process that these landholder bores are or will be affected, these bores would be plugged and abandoned and alternative water sources, or appropriate compensation, provided. Therefore no pathway to these receptors would remain for potential groundwater contaminants of concern.
- The permitted activity for cumulative CSG production in the Surat CMA also removes future potential for EV's in the Springbok Sandstone and Walloon subgroup themselves as indicated by the IAA and LAA.

6.3.2 Broader context of groundwater at the former Linc Energy site

Groundwater is particularly relevant to this EA amendment application because of the contamination associated with the underground coal gasification operation at the former Linc Energy site on Lot 40 DY85. The rehabilitation and restoration of the site has passed to the Queensland Government.

Arrow has undertaken significant groundwater assessment to support this application. A summary of the outcomes is provided below, with details provided in Appendix E.

6.3.2.1 Depth to groundwater

Within the vicinity of Lot 40 DY85, depth to the aquifers starts at approximately 70 m for the Springbok Sandstone and 120 m for the Macalister unit of the Walloon Coal Measures (WCM) and continues to underlying units such as the Hutton Sandstone at about 480 m depth. These units dip to the southwest at an angle of 1 to 2 degrees. The units are confined aquifers and water pressures are sub-artesian.

OGIA (2019) notes that coal occurs within the WCM as discontinuous seams, comprising less than 10% of the total thickness of the WCM, and each seam is typically less than 1 m

thick and extend from 500 to 3,000m. The discontinuous nature of the individual coal seams reduces the lateral propagation of groundwater drawdown or depressurisation within the WCM. The WCM at Lot 40 DY85 start at approximately 120 m below ground level with the Macalister seam package and extends to a depth of approximately 450 m below ground level at the base of the Condamine seam package. Of Arrow's proposed production wells in PL253, approximately half will extract water and gas from the full thickness of the WCM and half will only extract from the deeper sections of the WCM and thus exclude the Macalister seam package.

6.3.2.2 Direction and speed of regional groundwater movement

The groundwater moves slowly (about 1.2 to 1.6 m per year on average on the former UCG site) and generally in a north-east to south-west direction regionally in all aquifers and coal seams (Arrow 2018).

The coal seams are bedded between layers of siltstone (i.e. aquitards) that limit vertical movement of groundwater between each aquifer unit as observed my monitoring data at the Arrow Energy Hopeland Pilot wells. This observed data has been used in the groundwater assessment. Changes in groundwater pressure gradient does result in some vertical movement, generally downward from the Springbok Sandstone to the Macalister, and upward from the Hutton Sandstone to the Macalister (Arrow 2018) as shown in the conceptual model in Figure 1.

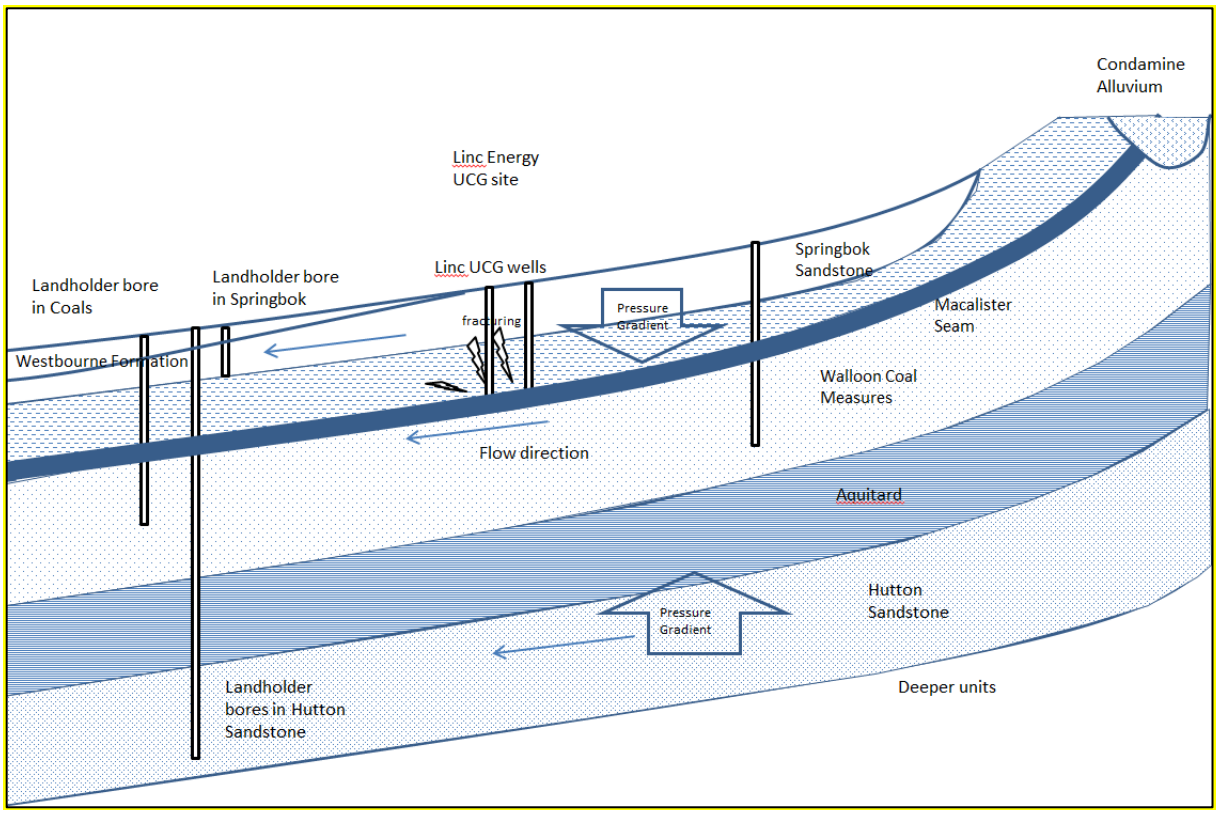

Figure 1 Conceptual model of groundwater movement

6.3.2.3 Contamination movement at Lot 40 DY85

On 8 August 2018 Arrow were authorised by the Department of Environment and Science (DES) to install groundwater monitoring bores up-gradient and down-gradient of the former Linc Energy site (authorised under EA0001401). The bores had the following purpose:

- up-gradient sampling bores are to provide a baseline of groundwater quality prior to it moving through Lot 40 DY85
- down-gradient sampling bores are to be located ahead of a potential contaminant plume to act as an early warning trigger of movement of contaminants from Lot 40 DY85.

The location of the bores was assessed by Arrow using the OGIA 2016 regional groundwater model in 2018. At that time Arrow did not have access to any of the groundwater sampling data from the former Linc Energy site (e.g. contaminant levels, pressure gradients).

Arrow installed eight (8) monitoring bores, 6 bores located approximately 100 m downgradient from the boundary of Lot 40 DY85 and 2 bores approximately 1 km upgradient in late 2019 / early 2020 and started sampling these bores recently (noting that both Arrow and DES sampled the same bores at the same time for quality assurance purposes). The sampling has confirmed the accuracy and value of the regional model in that no contaminants related to the UCG operation from Lot 40 DY85 have been confirmed within these groundwater sampling bores (see Appendix F for details).

DES provided Arrow with the sampling results from the existing bores located on Lot 40 DY85 commencing in June of 2019, with most recent update provided in July 2021. This on-site data has also been incorporated into our most recent modelling and has significantly improved our understanding of existing contamination at the site.

6.3.2.4 Modelling

Arrow has continued to refine our groundwater model to not only improve our ability to predict changes in groundwater direction, speed and fate and transport tracking of contaminants, but more importantly to address comments from DES' reviewer.

With the knowledge of the existing contaminant concentrations at the site gained from analyses of the on-site sampling bores, the observed rate of reduction in contaminant concentrations is evident and we can calculate the timeframe that these contaminants will persist in the groundwater (i.e. how long before they breakdown and drop to acceptable concentrations).

The sensitivity testing addressing the reviewer comments also indicates minimal changes in model results, whilst changes in porosity contribute a 3m change in groundwater movement over 20 years.

With this detailed understanding, Arrow are now able to seek an amendment to our existing Hopeland EA (EA0001401) to include planned production wells on our Hopeland Petroleum Lease (PL253). As presented in the remainder of this chapter and detailed in Appendix E, we are also confident that Arrow's proposed Stage 1 development case of 55 wells in PL253 can occur without a measurable change or worsening of existing environmental harm. In the event observed data departs from predicted trends Arrow Energy has prepared an adaptive management program using the NEPM recommendations for contaminant assessment and for completeness have included a contingency for a containment system that could be installed if trigger thresholds are exceeded.

6.3.2.5 The 2018 to 2020 models

Arrow used the OGIA model in support of our assessment of groundwater in the 2018 EA applications for neighbouring PLs. This model was acknowledged by the Office of Water Science as 'fit for purpose' (OWS 2017-030).

The OGIA model used represents the hydrostratigraphy of the Surat Basin numerically using 32-layers (OGIA 2016). This includes a number of stratigraphic units that are represented by multiple model layers. In particular, the main target coal reservoir (the Walloon Coal Measures) are represented using six layers to allow a more accurate representation of aquifer geometry, as well as allowing for improved simulation of vertical gradients induced by CSG extraction.

The limitation of this model when applied specifically to assessing behaviour around Lot 40 DY85 is the large cell sizes (1.5 km) in lateral extent, which were not designed for assessing local movement at the scale of Lot 40 DY85. Nevertheless, the Australian Groundwater Modelling Guidelines (National Water Commission 2012) state a 5 – 10% target performance measure for scaled room mean squared (SRMS) error and the statistics for the 2018 model calibration presented a scaled root mean squared (SRMS) error of 4.5% in the Springbok Sandstone and between 3.7% and 7.8% in the WCM. It is also noted that OGIA use this model to assess whether landholder bores are subject to 5 m of drawdown as a trigger for 'make good' requirements. As such, and based on the calibration data, the 2018 Arrow model was suitable for use for the EA applications for EA South.

Subsequent refinements in a model developed specifically to use data from the Lot 40 DY85 and the Hopeland area as reported in prior reports included a fine mesh size around Lot 40 DY85, inclusion of explicit coal layers and solute transport simulations.

6.3.3 The 2021 model

Arrow's 2021 numerical model represents the latest stage in the development of numerical models and has been revised to assess comments from DES' reviewer to assess groundwater movement and potential impacts from contamination at the former Linc Energy site.

The following improvements to the model design and calibration were implemented (see Appendix E Section 3 and 4).

6.3.3.1 Model design

- The number and location of stratigraphic units that are represented as model layers in the target coal seams was improved by analysis and inclusion of Arrow's gas reservoir model which uses drill stem tests (DST) to accurately determine the location and thickness of target coal seams. This established that the coal seams in the Macalister coal seam package in the PL253 area are 7–12 m thick and was confirmed by Arrow's drilling around Lot 40 DY85. The model simulates the groundwater system from the surface including the Springbok Sandstone, WCM and the underlying Hutton Sandstone. The model comprises 18 layers including the overlying Springbok Sandstone, explicit realisation of the six main coal seam packages targeted for production, intervening interburden layers the underlying Eurombah Formation aquitard and underlying Hutton Sandstone. This is a refinement from the prior vertically averaged and upscaled representation of the WCM that did not have individual coal seams represented. This provides the model with greater ability to predict behaviour in and around the coal seams. The refinement to location and depth of the model layers in the 2020 model

provides improved accuracy in predicting the lateral migration of particles from Lot 40 DY85 which were previously estimated in the 2018 model.

- Cell sizes from the 2019 and 2020 model were retained in the 2020 model whereby cells located over and within 2 km of Lot 40 DY85 have now been refined from 1.5 km down to a size of 50 m. This refinement is also progressively scaled out from Lot 40 DY85 with cell sizes being 100 m between 2 and 5 km from the site and 200 m between 5 km and 8 km which is within the EA area. In background areas of the model, cells sizes range up to 1.5 km to 4.8 km at the extremity of the model domain boundary outside PL253.

- The model now includes the 2020 data provided by DES from 11 groundwater sampling bores located on Lot 40 DY85 and data from bores installed by Arrow Energy around Lot 40 DY85.

- Modelled recharge parameterisation was also revised compared to the 2018 model to include three zones representing areas where the Condamine Alluvium, Gubberamunda Sandstone and Westbourne Formation are present at outcrop. Recharge rates for each of these three zones were taken from the updated modelling completed by OGIA in 2019 (OGIA 2019) as follows:

    - Condamine alluvium: 3.5 mm per year

    - Gubberamunda Sandstone: 1.0 mm per year

    - Westbourne Formation: 0.2 mm per year.

- Functionality developed for the 2020 model to allow simulation of deviated wells (i.e. multiple non-vertical wells drilled from single well pads to minimise land disturbance) was retained. This presents a greater accuracy when assessing potential impacts of our development because the model can now interrogate the actual groundwater drawdown from each cell in the model (rather than the model simulating all vertical wells). This is particularly important because deviated wells typically extend 700 to 1,000 m from the drill pad and in PL253 the current field development plans for approximately 30% of the wells approximate 280 wells to be deviated.

- As a conservative approach, the 2018 model did not have representation of the depressurisation at the former UCG site forming a sink for groundwater movement. The 2021 model retains depressurisation from UCG activity informed by publicly available data (see Appendix E), pressure data provided to Arrow by DoR from monitoring bores on site, and monitoring wells installed by Arrow. In addition, potential fracturing from the gasifiers into the base of the overlying Springbok Sandstone is represented in the model to reflect the potential pathway for contaminants from the coal to the Springbok Sandstone.

The porosity derived from model calibration in the 2020 model was considered to be too high by DES' reviewer because general CSG experience is that the porosity is lower. However, the conceptual model for UCG includes fracturing that could result in higher porosity. However, As documented in the previous report (Table 4.2; AGE, 2020) model calibrated specific yield (or effective porosity) in modelled coal seams was 2%. During calibration this parameter was also allowed to vary widely between 0.1% and 10%, a range which encompasses the peer reviewer's preferred value of 1% (RDM Hydro, 2021). Furthermore, as shown in Table 3.3 (AGE 2021), the mean calibrated value for the Macalister coal seam in the vicinity was 1.1%. The same range of effective porosity values used for calibration was also used for uncertainty analysis purposes.

For contaminant transport purposes an additional porosity parameter is required, and this effective porosity parameter was allowed to vary between 0.9-1.3 in the Macalister seam around MDL309. This addresses the reviewer's comments regarding porosity.

- The refined 2020 numerical groundwater flow model formed the basis for the contaminant fate and transport simulations undertaken using the MODFLOW Block Centred Transport (BCT) package (GSI 2019) and included simulation accounting for the following transport and natural attenuation processes (see Appendix E for details):
    - Advective transport
    - Dispersion (lateral and transverse)
    - Linear/non-linear adsorption
    - Biodegradation (simulated by first order decay).
- A 2021 model included the broad dissolved phase plume represented in the 2020 model but also includes a constant source term in the gasifiers of 1,000 ug/L to represent these observed concentrations at one location onsite as being representative of a continuous napl phase.
- The assumptions made in the model simulation provide a conservative scenario that simulates a 'worst case' scenario that can still be calibrated and provides confidence that potential impacts are likely to be less than that simulated. The presence of coal layers simulated as continuous layers rather than the heterogeneous discontinuous layers that occur in the Walloon subgroup also provides simulations that provide from more potential movement of groundwater than would occur in reality.

6.3.3.2 Model calibration

- Over four years of data from Arrow's six (6) Hopeland pilot CSG wells located less than 10 km south-west of the former Linc Energy site were included in this 2021 model. While these wells were also included in the 2018 model they were 'corrected' prior to use in the 2020 model through application of the Theim equation. This correction was required because:
    - intermittent extraction was occurring from each well during the monitoring period
    - the model cells in which each well sits are substantially larger than the diameter of each well.
    - without correction the observed head in each well during pumping will tend to be much lower than that calculated using a numerical model unless the diameter of the model cell and well are the same. As outlined in Anderson and Woessner (1991), the Theim equation provides a means by which observed heads in a pumping well can be corrected to account for the difference between the effective radius of the well and model cell.
- The 2021 model achieves a SRMS error of 8.9% including Hopeland pilot data that represents dual phase conditions and 6.9% without this dual phase data and therefore well within the 5 - 10% target performance measure of the Groundwater Modelling Guidelines (National Water Commission 2012).

- Calibration of the fate and transport model was undertaken using PEST_HP (Watermark Numerical Computing 2020). The main contaminants of concern within Lot 40 DY85 are Benzene and Naphthalene due to the carcinogenic nature of Benzene and the high solubility of Naphthalene in water compared to the other PAHs. As such these two contaminants were the focus of the fate and transport model. The SRMS for these contaminants in the model range from 13.1% for Benzene and 4.8% for Naphthalene. The slight increase in SRMS for the fate and transport model maybe influenced by the inclusion of constant source terms at the gasifiers.

6.3.4 Model Scenarios

This section describes the current baseline scenario and the FID1 development case of this amendment submission.

The extent of development in a baseline case without Arrow Energy development on PL253 and the location of 55 wells on PL253 proposed in this amendment are shown in Figure 2.

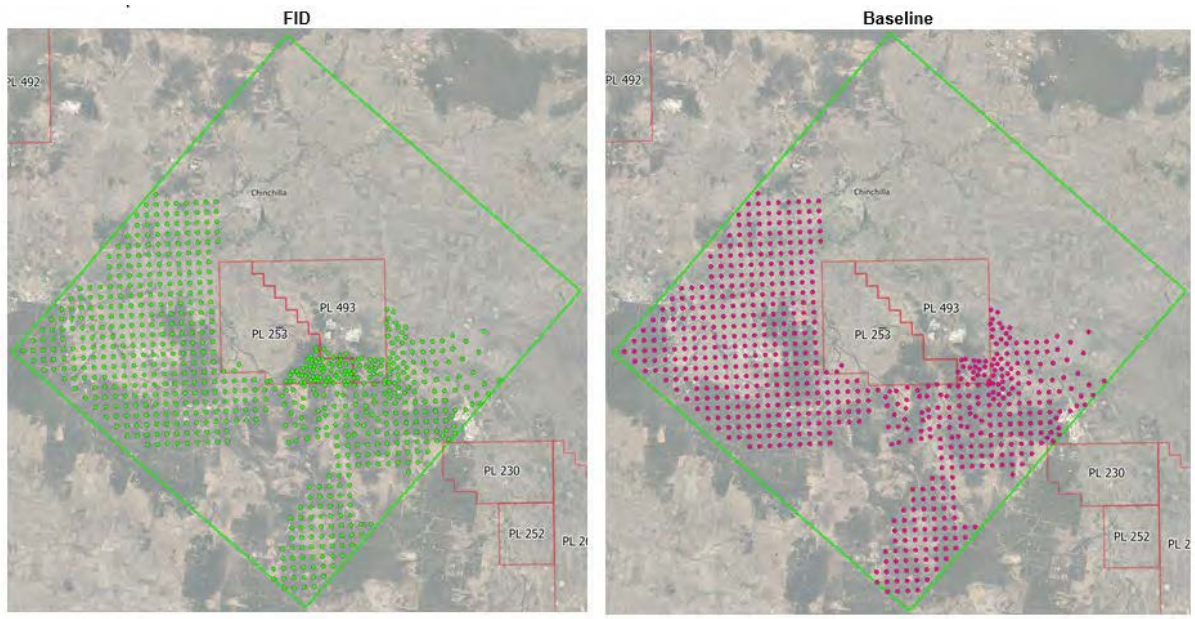

Figure 2 Base and Development Case Well Layouts

The well layouts show that the proposed wells in PL253 are located in the south-east corner of PL253 between 4 and 5 km from the area of prior UCG operation.

6.3.4.1 Predicted Groundwater Movement

A summary of the distances travelled by groundwater as simulated with particle tracking the groundwater model are provided in Table 1.

Scenario	Total Distance Travelled (m)			Predicted Impact (m)		
	Min	Average	Max	Min	Average	Max
Springbok Sandstone						
Baseline	3	35	183	NA	NA	NA
Arrow FID scenario	3	35	183	<1	<1	<1
Macalister Coal Seam						
Baseline	3	13	29	NA	NA	NA
Arrow FID scenario	3	13	29	<1	<1	<1

Table 3 Groundwater Particle Movement

This shows that over a 20-year period from January 2020 to January 2040 there is no measurable impact to the groundwater movement distance for the proposed development case. The differences between the base case and the development case are in order of less than 20 cm and within the error range of the model.

Particle tracking maps shown in Figure 3 Particle Track Maps in Springbok Sandstone and Macalister Coal Seam show the scale of potential movement of groundwater from the gasifier areas.

Figure 3 Particle Track Maps in Springbok Sandstone and Macalister Coal Seam

6.3.4.2 Groundwater movement prediction for prior full field development case

The previous EA amendment submission provided simulation of a 280 well development case for the entirety of PL253 with a field development plan adapted to minimise impact to the Macalister coal seam groundwater by omitting production from this coal seam over approximately 50% of the PL area as shown in Figure 4. This shows currently approved Arrow Energy wells in pink, and the previously proposed wells in PL253 that omit the Macalister coal seam in light green and wells that include production from the Macalister coal seam in dark green. Wells subject to production by other CSG proponents are represented in blue. It should be noted that CSG wells approved by other proponents immediately south of the eastern portion of PL253 were not included in this prior mode simulation as data was not available at that time. These wells are included in the current simulation as shown in Figure 3. These other wells will have an incremental impact on groundwater movement in the area.

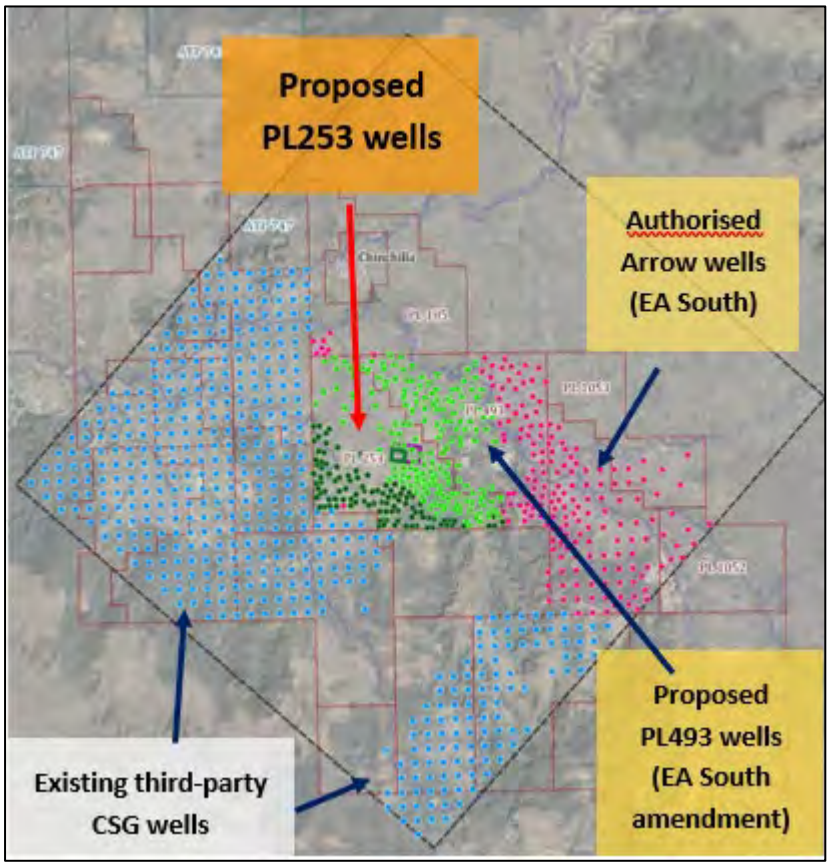

Figure 4 Prior development case

The average distance moved by groundwater particles in the full 280 well PL253 development simulation is shown in Table 2. This shows differences in the absolute movement of groundwater due to different well scenarios, including the impact of wells approved on tenure operated by other proponents and amendments to the model made in order to address peer review comments of the model.

The impact due to Arrow Energy's proposed plan was minimal and so small as to not be measurable from groundwater pressure differences. As shown in Table 2, the reduced 55

well development case the subject of this EA amendment further reduces the change to non-measurable.

Unit	Base line Scenario (m)	Development Scenario (m)	Project Impact (m)
Springbok sandstone	13	19	6
Macalister coal seam	16	24	8

Table 4 Prior 280 well development case impact predictions of average particle movement over 20 years (m)

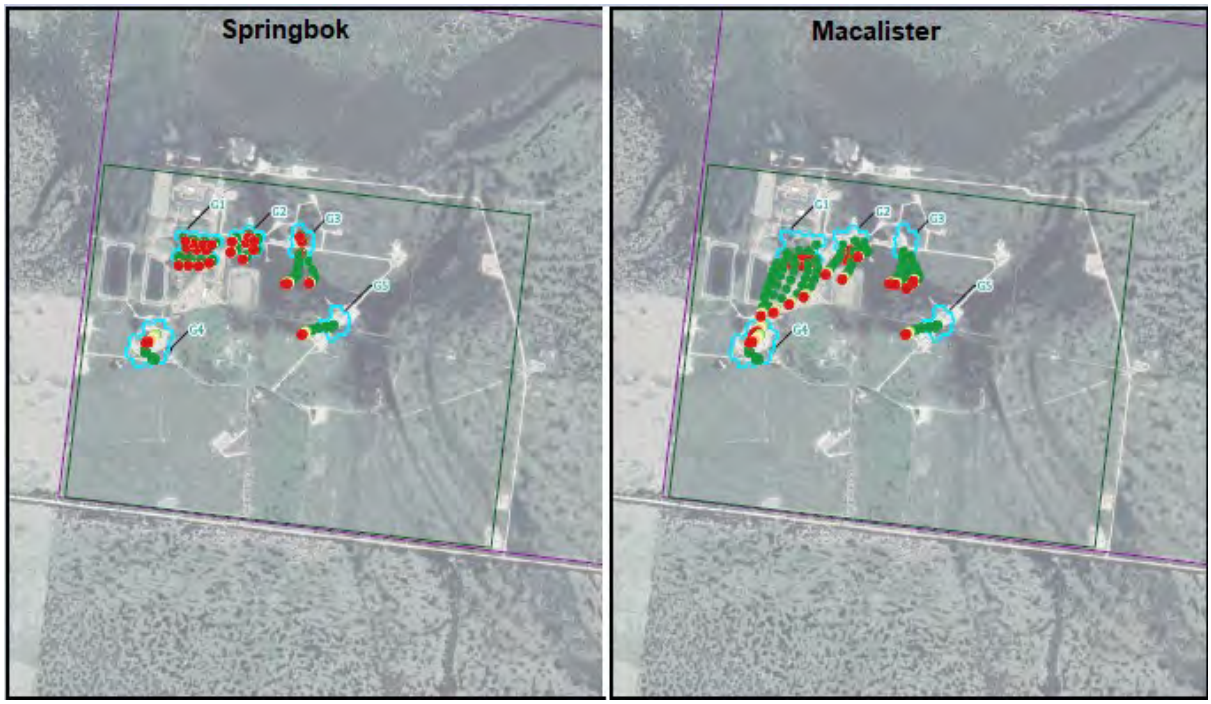

Figure 5 Particle track maps for Springbok sandstone and Macalister coal seam in prior development scenario.

It is apparent that potential contamination from gasifiers would not travel to the site boundary due to Arrow Energy's operations. It is also apparent that if contaminated groundwater was at the site boundary it would migrate across that boundary in the base case without Arrow Energy operations occurring due to the background regional groundwater migration rates. Having said, the operations at the former Linc site have created a groundwater 'sink' towards the gasifiers and therefore contaminant movement away from the site is not occurring.

6.3.5 Groundwater quality

Groundwater quality from landholder and Arrow monitoring bores for the Springbok Sandstone are provided in Appendix B and shown graphically in the Piper diagram in Figure 6. Groundwater within this formation is typically near neutral to slightly alkaline, brackish to saline, and of a sodium-chloride type. The quality of the groundwater within the Springbok Sandstone is suitable for livestock watering and crop spraying, and it is used for this purpose

within the area of PL253. The brackish to saline nature of the groundwater precludes its use as drinking water without treatment, however it may be used for other domestic purposes.

Within the site of the former Linc Energy UCG operations on Lot 40 DY85, the Springbok Sandstone contains varying levels of the contaminants of concern, and the groundwater also tends to be moderately acidic and more saline than the Springbok Sandstone regionally.

Concentrations of Benzene and Naphthalene on site have been decreasing over time as shown in Figure 7 and Figure 8 respectively. These contaminants have not been detected in the groundwater samples obtained from Arrow's monitoring bores installed down-gradient of Lot 40 DY85.

