DES Information Request - Hopeland EA Amendment Application – PL253

TO:	Clancy Mackaway – Department of Environment Science (DES)
FROM:	Andrew Hall - Arrow Energy (Arrow)
SUBJECT:	Your reference: EA0001401 Application reference number: APP0056458 Hopeland EA Amendment Application - Information Request
DATE:	21 December 2020

Background

- On 8 August 2018, Arrow was granted a site-specific Environmental Authority (EA) for the conduct of petroleum and specific relevant activities in the Hopeland area (EA0001401). This EA supported a successful application for the grant of Petroleum Lease (PL) 253.
- On 6 July 2020, Arrow lodged an EA Amendment Application via the Department of Environment and Science (DES) Online Connect System.
- The EA Amendment Application seeks to authorise the planned activities for Arrow's Surat Gas Project (SGP) on PL253. These activities include an additional 280 gas production wells and associated water and gas gathering pipelines.
- It is noted that the planned activities on PL253 are pivotal to the successful delivery of the SGP. Also, that the SGP was approved by the Australian and Queensland governments in 2013 via the approval of Arrow's Environmental Impact Statement (EIS).
- 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. An information request is issued by the administering authority (i.e. DES) to request further information needed to assess an amendment application for a site-specific EA.
- This memorandum describes and responds to the additional information requested by DES.

Response to DES Information Request

The Information Request received from the DES (dated 27 August 2020) is provided in its entirety as Attachment A. The following identifies each of the seventeen (17) information requests received from DES followed by the Arrow response. The numbering below (a to q) follows that of the DES Information Request.

(a) The current environmental authority (EA) (effective date of 25 June 2020) details the authorised activities in EA condition General 1. The activities listed in Table 1 of General 1 includes the scale and intensity of gathering pipelines, raw water pipelines, access tracks, a borrow pit, and sediment ponds. The proposed table in section 5.1 of the EA Amendment Application Report does not detail what increases in scale and intensity are being sought for the previously mentioned items. Please provide a revised table of proposals that aligns with the current details prescribed in EA condition General 1.

RESPONSE

The total scale (shown as intensity and maximum as per the format in the current EA table) for each of the five activities identified above by the DES are provided in the table below.

General, Table 1 – Authorised petroleum Activities

Petroleum activities and infrastructure	Scale	
	Intensity	Maximum
Gathering pipeline	442 ha[1]	N/A
Raw water pipeline	443 ha[1]	N/A
Access tracks	210 ha[2]	N/A
Borrow pit	5 ha[2]	10 borrow pits
Sediment pond	2 ha[2]	5 sediment ponds

[1] – These areas include newly proposed and rounded up existing areas. The newly proposed intensity is shared equally between gathering pipelines and water pipelines (noting that 220km x 40m in width = 880ha of newly proposed area)

[2] – These areas include newly proposed and rounded up existing areas

(b) The applicant proposes that 440km of gas and water gathering pipelines are required, however in section 4.3 (page 22) of the EA Amendment Application Report, it states that approximately 220km of gathering lines will be constructed across PL253. Please confirm the correct value each of gas and water gathering lines being applied for.

RESPONSE

Arrow confirms that a total combined length of 440 km of gas and water gathering pipelines are to be constructed on PL253. This comprises 220 km of gas gathering pipeline and 220 km of water pipeline, which are proposed to be co-located within the same right of way (RoW).

(c) The applicant proposes to amend the definition of Essential Petroleum Activities to include communications towers. Please provide an indication of how many communications towers are required, what infrastructure is involved, the maximum size of disturbance/footprint required for each and what impact this may have on environmental values.

RESPONSE

There are two (2) Communication Towers proposed to be constructed on PL253 (Tower Number 10 and Tower Number 28). The final locations for these towers will be determined by negotiations with landowners but the current notional locations are towards the south eastern corner of PL253 (Tower 28) and towards the western boundary of PL253 (Tower 10).

At ground level, the tower site will include a communications hut, diesel generator and 1,000 L fuel tank. The tower facility footprint is 30 x 20 metres with additional area required for fire clearance and provision for perimeter roads for light vehicle access and also for crane access during the construction of the tower and for future maintenance activities.

The fire break for each site will differ in size dependent on the vegetation level and the height and the slope of the ground, however the entire site will be limited to:

- 1 ha for a standalone tower; or
- 1.5 ha in circumstances where a tower is co-located on a single well pad; or
- 3 ha for co-location on a multi-well pad.

These sizes are consistent with the definition of essential petroleum activities in Arrow Energy's Dalby Expansion Project (DXP) EA (EPPG00972513). Each tower will be 55 m in height.

The specific environmental values impacted during construction and operation of the communication towers is yet to be determined as agreements with landholders for locating the infrastructure are yet to occur. However, Arrow is familiar with the environmental values relevant to the two areas proposed for the towers and the potential impacts associated with the proposed activity. The relevant environmental values that Arrow will seek to avoid and/or minimise impacts to are:

- Biological environment;
- Air quality ; and
- Visual amenity.

Biological environment

Based on a desktop assessment of the site for Tower 10, it has notionally been located in a cleared area within non-remnant vegetation. However, this area is close to mapped 'core habitat possible' for the grey snake. As such, Arrow will conduct a pre-clearance field assessment with a suitably qualified ecologist to determine if the area to be impacted is indeed habitat that may support the grey snake and if so will apply appropriate mitigation measures as per our DES approved Arrow Species Management Program for tampering with animal breeding places (ORG-ARW-HSM-PLA-00070).

Tower 28 is notionally located in an area of remnant least concern vegetation with the following Eucalypt woodland regional ecosystems present, 11.5.1a/11.5.1/11.5.20. Also, the site is on the

edge of mapped essential habitat for golden-tailed gecko which is a Near Threatened species only and isn't subject to offset requirements for resources activities. To ensure that no unplanned impacts occur on listed species, ecological site assessments will be undertaken across all sites and if necessary, a fauna spotter catcher will attend sites prior to, during and following construction activities. Site activities will be planned for minimum disturbance and clearing boundaries will be clearly marked in the field to avoid any unplanned clearing of vegetation.

The land zones in the areas of the proposed towers are land zone 4 (Tertiary-early Quaternary loamy and sandy plains and plateaus) and land zone 