Samples collected by DoR from wells located several hundred metres north (HSMB6) and west (HSMB7) of the site have reported trace levels of the compounds benzene and naphthalene. As these compounds can be derived from several sources, namely:

- Site contamination from the UCG process,
- from coal; and
- from lubricant/hydrocarbon compounds used when installing and developing wells.

The source of the compounds must also be assessed. Importantly, sporadic low levels (1-2 ug/L benzene) have been reported by CSIRO from wells in the Walloon subgroup and published work has reported detectable benzene derived from coals.

Additionally, naphthalene is a common component of coals and occurs sporadically in low levels in coal environments.

The results from bores HSMB7S and HSMB6S monitoring the Springbok Sandstone included 2 ug/L benzene and 1.3ug/L naphthalene in HSMB7S and 10 ug/L benzene and no detectable naphthalene in HSMB6S.

The data from HSMB6S also reported toluene, ethylbenzene and xylene as well as 2.2ug/L naphthalene. A full suite of detectable BTEX occurs in 5 of the 41 sampling points and where it is seen benzene is elevated at more than 100 ug/L. Thus, the above suite is not consistent with the ratios of these compounds seen on-site indicating the compounds may not be from the same source as on-site detections.

HSMB7S reported 2 ug/L benzene in one analysis and below detection in other analyses suggesting it may be a transitory effect or represent background conditions. Similarly, naphthalene was detected both just above and also below the detection limit.

Results from HSMB6D and HSMB7D co-located with the above wells and monitoring the Macalister coal seam reported 18-30 ug/L benzene in HSMB7D with other BTEXN below detection limit with the exception of xylene at 3 to 5 ug/L. HSMB6D reported xylene at 2 to 5 ug/L with other BTEXN below detection limit. The presence of xylene without elevated benzene is inconsistent with the site signature for BTEX. The presence of benzene in HSMB7D maybe consistent with the site signature, however, non-detectable results in wells between HSMB7D and the site do not support migration from the site in groundwater.

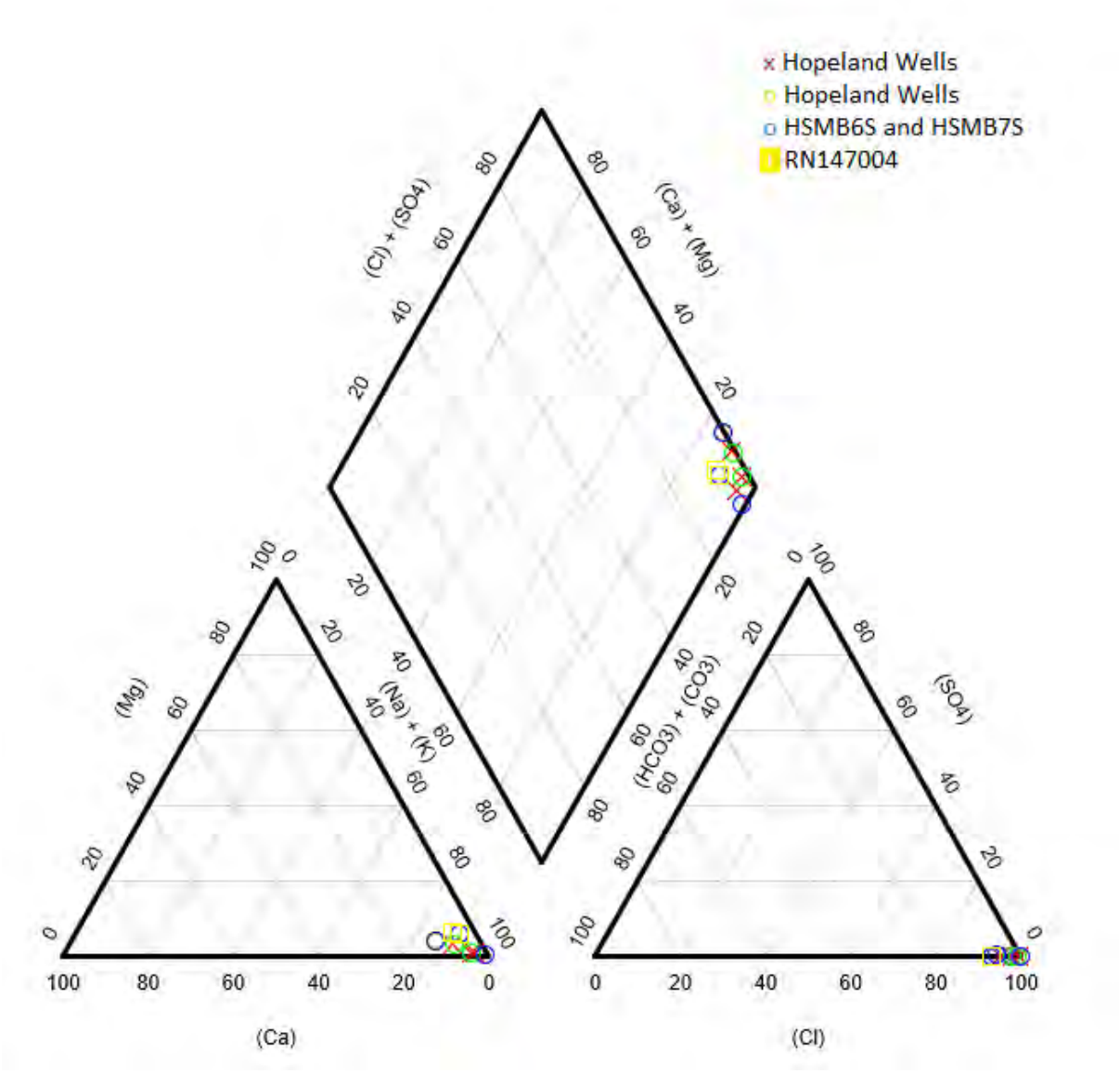

Figure 6 Piper diagram of major ion chemistry for the Springbok Sandstone

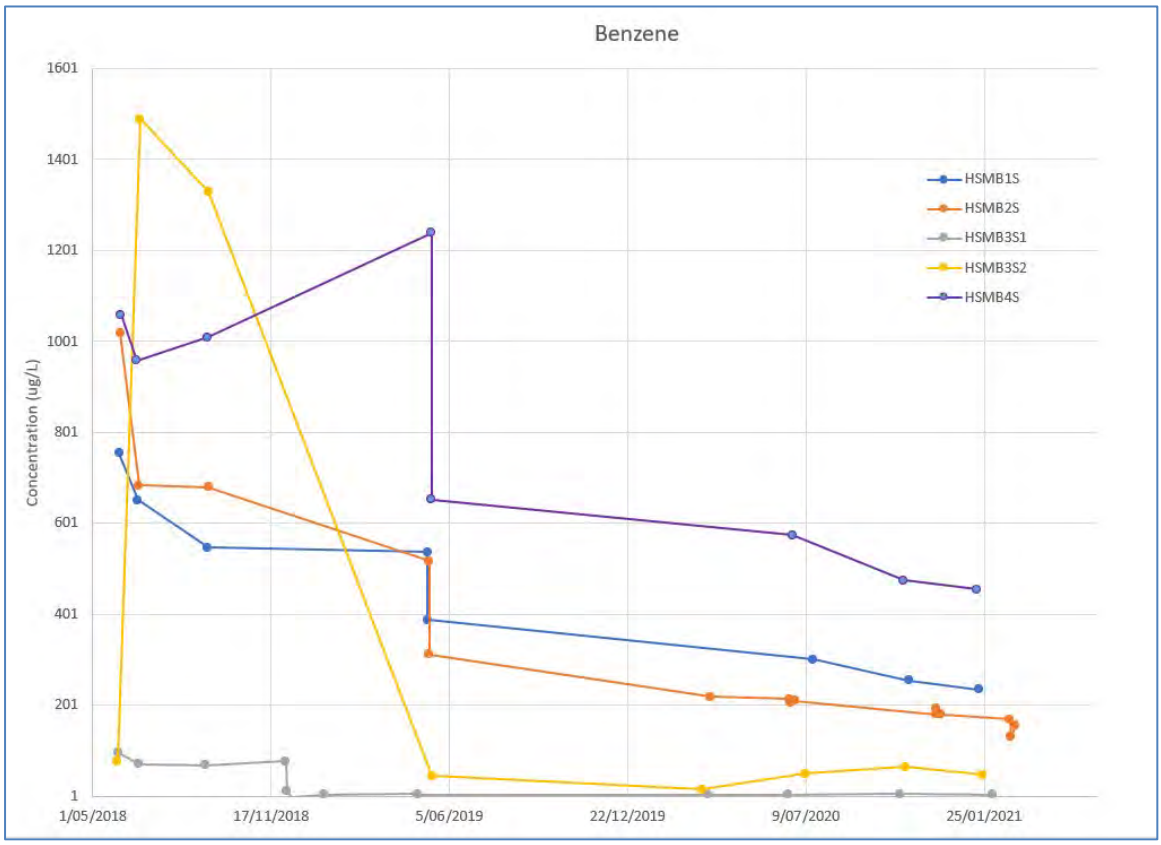

Figure 7 Benzene Attenuation

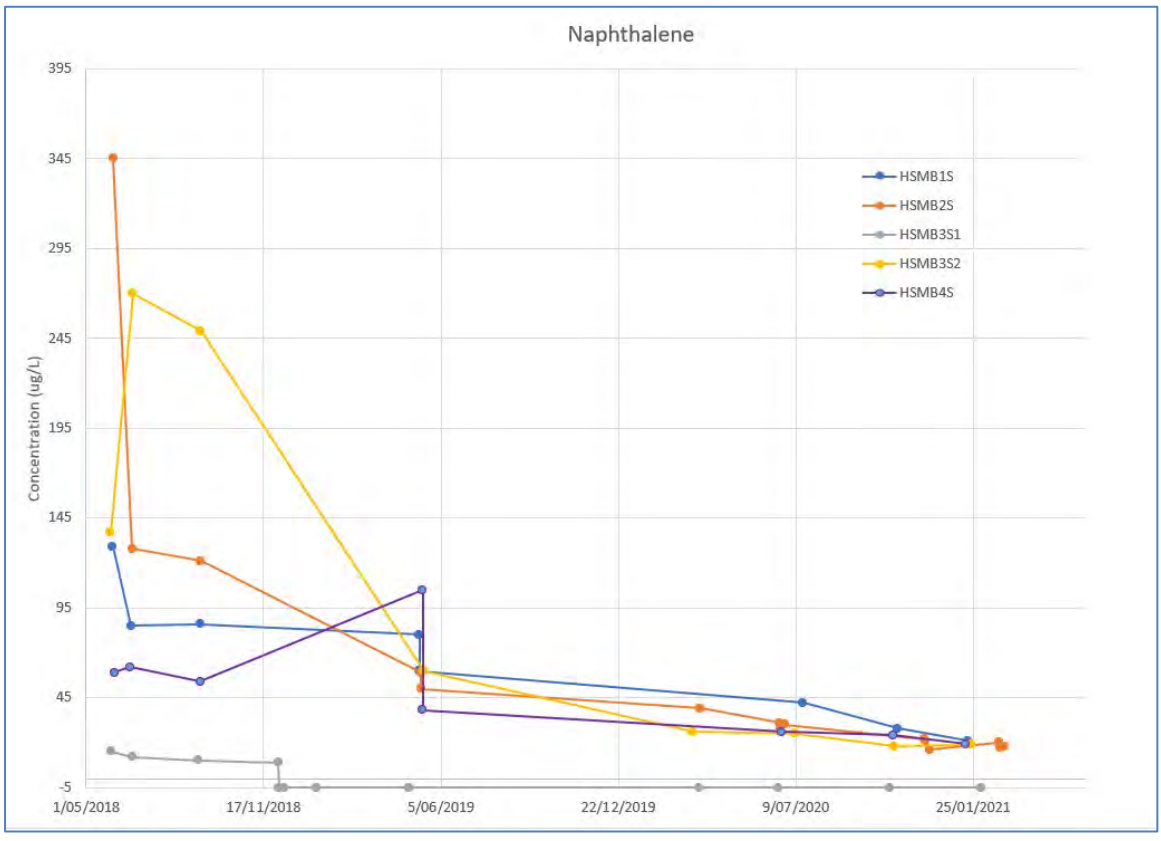

Figure 8 Naphthalene Attenuation

Groundwater quality from landholder and Arrow monitoring bores for the Walloon Coal Measures are provided in Appendix B and shown graphically in the Piper diagram in Figure 9. Groundwater within this formation is typically moderately alkaline, brackish, and of a sodium chloride-bicarbonate type. The quality of the groundwater within the WCM is suitable for livestock watering and crop spraying together with limited domestic use, and it is used for this purpose within the area of PL253. The brackish nature of the groundwater precludes its use as drinking water without treatment, however it may be used for other domestic purposes.

Within the site of the former Linc Energy UCG operations on Lot 40 DY85, the Macalister seam of the Walloon Coal Measures is contaminated with varying levels of the contaminants of concern, and the groundwater also tends to be more alkaline and saline than the WCM regionally. Concentrations of Benzene and Naphthalene on site have been decreasing over time as shown in Figure 10 and Figure 11 respectively. These contaminants have not been detected in the groundwater samples obtained from Arrow's Macalister seam or Wambo seam monitoring bores installed down-gradient of Lot 40 DY85 or in the up-gradient site.

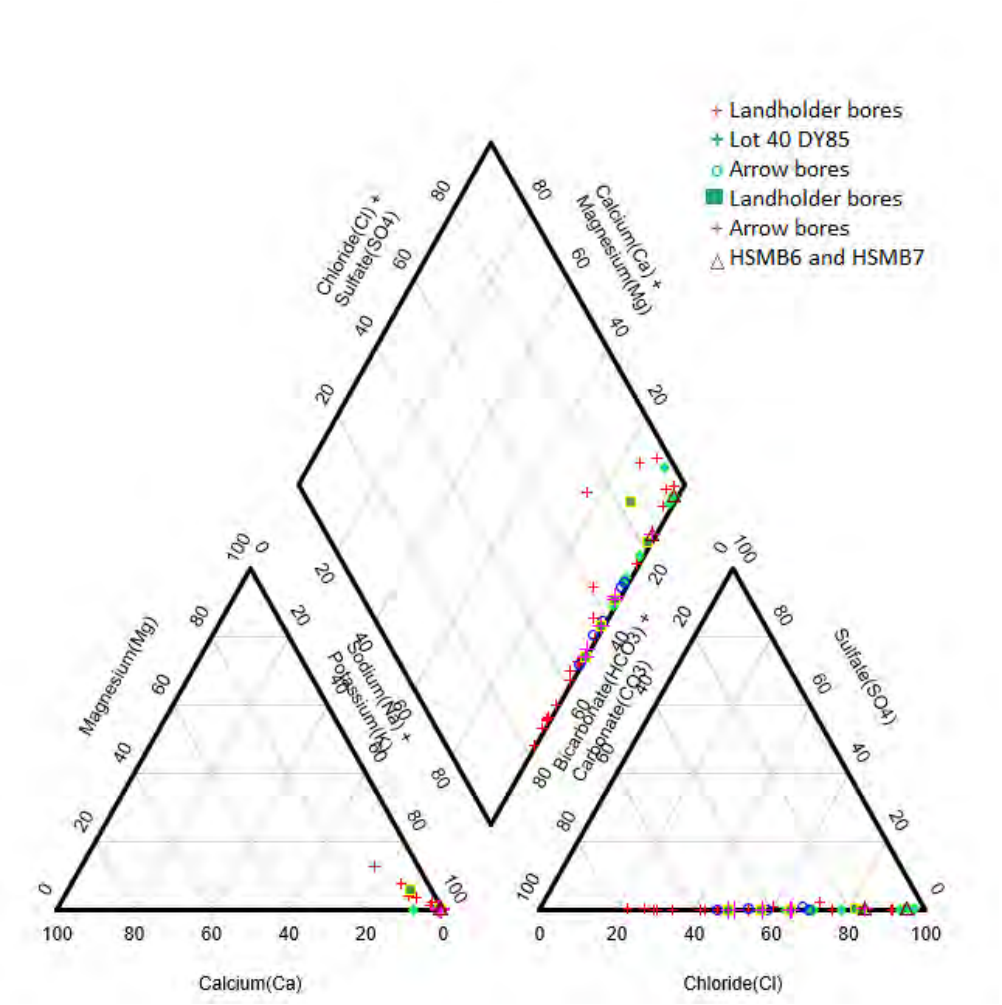

Figure 9 Walloon Coal Measures Major Ion Chemistry

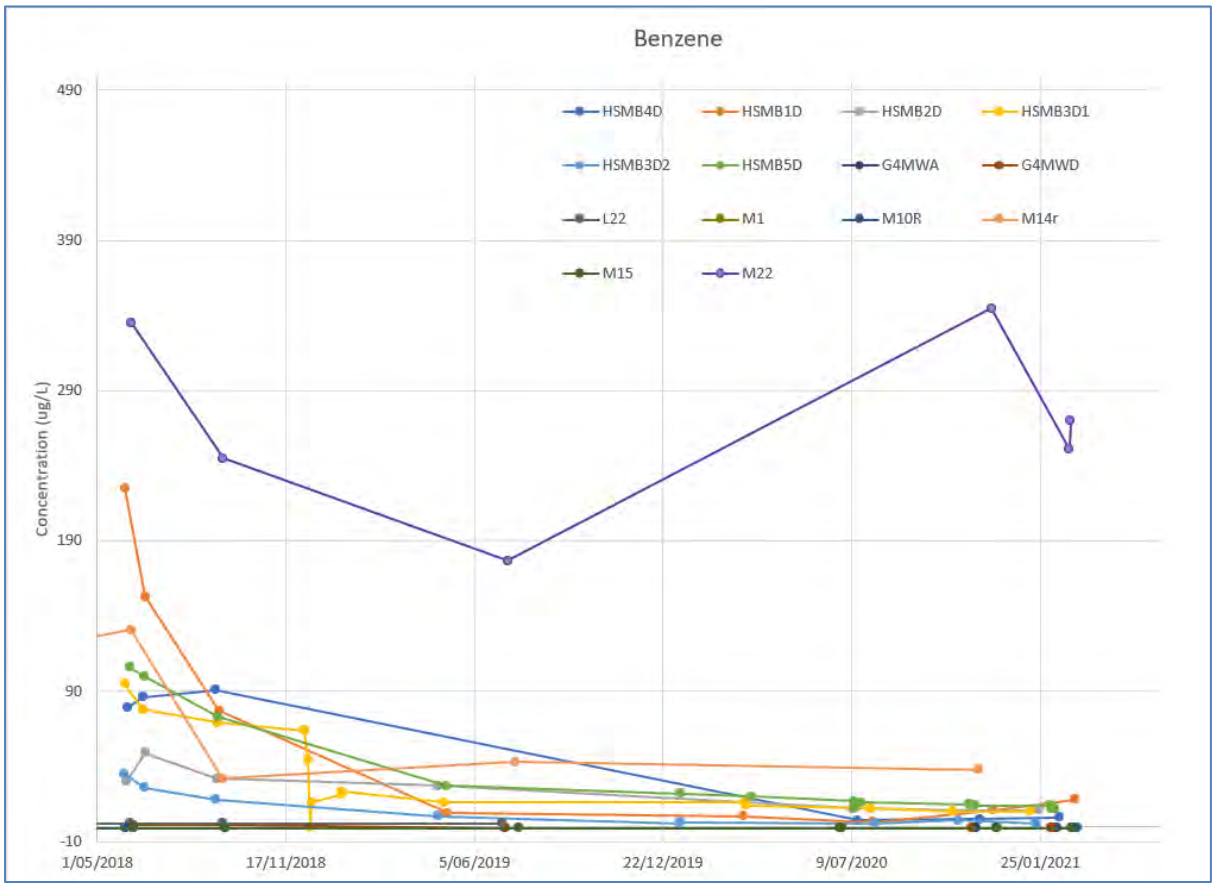

Figure 10 Benzene Attenuation in the Macalister Coal Seam

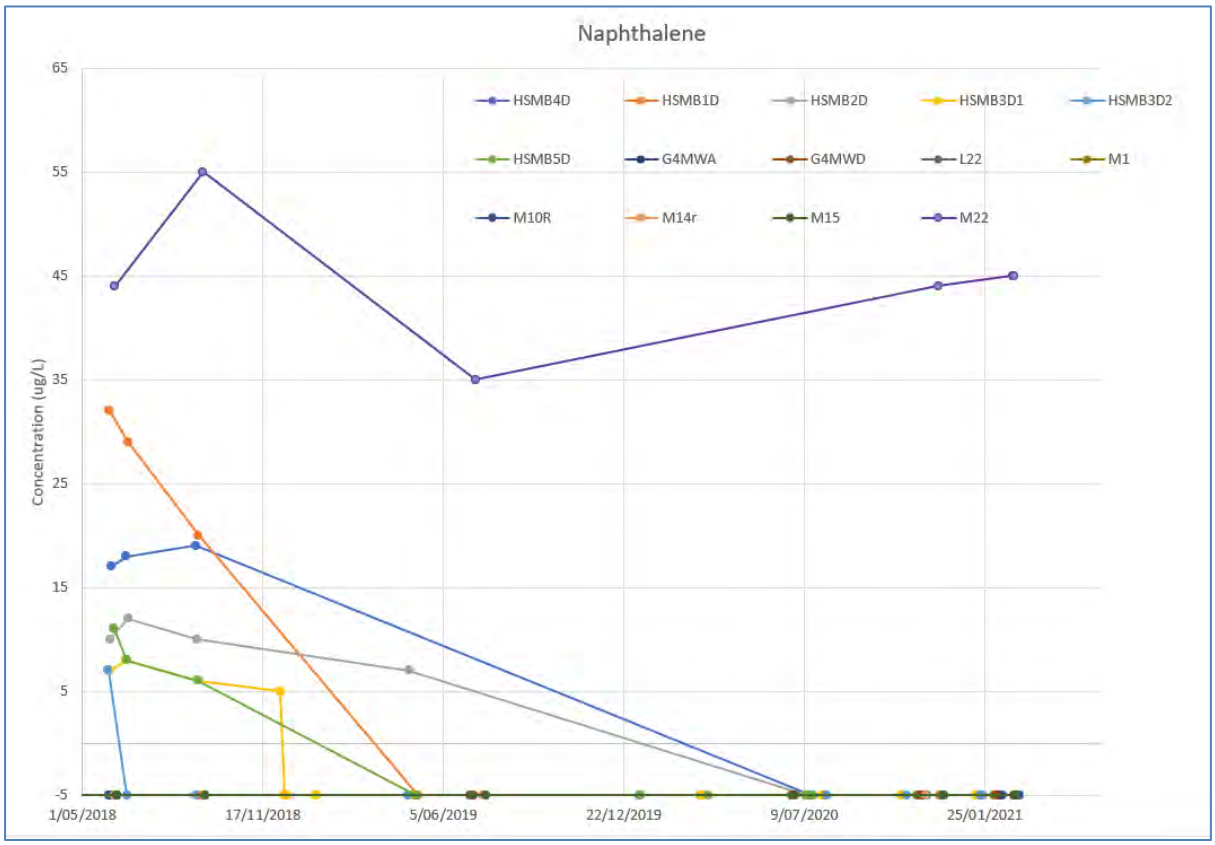

Figure 11 Naphthalene Attenuation in the Macalister Coal Seam

6.3.6 Groundwater Contaminant Behaviour

The main contaminants of concern within Lot 40 DY85 are Benzene and Naphthalene. These two contaminants above others present at Lot 40 DY85 have been selected for assessment because:

- they are the most carcinogenic (Benzene) and most soluble (Naphthalene) and therefore are the contaminants that provide the greatest potential risk to human health and the environment (see below); and

- as these are hydrocarbons present at the majority of monitoring locations forming a coherent plume they are both direct indictors of UCG impact and are amenable to numerical modelling.

Benzene is an organic chemical compound with the molecular formula C6H6. The benzene molecule is composed of six carbon atoms joined in a ring with one hydrogen atom attached to each. As it contains only carbon and hydrogen atoms, benzene is classed as a hydrocarbon. Benzene is a colourless and highly flammable liquid with a sweet smell and is responsible for the aroma around petrol stations. The major sources of benzene exposure are tobacco smoke, automobile service stations, exhaust from motor vehicles and industrial

emissions. However, ingestion and dermal absorption of benzene can also occur through contact with contaminated water. Benzene is classified as a carcinogen.

Naphthalene is the simplest and most soluble polycyclic aromatic hydrocarbon (molecular formula C10H8) in water. It is a component of fuels and oils. Exposure to large amounts of Naphthalene may damage or destroy red blood cells. The International Agency for Research on Cancer (IARC) classifies Naphthalene as possibly carcinogenic to humans and animals (Group 2B).

The movement of contaminants is affected by the physical, chemical and biological processes affecting the contaminants. These processes are widely documented in US EPA and Australian contaminated land literature:

- Physical processes include dispersion. As the contaminant moves with the groundwater flow path it becomes diluted by dispersion both laterally and vertically.

- Chemical processes include sorption, whereby organic hydrocarbons will sorb to organic carbon in the solid aquifer matrix. This reduces the amount of hydrocarbon in the groundwater resulting in a reduction in dissolved concentrations in groundwater. It also causes the contaminant to move more slowly than the groundwater (as it stops when it sorbs to the aquifer solid media). Coal is about 80% organic carbon and therefore has a very strong capacity to sorb hydrocarbons.

- Biological processes include the degradation of hydrocarbons by microorganisms that facilitate chemical reactions which result in the breakdown of hydrocarbons and resultant reduction in hydrocarbon concentrations.

Degradation of contaminants has already been established at Lot 40 DY85. The DES sampling results between June 2018 and 2021 have already shown significant reduction in concentrations for Benzene and Naphthalene. Figures 7, 8, 10 and 11 highlight this attenuation over time, showing the results from 9 locations and 76 data points from the Springbok Sandstone and 20 locations and 184 data points from the Macalister.

As noted above, the impact of sorption on contaminant movement results in contaminants moving more slowly than groundwater. Given that groundwater movement impact from the proposed development is not measurable there is therefore not predicted to be an impact to groundwater contaminants from the proposed development.

6.3.6.1 Prior development case contaminant degradation

The prior full 280 well PL253 development case simulation of contaminant degradation provided estimates for the time for contaminants to degrade to less than 1 ug/L. These simulations used existing monitoring of reducing contaminant concentrations to establish the rate of degradation. These are summarised in Table 3. These indicate that contaminants would degrade to these levels in less than a decade. Given the very slow groundwater movement rates this supports the low risk of off-site impact from these contaminants due to Arrow Energy activities.

Metric	Benzene	Naphthalene
Number of years before the contaminant concentration would be <1 ug/l in the Springbok Sandstone	7.5 years	3.5 years
Number of years before the contaminant concentration would be <1 ug/l in the Macalister coal seam	5.5 years	2.5 years

Table 5 Benzene and Naphthalene degradation in prior Development case simulation.

6.3.6.2 Contaminant degradation under Proposed FID1 development case

There is no measurable difference in groundwater movement at the former UCG site in the simulation of the proposed FID1 case and the baseline case without Arrow Energy. Therefore, there would be no difference to attenuation rates of the contaminants of concern due to Arrow Energy operations.

Monitoring completed by Arrow Energy over the last two years is consistent with the above findings as no detectable contaminants of concern have been observed in Arrow Energy monitoring wells.

6.3.7 Groundwater dependent ecosystems (GDEs)

Groundwater-dependent ecosystems (GDEs) are ecosystems whose species and ecological processes rely on groundwater, either entirely or intermittently. In the Surat Basin, there are two types of GDEs that Arrow investigates to understand potential impacts from our operations:

1. Ecosystems that are dependent on the subsurface presence of groundwater. In the Surat these are dependent on groundwater from the Great Artesian Basin (GAB) and are termed ‘spring GDEs’.

2. Ecosystems that are dependent on shallow perched groundwater aquifers or the surface expression of groundwater. These are termed ‘non-spring GDEs’.

Arrow has undertaken comprehensive assessments to understand spring and non-spring GDEs associated with the SGP. These ecosystems were addressed as part of the SGP EIS/SREIS but additional more detailed field surveys and modelling studies were undertaken to inform:

- Arrow’s input into OGIA’s Underground Water Impact Report (UWIR) for spring GDEs. This full report is publicly available at https://www.business.qld.gov.au/industries/mining-energy-water/resources/environment-water/coal-seam-gas/surat-cma/uwir

- Arrow’s Australian Government approved EPBC Act Stage 1 and Updated Water Monitoring and Management Report. These reports are publicly available at https://www.arrowenergy.com.au/environment/environmental-management-plans-and-reports and in particular Appendix D of the Stage 1 WMMP includes a very detailed and comprehensive assessment in the form of a *GDE and Aquatic Ecosystems Technical Memorandum*: https://www.arrowenergy.com.au/__data/assets/pdf_file/0008/29996/Appendix-D-GDE-and-Aquatic-Ecosystem-technical-memorandum.pdf

In terms of baseline conditions associated with GDEs for PL253:

- There are no spring GDEs located on PL253
- There is 1 non-spring GDE, termed the Orana 3, which is a spring with a local alluvial source aquifer from the surficial Cenozoic sediments and is not linked to the Great Artesian Basin formations.

The potential impacts on this non-spring GDE are discussed in the following section.

6.3.8 Potential groundwater drawdown and GDE impacts

Potential groundwater impacts of the Project have been assessed in the SGP EIS and SREIS (refer Chapter 14 of EIS and Chapter 8 in SREIS plus associated appendices). The UWIR has assessed potential impacts on groundwater levels arising from CSG extraction in the CMA by taking into account all existing and proposed CSG projects, including proposed activities on PL253. The UWIR identifies 'Immediately Affected Areas' (IAA) and 'Long-term Affected Areas' (LAA) where the decline in groundwater level, due to CSG-related groundwater extraction, was predicted to exceed the 'Bore Trigger Threshold' (i.e. 2m for an unconsolidated aquifer and 5m for a consolidated aquifer) over the 3 year period of the UWIR. The UWIR is updated by the Office of Groundwater Impact Assessment (OGIA) every three years and is based on actual water extraction and modelling. Arrow is obligated to operate in line with the UWIR as part of its environmental approvals.

The extraction of CSG will result in depressurisation of the WCM which will lower aquifer pressures, which could potentially result in the following direct impacts:

- Reduced groundwater supply to existing or future groundwater users accessing groundwater from the Springbok Sandstone or WCM.
- No potential for direct impact to GDEs as there are no spring GDEs fed by the WCM.

Depressurisation of adjacent aquifers has the potential to cause aquifer interflow and groundwater drawdown, resulting in the following potential indirect impacts:

- Diminished groundwater quality in aquifers above and below the WCM. This relates to groundwater mixing as drawdown in the WCM aquifers induces flow across deeper and shallower aquifers.
- Reduced groundwater supply to existing or future groundwater users accessing groundwater from the adjacent aquifers.
- Land subsidence and changes to surface water flow regimes and landforms.

The above provides a summary of potential impacts common to groundwater and CSG activities. With specific relevance to this PL253 amendment application:

- The source aquifer for the Orana GDE is attributed to ephemeral discharge from the adjacent Cenozoic sediments, The 2019 UWIR spring risk assessment resulted in a risk rating of 'moderate' for impact due to CSG development, with an impact of 0.2 to 0.5 m of drawdown in the source aquifer in greater than 100 years.
- The two aquifers potentially affected by groundwater drawdown as per the OGIA UWIR are the Springbok Sandstone and WCM and Figure 12 illustrates the modelled extent of the IAA and LAA in these aquifers The 2019 Surat CMA UWIR model produced

outcomes that indicate that the southwest part of PL253 is within the IAA for Springbok Sandstone, with the former Linc UCG site outside of the IAA. The LAA for the Springbok Sandstone extends further north and east, encompassing the former Linc Energy UCG site and most of the tenement apart from a small section in the north. All of PL253 is within both the IAA and LAA for the WCM.

- With regards to existing groundwater users, Arrow has been undertaking bore assessments and entering into 'make good' arrangements with landholder bores predicted to be impacted, with the current status provided in Figure 12. Of the 26 potentially impacted bores within PL253, Arrow has entered into 12 'make good' agreements and is continuing to progress to 'make good' agreements on the remaining. Arrow is also compliant with its Make Good obligations as set out in the 2019 Surat CMA UWIR.

Figure 12 IAA and LAA boundaries and potentially impacted landholder bores within PL253

6.3.9 Management measures

The National Environmental Protection Measure's (NEPM) desired environmental outcome is to provide adequate protection of human health and the environment whilst preventing contamination, or further contamination of a site and there should be no noticeable or measurable change in the characteristics of soil, or associated ground or surface waters.

The work undertaken by Arrow has provided an outcome where predictions indicate no measurable difference in contaminant movement between the base case and development case, thus supporting the NEPM goal.

This indicates a very low potential for impact (if any) from Arrow Energy's proposed development to the groundwater contaminants at the former UCG site.

Therefore, an adaptive management program is proposed based upon the National Environment Protection Assessment of Site Contamination (ASC NEPM 2013) and therefore aligned with regulatory approaches to site contamination. The NEPM (2013) lists the design components as:

- Establishing the objectives of the investigation
- Development of a site conceptual model
- Development of the data quality objectives; and
- Design of a sampling strategy and decision outcomes.

The proposed system is described below.

6.3.9.1 Problem Statement

The objectives are captured in a rigorous adaptive management regime underpinned by a clear problem statement that addresses the site issue below:

"The problem statement is to develop a monitoring program that provides early indication of changes to the groundwater regime in order to assess whether groundwater from the former Linc UCG site may be mobilised in such a way that increases the risk of harm to groundwater environmental values and/or human health."

The site conceptual model has been documented in the conceptual model report previously submitted and included is described in Appendix E.

6.3.9.2 Brief Summary of the Contamination Problem

The groundwater contamination at Lot 40 DY85 comprises dissolved phase hydrocarbons at between 70m to 120m below ground in the Springbok Sandstone and the Macalister Coal seam.

Arrow Energy proposes development of surrounding area in PL253 whilst imparting minimal change to the movement of groundwater and hence minimal impact to the groundwater contamination.

Further detail is provided in the Conceptual model report and groundwater modelling reports provided in Appendix E.

6.3.9.3 Identify the members of the planning team

Arrow Energy, Department of Environment and Science (DES), Department of Resources (DoR), groundwater sampling and modelling consultants.

6.3.9.4 Develop/refine the conceptual site model, including a summary of the exposure scenarios.

The CSM is described in the Conceptual Site Model report provided in Appendix E.

Sources - groundwater contaminants are migrating in groundwater at 70m to 120m below ground, and Arrow Energy activities have a potential to exacerbate groundwater movement.

Receptors – there are no potential off-site receptors. As described in the conceptual site model report, there are no natural pathways for groundwater at depth to the surface to impact environmental values. Landholder bores several hundred metres from the site will be decommissioned and alternate water supply arrangements provided by Arrow Energy in accordance with 'make good' provisions of the Water Act for Coal Seam Gas companies.

Modelling by University of Queensland (UQ 2020) has shown minimal opportunity for changes in groundwater movement predicted from Arrow's proposed development to result in changes to free gas movement on site.

6.3.9.5 Available resource and constraints

Arrow Energy have emplaced monitoring wells and undertaken groundwater sampling and modelling to assess water quality off-site and to predict potential migration rates of groundwater and the fate and transport of contaminants in groundwater. Arrow Energy seeks to resolve potential impact predictions in order to allow submission of amendment of the Environmental Authority for PL253 in August 2021.

The continued access to third party bores on-site is a potential constraint on the program.

6.3.10 Identify the goal and principal questions

For monitoring data to be used in an adaptive management regime the questions that the monitoring data must address must be clear, as must the outcomes that the data seeks to inform.

These are provided below:

6.3.10.1 Principal Study Questions

- Does the monitoring data show a significant[1] change in hydraulic gradient due to Arrow operations that would allow groundwater to move off-site?
- Does the monitoring data show a significant[2] change in contaminant impact at Arrow monitoring wells?
- If not, what is the appropriate response?

[2] Significance is based on exceedance of levels that result in actions in this document

6.3.10.2 Identify the alternative outcomes or actions that could result from monitoring

- Monitoring indicates that the hydraulic gradient is not changing unacceptably.
- Monitoring indicates that the hydraulic gradient is changing more than predicted.
- Monitoring indicates contaminant concentrations are not being detected off-site.
- Monitoring indicates contaminant concentrations are being detected off-site.

6.3.10.3 Form the Decision Statements

Decision statements link the data collected to the questions the management program must address.

1. If the hydraulic gradient remains within predicted levels and contaminant concentrations are not detected off-site, continue monitoring.
2. If hydraulic gradients change and contaminants are not detected off-site re-assess rate of movement and monitoring frequency to assess potential for impact at monitoring wells.
3. If hydraulic gradients change and contaminants are detected off-site at levels exceeding trigger criteria due to changes in the hydraulic regime induced by Arrow Energy, implement management actions.

6.3.11 Identify the information inputs, trigger criteria and study bounds

The data to be collected to inform the above decision structure should be clearly identified as well as the basis for the derivation of action levels that drive decisions.

This data will be collected from monitoring points described below and analytes and sample procedures and frequencies described in the GCMP and/or methods and criteria sourced from Australian Guidance documents including the NHMRC. Site specific risk assessments will be based upon these guidance documents.

The spatial and temporal extent of data collection is also defined based upon the conceptual model, observed data and predictive modelling.

6.3.11.1 Decision Statement Input Data

Monitoring points are chosen to assess hydraulic gradients across the site (Figure 13).

- Monitoring of water pressures in HSMB1S, HSMB2S, HSMB3S1, HSMB3S2, HSMB4S, Hopeland 22 and Hopeland 25 to assess hydraulic gradients in the Springbok Sandstone.

- Monitoring of water pressures in HSMB1D, HSMB2D, HSMB3D2, HSMB4D, HSMB5D, G4MWD, L22, Hopeland 23 and Hopeland 26 to assess hydraulic gradients in the Macalister coal seam.

- Monitoring of HSMB3D1, M14r, G4MWD, HSMB4D, M15, HSMB5D, HSMB3S1, HSMB3S2, HSMB4S wells on-site for assessment of contaminant trends.

- Monitoring of Hopeland wells 20-27 to assess for contaminant migration.

- Modelling of groundwater migration and contaminant fate and transport under scenarios with no Arrow development and the proposed development scenario.

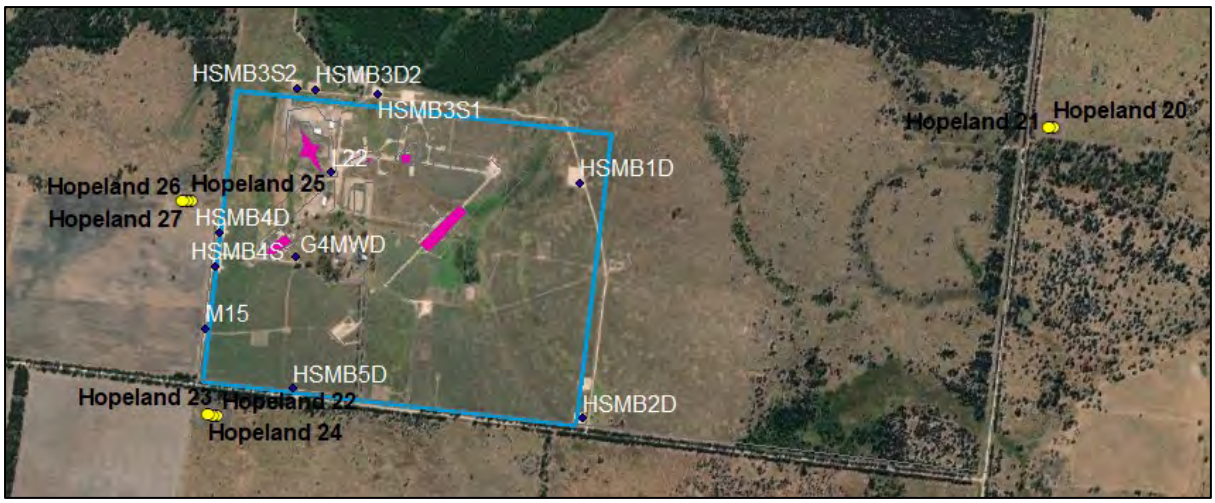

Figure 13 Proposed Monitoring Locations

6.3.11.2 Information needed to establish the trigger levels

Investigation criteria are sourced from a review of risk based criteria summarised in Table 6 and detailed in the report in Appendix B.

The final SSTV have been selected, taking into account that the groundwater triggers should protect the human, agricultural and environmental users of groundwater from increases in toxicant concentrations attributed to CSG activities and not natural processes.

For each compound, separate published groundwater quality screening levels have been identified for each of the following scenarios:

- ***Risk-based standards (human health):*** the levels of contaminants that could be present within the Springbok Sandstone aquifer and Walloon Coal Measures in the area surrounding the site without representing a risk to human users of extracted groundwater
- ***Risk-based standards (agricultural):*** the levels of contaminants that could be present within the Springbok Sandstone aquifer and Walloon Coal Measures in the area surrounding the site without representing a risk to livestock or crop plants exposed to extracted groundwater
- ***Risk-based standards (environmental):*** the levels of contaminants that could be present within the Springbok Sandstone aquifer and Walloon Coal Measures in the area surrounding the site without representing a risk to aquatic organisms and aquaculture species exposed to extracted groundwater.

The lowest of the range of screening levels for each CoPC has been selected as the SSTV. For each CoPC, consideration has also been given to the background CoPC concentration to confirm that the SSTVs are not below the levels that may be associated with natural processes.

6.3.11.3 Sampling methods

Sampling and analytical methods are consistent with existing guidance including NEPM (2013, B2 and B3) and Monitoring and Sampling Manual 2018 DES (2018). Analytical laboratories are NATA accredited and use analytical methods based upon NEPM, USEPA and APHA methods.

6.3.12 Define the boundaries of the study

6.3.12.1 Define the target population of interest and its relevant spatial boundaries.

The hydraulic gradient across the site is a target dataset of interest and will be monitored by groundwater pressures measured at sites located across the site as summarised in

Table 4 below and shown in Figure 13.

Pressure Monitoring Locations	Unit	Rationale
HSMB4D to Hopeland 26	Macalister	Provides indication of off-site gradient to the west.
G4MWD to Hopeland 23	Macalister	Provides indication of off-site gradient to the south.
G4MWD to HSMB5D	Macalister	Provides indication of off-site gradient to the south.

L22 to HSMB3D2	Macalister	Provides indication of off-site gradient to the north.
HSMB3S1 to Hopeland 22	Springbok Sandstone	Provides indication of off-site gradient to the south.
HSMB3S2 to Hopeland 25	Springbok Sandstone	Provides indication of off-site gradient to the west.

Table 6 Hydraulic Gradient Pressure Monitoring Locations

Control charts have been prepared for the proposed monitoring wells where the data is stable. This omits the large variations in data that may be influenced by other factors than site contamination and provides a lower threshold for action levels.

The contaminant concentrations in groundwater on PL253 is a target dataset of interest and The contaminant concentrations are monitored at the locations summarised in Table 5 for trigger and/or trend analysis.

Contaminant Monitoring Locations	Unit	Purpose
Hopeland 22,	Springbok Sandstone	Trigger monitoring location
Hopeland 23	Macalister	Trigger monitoring location
Hopeland 25	Springbok Sandstone	Trigger monitoring location
Hopeland 26	Macalister	Trigger monitoring location
HSMB3D1, M14r, G4MWD, HSMB4D, M15, HSMB5D	Macalister	Trend monitoring location
HSMB3S1, HSMB3S2, HSMB4S,	Springbok Sandstone	Trend monitoring location

Table 7 Contaminant Monitoring Locations

6.3.12.2 Define the Sampling Unit

Sampling units will consist of:

- Pressure monitoring data; and
- Analytical samples of laboratory specified sample containers.

6.3.12.3 Temporal boundaries and practical constraints on data collection

The monitoring program is currently occurring and will continue for the life of the proposed field development provided in the amendment.

Arrow Energy can access and monitor the Hopeland 20-27 series wells. On-site wells are monitored by DoR.

The groundwater impacts with potential to be impacted by Arrow Energy are 70 to 120m below ground in the Springbok Sandstone and Macalister Coal Seam. Hence dense sampling networks are not feasible.

The drilling equipment required to complete wells to this depth and the presence of coal provides anthropogenic and natural sources of some of the same analytes comprising the contaminants of concern (ie Benzene and Naphthalene) requiring the assessment of detectable concentrations against these potential sources as well as from the contamination source term.

6.3.12.4 Specify the smallest unit on which decision estimates will be made

Due to the slow movement of groundwater, the potential for anthropogenic and natural sources of the contaminant concentrations and the objective of assessing if impacts are moving off-site the data will be assessed at the points described in Table 4 and Table 5 over seasonal cycles (wet and dry seasons) for two years.

6.3.12.5 Develop the analytical approach

A pre-determined approach that assesses background concentrations, early warning trend indicators and trigger level criteria provides clarity and certainty in implementing the adaptive management approach. These can be developed and contained in the GCMP to manage the risk posed by the site and provide an agreed decision tree for adaptive management. A proposed flow chart that summarises the process is shown below (Figure 6) and the statistical criteria and action levels are described below.

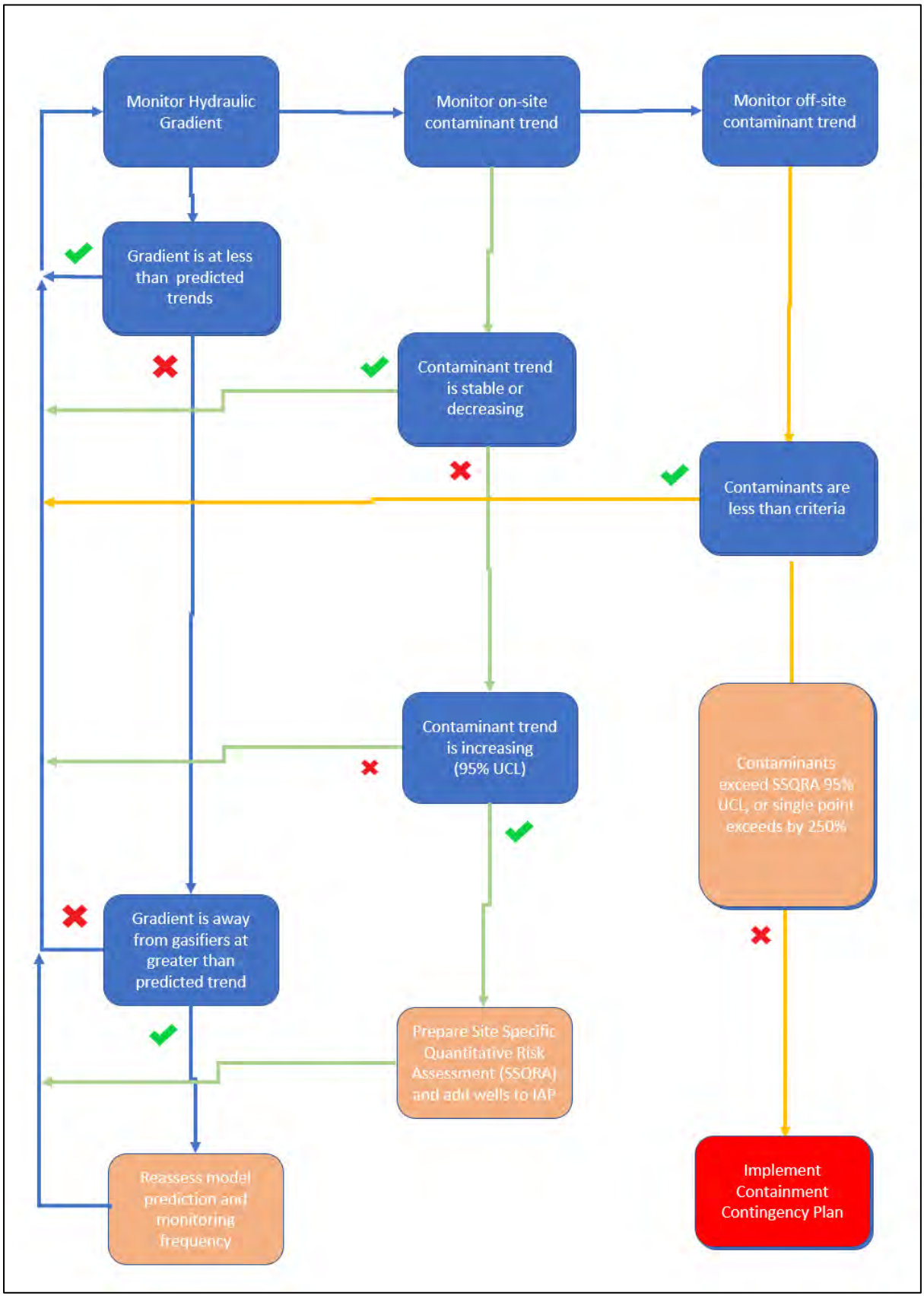

Figure 14 Decision Flow Chart

6.3.12.6 Specify the Statistical parameter that characterises the population of interest.

6.3.12.6.1 Assessment of rate of change of hydraulic gradient.

Water pressures currently indicate an inward gradient. The statistical parameter for the hydraulic gradient will be a Sens test undertaken over two seasonal cycles that indicates a 95% likelihood that the gradient has become an outward off-site gradient.

Based on current data this is achievable because the current observed hydraulic gradients indicate a depressed water pressure on the site around the gasifiers. The available data describes a complex pattern of water pressures that recover at slightly different rates around different gasifiers. This is anticipated to be due to the different characteristics of the different gasifiers.

The current prediction of the rate of groundwater movement at the site is very slow, as reported (AGE 2021) in the Springbok Sandstone the rate of movement without Arrow's PL253 development was 32 m over 20 years or an average of 1.6 m per annum. There was no measurable change with the proposed Arrow development.

In the Macalister the same movement prediction is on average 25m of movement over 20 years or an average of 1.25m per annum without Arrow's PL253 development. There was no measurable change with the proposed Arrow development.

The closest distance from a perimeter monitoring well with detectable benzene to the Lot boundary is 15 m at bore HSMB5D. At a rate of 1.6m per annum, it would take approximately 9 years for the groundwater at this location to reach the boundary from the time the groundwater gradient reverses. At other perimeter locations that are further from the Lot boundary it would take longer for groundwater to travel to the site boundary.

Given the travel times for groundwater the change in hydraulic gradient can be assessed via a Sens test that shows the gradient has changed by a statistically significant amount and has been consistent across two seasonal cycles during which groundwater would have moved 1/3 of the distance from the HSMB5D to the boundary and allows for this statistical parameter to be used without off-site impact.

6.3.12.6.2 Assessment of on-site contaminant trends

Perimeter wells (i.e. HSMB series wells) and on-site wells nominated in Section 4.1 are used as indicators of changing contaminant trends on the site that can provide an early warning of potential for off-site contaminant migration.

Currently the hydraulic gradient is inwards towards the site and concentrations in HSMB wells are decreasing or at non-detectable levels. Figure 15 shows current trends at wells indicating most locations have declining trends and no detectable benzene has been detected off-site.

The statistical parameter for assessment of the on-site dataset trend will be the 95% UCL of the on-site monitoring dataset (where the standard deviation is less than 50% of the trigger criteria and no single value has changed by more than 250%).

6.3.12.7 Assessment of off-site contaminant Impact

Hopeland 22, 23, 25, 26 are proposed locations for monitoring off-site contaminant criteria as these have been installed by the operator and shown to provide representative data.

The statistical parameter for the assessment of this data will be the the 95% UCL of the off-site monitoring dataset (where the standard deviation is less than 50% of the trigger criteria and no single value has changed by more than 250%).

As these current criteria are generic and not site-specific criteria some criteria (most usually metals or inorganic analytes) may exceed background concentrations. Therefore, the following checks will be undertaken prior to assessment of the above statistical parameter.

1. Do concentrations exceed background concentrations? – Collate and assess the background data to assess whether observed data are within background ranges. This is most useful for dissolved metals and inorganic species although organic contaminants such as benzene and PAHs may also occur at naturally occurring background levels in coals or from other anthropogenic sources (i.e. groundwater pumps). Background data will be assessed and displayed as box and whisker plots to show median, minimum, maximum, and quartiles (Figure 15 Box and Whisker Plot). Where generic contaminant trigger levels are within the quartile ranges these values are flagged for site specific assessment if the generic criteria are exceeded in monitoring wells.

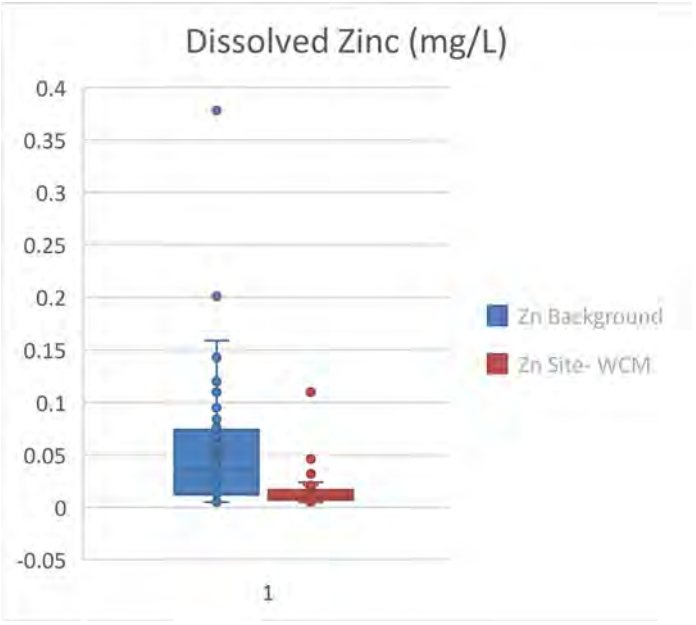

Figure 15 Box and Whisker Plot

6.3.13 Specify the action level for the decision

6.3.13.1 Action level for hydraulic gradient change

The action level for the hydraulic gradient is for the gradient to reverse and flow to be directed off-site as measured by the statistical parameter described above.

Where the hydraulic gradient is assessed to be changing at a rate greater than the modelled prediction the monitoring frequency will be reassessed to ensure data is collected in a timely manner to support the decision framework. The model will also be updated to assess the impact of the rate of change of the gradient on the DQO process.

6.3.13.2 Action level for on-site contaminant trends

The current on-site monitoring data generally indicates decreasing trends across the site (Figure 16).

When an increasing trend in on-site contaminant concentrations is indicated by the nominated statistical parameter this will provide the early warning indicator for the following actions:

- A site-specific quantitative risk assessment will be undertaken to set appropriate trigger criteria for long term off-site monitoring; and
- The containment wells will be scheduled in the Arrow Energy Integrated Activity Plan (IAP).

The inclusion of wells in the IAP at this stage is undertaken because the lead times for drill rigs to be scheduled can be 12 to 18 months.

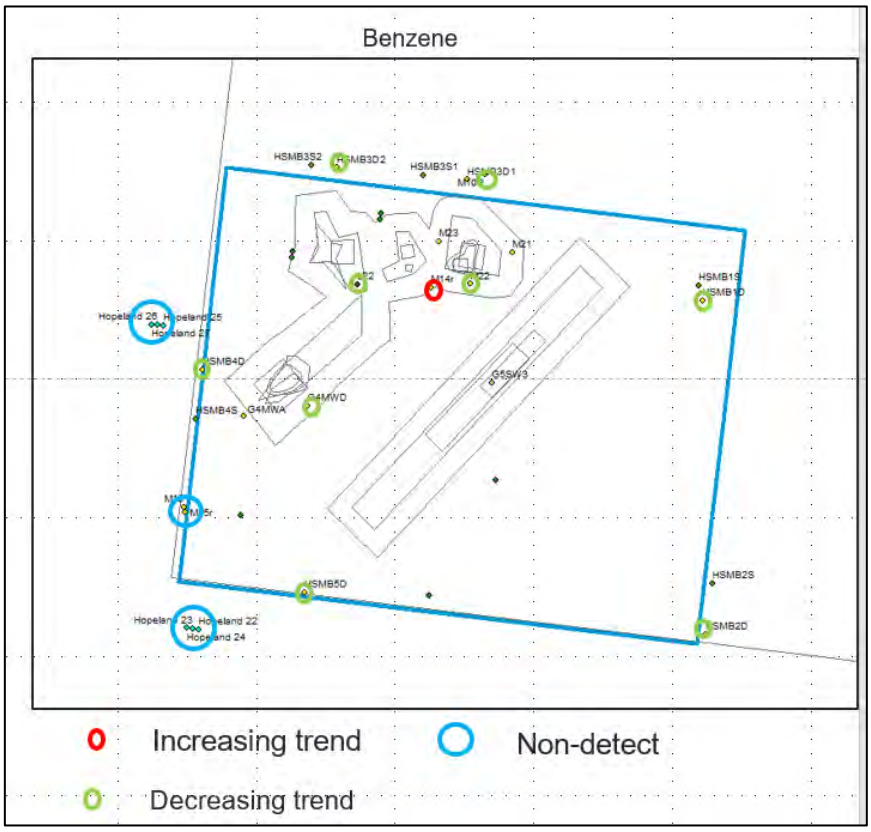

Figure 16 Benzene concentration trends

6.3.13.3 Action level for off-site contaminant trends

The current off-site monitoring reports no detectable benzene or naphthalene contaminants.

The action levels for the statistical parameter to be compared to for contaminants are provided in Table 6 Generic Human Health and Environmental Risk Assessment Criteria. These maybe updated by site specific quantitative risk assessment.

When a contaminant exceeds this action level for the statistical parameter then the remedial measure will be implemented.

Chemical	Non-Potable Human Use (mg/L)	Livestock Watering (mg/L)	Irrigation (mg/L)	Aquatic organism protection (mg/L)
Metals				
Arsenic	0.1[1]	0.5[5]	0.1[6]	0.042[7]
Barium	13[2]	1.3[8]	-	-
Beryllium	0.6[1]	0.06[8]	0.1[6]	-
Boron	40[1]	5[5]	0.5[6]	0.68[7]
Cadmium	0.02[1]	0.01[5]	0.01[6]	0.004[7,D]
Chromium (VI)	0.5[1]	1[5]	0.1[6]	0.006[7]
Chromium (total)	N/A[A]	N/A[A]	N/A[A]	N/A[A]
Cobalt	0.06[2]	1[5]	0.05[6]	0.0014[7]
Copper	20[1]	0.4[5]	0.2[1]	0.0018[7,D]
Mercury	0.01[1]	0.002[5]	0.002[6]	0.00006[7,C]
Manganese	5[1]	N/A[B]	0.2[6]	2.5[7]
Nickel	0.2[1]	1[5]	0.2[6]	0.013[7]
Lead	0.1[1]	0.1[5]	0.1[6]	0.0056[7,D]
Selenium	0.1[1]	0.02[5]	0.02[6]	0.005[7,C]
Vanadium	0.1[1]	0.01[8]	0.1[6]	0.006[7]
Zinc	30[1]	20[8]	2[6]	0.015[7]
Phenolic compounds[4]				
Phenol	58[3]	5.8[8]	1.8[2]	0.6[7]
Cresols (sum)[F]	15[3]	1.5[8]	-	-
2,4-dimethylphenol	3.6[3]	0.36[8]	-	0.002[7]
Total petroleum hydrocarbons				
TPH>C_{10}–C_{16}	0.9 (aromatic) – >S^{I} (aliphatic)[4]	$S^{10,H}$	>$S^{10,H}$	0.056 (aromatic) – S^{H} (aliphatic)[H]
TPH>C_{16}–C_{34}	>$S^{4,H}$	>$S^{10,H}$	>$S^{10,H}$	>S^{H}
TPH>C_{34}–C_{40}	>S^{H}	>S^{H}	>S^{H}	S^{E}
Polycyclic aromatic hydrocarbons				
Anthracene	18[3]	1.8[8]	-	0.0015[7]

Chemical	Non-Potable Human Use (mg/L)	Livestock Watering (mg/L)	Irrigation (mg/L)	Aquatic organism protection (mg/L)
Acenaphthene	5.3[3]	0.53[8]	-	0.0058[11]
Acenapthylene	-	-	-	-
Fluorene	2.9[3]	0.29[8]	-	0.003[11]
Naphthalene	0.02[2]	0.16[11]	0.8[11]	0.037[7]
Phenanthrene				0.0006[7,C]
BTEX				
Benzene	0.01[1]	4[11]	0.8[11]	1.3[7]
Toluene	8[1]	8[11]	39[11]	0.23[7]
Ethylbenzene	3[1]	4[11]	18[11]	0.11[7]
Xylenes	6[1]	8[11]	13[11]	0.1[7,G]

Table 8 Generic Human Health and Environmental Risk Assessment Criteria

The generic human health and environmental risk assessment criteria were developed by GHD (2019). The HHERA report is provided as Appendix F.

6.3.13.4 Confirm that measurement detection will allow reliable comparisons with the action levels.

Water pressures are recorded to the nearest centimetre and are suitable for assessing the change in hydraulic gradient.

Samples will be submitted to NATA accredited laboratories, the LORs are suitable below the adopted criteria.

6.3.13.5 Combine outputs from previous DQO steps to develop if…then…else theoretical decision based rule.

If hydraulic gradient is inwards to the site and on-site wells continue decreasing trend and off-site wells continue non-detectable contaminants then continue monitoring, else:

Monitor off-site hydraulic gradient for two seasonal cycles to ensure consistent or increasing off-site gradient.

If gradient is consistently or increasing off-site, then re-assess monitoring frequency for on-site and off-site wells for contaminants.

If on-site wells report increasing trend undertake Site Specific Quantitative Risk Assessment and enter containment wells into Arrow Energy Integrated Activity Plan (IAP), else continue monitoring.

If off-site wells <95% UCL of criterion with standard deviation less than 50% of criterion and no single result more than 250% of criterion then continue monitoring, else start process to install and operate remedial measure.

6.3.13.6 Specify performance or acceptance criteria

Specify probability limits for false rejection and false acceptance decision errors.

6.3.13.7 Specify the decision rule as a statistical hypothesis test

The null hypothesis is that the groundwater off-site will become contaminated and exceeds the adopted criteria. The alternative hypothesis is that the groundwater is not contaminated above the criteria.

6.3.13.8 Examine consequences of making incorrect decisions from the test

The groundwater being predicted not to become contaminated above adopted criteria when it will, thereby potentially risking an impact.

Unnecessary installation and operation of containment system, imposing needless financial and resource burdens on the project and proponent.

6.3.13.9 Place acceptable limits on the likelihood of making decision errors, including acceptable alpha (ά) and beta (β) risk levels.

Stated hypothesis:

Null hypothesis (H_o): the 95% UCL and other requirements are > the action level; and

Alternate hypothesis (H_A): the 95% UCL and other requirements are < the action level.

Potential outcomes include Type I and Type II errors.

Type I error of determining the groundwater quality is acceptable and not impacting off-site when it is not (wrongly rejects true H_o)

Type II error of determining the groundwater quality is unacceptable and impacting off-site when it is acceptable (wrongly accepts false H_o).

For performance criteria, the acceptable limits on the likelihood of making decision errors to be applied are:

- alpha risk (Type I error) of ά= 0.05
- beta risk (Type II error) of β= 0.2.

6.3.14 Optimise the design for obtaining data

6.3.14.1 Document the final sampling and analysis design

The current groundwater sampling and monitoring points described above are the available locations to monitor and collect data due to the site constraints identified in 5.4.3.

6.3.14.2 Detail how the design should be implemented

The field methods for monitoring and sample collection are documented in the standard operating procedures (SOPs). Contingencies include installing further monitoring wells if results indicate the current conceptual model is no longer fit for purpose.

6.3.14.3 Determine the quality assurance and quality control (QA/QC) procedures that are to be performed to detect and correct problems to ensure defensible results.

The required field QA/QC and the field laboratory QA/QC are described in the SOPs.

6.3.14.4 Document the operational details and theoretical assumptions of the selected design in the SAQP.

Theoretical assumptions include:

- The site assessment data is representative of the groundwater contamination.
- The groundwater modelling is conservative and actual migration rates for groundwater and contaminants are less than predicted.

6.4 Groundwater Containment

The information contained in this groundwater chapter for the Stage 1, 55 well, development case demonstrates that the development the subject of this EA amendment application will not cause a measurable effect to groundwater or contaminant movement at the former Linc site. On this basis, a containment system is not considered appropriate or required for this Stage 1 application. The following is provided for completeness and for consideration when Arrow applies for the Stage 3 EA amendment for the full PL253 development case

6.4.1 Abstraction Wells

Hydraulic containment refers to the control of movement of contaminated groundwater, typically to prevent the continued expansion or migration of a dissolved phase plume but can also apply to source containment. Potential configurations based on groundwater modelling are provided in Figure 17.

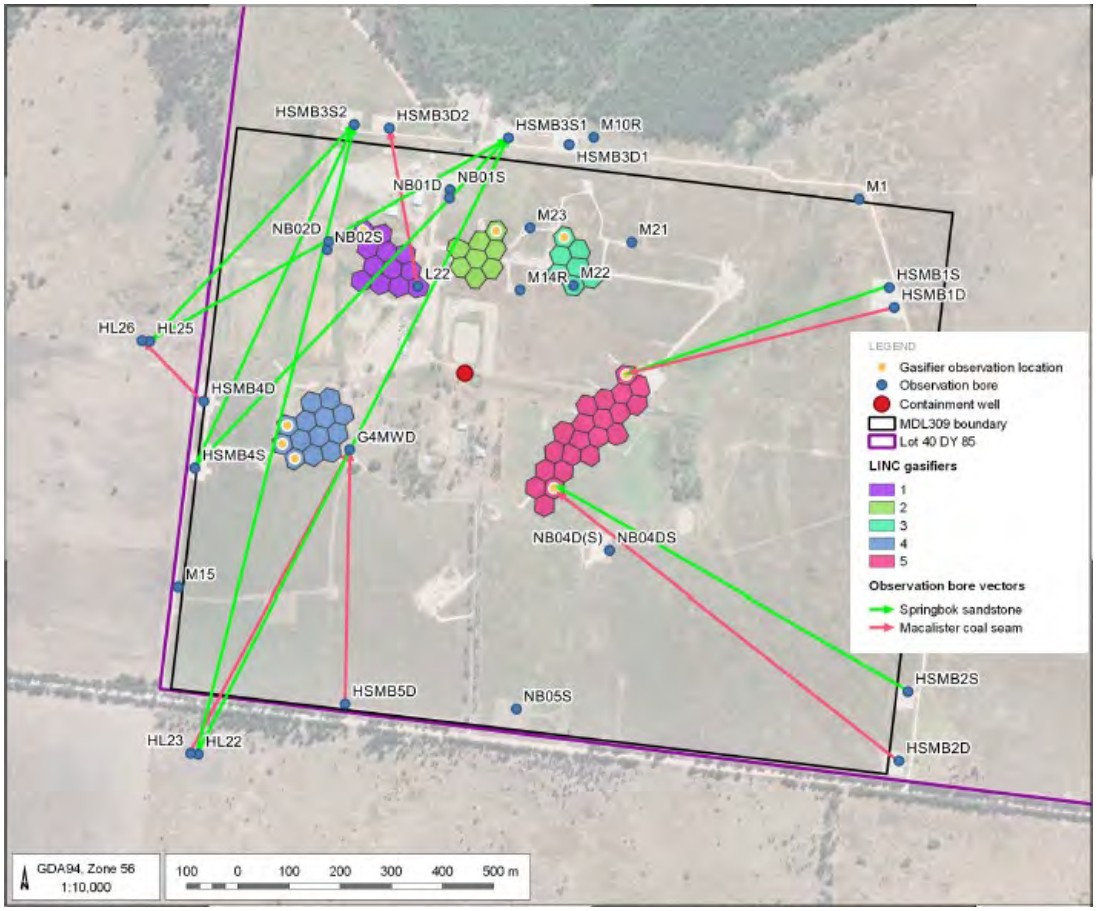

Figure 17 Simulated Containment Well Location

Site specific tests are required to determine well pumping rates and cone of depression drawdowns, capture zone, assess final well locations and pumping rates needed for full-scale operation.

The area within the cone of depression encompasses the containment zone, whilst the capture zone defines the area of contaminated water extracted and treated by the well(s).

A constant-rate pumping test will be conducted on well(s) on site to evaluate hydraulic parameters. The pump tests will include groundwater extraction at a constant rate and recording of the drawdown of the control well and observation wells within the ROI of the control well. The goal of a constant-rate pumping test is to estimate hydraulic parameters of aquifers. Once these parameters are established, the extraction rate of the system can be confirmed.

6.4.2 Treatment System

The treatment system for groundwater will be designed and installed to treat hydrocarbon related compounds. Such systems have successfully remediated elevated MAH/PAH impacts to groundwater in similar subsurface environments. Full-scale remediation systems provided for the site will be housed in an enclosure complete with lighting and ventilation that will provide walk-in access to all equipment.

Input parameters to system design will include:

- The Design flow rate is the expected flow rate of the system and is calculated from estimated extraction rates necessary to achieve containment objectives (e.g. plume capture). This value is used to select treatment components and to calculate the design mass removal rate.

- The maximum expected flow rate informs the hydraulic capacity that allows sizing of pumps, piping, and tanks.

- The Design influent concentration, the expected blended influent concentration from all extraction sources based on concentrations obtained from sustained pumping conditions and provides the design mass removal rate. This can be calculated using data from representative wells, which is averaged (and weighted based on the flow per well) to give the design influent concentrations for each constituent. The use of concentration data obtained during sustained pumping conditions, rather than during non-pumping or low flow conditions, reduces the chance of over designing the system to handle an erroneously high mass removal rate and is required for final design.

- The Maximum expected blended influent concentration from combined extraction, typically calculated by multiplying the design influent concentration by a factor of safety between 1.0 and 2.0. The treatment system should be able to treat this concentration and is used in the selection of a treatment process (i.e. GAC or air-stripping).

- The Estimated mass loading rate (kilograms per day) to the treatment plant of contaminants in extracted ground water is calculated by multiplying the design flow rate by the design influent concentration. This value should be used for estimating materials/utilities usage (i.e. GAC mass) when analysing costs of various treatment options.

Concentrations of hydrocarbons above solubility limits have not been detected and napl has not been recorded. However, as the composition of remnant potential napl around gasifiers is not known a contingency for separate-phase hydrocarbons (SPH) is included. Removal of SPH would include pumping the water through a triple interceptor trap and sending product into a temporary holding tank, and subsequently pumping the holding tank contents into a vacuum truck and transporting it to the appropriate disposal facility.

This equipment's final design will be based on the scale, type and location of contaminants triggering system installation, and may include:

- PLC panel module and system with an integrated groundwater extraction system; the system will be an automated, programmable, turnkey equipment platform that will utilize a 1-phase, 110/220V, 100-amp circuit power supply.
- SPH removal.
- A tank for the extracted groundwater and if required a transfer pump to transfer groundwater through bag filters to remove total suspended solids.
- A holding tank with associated floats (external to system).
- GAC vessels and/or air stripping.
- Holding/containment tanks and connection to gathering system.

6.4.3 Commitments

Arrow will implement the commitments it made in the EIS and updated in the SREIS in order to effectively manage and monitor the effects of CSG water extraction and related activities on local and regional groundwater values. These commitments are consistent with the existing legislative framework, specifically Chapter 3 of the Water Act. These legislative requirements are further detailed in the UWIR (Sections 8, 9 and 11, where applicable to the SGP) and Arrow's Stage 1 and Updated Water Monitoring and Management Plan (WMMP) (the direct links to these reports were provided above).

The commitments summarised below will be adapted to allow management decisions based on an increased knowledge developed over time.

6.4.4 Design and planning commitments

The following measures have been developed to manage the potential impacts on groundwater values during the design and planning phase of the project:

- Arrow has prepared a baseline assessment plan to establish benchmark data in registered third party bores (where possible) prior to the commencement of Arrow extraction activities in the PL253 area in accordance with the Water Act 2000, including the preparation and implementation of a groundwater monitoring and investigation strategy.

- Consider local biological, groundwater and surface water conditions when identifying sites for CSG infrastructure including storages.

- Consider local groundwater conditions when identifying sites and routes for the installation of buried infrastructure (e.g. gathering lines).
- Avoid unnecessary impervious surface coverings and minimise land footprint and vegetation clearing when designing facilities.
- Develop make-good agreements that include the outcome of bore assessments and implementation of make-good measures in the event that impaired capacity occurs.
- Continue a program of aquifer testing in dedicated groundwater monitoring bores to increase the amount of data on aquifer properties and groundwater movement that can be used in predictive numerical groundwater models.
- Ongoing collection of relevant geological and hydrogeological data from existing and future production wells, monitoring bores and registered third party bores (where possible) together with information collated collaboratively with other proponents and regulatory authorities.
- Maintain water balance models for long-term planning and management of CSG water. Review and update modelling in alignment with the production forecasting schedule.

6.4.5 Construction commitments

The following mitigation, monitoring and management measures have been developed to address the potential impacts on groundwater values during the construction phase of the project:

- Avoid disturbance of contaminated soil and groundwater when it is identified or observed during intrusive works.
- Manage disturbed contaminated soil or groundwater that cannot be avoided through physical investigation; manage quantification of the type, severity and extent of contamination; and remediate or manage in accordance with the relevant Queensland Government's legislation and guidelines.
- Construct all monitoring bores in accordance with the relevant regulation, such as the Minimum Construction Requirements for Water Bores in Australia, the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland, and the Code of Practice for the Construction and Abandonment of Petroleum Wells and Associated Bores in Queensland.
- Select drilling fluids to minimise potential impacts to groundwater. Oil based drilling fluids will not be used.
- Ensure well drilling is monitored by a suitably qualified geologist to ensure aquifers are accurately identified so wells are constructed correctly to protect groundwater.

6.4.5.1 Operational commitments

The following measures have been developed to address the potential impacts on groundwater values during the operations phase of the project:

- Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater that has occurred as a result of project activities.
- Manage potential impacts to identified spring complexes by:
    - Supporting the identification of specific aquifers that serve as a groundwater source for discharge springs
    - Assessing springs that are predicted to be subject to unacceptable impacts through the source aquifer
    - Developing monitoring and mitigation strategies to avoid or minimise unacceptable impacts
- Implement a well integrity management system during commissioning and operation of production wells.
- Minimise impacts of groundwater depressurisation on sensitive areas (e.g. groundwater dependent ecosystems).
- Develop a procedure for investigating any impaired capacity of third party bores that may become evident through monitoring and landholder liaison.
- If impaired capacity is confirmed (bore can no longer produce quality or quantity of groundwater for the authorised purpose, and the impact is due to CSG activities), implement make-good measures in accordance with the Water Act.

6.4.5.2 Decommissioning commitments

All production wells and monitoring bores will be decommissioned or repaired either at the end of their operating life span or, in the event of a failed integrity test, in accordance the *Petroleum and Gas (Production and Safety) Act 2004* and *Water Act 2000* and relevant regulations. Should production wells be converted into monitoring bores, it will be done in accordance with relevant regulations.

6.4.6 Regional groundwater monitoring program

The following describes in broad terms the proposed monitoring program and has been provided to the Australian Government consistent with Condition 17 (Updated CSG Water Monitoring and Management Plan) of the EPBC approval for the Surat Gas Project (EPBC 2010/5344). While the SGP EIS and SREIS described locations to be monitored, monitoring requirements have changed due to the absence of any CSG processing and CSG water discharges within the PL253 area.

A water monitoring strategy (WMS) is included in the Surat CMA UWIR. The WMS includes an integrated regional groundwater monitoring network to collect data on water pressure and water quality in the Surat CMA. The monitoring points and sites are designed to monitor all major aquifers and aquitards in the Surat CMA. The objectives of the WMS are to:

- Understand background trends
- Identify pressure changes near areas of P&G development

- Understand groundwater flow near connectivity features
- Understand groundwater flow near high value assets
- Improve conceptual understanding and future groundwater flow modelling.

The WMS assigns requirements to petroleum tenure holders to establish the regional monitoring network, undertake routine monitoring and reporting of results and report water production data from petroleum and gas wells. The OGIA will routinely assess the monitoring results and report on these annually. Arrow will implement the elements of the UWIR WMS for which it has been assigned responsibility.

Arrow has installed a comprehensive regional groundwater monitoring network (that satisfies Arrow's obligations as described in the groundwater impact reports in the EIS/SREIS and confirmed in Chapter 8 of the UWIR) to:

- Establish baseline groundwater level and groundwater quality conditions
- Assess natural variation (i.e. seasonal variations) in groundwater levels
- Monitor groundwater levels during the operations phase
- Establish suitable datum levels for each aquifer system
- Target sensitive areas where more frequent monitoring and investigation is required (e.g. groundwater dependent ecosystems)
- Monitor groundwater drawdown as a result of CSG extraction
- Monitor impacts in accordance with the Water Act and regulations
- Provide an 'early warning system' that identifies areas potentially impacted by project activities to allow early intervention and adaptive management.

6.4.7 Commitments in relation to Lot 40 DY85

Modelling allows Arrow to explore potential impacts in the future under different scenarios in order to assess the risk posed by our activities. It is important to understand that models do not represent a prediction of what may happen in the future. Rather, they determine the potential outcomes under a set of assumed conditions and are therefore a powerful tool to assess potential change, to indicate risk and to identify scenarios that have a low likelihood of occurring.

Arrow's 2021 groundwater model shows that:

  - groundwater movement away from Lot 40 DY85 is slow as it has been in all simulations since 2018

- Arrow's proposed development on PL253 will have no significant impact on either the rate of groundwater movement or the quality of groundwater. This is highlighted by:

- Groundwater movement in the Springbok and Macalister coal seam is impacted by less than 1 m over 20 years.

Given the above, the focus of our future management of groundwater on PL253 is appropriately placed on managing risk. The following will be undertaken:

- Arrow will maintain and sample on a quarterly basis the groundwater monitoring bores recently drilled up-gradient and down-gradient of Lot 40 DY85. These bores are appropriately placed to operate as an early warning trigger mechanism.
- Groundwater will continue to be sampled and reported to DES on an annual basis as per our existing Groundwater Characteristics Monitoring Program.
- Our groundwater model will be updated on an annual basis to include the current year of sampling results and predictions with regards to groundwater movement and particle tracking in the Springbok Sandstone and Macalister. This information will be included in the above-mentioned Groundwater Characteristics Monitoring Program.
- If the sampling results from any monitoring bores located off Lot 40 DY85 exceed any of the trigger limits specified in our Environmental Authority, Arrow will:
    - notify DES within forty-eight (48) hours of receiving the results
    - complete an investigation into the potential for environmental harm
    - provide a written report of the investigation to DES within 90 days of receiving the result, with the report outlining details of the investigation conducted and proposed actions to prevent environmental harm.
- Arrow will expand our monitoring program to validate and monitor the proposed activities and gas conditions.

6.5 Noise and Vibration

The EHP Assessment Report of the EIS/SREIS requested site-specific noise and vibration assessments for each proposed infrastructure location. The main noise and vibration generating activities relevant to this amendment application are drilling of wells, installation of low-pressure HDPE gathering lines and the introduction of borrow pits. This section discusses noise and vibration related to these activities.

Environmental values

Section 3 of EPP (Noise) states that the following environmental values are to be enhanced or protected under the policy:

a) *The qualities of the acoustic environment that are conducive to protecting the health and biodiversity of ecosystems; and*

b) *The qualities of the acoustic environment that are conducive to human health and wellbeing, including by ensuring a suitable environment for individuals to do any of the following:*
   - *i. sleep;*
   - *ii. study or learn;*
   - *iii. be involved in recreation, including relaxation and conversation; and*

c) *The qualities of the acoustic environment that is conducive to protecting the amenity of the community.*

Quality objectives are set to protect these environmental values, as well as relative limits to control 'background creep', which can occur with multiple developments in an area. The quality objectives from Schedule 1 of the EPP (Noise) and the environmental values they seek to protect are listed in Table 6.6.

Table 6.9 Environmental values for noise

Sensitive receptor	Time of day	Acoustic quality objectives			Environmental value
		$L_{Aeq, adj, 1h}$	$L_{A10, adj, 1h}$	$L_{A1, adj, 1h}$	
Dwelling (for outdoors)	Day time (0700 – 1800) Evening (1800 – 2200)	50 dBA	55 dBA	65 dBA	Health and wellbeing
Dwelling (for indoors)	Day time (0700 – 1800) Evening (1800 – 2200)	35 dBA	40 dBA	45 dBA	Health and wellbeing
	Night time (2200 – 0700)	30 dBA	35 dBA	40 dBA	Health and wellbeing, in relation to the ability to sleep

At night (22:00 to 07:00 hours), the key environmental value to be protected under the Environmental Protection (Noise) Policy 2008 (EPP Noise) is human health and wellbeing in relation to the ability to sleep. During the day (07:00 to 18:00 hours) and evening (18:00 to 22:00 hours), the qualities of the acoustic environment for learning and recreation become more important for human health and wellbeing.

Existing noise environment

The development area is situated primarily in a rural area which, in general, has low background noise levels that follow a typical diurnal pattern. That is, the noise levels generally reduce during the evening and night-time when rural farming activities, bird and insect calls, and road traffic activity is reduced.

Noise criteria

To encourage a consistent approach to the assessment of noise from CSG activities, specific guidance has been prepared in the form of the document Prescribing Noise Conditions for Environmental Authorities for Petroleum Activities (PGA Noise Guideline, EHP 2013). The PGA Noise Guideline identifies common noise issues found in gas activities and recommends noise limits based on the type and duration of the noise emissions. The recommended noise limits are designed to comply with the objectives of the EPP (Noise).

Of relevance to this amendment application, the noise generating activities identified by the guideline include site preparation, clear and grade, drilling and operating wells. The guideline identifies these activities to fall into one of three classes as follows:

1. Short-term noise event: Noise exposure at the receptor which persists for an aggregate period not greater than eight hours and does not re-occur for a period of at least seven days

2. Medium term noise event: Noise exposure at the receptor which persists for an aggregate period not longer than five days and does not re-occur for a period of at least four weeks

3. Long term noise event: Noise exposure at the receptor which persists for a period greater than five days, even when there are respite periods when the noise is inaudible within those five days.

Re-occurrence is deemed to apply where a comparable level is observed at the same receptor location for a period of one hour or more, even if it originates from a different source or location.

The guideline recommends the adoption of the best practice noise limits set out in Table 6.7. The bulk of the activities proposed under this amendment application will fall within the 'Long Term Noise Event' class.

Table 6.10 Best practice measured noise emission limits as per the EHP Guideline (2013)

Time Period	Metric	Short Term Noise Event [a]	Medium Term Noise Event [a]	Long Term Noise Event [a]
Day 0700 – 1800 h	$L_{Aeq,\ adj,\ 15\ min}$	45 dBA	43 dBA	40 dBA
Evening 1800 – 2200 h	$L_{Aeq,\ adj,\ 15\ min}$	40 dBA	38 dBA	35 dBA
Night 2200 – 0600 h	$L_{Aeq,\ adj,\ 15\ min}$	28 dBA	28 dBA	28 dBA
	$max L_{pA,15\ min}$	55 dBA	55 dBA	55 dBA
Early morning 0600 – 0700 h	$L_{Aeq,\ adj,\ 15\ min}$	40 dBA	38 dBA	35 dBA

[a] Deemed background noise levels are: Day: 35 dBA; Evening: 30 dBA; Night: 25 dBA; Early morning: 30 dBA.

Where the existing background noise levels are above the deemed background values, the standard procedure for setting noise limits from Planning for Noise Control can be applied, whereby the noise limit at night is set 3 dBA over the background noise level. Where the noise at a receptor contains either tonal or impulsive characteristics (or both), an adjustment to the noise level shall be made using Table 6.8.

Table 6.11 Character adjustments to noise levels at receptors

Noise Characteristic	Adjustment to Noise
Tonal characteristic is just audible	+2 dBA
Tonal characteristic is clearly audible	+5 dBA
Impulsive characteristic is just audible	+2 dBA
Impulsive	+5 dBA

Sleep disturbance

The primary goal of night-time noise limits is to protect sensitive receptors from sleep disturbance. The sources of noise levels designed to protect against sleep disturbance are those recommended by the World Health Organisation's Guidelines for Community Noise. The WHO guidelines generally prescribe two noise levels at residential locations to ensure that sleep is not adversely affected, being:

- 30 dBA L_{Aeq} for continuous noise
- 45 dBA L_{Amax} for single events (maximums).

The above noise levels are at the person's ear (i.e., within the residential building). With regards to the maximum noise levels, the WHO guideline also states that it is important to consider the character of the noise (i.e., number of noise events and the difference between the maximum noise level and the background noise level). It is referred to that for a good night sleep the criterion of 45 dBA L_{Amax} should not be exceeded more than 10 – 15 times per night. The corresponding external noise level, assuming partially closed windows is 52 dBA max L_{pA}, measured in the free field which corresponds well to the recommended noise limit in DES's Guideline.

The noise limits for continuous sources recommended by WHO are consistent with the night-time noise limit in the EPP (Noise) (i.e., 30 dBA internal). The night-time noise limit presented in the DES guideline is more stringent at 28 dBA (external) which is set due to low background noise levels in isolated rural areas and to protect against background creep. There is no sleep disturbance noise limit for the day and evening periods.

The WHO guidelines do note that to protect sensitive persons, a still lower guideline value would be preferred (than 30 dBA internal) when the background level is low.

Construction noise control

Construction noise impacts from petroleum activities are also regulated through the application of EHP's guideline, Prescribing noise conditions for environmental authorities for petroleum activities. The guideline was designed such that short term and medium-term events would be applied to activities such as drilling and well activities such as well

workovers (Ron Rumble 2011). However, CSG construction activities such as drilling do not fit into the time definitions of short-term or medium term provided in EHP's guideline.

To set appropriate night-time noise limits for CSG construction activities a review of other local and international noise standards identifies the following aspects that may be considered in developing reasonable noise goals for the night period:

- The NSW Interim Construction Noise Guideline (2009) which provides criteria specifically for construction activities, allows for a 5 dB increase to background noise levels to define night-time criteria. The NSW guideline also specifies a minimum background of 30 dBA. Therefore, the lowest possible night-time criteria is 35 dBA; and

- The World Health Organisation 'Guidelines for Community Noise' specifies an internal noise level of 30 dBA to avoid sleep disturbance. Assuming a 5 dBA attenuation for a façade with a fully opened window, an external 35 dBA criteria would be applicable for avoiding sleep disturbance.

Other Environmental Authorities (EAs) for CSG construction activities with a 28 or 30 dBA internal noise limit applied to drilling activities undertaken between 10:00 pm to 7:00 am include the recently issued EAs for Arrow (e.g., SGP South EA). This noise level (28 dBA internal) is equivalent to a 33 dBA noise limit for drilling by applying a 5 dBA attenuation for a façade with a fully opened window as per the Planning for Noise Control Guideline (DERM 2004).

Summary of noise limits

In summary, the noise limits that are considered appropriate and have been issued by DES to CSG proponents including Arrow are those sought in this amendment application as per Table 6.9.

Table 6.12 Noise emission limits for this amendment application

Time Period	Metric	Short Term Noise Event [a]	Medium Term Noise Event [a]	Long Term Noise Event [a]
Day 0700 – 1800 h	$L_{Aeq,\ adj,\ 15\ min}$	45 dBA	43 dBA	40 dBA
Evening 1800 – 2200 h	$L_{Aeq,\ adj,\ 15\ min}$	40 dBA	38 dBA	35 dBA
Night 2200 – 0600 h	$L_{Aeq,\ adj,\ 15\ min}$	28 dBA	28 dBA	28 dBA
	$_{max}L_{pA,15\ min}$	55 dBA	55 dBA	55 dBA
Early morning 0600 – 0700 h	$L_{Aeq,\ adj,\ 15\ min}$	40 dBA	38 dBA	35 dBA
Drilling activities undertaken from 2200 – 0700 h [b]	$L_{Aeq,\ adj,\ 15\ mins}$	28 dBA (measured indoors) 30 dBA (measured outdoors)		

a L_{ABG} is the deemed background noise levels which are:

7:00 am – 6:00 pm:	35 dBA
6:00 pm – 10:00 pm:	30 dBA
10:00 pm – 6:00 am:	25 dBA
6:00 am – 7:00 am:	30 dBA

b Drilling activities (e.g., drilling, workover, completion activities) undertaken from 10.00 pm – 7.00 am must be temporary and mobile in nature and must not contribute to long-term background creep.

Noise risks and impacts

The highest noise generating activities included in this amendment application are:

- Construction activities (i.e. site preparation, clear and grade) at the well pad sites
- Drilling of wells at well pad sites
- Installation of gas and water gathering lines
- Operation of well pads
- Operation of borrow pits.

Construction activities at well pad sites and drilling of wells (i.e., well development)

The dominant noise sources associated with well development are listed in Table 6.10. The well development process involves several subtasks that emit different levels of noise for varying lengths of time. Drill rig setup and pull down are typically quieter than the main well drilling activity.

Table 6.13 Dominant noise sources – well development

Gas well development stage	Approximate duration	Significant noise sources
Well development activities		
Well site preparation (daytime only)	3-4 days	• Bulldozer, excavator, two to five trucks, bucket loader and rolling compacting machines for forming the well lease work pad and access road preparation • Woodchipper, if required, to mulch vegetation
Drill rig setup (daytime only)	12 hours	• Movement of approximately 10 to 20 semi-trailer loads of mechanical plant and trailer-mounted buildings to site during daylight hours • Front-end loader forklift unloading of semi-trailer plant and equipment • Diesel-driven electricity generator • Metal-to-metal impacts associated with erection of drill-rig mast and set-up of compressed air, water treatment, mud-pumps and power systems
Well drilling (24 hr/day)	3 – 5 days	• Diesel-driven electricity generator • Drill-rig engine and drill-string hydraulic drive and elevation motors

		• Mud-pump and air-compressor diesel engines • Periodic operation of diesel-driven air-compressors, and 'hissing' compressed-air noise during venturi-induced well-unloading • Metal-to-metal impacts associated with connection/disconnection of drill-string segments and automated handling of drill-string segments
Cementing noise (daytime only)	30 – 60 minutes	• Diesel-driven electricity generator • Multiple diesel-driven high-pressure pumps used to inject cement slurry into cavity surrounding the well casing
Drill rig pull-down (daytime only)	12 hours	As for drill rig setup
Well completion activities		
Setup of well completion / workover rig (day time only)	12 hours	As for drill rig setup
Well completion (24hrs/day)	3 to 5 days	• Diesel driven electricity generator • Multiple diesel-driven high-pressure pumps to clean the well for production
Drill rig pull-down (daytime only)	12 hours	As for drill rig setup

Arrow has been operating rigs in the Surat Basin since 2006 and is familiar with the noise generated by well development activities. To complement this understanding, a noise and vibration impact assessment was undertaken in 2018-19 to assess the potential impacts on the ambient noise and vibration environments at the sensitive receptor locations surrounding the SGP in accordance with the requirements outlined in the DES guideline Application requirements for petroleum activities (DES 2013).

As part of the scope, rig noise and vibration emissions were assessed to identify offset distances required to meet relevant criteria for rig operations and to understand how noise levels vary during different rig activities and potential areas of rig noise attenuation.

The noise assessment established that a separation distance between the rig activities and the nearest sensitive receptor of approximately 1,000 m is required to meet the 33 dBA night-time external noise criterion and approximately 580 m to meet the 40 dBA day time noise criterion.

For the proposed well development activities on PL253, there are 35 sensitive receptors that are located within 1,000 m of a well pad (15 confirmed and 20 suspected).

If well pads are located closer than 1,000 m to a sensitive receptor, an Alternative Arrangement with the affected party will be sought. This process is carried out according to the Arrow Environment Noise and Vibration Management Plan (ORG-ARW-HSM-PLA-00043). Also, within Arrow's Environment Noise and Vibration Management Plan are rig noise performance criteria that are built into rig contracts to drive low noise performance through rig design and rig contracting considerations.

Gathering lines (and access roads where required) installation

The dominant noise sources associated with gathering line installation are listed in Table 6.11.

Table 6.14 Dominant noise sources – construction of gathering lines

Activity	Description	Typical Equipment	Notes
Clear and grade	Clearing and levelling ROW	1 D8 dozer 1 14g grader 1 30t excavator 1 mulcher 1 water truck	Worst case assumes all items operating simultaneously within a 200 m section
Trenching	Excavating the trench	1 trencher 1 30t excavators 1 ute	Worst case assumes all items operating simultaneously
Padding and Backfilling	Padding the trench and lowering pipe and backfilling	1 padder 1 30t excavator 1 dozer 3 side booms 1 water truck	Worst case assumes all items operating simultaneously within a 200 m section
Access road construction (where required)	Clearing and levelling road surfaces, compaction and gravelling	1 D8 dozer 1 14g grader 1 30t excavator 1 mulcher 1 water truck 1 vibratory roller 2 B-double side tippers	Worst case assumes all items operating simultaneously within a 200 m section

Arrow has been installing linear infrastructure such as gathering lines and access tracks in the Surat Basin since 2006 and is very familiar with the noise generated by the required construction activities. As part of the recent impact assessment, noise modelling was conducted to determine the required offset distance that would be required between the planned gathering and access tracks construction and receptor locations to achieve the relevant noise criterion.

The modelling established that the separation distance to achieve the daytime noise criterion of 40 dBA L_{Aeq} for the construction stages associated with the gathering lines and access track construction is up to 600 m. The number of sensitive receptors on PL253 potentially impacted by noise from gathering installation is 25 (12 confirmed dwellings and an additional 13 suspected dwellings). This number is likely to reduce as some of the suspected sensitive receptors are ground-verified and found to be uninhabited or otherwise do not meet the definition of a sensitive receptor, proposed infrastructure is moved further away from confirmed sensitive receptors and other noise mitigation strategies are employed. This process is carried out according to the Arrow Environment Noise and Vibration Management Plan.

Well Pad Operation

A detailed noise study was also undertaken in 2019 to characterise noise emissions from Arrow's operational well pads. Noise assessment was completed through noise measurement and modelling on a variety of well pad configurations to understand the

required separation distances from the entire range of operational well pads under varying loads to achieve relevant noise criteria.

The noise generated by the longer-term operation of the well is significantly less than during the well pad rig activities. For instance, during this operational phase, the separation distance required to meet the 28 dBA noise night-time (outdoors) criterion is 420 m for a single vertical well pad powered by a CSG engine at full load with a coal depth of 500 m.

The required separation distances from multi-well pads to achieve the night-time noise criteria of 28 dBA varies depending on the well pad design type, required number of gensets and well pad load. The maximum separation distances to achieve the night-time noise criteria of 28 dBA at full load are summarised in Table 6.12.

Table 6.15 Separation distances to achieve night-time noise criterion from multi-well pads

Multiwell pad type	Maximum separation distance to achieve night-time noise limit of 28 dBA (m)
2 wells, 2 gensets	660
3 wells, 3 gensets	750
4 wells, 4 gensets	820
4 wells, 5 gensets	880
5 wells, 4 gensets	820
5 wells, 5 gensets	880
6 wells, 5 gensets	880
6 wells, 6 gensets	940
7 wells, 6 gensets	940
7 wells, 7 gensets	990
8 wells, 6 gensets	940
8 wells, 7 gensets	990

Options to reduce operational noise impacts from operating well pads at noise sensitive locations include:

- The use of re-specified well pad generators and low noise performance gen-set canopies
- Reducing well pad power load during the night period
- Re-orientating well pads to maximum distance between sensitive receptors and gensets
- Locating gen sets offset from well pad to minimise noise impact
- Noise barriers
- Reticulation of electricity to well pads.

These noise attenuation options are investigated and applied as necessary. The process for assessing noise risk from operational well pads is described in Arrow's Environment Noise and Vibration Management Plan (ORG-ARW-HSM-PLA-00043) and is as illustrated in Figure 6-11.

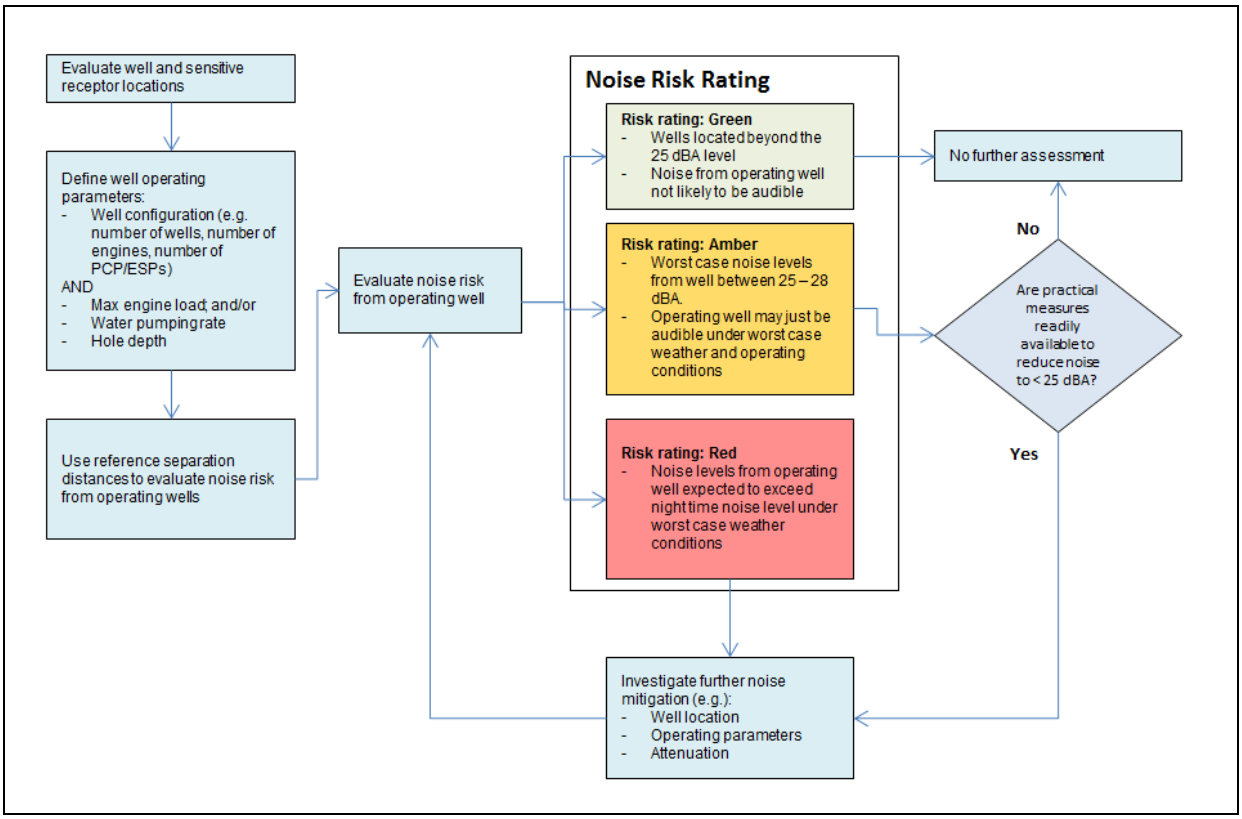

Figure 6.18 Process for assessing noise impacts from operational well pads

It should be noted that there are only single well pads, 2-well and 4-well multi pads the subject of this application. Where further noise control measures cannot be reasonably implemented, alternative arrangements will be sought with these landholders as required.

The number of noise sensitive receptors will be reduced further following landholder consultation and optimisation of the field layout and well pad design during detailed engineering. There will be no infrastructure within 200 m of a sensitive receptor consistent with the requirements of the Mineral and Energy Resources (Common Provisions) Act 2014 (MERCP Act).

Operation of Borrow pits

Noise impacts and the required separation distance have been assessed for quarrying equipment. Assumed equipment required for quarrying include:

- Truck
- Front end loader
- Crusher
- Screen
- Drill
- Water cart.

Quarrying activities will be limited to daytime hours only. The required separation distance determined through noise modelling and assessment to achieve the relevant noise criteria are:

- 1,200 metres to achieve 40 dBA
- 1,750 metres to achieve 35 dBA.

Arrow will ensure that quarrying activities are located at appropriate separation distances from sensitive receptors to achieve the noise criteria.

Vibration impacts and risks

The attenuation of ground vibration levels with distance for a range of common mechanical construction vibration sources is shown in Figure 6-12. This shows that normal construction activities are unlikely to generate vibration levels over 1 mm/s at receiver distances greater than 100 m. Beyond this distance, it is highly unlikely that structural damage to buildings or human discomfort will occur. None of the sensitive receptors will be located within 200 m of the proposed construction activities as per the restricted land provisions and Arrow's SGP EIS commitment and therefore no receptors will be impacted by vibration.

Transient vibration impacts due to road transportation are not expected to occur because of the development due to the minimum separation distance between any given receptor and a major roadway being greater than 50 m. At this separation distance, vibrations levels would be limited to < 1 mm/s.

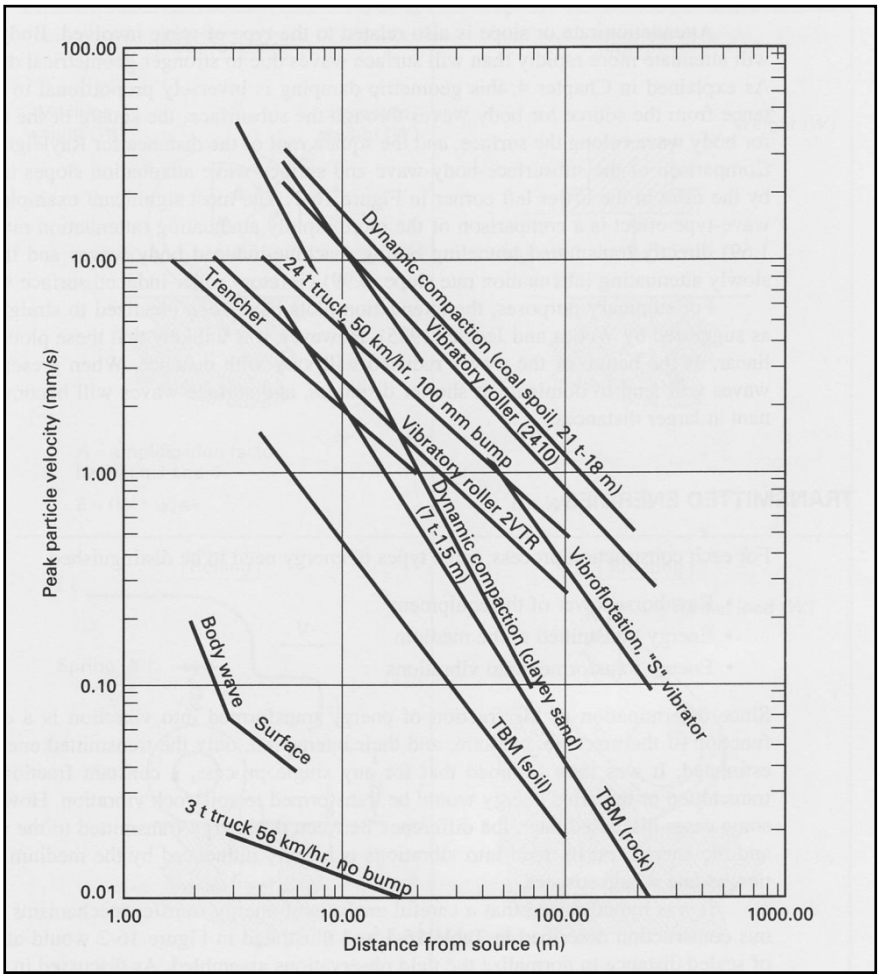

Figure 6.19 Attenuation of ground vibration with distance from mechanical equipment (source: p247 Construction Vibrations; Dowding 2000)

Management practices for noise and vibration

The commitments provided within the SGP EIS / SREIS relating to noise management are:

- Manage noise in accordance with the relevant EA conditions. Where night-time activities are planned (10 p.m. to 6 a.m.) and are likely to exceed the prescribed noise criteria, conduct prior consultation with affected parties [C304]
- Consult with those who may be affected by increased noise levels due to construction activities with reference to the type and timing of works [C305]
- Implement a grievance management system that responds to noise complaints. If necessary, undertake noise monitoring of construction activities to facilitate a response to the grievance [C307]
- Preferential selection of sites in sparsely populated areas [C309]
- Locate equipment associated with production wells and associated wellhead infrastructure at 200 m or more from a sensitive receptor [C311].

Further to these commitments, Arrow will not commence activities until an agreement is signed between Arrow and the relevant landholders. These written agreements are

determined on a case-by-case basis and may include alternative arrangements to address potential noise nuisance impacts if required.

In addition to the above management practices, the following noise control measures from *AS 2436-1981 Guide to Noise Control on Construction, Maintenance and Demolition Sites* are relevant to the construction activities covered by this amendment application:

- The best orientation of the activity to minimise noise will be selected, wherever practicable given other constraints
- The quietest plant and equipment that can be practically used to undertake the work will be selected
- Temporary noise barriers may be used depending on the situation
- Regular maintenance of equipment will be undertaken in order to keep it in good working order
- Construction work will preferentially occur within the daytime period (see Table 6-14 for timing of activities)
- Operators of construction equipment will be made aware of the potential noise impacts and of techniques to minimise noise emission through a process of operator education
- Reversing alarms within construction areas generally cannot be avoided for safety reasons. Consideration will therefore be given to sourcing 'quiet' white noise alarms whose tonal character diminishes quickly with distance and self-adjusting alarms which adjust emission levels relative to the local background noise level
- Horn signals will be kept to a low volume, where feasible.

As per the EPP (Noise) hierarchy of avoid, minimise and manage, the following practices have been implemented with regards to noise:

- Avoid – the infrastructure siting philosophy as discussed in Section 6.2 includes consideration of noise levels when determining proximity of infrastructure to sensitive receptors
- Minimise – reducing noise levels at sensitive receptors is achieved via the siting philosophy, the selection of quieter equipment during the procurement phase, and the implementation of the relevant EIS commitments as noted above
- Manage –Table 6.13 and Table 6.14 provide noise management plans specific to construction noise and drilling noise respectively. These tables will be a component of a broader Noise Management Plan that has been prepared for the SGP.

With regards to management practices associated with construction traffic and transport:

- Deliveries to construction sites will occur in compliance with an approved traffic management plan to minimise noise disturbance during the night or early morning; and
- Road maintenance will be carried out as required to keep the surface of the access roads in good order to minimise impulsive noise due to road irregularities.

Table 6.16 Construction Noise and Vibration Management Plan

Construction Noise and Vibration Management Plan	
Policy	• To construct the project in a manner that minimises the impact of noise and vibration on the surrounding environment, consistent with the requirements of the EA, the Environmental Protection (Noise) Policy and the EP Act.
Performance criteria	• No exceedance of derived noise criteria at sensitive receptors. • Respond to all noise-related complaints received from residents and landholders and implement noise mitigation measures where required. • Consultation with potentially affected sensitive receptors.
Implementation Strategy	• Continual refinement and improvement to maximise the separation distance between the construction activities and nearby sensitive receptors to minimise the potential for noise and vibration impact by continually: o Determining proximity of construction activities to sensitive receptors. o Determining the noise sources from construction activities. o Estimating the noise levels that would be experienced at various distances from construction activities. **For activities with limited potential to impact receptors at any time:** • Construction activities excluding drilling will occur during daylight hours from 7:00 to 18:00, 7 days per week, unless there is specific construction (shiftwork) or emergency requirements that require 24-hour continuous activity. **For activities occurring during daylight hours (07:00 to 18:00) with the potential to impact receptors:** • Determine whether noise from construction activities may exceed noise limits at potentially affected sensitive receptors. • Inform receptors who may experience increased noise levels of the expected duration and working hours of construction activities. Implement reasonable and practicable measures that can be taken to reduce construction noise and/or consider alternative arrangements within landholder agreements. • Implement reasonable and practicable measures that can be taken to reduce construction noise. **For construction activities that are planned to occur outside of daytime hours (18:00 to 07:00):** • Based on actual noise levels of equipment to be used during this period, use noise modelling results to determine the potential noise level experienced by receptors. • Consider the predicted noise level at the receptor and the duration of the construction activity in assessing the potential impact on receptors. • Inform receptors who may experience increased noise levels of the expected duration and working hours of construction activities. • Implement reasonable and practicable measures that can be taken to reduce construction noise and/or consider alternative arrangements within landholder agreements. **General** • Where construction noise levels exceed noise limits, consider mitigation measures to reduce the impact. This may include rescheduling construction activities, limiting the use of certain equipment or alternative arrangements with the affected receptors where reasonable and practicable. • In some circumstances the noisiest activities may be scheduled to occur when they would generate least disruption or managed through negotiation of alternative arrangements with the affected resident. • Utilisation of equipment with, as far as reasonably practical, the lowest sound power levels. • Where necessary, vehicles and equipment will be fitted with noise control devices. • All machinery and equipment are well maintained. • Construct and maintain noise barriers and enclosures around noisy equipment or along the noise-transmission paths where reasonably practicable.

Construction Noise and Vibration Management Plan	
	• Prepare a detailed site-specific Construction Noise Management Plan where construction noise at any location may adversely impact receptors. • Implement noise monitoring and ensure all noise complaints are recorded and addressed. **Vibration** • In the unlikely event that construction activities result in vibration impacts at sensitive receptors: • Assess whether vibration may adversely impact any structures. • Assess dilapidated dwellings prior to and following activities that are likely to result in vibration impacts. • In consultation with receptors/landowners, consider relocating any livestock that may be sensitive to vibration. • Conduct such activities only during daylight hours, Monday to Saturday. • Inform all potentially affected receptors of the expected timing and duration of activities. • Complaints received from external stakeholders will be investigated as soon as is practicable to do so. • The results of the investigation will be communicated to the complainant within 24 hours of the investigation being completed. • A record of the complaint and corrective actions will be recorded in the complaints database. • Rectify damage where investigations confirm activities are the cause and where repairs are necessary.
Monitoring and auditing	• Maintain records of all noise assessments, including potential reduction in noise levels experienced at potentially affected sensitive receptors following implementation of acoustic mitigation measures. • Receptor complaints relating to noise and vibration will be recorded and closed out. • Noise monitoring at relevant residences / receptors will be undertaken where required to determine potential impacts or at the request of the administering authority. • The method of measurement and reporting will be conducted in accordance with the DES Noise Measurement Manual and/or AS 1055.
Reporting and corrective actions	• Complaints relating to noise will be addressed promptly, with further investigations and reporting to the DES if required. • Noise monitoring will be conducted at the source of the complaint to determine compliance with noise limits. • Where noise limits are exceeded, Arrow will develop additional mitigation measures in consultation with the complainant. • All works that deviate from normal operating conditions will be reported and action initiated to prevent a recurrence of the incident. • Non-compliance and incident reports will be reviewed and closed out by senior management. • Regular reviews, recommendations and corrective actions shall be implemented.

Table 6.17 Drilling Noise Management Plan

Drilling Noise and Vibration Management Plan	
Policy	• To conduct drilling in a manner that minimises impact of noise and vibrations on the surrounding environment, consistent with the requirements of the EA, Environmental Protection (Noise) Policy) and the EP Act.
Performance criteria	• No unauthorised exceedance of derived noise criteria at sensitive receptors (as above). • Respond to all noise-related complaints received from residents and landholders and implement mitigation measures. • Consultation with potentially affected sensitive receptors.

Implementation Strategy	• Implement constraints planning to maximise the separation distance between drilling activities and nearby sensitive receptors and to minimise the potential noise and vibration impacts. • Drilling will not occur within 200 metres of a sensitive receptor. • Consult with landholders potentially affected by drilling noise (where drilling noise levels are greater than 33 dBA $L_{Aeq, adj, 15\ mins}$, measured outdoors). • Undertake site-based modelling for drilling utilising expected component noise sources and equipment specifications as required. • Should an exceedance of the relevant noise criteria be predicted, undertake noise modelling for reasonable and practicable noise mitigation measures, such as that the optimal mitigation measures can be selected to comply with noise limits. Utilise the noise model to calculate predicted reduction in noise levels experienced at potentially affected sensitive receptors before and after acoustic mitigation measures. • Notify the sensitive receptors of proposed activity and record outcomes from consultation.
Monitoring and auditing	• Maintain records of all noise assessments, including potential reduction in noise levels experienced at potentially affected sensitive receptors following implementation of acoustic mitigation measures. • Noise monitoring at relevant residences / receptors will be undertaken where required to ensure compliance or at the request of the administering authority. • Landholder complaints related to noise and vibration will be recorded and closed out. • The method of measurement and reporting will be conducted in accordance with the DES Noise Measurement Manual and/or AS 1055.
Reporting and corrective actions	• Complaints relating to noise will be addressed promptly, with further investigations and reporting to the DES if required. • Noise monitoring will be conducted at the source of the complaint to determine compliance with noise limits. • Where noise limits are exceeded, Arrow will develop additional mitigation measures in consultation with the complainant. • All works that deviate from normal operating conditions will be reported and action initiated to prevent a recurrence of the incident. • Non-compliance and incident reports will be reviewed and closed out by senior management. • Regular reviews, recommendations and corrective actions shall be implemented.

6.6 Waste management

The SGP EIS Assessment Report requested information about:

- Management of sewage
- Management practices that will minimise environmental harm caused by uncontrolled release of waste
- Consideration of bio-accumulation of chemicals in the environment from discharges of hydrotest water, sewage, CSG water and runoff
- Proposed reuse of soils, drill cutting, hydrostatic test water and waste or washout liquids
- Generation and management of hydrostatic test water including quantity, source, quality and additives, storage and disposal.

Management of sewage

Arrow will manage sewage in accordance with the EA Streamlined Model Conditions Waste 11 to Waste 14, noting:

- Treated sewage effluent would be released to land only after it met or exceeded secondary treated class C standards for treatment systems with a daily peck design capacity of less than 150 EP (i.e., any systems <21 EP not specifically identified as an ERA).

Furthermore, the selection of sites for mobile camps will consider the following objectives:

- No clearing of remnant vegetation
- Not to be located within 100 m of a watercourse.

Uncontrolled release of waste

Arrow will minimise environmental harm of its operations by upholding the commitments provided in the SGP EIS/SREIS with regards to uncontrolled release of waste (SREIS commitment number provided in parenthesis). In particular:

- Allocate bins for different waste streams to achieve solid waste segregation. Provide appropriate domestic waste disposal facilities at designated work sites to assist in segregation of waste (C051)
- Arrow will apply the following hierarchy of management options to all waste generated during the project activities (C058):
    - Source reduction: avoid, eliminate, change or reduce practices that result in the generation of wastes.
    - Reuse: reuse waste materials that are in their original form.

  - Recycling: where possible, send waste to appropriate facilities to convert waste into other usable materials.

  - Treatment and disposal: render waste safe by neutralisation or other treatment methods and dispose of waste products that can no longer be reused or recycled either through landfilling or incineration.

- When operating on black soils, collect, contain and store drilling fluids and waste (solid and liquid) on site in appropriate storage tanks until recycled, treated (if necessary) or disposed of offsite (C100).

- Store and manage all waste materials (domestic and industrial) in accordance with industry regulations and DES conditions. Use licensed waste management contractors. Conduct audits of disposal facilities, disposal permits and onsite operations to ensure adherence to regulations (C149).

- Store liquid waste generated (other than coal seam gas water and sewage) and periodically remove it for disposal or recycling (C226).

- Dispose of waste that cannot be reused or recycled at appropriately licensed facilities (C257).

- Dispose of food scraps in large skips or bins that prevent animal access. Empty these storage devices regularly in a manner that does not involve disposal to onsite trenches or waste dumps (C258).

- Store putrescible solid waste in covered containers to prevent odours, public health hazards and access by fauna (C330).

- Develop onsite waste storage areas in accordance with industry practice and relevant waste management regulations (C490).

- Handle, store and dispose of regulated wastes in accordance with relevant standards and the Environmental Protection (Waste Management) Regulation 2000 (C494).

Bio-accumulation of chemicals

The SGP EIS Assessment Report requested that the potential for bioaccumulation of chemicals in the environment from discharges of hydrotest water, sewage, CSG water and runoff is considered.

Any releases to the environment from these activities will first be treated to the appropriate standards as per the relevant EA conditions (e.g., Waste 6, 8, 9, 11, 12, 13, 16 and 18). Also, these conditions were included in the DES risk assessment and were ranked as a low residual risk (i.e., risk assessment line items 50 to 53 and 189). The actions provided in the DES risk assessment to reduce the unmitigated risk to the residual risk will be implemented.

For example, the following actions will be adopted:

- Erosion and sediment control measures will be in place and maintained

- Contaminant release limits for microbial quality and nutrients will be adopted to ensure sustainability

- Appropriate operation and maintenance of irrigation areas will occur as required, resulting in no runoff or ponding or aerosols

- Appropriate buffers of any releases to waters will be applied.

Reuse of soils, drill cutting, hydrostatic test water and waste or washout liquids

Reuse of soils

Strict soil handling and reuse practices will be adopted in areas of ground disturbance activities that will then be progressively rehabilitated soon after infrastructure installation (e.g., well pads and gathering RoWs), topsoil and subsoil will be stripped according to profile depths and stockpiled separately. The soil assessment conducted for the SGP EIS established that topsoil depths vary across the Project area from 0.3 – 1.5 m, and therefore stripping depths for disturbance areas will be subject to further field investigations during stripping activities.

The following EIS commitments are relevant to reuse of soils:

- Strip, salvage and stockpile topsoil near the work site separately to subsoils (in consultation with landowners). Ensure topsoil stockpiles are designed in accordance with best practise principles and are protected from erosion by wind, rain and floods. Stockpile topsoil to a maximum height of 2.5 m to maintain fertility and if stored for extended periods, sow with appropriate vegetation to maintain organic matter and microbial activity (C062).

- Locate soil stockpiles away from watercourses and wetlands to minimise reduce potential for sediment runoff to enter the watercourse or wetland (C170).

- Stabilise and revegetate long-term stockpiles as soon as possible to reduce potential for erosion (C542).

Drill cuttings

Drill cuttings are the rock formation that has been broken by the advancing drill bit and are brought to the surface by drilling fluid. The drilling fluid serves to lubricate the drilling assembly, bring the drill cuttings to the surface, keep the drill bit cool and clean, maintain hydrostatic pressure control of the well, and stabilise the hole being drilled.

The standard drilling fluid used by Arrow is water based. Potassium chloride is the principal salt component and it is often used to help control swelling clays.

Organic and mineral based polymers (volatile and semi-volatile free) and clays may be added to the base fluid to raise the viscosity and assist in the removal of drill cuttings. Drilling fluid brought to the surface is stored temporarily in appropriate fluid storage systems, such as tanks for in situ treatment or disposal. Drilling fluids are selected and managed to ensure all products are used in accordance with the manufacturer's recommendations and relevant Safety Data Sheets (SDS). The name, type and quantity of each drilling fluid additive used on each well are recorded by Arrow.

The following additives are used to drill wells on existing Arrow PLs:

- Potassium chloride
- Biocide (glutaraldehyde based)
- The above are mixed in low concentrations with produced water, RO processed water or rain-water.

At the completion of drilling the well, Arrow displaces the wellbore volume once with the following an oxygen scavenger and corrosion inhibitor (in addition to above list). These are biodegradable and provide temporary protection for the well prior to it being brought online.

The volume of drill cuttings will depend on the depth and diameter of the well. The depth range for the wells proposed for this amendment application is 200 - 800 m, with an average depth of 450 - 500 m. To minimise the volume of solid waste from drilling activities going to a licensed landfill, Arrow's preference will be for on-site spreading and / or mix-bury-cover of the residual drilling material. This will occur in accordance with the relevant EA conditions and other landholder conditions.

Other activities which Arrow undertakes related to the minimisation and management of waste include the use of CSG water for dust suppression, construction and drilling materials; discharge of treated effluent or greywater to land; use of green waste for rehabilitation or sediment control; and supply of CSG water to third party. These activities are undertaken as part of Arrow's activities in compliance with the relevant EA and are consistent with the SMC.

Hydrostatic test water

As discussed in Section 5.5.2 of the SGP EIS, water used for hydro-testing of pipelines will be diverted to holding dams for re-use and/or disposal through the CSG water management system. Water quality will be tested prior to release to ensure hydrotest water that is discharged or recycled for secondary uses meets relevant statutory water quality guidelines.

Any hydrostatic test water that is released to land will meet the criteria in SMC Waste 6. Water will also be obtained from third party providers if required. On average, 50-60 litres of water are used to test each metre of gas gathering line and 10-20 litres of water is used to test each metre of water gathering line.

Waste or washout liquids

Waste or washout liquids from production facilities will typically be stored and periodically removed by licensed tanker to nearby integrated processing facilities for treatment prior to disposal or recycling (as per EIS/SREIS Commitment C226).

6.7 Air quality

The SGP EIS Assessment Report requested a site-specific air quality assessment for each proposed infrastructure location that describes point source and fugitive emissions. This EA amendment application does not include any new gas compression facilities and therefore the requirements from the EHP Assessment Report regarding air quality assessments is not relevant to this amendment application.

Nevertheless, the proposed construction activities, ground disturbance, vegetation clearing, flaring and gas and diesel generators will generate dust and other emissions and therefore information of relevance is provided below.

Environmental values

The following legislation, policy and guidelines are relevant to identifying values and mitigating and managing impacts on air quality for the project.

- *Environmental Protection Act 1994* (EP Act): The objective of the EP Act is to protect Queensland's environment by promoting ecologically sustainable development. The Environmental Protection Regulation 2008 provides a mechanism to enforce the EP Act and allows for an assessment of the risk that an environmentally relevant activity poses to ESAs.

- *Environmental Protection Policy (Air) 2019* (EPP (Air)): This policy sits under the EP Act and aims to protect and enhance environmental values relating to Queensland's air environment. The EPP (Air) provides air quality objectives for the protection and enhancement of the environmental values.

In accordance with the EPP (Air), the environmental values in and around the project area include:

- The qualities of the air environment that are conducive to protecting the health and biodiversity of ecosystems

- The qualities of the air environment that are conducive to human health and wellbeing

- The qualities of the air environment that are conducive to protecting the aesthetics of the environment, including the appearance of buildings, structures and other property

- The qualities of the air environment that is conducive to protecting agricultural use of the environment.

Regulatory air quality parameters, objectives and environmental values relevant to the project are provided in Table 6.15.

Table 6.18 Relevant air quality objectives

Substance		Objective (µg/m³)	Environmental Value	Time Period	Regulatory Agency	Allowable Exceedance (days per annum)
Carbon monoxide (CO)		11,000	Health	8 hr	EPP (Air)/NEPM	1
Nitrogen dioxide (NO_2)		250	Health	1 hr	EPP (Air)/NEPM	1
		62	Health	Annual	EPP (Air)/NEPM	n/a
		33	Health and biodiversity of ecosystems	Annual	EPP (Air)	n/a
Ozone (O_3)		210	Health	1 hr	EPP (Air)/NEPM	1
		171	Health	4 hr	EPP (Air)/NEPM	1
Total suspended particulate matter		90	Health	Annual	EPP (Air)	n/a
Particulate matter < 10 µm (PM_{10})		50	Health	24 hr	EPP (Air)/NEPM	n/a
Particulate matter < 2.5 µm ($PM_{2.5}$)		25	Health	24 hr	EPP (Air)	n/a
		8	Health	Annual	EPP (Air)	n/a
Sulfur dioxide		570	Health	1 hr	EPP (Air)/NEPM	1
		229	Health	24 hr	EPP (Air)/NEPM	1
		57	Health	Annual	EPP (Air)/NEPM	n/a
		31	Agriculture	Annual	EPP (Air)	n/a
		21	Health and biodiversity of ecosystems (for forests and natural vegetation)	Annual	EPP (Air)	n/a
Dust deposition		120 (mg/m²/day)	Nuisance	Monthly	Informal criterion	n/a
Odour	Tall stacks	0.5 (OU)	Nuisance	1 hr	Qld guideline	44
	Ground level/short stacks	2.5 (OU)	Nuisance	1 hr	Qld guideline	44

Existing environment

This section provides a description of the relevant air pollutants, the climate and meteorology of the region, and the air quality of the regional airshed including concentrations of key pollutants.

The study area has a climate typical of subtropical regions and is summarised as follows:

- Mean monthly minimum temperatures range from 3.6°C in winter (June to August) to 21°C in summer (December to February)
- Mean monthly maximum temperatures range from 17°C in winter to 35°C in summer
- Rainfall displays a consistent pattern across the study area and ranges from an average of 20 to 40 mm in winter to 70 to 100 mm summer
- Evaporation rates are up to approximately five times higher in summer months than in winter months
- Wind patterns across the Dalby area are characterised by easterly/westerly flow in the afternoons. There is a high frequency of calm (less than 0.5 m/s) and very light winds across the region. Calm winds form 19% of morning winds (at 9:00 am) and 9% of afternoon winds (at 3:00 pm) at Dalby
- Mean daily solar exposure changes throughout the year in line with the seasons, with values ranging from 12.1 MJ/m² in winter (June) to 25.3 MJ/m² in summer (January). Evaporation rates are highest during the summer months because of higher temperatures and solar radiation. Daily evaporation rates range from 3.2 mm in winter to 7.8 mm in summer
- Relative humidity varies with season, increasing through summer and autumn before reaching a maximum in winter (June) and falling in spring. The lowest relative humidity occurs in September and October (spring). Relative humidity is generally higher at 9 am (56 % to 74 %) and lower at 3 pm (38 % to 49 %)
- Around 20 thunderstorm days per year occur within the study area, often involving strong winds, heavy rainfall and flooding.

Relevant air pollutants

The main air pollutant sources will be combustion emissions from well head gensets, power generation for drill rigs and construction activities. Air pollutants released from these sources are:

- Oxides of nitrogen (NOx)
- Carbon monoxide (CO)
- Particulate matter (PM).

Emissions of sulfur dioxide and volatile organic compounds from these sources are negligible.

Ozone is a regional air pollutant that is formed from photochemical reactions between NO_x and VOCs. Ozone is mainly relevant for condensed urban areas and in constrained airsheds (e.g., Sydney, Southeast Queensland). Regional assessment of ozone has been conducted for the Surat Basin and is well within recommended air quality guidelines for the entire region even when considering planned project expansions within the region (SGP EIS and SREIS, Arrow Energy 2012, 2013). The project is expected to have negligible impact on regional ozone levels.

Also, as CSG contains negligible odorous compounds (e.g., sulfur compounds) and combustion is one of the most effective methods for controlling odour, nuisance impacts from odour at the production testing wells are not expected from the project emissions.

The main air pollutant of concern from combustion (flaring and drill rigs) is nitrogen dioxide (NO_2). Nitrogen dioxide is formed in gas engines through 'thermal NO_x'. Thermal NO_x is the process of thermal dissociation and subsequent reaction of nitrogen (N_2) and oxygen (O_2) molecules in the combustion air to form NO_x.

Combustion also results in carbon monoxide (CO) emissions through incomplete combustion of fuel. However, as the combustion efficiency of flares and diesel engines is so high, and background levels of CO are so low, potential impacts from CO emissions are negligible.

Particulate matter emissions are likely to be caused by construction activities and due to the disturbance and handling of material. Construction emissions will be infrequent and transient and will be managed through best practice measures to avoid dust emissions through a Construction Environmental Management Plan (see 'Management practices' below for further details).

The key pollutants identified under applicable legislation that are relevant to CSG activities are described in Table 6.16.

Table 6.19 Key air pollutants relevant to CSG activities

Pollutant	Description/Potential Impact
Carbon monoxide (CO)	Produced from incomplete combustion of carbon-based materials and harmful to human health when inhaled.
Oxides of nitrogen (NO_x)	Oxides of nitrogen include nitric oxide (NO) and nitrogen dioxide (NO_2). The ratios of these pollutants post-release are determined by photochemical activity in the atmosphere, and pollutants can be converted to a more toxic form, e.g., conversion of NO to NO_2 in the presence of oxygen. NO_2 is the primary pollutant of concern associated with the combustion of gas. Biogenic sources of NO_2 are from soil, vegetation, and bushfire emissions. Net releases of NO_2 into the air can contribute to acid rain, eutrophication (increased nutrient load) of watercourses and formation of photochemical smog. Eutrophication is likely to be a potential issue due to excess nutrients from agricultural runoff and sewage discharge potentially resulting in inputs of phosphorus and nitrogen to watercourses.
Photochemical smog (O_3)	O_3 is the primary pollutant of concern within photochemical smog and is commonly used as a key indicator of smog. Volatile organic compounds (discussed below) can contribute to reactions that form O_3 by reacting with nitric oxide and NO_2 in the presence of sunlight. O_3 is a strong oxidiser and is active in converting nitric oxide to the more hazardous NO_2. Significant exposure to O_3 can cause damage to living cells.
Particulate matter	Particulate matter refers to suspended solids or liquids in air. Particulate matter is emitted via mechanical processes such as wind erosion and vehicle disturbance of dust or chemical processes such as incomplete combustion or formed as a secondary product of photochemical smog reactions. Particulate matter is classified by size. Particulate matter less than10 µm (PM_{10}) and particulate matter less than 2.5 µm ($PM_{2.5}$) can remain suspended in the air for many days and are generally associated with greater health impacts than larger particle sizes. These small-sized particles can enter the respiratory tract and impact human health. Deposited particulate matter (dust) can also impact amenity through accumulation on surfaces such as laundry and cars.

Pollutant	Description/Potential Impact
Sulfur dioxide (SO_2)	SO_2 is formed when substances containing sulfur are burnt. Inhalation of high concentrations of SO_2 can lead to respiratory and other illnesses, and SO_2 is a major precursor to acid rain. The combustion of diesel and the operation of large coal-fired power stations within the study area will produce emissions of SO_2.
Volatile organic compounds (VOC)	VOCs include several organic compounds emitted from natural and anthropogenic processes, some of which are toxic. VOCs can contribute to photochemical smog when combined with NO_x in the presence of sunlight. CSG contains negligible VOCs.
Odour	Odour can lead to annoyance and some potential health effects. Hydrogen sulfide is a key source of odour; however, no significant impacts are expected from the project as hydrogen sulfide is present only in trace quantities in the gas stream. Flaring and unplanned releases are expected to be infrequent, and it is not anticipated that odour will cause nuisance. Odour has not been considered further in the assessment of air quality.
Carbon dioxide (CO_2)	CO_2 is created through natural biological processes and as a by-product of combustion.

Existing air quality

Table 6.17 provides the existing maximum ground level concentrations of pollutants modelled within the study area (as per the SGP EIS; Arrow Energy 2013 and updated air quality assessment completed by SLR Consulting Australia Pty Ltd in 2018). Health-based EPP (Air) objectives are provided for reference and indicate that existing ground level concentrations of all key pollutants within the study area would be below the objectives.

Table 6.20 Existing maximum ground level concentrations of key pollutants

Pollutant	EPP (Air) Objective ($\mu g/m^3$)[a]	Averaging Period	Existing Concentration ($\mu g/m^3$)
Nitrogen dioxide (NO_2)	250[b]	1 hr	85[c]
	62	Annual	10[c]
Ground level ozone (O_3)	210[b]	1 hr	136[e]
	160[b]	4 hr	123[e]
Sulfur dioxide (SO_2)	570	1 hr	40.0[d]
	229	24 hr	5.7[d]
	57	Annual	2.9[d]
Carbon monoxide (CO)	11,000	8 hr	2,840[c]
Particulate matter (PM_{10})	50	24 hr	25.7[d]
Particulate matter ($PM_{2.5}$)	25	24 hr	6.8[d]
	8	Annual	3.6[d]

[a] Health-based objectives at standard temperature and pressure (0°C, 1 atm).
[b] Allowed one-day exceedance per annum.
[c] Derived from an updated review of air quality monitoring data from the Toowoomba air quality monitoring station and the Darling Downs Queensland Monitoring Stations completed by SLR Consulting Australia Pty Ltd in 2018
[d] Average of DERM monitoring station results for Toowoomba with the exception of SO_2, which is taken from Flinders (DERM, 2007, DERM, 2008, DERM, 2009, DERM, 2010). The ninetieth percentile of the data was taken for sub-annual averaging periods.
[e] Second highest day per annum.

Risks and impacts

The key emission sources for the activities addressed in this amendment application are:

- CSG combustion emissions from well head gensets
- Drill rig diesel combustion emissions
- construction activities (e.g., clearing, grading, excavation, vehicles travelling on unpaved roads).

Operation of Wellhead gensets

Site specific air quality modelling and assessment was conducted for the Surat Gas Project petroleum leases by SLR Consulting Australia Pty Ltd in 2018. The main air pollutant of concern for CSG combustion emissions is NO_x. The air quality assessment showed that the maximum predicted incremental NO_2 concentrations are below the 1-hour average ground level NO_2 criterion of 250 µg/m^3 within approximately 110 m of the source. If the conservative background concentration of 85 µg/m^3 was included, the 1-hour NO_2 criteria occurs within 200 m of the well pad as shown in Figure 6-13.

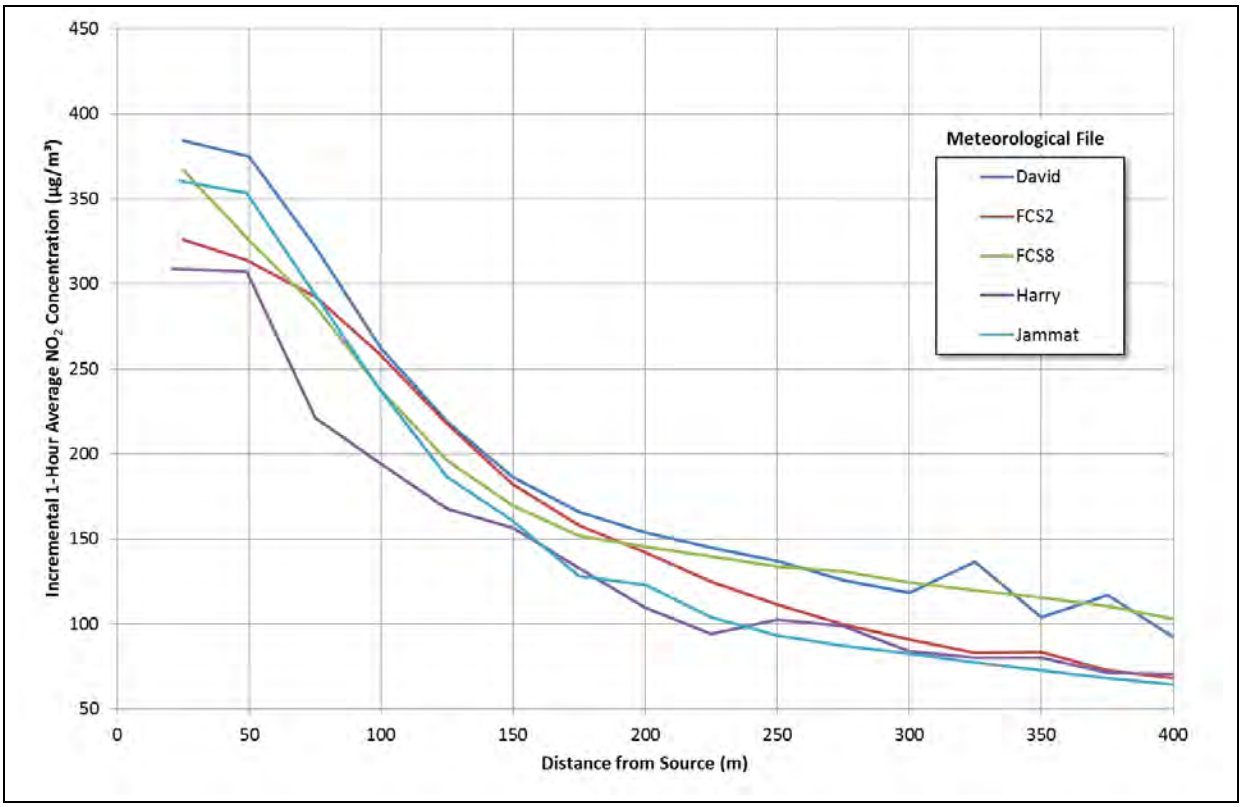

Figure 6.20 Maximum Predicted Downwind NO2 concentrations – dewatering pump genset emissions (Source: SLR Consulting (2018), Surat Gas Project – Air Quality Impact Assessment (S00-SPGO-ENV-REP-00007)

As previously noted, all well pads are located further than 200 metres from sensitive receptors. As such, the air quality assessment results for NO_2 do not show a significant risk for adverse air quality impacts.

The air quality assessment also concludes that since CO emissions from the well head gensets are less than 10% of the NO_x emissions, and the CO air quality guideline is much higher than those for NO_2, there would be no risks associated with CO emissions from the well head gensets.

Drill rig diesel combustion emissions

The main source of air pollutant emissions from drilling activities is from diesel power generation for drilling operations. NO_x emissions from diesel combustion are of most relevance to air quality impacts.

Updated air quality modelling and assessment for the Surat Gas Project by SLR Consulting Pty Ltd in 2018 shows that the maximum predicted incremental NO_2 concentrations are below the 1-hour average ground level NO_2 concentration of 250 µg/m³ within approximately 200 metres of the rig (see Figure 6.14). These predictions do not include background NO_2 levels, which have been conservatively estimated at 85 µg/m^3. However, the rigs only operate for limited time periods at each well location (approximately 3 - 5 days). The potential for adverse air quality impacts is therefore not considered a significant risk.

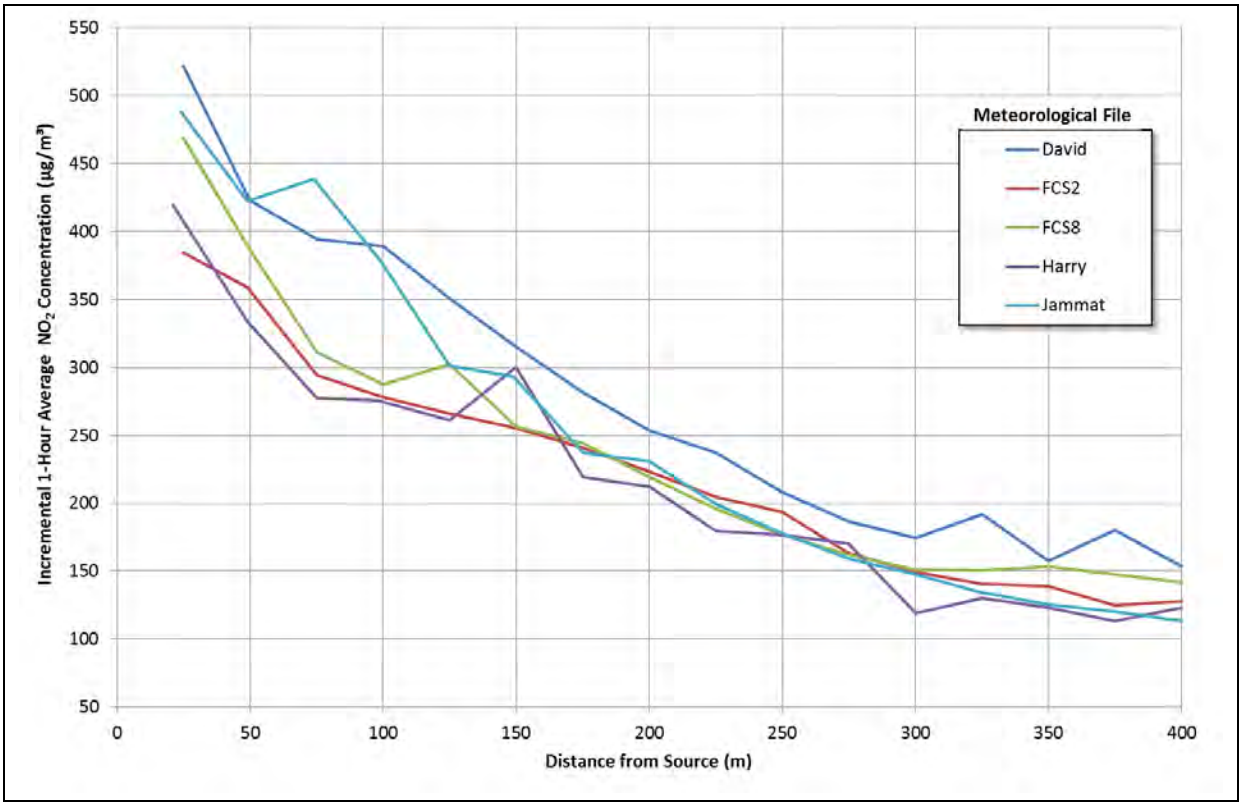

Figure 6.21 Maximum Predicted Downwind NO2 concentrations – drill rig emissions (Source: SLR Consulting (2018), Surat Gas Project – Air Quality Impact Assessment (S00-SPGO-ENV-REP-00007)

Most wells are located more than 200 m from a sensitive receptor, with almost all located more than 400 m from a sensitive receptor. In addition, noise impacts from drilling activities constrains how close drill rigs can operate to sensitive receptors, with unacceptable operational noise impacts predicted for sensitive receptors located less than 400 m from a well site. Given this, drill rig air assessment results for NO_2 do not indicate a significant risk for adverse air quality impacts. This is consistent with DES's guidance notes for assessment of drill rigs (DES, 2016):

> *Any fuel burning or combustion facility that is temporary or mobile is not considered a significant risk to the environment because the emissions are occurring on a temporary basis within the airshed (e.g., emissions from a generator used on a drilling rig, or standby or emergency generators). It is not necessary or desirable to condition emission limits or require monitoring of emissions from a temporary or mobile facility. A fuel burning or combustion facility that is temporary or mobile or does not meet the 500 kg in an hour threshold is covered by environmental nuisance provisions.*

Given that the CO emissions from the drill rigs are less than 20% of the NO_x emissions and the CO guideline is much higher than those for NO_2, the assessment indicates there is no significant risk associated with CO emissions from the drill rig.

Construction activities

The potential for air quality impacts from SGP construction activities were assessed by SLR Consulting Pty Ltd in 2018.

The key potential air pollution and amenity issues associated with fugitive dust emissions from construction related activities are:

- Nuisance due to dust deposition (soiling of surfaces) and visible dust plumes; and
- Elevated suspended particulate concentrations (PM10).

Modelling of dust from construction activities is generally not considered appropriate, as emission rates can vary significantly depending on a combination of the activity and prevailing meteorological conditions (i.e., rainfall and wind speed), which cannot be reliably predicted.

A qualitative assessment was therefore performed of the potential risks to air quality associated with dust from construction activities associated with the SGP, based on the IAQM Guidance on the Assessment of Dust from Demolition and Construction developed in the United Kingdom by the Institute of Air Quality Management (IAQM 2014).

The risk-based assessment of potential heath and nuisance impacts from fugitive dust emissions associated with construction of the major infrastructure sites proposed as part of the SGP, concluded that there is a negligible risk of any adverse impacts due to the large separation distances between these sites and nearby sensitive receptors. The fugitive dust risk assessment also concluded that there is a negligible risk of adverse air quality impacts associated with the construction of well pads, gathering pipeline and access roads associated with the SGP. Nonetheless, Arrow implements a range of dust mitigation measures to ensure that adverse air quality impacts do not occur during construction activities, including the use of water carts and minimising the extent of disturbed areas.

To improve Arrow's dust management practices, SLR Consulting Pty Ltd were also commissioned to conduct air quality modelling and assessment of wheel generated dust due to unpaved road travel associated with a typical rig movement (~ 40 trucks per day and 10 light vehicles per day travelling on an unpaved road). The air quality assessment shows that short term air quality goals for PM10, PM2.5 and dust deposition are achieved within 50 metres offset distance from the unpaved road. Please refer to Figure 6-15, Figure 6-16 and Figure 6-17 for air quality modelling results from rig movements on unpaved roads.

Similar to the management of infrastructure construction dust emissions, Arrow implements a range of dust mitigation measures to further ensure that adverse air quality impacts do not

occur during rig movements, including use of water carts, limiting speed near identified sensitive areas and route optimisation to avoid nearest sensitive receptors.

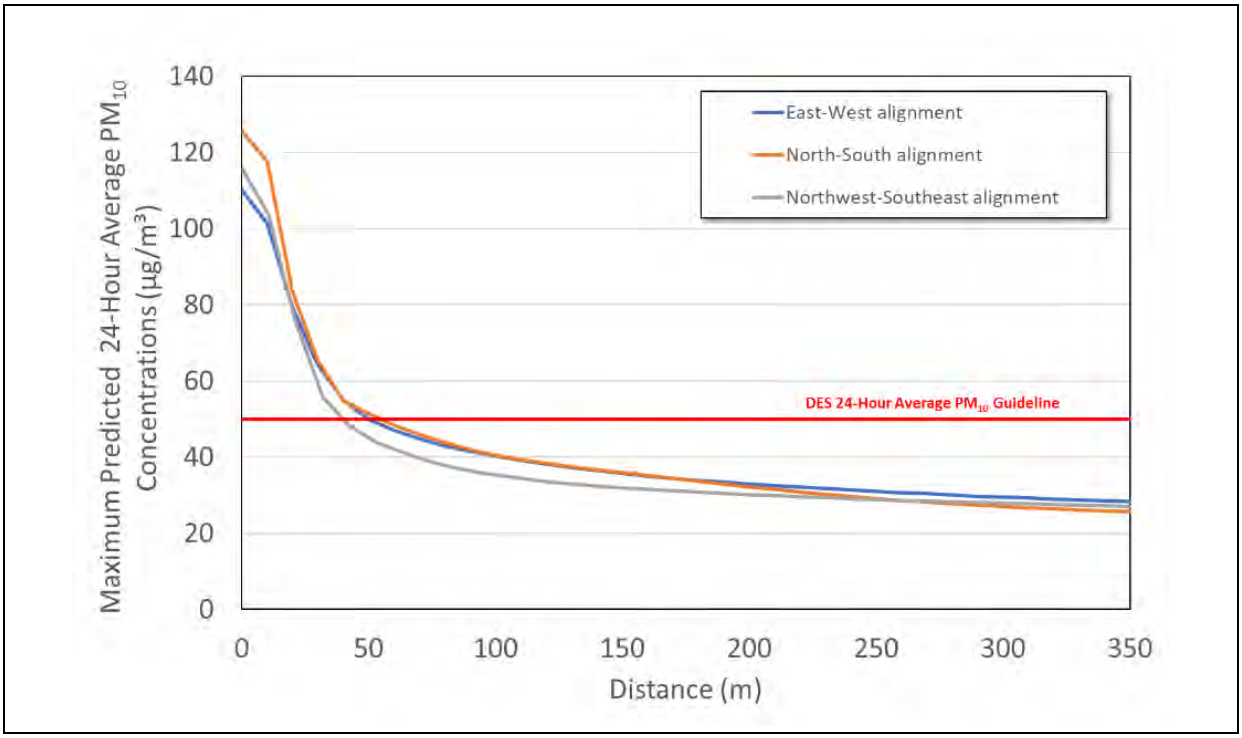

Figure 6.22 Maximum PM10 concentrations at distances from an unpaved road due to a rig movement (Source: SLR Consulting, Memorandum - Estimation of Separation Distance Unpaved Road Usage, 27 March 2020)

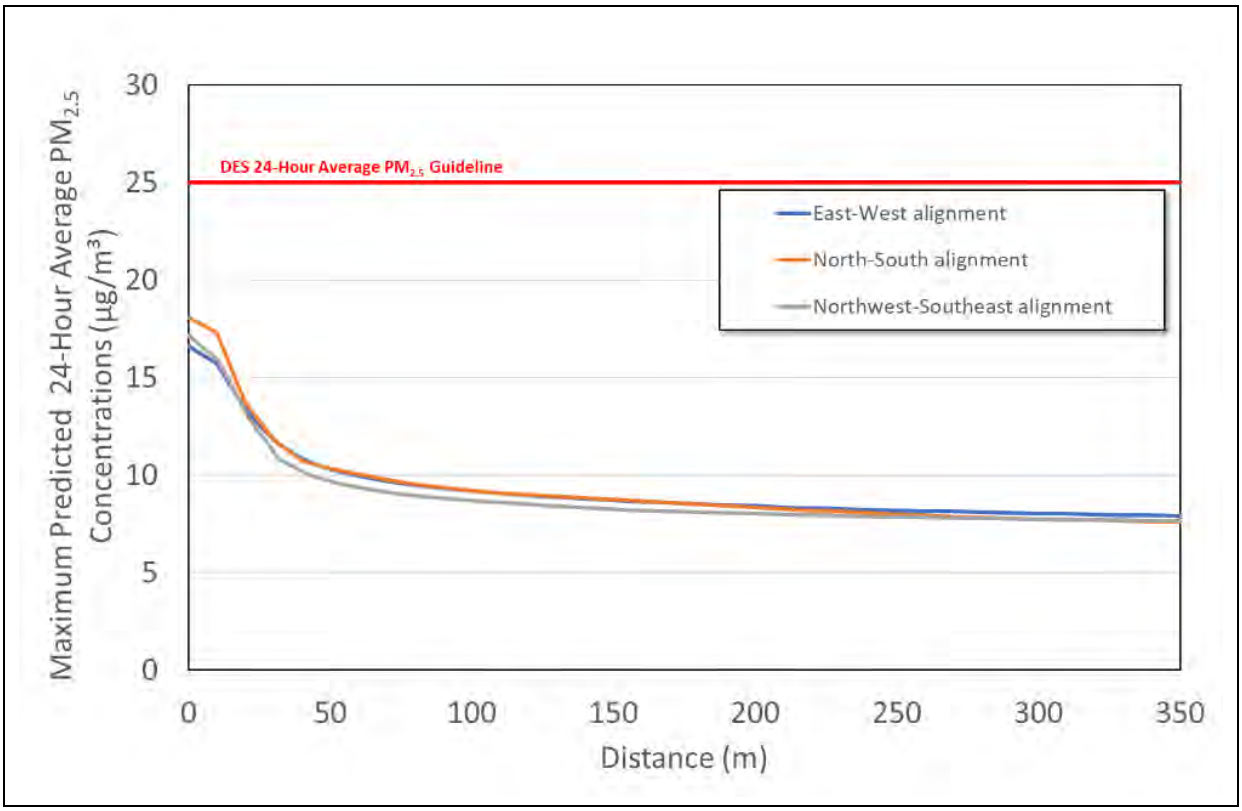

Figure 6.23 Maximum PM2.5 concentrations at distances from an unpaved road due to a rig movement (Source: SLR Consulting, Memorandum - Estimation of Separation Distance Unpaved Road Usage, 27 March 2020)

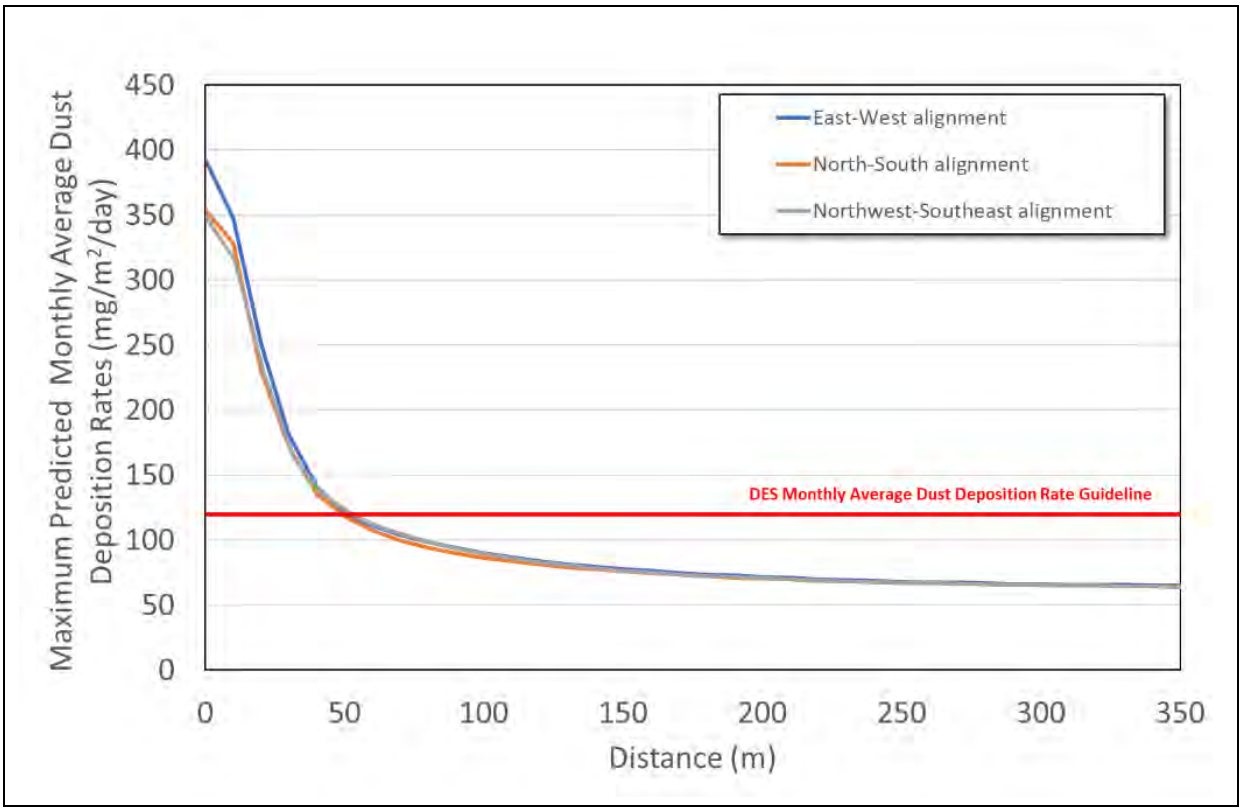

Figure 6.24 Figure 6-17 - Maximum monthly dust deposition rate at distances from an unpaved road due to a rig movement (Source: SLR Consulting, Memorandum - Estimation of Separation Distance Unpaved Road Usage, 27 March 2020)

Management practices

The impacts of dust during construction activities will be managed through the Construction Environmental Management Plan and subsidiary plans (e.g., Erosion and Sediment Control Plan, Air Quality and Dust Management Plan). These plans will be developed during FEED with reference to the EIS commitments included in Table 6.18 below and relevant EA conditions.

Table 6.21 Air Quality Management EIS Commitments

SREIS Number	Commitment
C001	Conduct site-specific air quality modelling once site locations are known to ensure show demonstrate that project-related air emissions meet EPP (Air) objectives at the nearest sensitive receptor
C002	Select equipment with consideration for low emissions to air (NOx, SOx), high energy efficiency and fuel efficiency
C012	Implement dust suppression measures for roads and construction sites where there is a potential for to ensure that dust to does not cause a nuisance effects
C013	Cover dust-generating materials prior to transportation on public roads
C016	Prevent venting and flaring of gas as far as practicable and where safe to do so.
C017	Manage odours so that they do not cause a nuisance or harm to sensitive receptors
C018	Optimise gas-engine operation to minimise duration of operation at low-efficiency levels that may result in increased emissions. maintain high efficiency levels to keep greenhouse gas and air emissions as low as practicable

C031	Arrow will manage its impacts to maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council
C034	Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls, established based on the sensitivity of the surrounding environment
C394	Develop and implement mitigation measures that address the potential impacts relating to air and noise emissions through environmental management plans
C511	Monitoring and inspection of mitigation and management measures will be implemented to ensure that the calculated ground-level concentrations of relevant pollutants do not exceed EPP (Air) objectives throughout the lifetime of the project

6.8 Greenhouse Gas

The SGP EIS Assessment Report requested details of a greenhouse gas management strategy, including:

- Potential impacts of the project on state and national GHG inventories
- Best practice methods for minimisation of GHG emissions
- Commitments to continuous improvement of GHG emissions.

GHG Management Framework

With regards to the strategy, greenhouse gas is managed using Arrow's Greenhouse Gas Standard under Arrow's HSEMS. This company-wide standard sets out Arrow's approach and requirements to managing greenhouse gas and energy consumption. The Standard requires all projects to develop a greenhouse gas and energy management plan (GHGEMP) to:

- Avoid, minimise and mitigate greenhouse emissions,
- Monitor controls and emissions, standardise reporting, and
- Establish an audit program.

Along with the Greenhouse Gas Standard, Arrow also has a mandatory Venting and Flaring Standard under the HSEMS. The Venting and Flaring Standard requires that:

- Intentional venting and flaring are reduced to as low as practical
- Venting is restricted to situations where flaring is not technically possible or safe.

For major projects, such as the SGP a greenhouse gas and energy management plan (GHGEMP) are developed during project maturation stages such that greenhouse gas emissions and energy efficiency are considered during each stage of project scoping and design. Arrow also operates under an operational GHGEMP which covers all of Arrow's operational assets. Once a project enters Execution stage the management of greenhouse gas emissions and energy is incorporated into the operational GHGEMP.

A GHGEMP has been developed for the SGP. The GHGEMP builds on the specifics of the greenhouse gas emissions calculated for the EIS/SREIS but is updated to reflect changes to the project definition and design. The GHGEMP will be further updated during FEED and will be incorporated into the operational GHGEMP once the project commences. It is noted that the GHGEMP does not consider greenhouse gas emissions and energy management from an EA or petroleum lease boundary perspective but rather a whole of project perspective.

During Concept Select, the SGP was defined as illustrated in Figure 6-18.

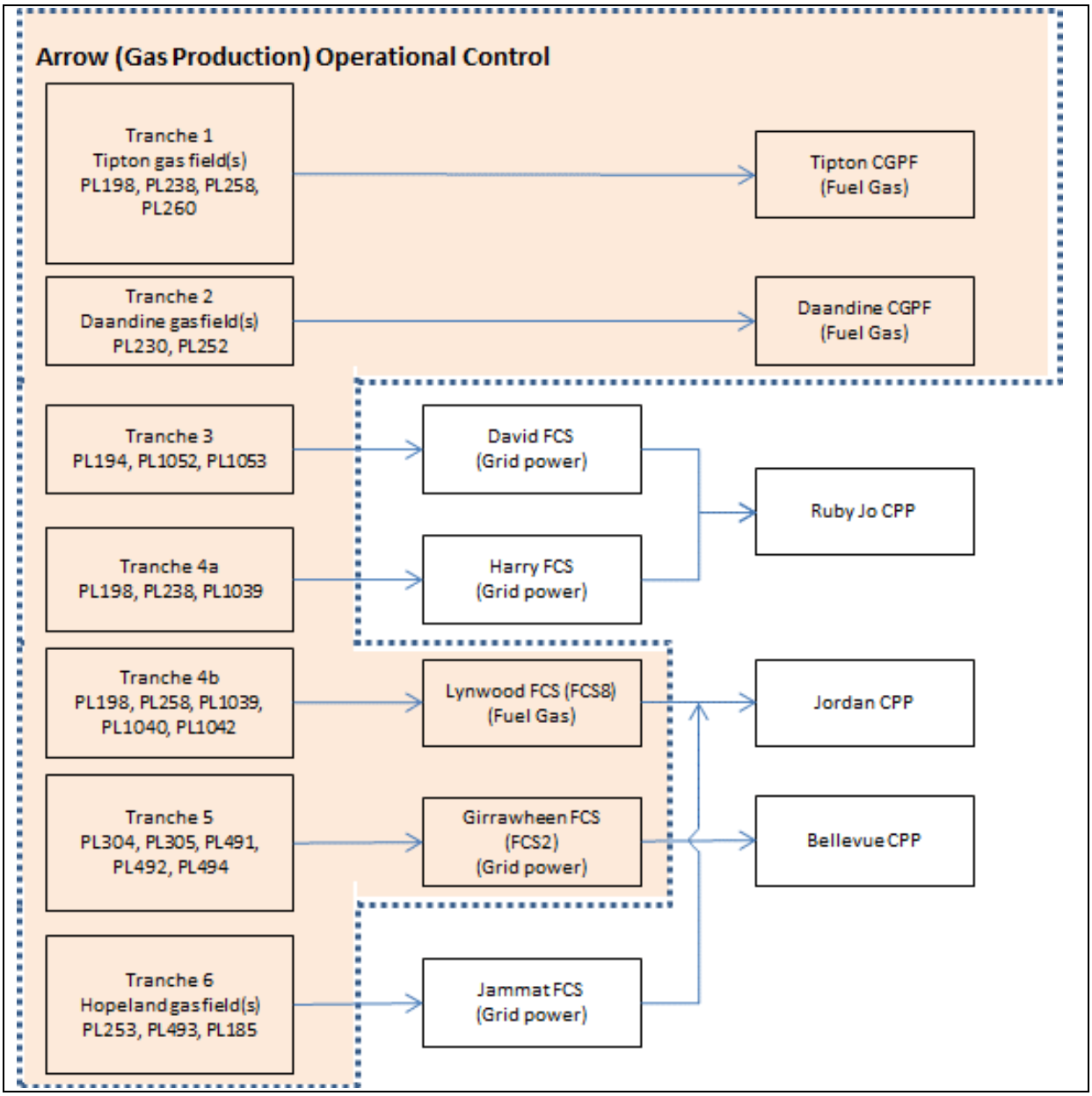

Figure 6.25 Surat Gas Project Infrastructure Interconnections and Arrow Controlled Facilities

Potential Impacts of the Project on State and National GHG inventories

Summary greenhouse gas emissions are presented in Figure 6-19 showing forecast scope 1 and scope 2 GHG emissions for sources within Arrow's operational control associated with the Surat Gas Project.

The distribution of scope 1 and 2 GHG emission sources over the life of the project is presented in Figure 6-20.

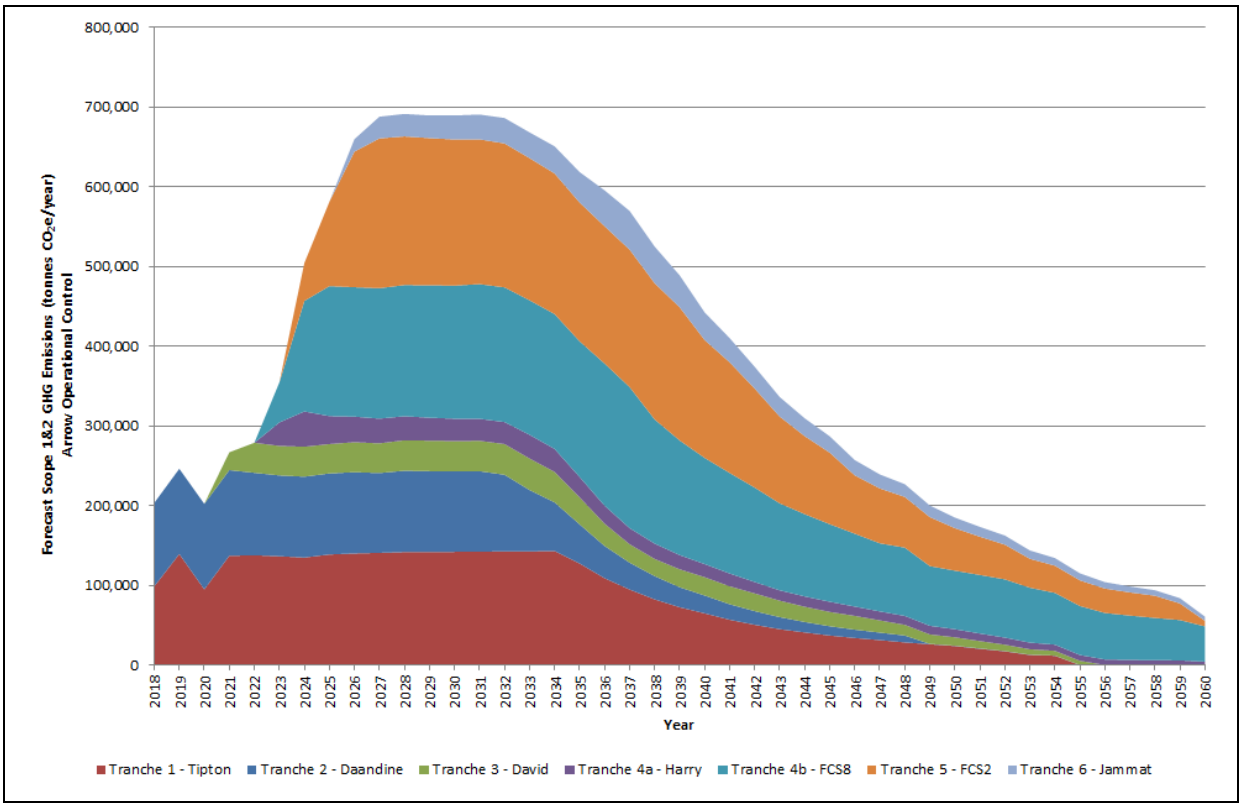

Figure 6.26 Forecast Scope 1 and 2 Greenhouse Gas Emissions - Surat Gas Project

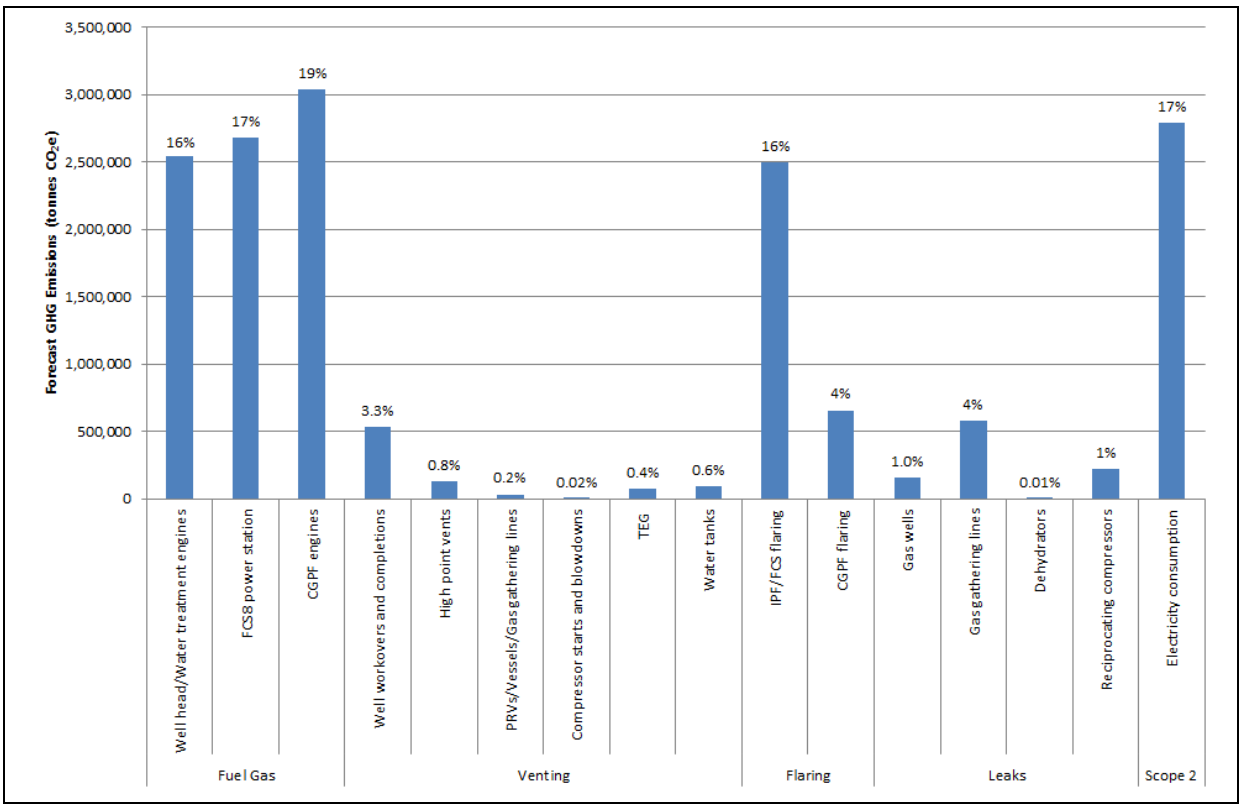

Figure 6.27 Forecast Scope 1 and 2 GHG Emissions – Source Apportionment

Annual average emissions over the life of the Project (2018 – 2060) are summarised as follows:

- Scope 1 emissions: 307,829 tonnes CO2-[e]
- Scope 1 & 2 emissions: 372,796 tonnes CO2-[e.]

The contribution of the Surat Gas Project to the state and national total greenhouse gas emissions are presented in Table 6.19. It is noted that GHG emissions associated with the Hopeland EA (PL253) are a portion of the total SGP GHG emissions. While contributions to total state and national GHG emissions appear minor GHG emissions are managed to ensure emissions are controlled as low as reasonably practical.

Table 6.22 Contribution of the Surat Gas Project to State and National Total GHG Emissions

Boundary	Total Annual GHG Emissions	Units
Surat Gas Project	372,796	tonnes CO_2e/annum
Queensland [a]	161,200,770	tonnes CO_2e/annum
Australia [a]	530,840,900	tonnes CO_2e/annum
Contribution to State Annual Total	**0.23%**	
Contribution to National Annual Total	**0.07%**	

[a] Source: Department of Industry, Science, Energy and Resources, *National Greenhouse Gas Inventory – Kyoto Protocol classifications*, 2017 inventory year (latest available). https://ageis.climatechange.gov.au/

Lifecycle greenhouse gas emissions from the Surat Gas Project from coal seam gas produced shows that electricity produced using Surat Gas Project gas is:

- 30% less greenhouse gas intensive than coal fired electricity generation if the gas is used in an open cycle turbine
- 50% less greenhouse gas intensive than coal fired electricity generation if the gas is used in combined cycle gas turbine technology.

This is consistent with lifecycle greenhouse gas emissions assessment for coal seam gas produced from the Surat Gas Project derived by the CSIRO in their report, *Whole of Life Greenhouse Gas Emissions Assessment of a Coal Seam Gas to Liquified Natural Gas Project in the Surat Basin, Queensland, Australia* (Schandl *et al*., 2019). The comparison of lifecycle GHG emissions from the Surat Gas Project compared to coal fired generation is presented in Figure 6-21.

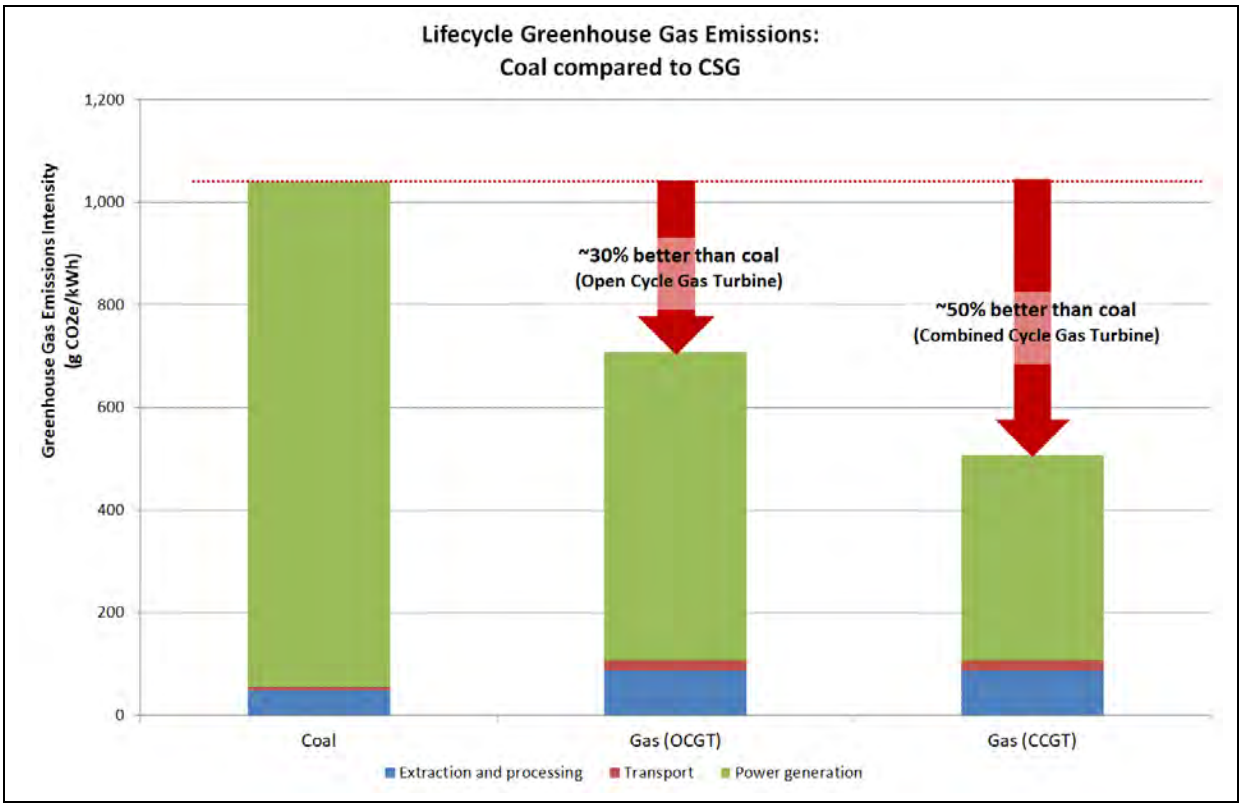

Figure 6.28 Forecast Scope 1 and 2 GHG Emissions – Source Apportionment

In addition, natural gas is also a potential complement to renewable energy in that it can provide cover for the intermittency of power generated by renewables. In a review by the United Nations Economic Commission for Europe in 2019, it is reported that the ability of natural gas to provide a relatively low carbon backup at peak energy usage times rather than providing traditional baseload power may prove to be the greatest contribution from natural gas to the forecast low carbon energy transition[3].

Considering the lower lifecycle GHG emissions intensity from coal seam gas produced by the SGP compared to coal and that natural gas facilitates a greater penetration of intermittent renewable power on electricity grids worldwide, in the near term, gas produced from the Surat Gas Project is likely to help drive electricity grid GHG emissions intensities down both within Australia and abroad.

Best Practice Methods for Minimisation of GHG emissions

The following best practice methods will be applied to the Surat Gas Project:

- Energy efficiency will be optimised during FEED. Considerations to optimise energy efficiency across the project include:
    - The allocation of energy efficiency class to all equipment

3 *How Natural Gas can Support the Uptake of Renewable Energy*, United Nations Economic Commission for Europe (UNECE) (2019) https://www.unece.org/fileadmin/DAM/energy/se/pdfs/CSE/PATHWAYS/publ/NG_RE.pdf

  - Energy efficiency will be used as an evaluation/selection criterion when selecting equipment
- Flaring:
  - Upstream distressed gas management is the wells and gas facilities response to failures in the upstream supply chain
  - Flares are located at each integrated processing facility (IPF), at each field compression facility (FCS) and at the existing Arrow CGPF's.
  - Low pressure flares at IPFs and FCSs will be used when a downstream compression train requires maintenance or there are downstream system upsets. Distressed gas management will be achieved by flaring at the IPFs and FCSs. Medium pressure flares to handle compressor blowdowns, PRV losses and other vessel blowdowns at FCSs are also included in the design case.
  - In relation to venting and flaring, the overall philosophy is to eliminate venting and minimise flaring (Venting and Flaring Standard). This is in alignment with the requirements under the P&G Act.

The management strategies to reduce the rate of flaring include:

- All production assets will be monitored and controlled via a single integrated Process Control and Production Information System referred to as the Process Automation System (PAS). The control system will be designed for 24/7 operation and have an availability of between 99.90% and 99.99% (value trade off to be completed).

- Assigning all wells to a turn down class (1-5) based on their risk of failure after a shutdown (1 being best to 5 being worst). The recovery performance will be determined by Well, Reservoir and Facilities Management (WRFM) in the first 12-24 months post start-up of the well.

- A control solution which will turn down well field production to match downstream demand by automatically turning down those wells that recover best (Class 1) first and progressively turning down subsequent well classes. Each field will include a block controller which allows the Control Room Operators (CRO) to turn down the field production from a single faceplate. The block controller will consider each well classification and adjust the wellhead metering skid pressure control valves to turn down the field flow.

- Interconnection between fields and facilities enabling distressed gas flows to be diverted to alternative delivery points.

- Venting and General Leaks.

Facility level venting and general leak emissions for upstream coal seam gas field operations and their controls incorporated into the current design are described in Table 6.20.

Table 6.23 Sources and controls for venting and general leaks incorporated into the SGP

Source Type	Source	GHG Controls
Venting	Gas transmission	- Leak detection and repair (LDAR) program as required under the *Petroleum and Gas (Production and Safety) Act (2004)*
	Cold process vents	- Eliminated from process design

Source Type	Source	GHG Controls
	Gas driven pneumatic devices	- Not used – compressed air or electrified devices are used instead of natural gas
	Vessel blow downs	- Potential vent emissions are redirected to medium pressure (MP) flare at FCSs
	Chemical injection pumps	- Natural gas driven chemical injection pumps eliminated from design
	Compressor starts and blowdowns	- Potential vent emissions are redirected to MP flare at FCSs
	Gas well workovers/completions	- Gas may be routed to a mobile flare to reduce venting emissions - Where possible well is overbalanced during workover/completion activities to avoid venting emissions - Fraccing is not included in current project design
	Well blowouts	- A range of prevention and maintenance measures are implemented throughout the life of a well to minimise the risk of a blowout occurring
	High point vents	- Where suitable, gas from high point vents to be rerouted to gas gathering lines (depending on gas produced, colocation of gas and water lines and suitable pressures)
General leaks	Gas well heads	- A leak detection and repair (LDAR) program is integral to the maintenance of all gas field and processing facilities, where on a regular cycle, gas detection equipment is used to identify any leak points within the piping networks and process plant. The implementation of a LDAR program is mandatory under Schedule 1 of the *Petroleum and Gas (Production and Safety) Act (2004)* and there are specific requirements for the reporting of all identified leaks over certain thresholds to the Petroleum and Gas Inspectorate. - Effective gas/water separation systems are ALARP for leak management for produced water.
	Gas gathering pipelines	
	Compressors	
	Produced water	

The estimated gas loss rate for all fugitive sources (venting, leaks and flares) is approximately 1.2% (i.e., tonnes gas lost per tonne gas sold). The estimated gas loss rate due to venting and leak sources is 0.15 – 0.20%.

Current emissions performance on Arrow's operating gas fields (Daandine, Kogan, Tipton and Moranbah) shows a gas loss rate of between 0.42 – 0.53%. This indicates that significant improvement in fugitive loss performance should be achievable for the SGP.

Commitments to Continuous Improvement of GHG emissions

The SGP is subject to international, national, state and corporate greenhouse gas policies with abatement objectives and performance standards. Arrow will comply with all mandatory

international, national and state objectives. Arrow is committed to the ongoing measurement and monitoring of the project's emissions, energy consumption and production.

Arrow monitors and manages well head emissions in accordance with the Code of Practice for CSG Well Head Emissions Detection and Reporting (COP) as required under Schedule 1 of the *Petroleum and Gas (Production and Safety) Regulation 2004*. The requirements of well head monitoring will be detailed in a Leak Management Plan (or similar plan).

Arrow will conduct a risk assessment to identify risks posed by leaks from well sites and will implement appropriate actions to reduce these risks to as low as reasonably practicable as required under the P&G Act. These actions will be incorporated into Arrow's Leak Management Plan. Mandatory requirements of the Leak Management Plan include (but are not limited to):

- Ensure formal integrity audits are conducted on 20% of the total number of gas well sites per annum
- Ensure a formal integrity audit is conducted on every operating gas well site facility at least once every five years
- Undertake formal integrity audits on individual gas well site facilities at an increased frequency as determined by the risk assessment and in consideration of previous audit/inspection findings for those specific facilities.

Arrow strives for continuous improvement in greenhouse gas emissions performance. To achieve this Arrow sets GHG emission intensity targets for operating assets both on a total GHG emissions level and on a venting and flaring loss rate basis. Annual emissions intensity targets incorporate continuous improvement elements.

To achieve the reduction in GHG emissions from Arrow's operating assets, Arrow has implemented a GHG abatement opportunity maturation process. The GHG opportunity process is illustrated in Figure 6-22. To further drive adoption of GHG emission abatement opportunities, Arrow incorporates a 'shadow' carbon price in the economic assessment of potential opportunities. This is an essential element of Arrow's operational GHGEMP which will be used to manage greenhouse gas and energy from the SGP once the facilities enter execute and operational phases.

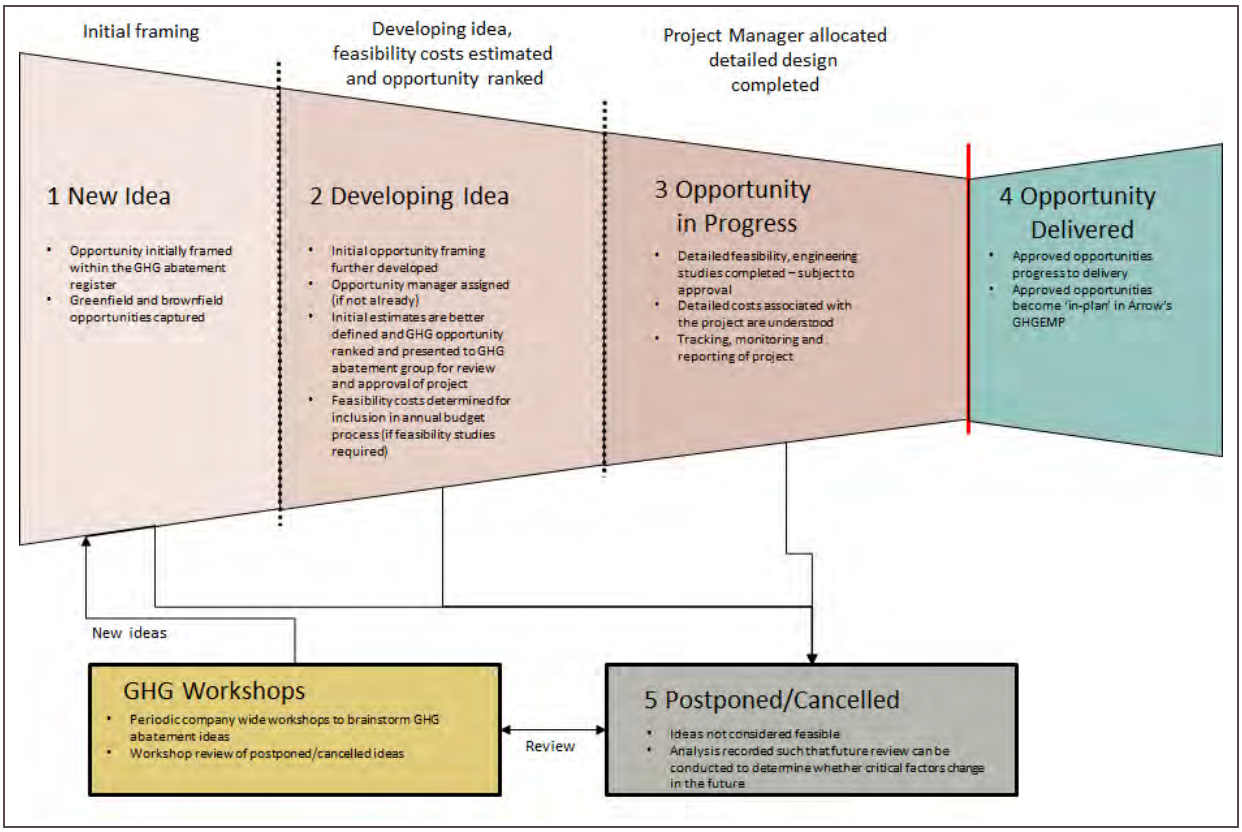

Figure 6.29 GHG opportunity process

6.9 Contaminated Land

The EHP Assessment Report requested details of existing contaminated land parcels on the Environmental Management or Contaminated Land Registers, and identification of the notifiable activities and locations that will require listing on these registers. Searches have been undertaken for the 132 land parcels the subject of this EA application.

These searches were undertaken and identified two land parcels which are listed on the Environmental Management Register (EMR) and / or Contaminated Land Register. Table 6.22 lists the land parcels which are included on the EMR. While these parcels are located on PL253, neither are located within the proposed 55 well development area the subject of this application.

A strategy was developed to inform the assessment and management of contaminated land as the project progresses (see Section 12.6.3 of the EIS and Figure 6-23). Arrow employs this strategy across all its operations to manage contaminated land. The general hierarchy to be followed is:

- Inspect and observe site locations for the presence of contamination prior to commencement of intrusive activities [C019]
- Avoid development on contaminated land through the completion of appropriate register searches and desktop investigations [C049]
- Conduct physical investigations on selected parcels of land to influence facility siting decisions on a localised scale [C050]
- Avoid disturbance of contaminated soil and groundwater when it is identified or observed during intrusive works [C064]
- Manage contaminated soil or groundwater that cannot be avoided through physical investigation; manage quantification of the type, severity and extent of contamination; and remediate or manage in accordance with the Queensland Auditor Handbook for Contaminated Land (DEHP, 2016), previously the Queensland Government's Draft Guidelines for the Assessment and Management of Contaminated Land (DE, 1998) [C065].

Table 6.24 List of Land parcels on the EMR/CLR

Table 6-22 – List of Land parcels on the EMR/CLR

Lot	Plan	Suburb	Address	EMRCLR Base or New Parcel?	EMRCLR Base Parcel Notifiable Activities	EMRCLR New Parcel Base Parcel Site Id's and Notifiable Activities
2	RP118543	HOPELANDS	CHINCHILLA-KOGAN RD	BP	SERVICE STATIONS;	N/A
40	DY85	CONDAMINE	16 MILE HALL ROAD	BP	COAL GAS WORKS; PETROLEUM PRODUCT OR OIL STORAGE;	N/A

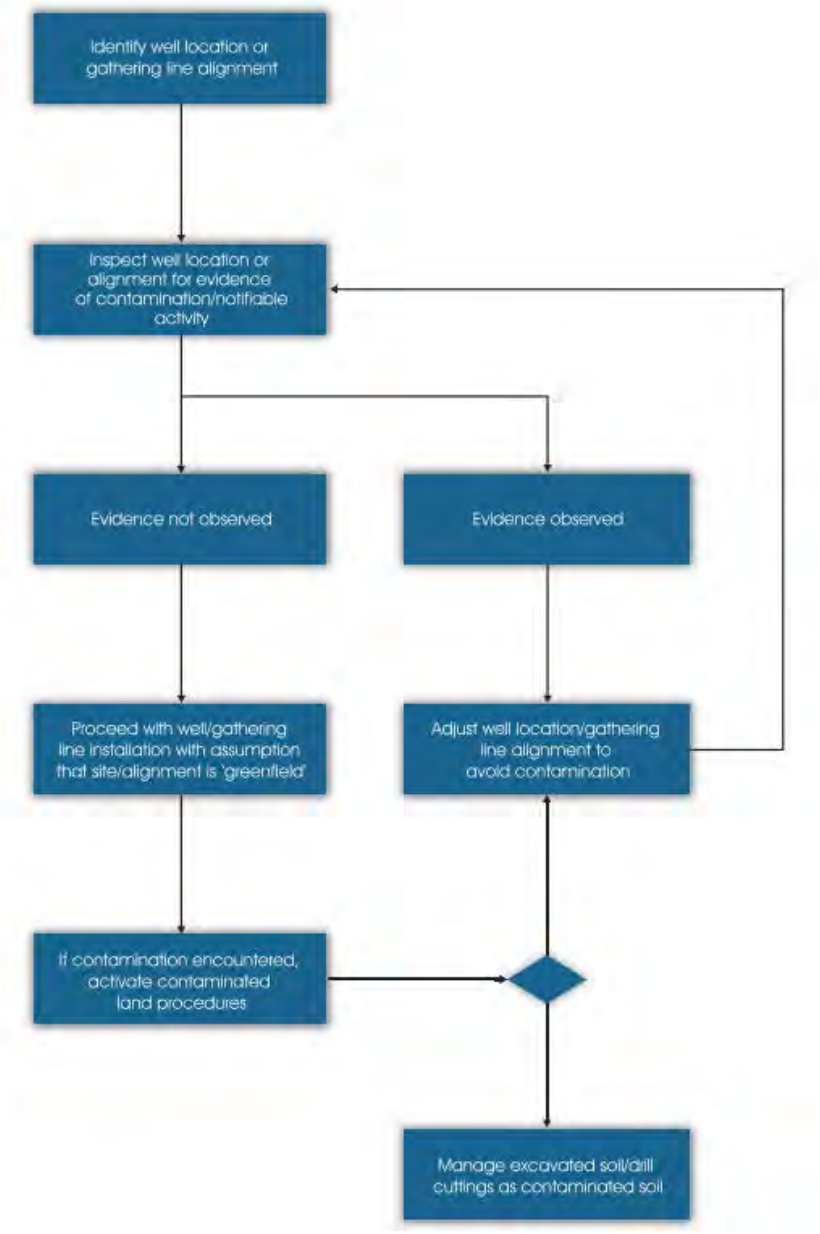

Figure 6.30 Contaminated land strategy: wells, gathering infrastructure and utilities (Figure 12-6 SGP EIS)

6.10 Topsoil handling and management

Section 3 of this report (Project Description) discusses the proposed method of soil disturbance and handling to facilitate gas field development including pipeline establishment and well pad construction.

In areas of ground disturbance activities that will be rehabilitated soon after infrastructure installation (e.g., well pads and gathering RoWs), topsoil and subsoil will be stripped according to profile depths and stockpiled separately. The soil assessment conducted for the EIS established that topsoil depths vary across the project area from 0.1 – 0.5 m with deeper topsoils in the alluvial cracking and non-cracking clays. Stripping depths for disturbance areas will be subject to further field investigations prior to stripping activities.

The works activities addressed in this EA amendment application are largely related to ground disturbing earthworks. As such, land management strategies including soil and topsoil handling and management, and erosion and sediment control measures, are particularly important. These activities were addressed in detail within the SGP EIS/SREIS.

The following EIS commitments are relevant to soil handling and erosion and sediment control (SREIS commitment number in parenthesis):

- Minimise the disturbance footprint and vegetation clearing (C020)
- Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities (C015)
- Design infrastructure located in cracking clays to withstand the differential shrink-swell ground movement (C042)
- Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls (C034)
- Strip, salvage and stockpile topsoil separately from subsoils (C062)
- Maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council (C031)
- Use existing roads and tracks, where practicable (C032)
- Confine project traffic to designated roads and access tracks, where practicable (C033)
- Time construction works and access to sites to avoid wetter periods, where practicable (C045)
- Design and plan the project to avoid steep slopes and areas dissected by gully networks, where practicable. Where these are unavoidable, ensure the required infrastructure (e.g., roads) is appropriately designed for erosion control purposes (C046).

The following commitments address avoidance, mitigation and management measures to be implemented for all activities that have the potential to cause land degradation:

- Reduce flow concentration and gully creation by minimising disruption to natural overland flow paths through the re-establishment of natural surface drainage lines (C052)

- Avoid disrupting overland natural flow paths and, where avoidance is not practicable, maintain connectivity of flow in watercourses (C053)
- Do not disturb or remove flood banks and artificial levees except in consultation with parties benefitting from the structures and the relevant authorities (C054)
- Avoid disturbance of contour banks and irrigation bays (C055)
- Locate pipelines to avoid or minimise impact on irrigation flow or current farming practices. If the RoW must cross actively farmed arable land, ensure soil cover above the pipeline is deep enough to allow normal cultivation practices to resume (C047)
- Avoid mounding of soil along pipelines in irrigated paddocks, to the greatest extent practicable, allowing for settlement of backfill (C056)
- Surface of soil stockpiles should be left in as coarsely structured condition as possible to promote infiltration and minimise erosion until vegetation is established or suitable erosion controls have been applied, and to prevent anaerobic zones from forming (C543)
- Conduct pipeline construction to minimise the duration of exposure of soils (C057)
- Stockpile cleared or mulched vegetation along the inside edge of the work sites (separate from soil stockpiles), to aid the control of runoff and ensure stockpiled vegetation does not pose a bushfire hazard (C106)
- Prevent subsurface water flows and erosion along the backfilled trench by appropriate means, such as trench blocks and compaction of backfilled soils (C503)
- Develop rehabilitation plans based on environmental sensitivities that address ground preparation requirements, natural and constructed drainage patterns, soil erodibility, contamination, slope steepness and length, rainfall frequency and intensity, potential flow magnitudes, vegetation cover, land use and landowner requirements (C070)
- Avoid excessive watering of saline soils to reduce leaching of salts and rising groundwater (C059)
- Avoid excessive watering of surface-crusting soils to reduce crust formation (C060)
- Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets (C066)
- Provide regular access points to pipeline construction RoWs to limit rutting and compaction of soils from vehicles travelling along the RoW (C061)
- Strip, salvage and stockpile topsoil near the work site separately to subsoils (in consultation with landowners). Ensure topsoil stockpiles do not exceed a maximum height of 2.5 m, where the future use is intended for rehabilitation, and are protected from erosion (C062)
- Backfill and rehabilitate excavations, particularly pipeline trenches and drilling sumps. Conduct backfilling in a manner that will promote successful rehabilitation, including capping of exposed subsoil with topsoil and replacement of the land surface to preconstruction levels to reduce trench subsidence and concentration of flow. Mounding of soils to allow for settling may be required in some areas. However, in laser-levelled

paddocks, this may not be practicable, and backfilling should be carried out in consultation with the landowner (C071)

- Remedy areas of differential settlement associated with buried infrastructure that interrupt the pre-existing surface water flow within intensively cultivated areas (C072).

6.11 Rehabilitation

The SGP EIS Assessment Report requested details of the rehabilitation plan be provided in the amendment application, and specifically five aspects of the plan namely rehabilitation hierarchy, rehabilitation methods, rehabilitation goals, monitoring program, progressive rehabilitation and timing. Arrow has developed a rehabilitation plan, which is applicable to all activities within Arrow's gas field tenements. The following summarises the main aspects of the plan relevant t to the five EHP requests.

Rehabilitation hierarchy

The rehabilitation hierarchy that will be adopted for the SGP is as follows:

- Progressive rehabilitation – stabilisation of disturbed areas to commence as soon as practicable following land disturbance
- Decommissioning – infrastructure is decommissioned and removed from the site
- Final rehabilitation – to commence as soon as practicable after infrastructure decommissioning
- Monitoring and maintenance – regular monitoring and timely maintenance of stabilisation/rehabilitation to ensure rehabilitation integrity
- Reporting – a final rehabilitation report (FRR) or progressive rehabilitation report (PRR) to be completed when monitoring has confirmed final rehabilitation acceptance criteria has been met for a tenure (FRR) or area within a tenure (PRR).

Rehabilitation methods

The methods employed for rehabilitation will be as follows:

- Progressive rehabilitation – this will be undertaken post construction, to stabilise areas disturbed by construction activities and not required for ongoing operational activities. The period between construction and rehabilitation of disturbed land not required for operations will be minimised to prevent degradation and loss of exposed soils. Surface structures, equipment and waste materials not required for the operational phase will be removed prior to rehabilitation.
- Decommissioning – at the end of the project infrastructure life, or when it is no longer required, infrastructure will be decommissioned by removal of surface facilities from the site. Subsurface infrastructure will generally remain in situ. Any contaminated soils will be remediated or removed to a licensed disposal facility.
- Final rehabilitation – where required, topography, re-profiling and revegetation of the site will be undertaken to return the disturbed land to as near as possible to its pre-disturbance state or agreed land use. Compacted areas will be ripped or scarified, and topsoil will be re-spread to encourage natural revegetation. In some cases, stabilisation measures will be used to ensure topsoil remains intact. Site-specific rehabilitation plans will be developed for areas where natural vegetation regeneration may be problematic.

The final rehabilitation will be as per EA requirements and agreements with the landholder.

Rehabilitation methods will be improved over time as additional knowledge is gained from the monitoring programs and different rehabilitation techniques are evaluated.

Rehabilitation goals

Arrow's rehabilitation goals for the SGP, which will form the basis for ongoing consultation with landholders and DES, are as follows:

- Decommissioning and rehabilitation activities meet stakeholder expectations and comply with relevant regulatory requirements and/or industry best practices
- Above ground infrastructure developed for the purpose of the project is decommissioned, safely removed and appropriately disposed of unless agreed with DES and landholder to remain
- Where appropriate, the progressive rehabilitation of disturbance areas will be undertaken throughout the life of the project
- The final landform is stable and an acceptable final land-use (in consultation with landholders and DES) for the disturbance area is achieved
- Where appropriate infrastructure such as dams or roads would be transferred to the landholder
- The potential for adverse environmental impacts is minimised, including but not limited to, contaminated run-off into local waterways, air quality from dust, and soil contamination from hydrocarbons or other chemicals
- Identifying analogue sites to measure rehabilitation success.

Monitoring program

Monitoring of rehabilitation will determine whether the rehabilitation is successful or underperforming. The following key aspects would be evaluated during monitoring:

- Soil erosion
- Revegetation success
- Weed infestation
- Integrity of diversion drains, waterways and erosion and sediment control structures.

A final rehabilitation report (FRR) including landowner agreement and rehabilitation status, will be prepared and submitted to DES for approval at the appropriate time and as per EA conditions.

Progressive rehabilitation and timing

Where appropriate, progressive rehabilitation of disturbed lands associated with the project shall proceed as soon as reasonably practicable to minimise the potential for erosion and sedimentation of surrounding waterways or reduced air quality. Activities that will be progressively rehabilitated include:

- Well pads – progressive rehabilitation of the pad will occur once drilling of wells on a particular pad is completed and the pad area is reduced to an operational footprint
- Gathering lines – following construction of the gathering lines, the RoW will be reduced to a width of 15 m as part of the project's progressive rehabilitation program and to maintain the gathering during operation.

7. Assessment level decision for amendment application

Under section 228 of the EP Act, the administering authority must decide whether the proposed amendment application will be assessed at either a major or minor level. Arrow provides the information below in support of this determination.

Minor Amendment for an environmental authority, means an amendment that the administering authority is satisfied that (as per the DES Guideline Major and Minor Amendments, dated 1 November 2019):	**Comment**
(a) is not a change to a condition identified in the authority as a standard condition	No changes to a standard condition are proposed
(b) does not significantly increase the level of environmental harm caused by the relevant activity	The amendment application does not significantly increase the level of environmental harm caused by a relevant activity.
(c) does not change any rehabilitation objectives stated in the authority in a way likely to result in significantly different impacts on environmental values than the impacts previously permitted under the authority	The amendment application does not change any rehabilitation objectives stated in the authority in a way likely to result in significantly different impacts on environmental values than the impacts previously permitted under the authority.
(d) does not significantly increase the scale or intensity of the relevant activity	The increase in scale and intensity beyond that currently authorised by the Hopeland EA is >10%.
(e) does not relate to a new relevant resource tenure for the authority that is— (i) a new mining lease; or (ii) a new petroleum lease; or (iii) a new geothermal lease under the Geothermal Energy Act; or	The amendment application does not relate to a new relevant resource tenure.

Minor Amendment for an environmental authority, means an amendment that the administering authority is satisfied that (as per the DES Guideline Major and Minor Amendments, dated 1 November 2019):	**Comment**
(iv) a new GHG injection and storage lease under the GHG storage Act.	
(f) involves an addition to the surface area for the relevant activity of no more than 10% of the existing area	The amendment application involves an addition to the surface area of more than 10% of the existing area
(g) for an environmental authority for a petroleum activity— (i) if the amendment involves constructing a new pipeline—the new pipeline does not exceed 150km; and (ii) if the amendment involves extending an existing pipeline—the extension does not exceed 10% of the existing length of the pipeline.	The amendment application does not involve the construction of a new pipeline or the extension of an existing pipeline by 10%.
(h) if the amendment relates to a new relevant resource tenure for the authority that is an exploration permit or GHG permit—the amendment application under section 224 seeks an amended environmental authority that is subject to the standard conditions for the relevant activity or authority, to the extent it relates to the permit.	The amendment application does not relate to a new relevant resource authority that is an exploration permit or GHG permit.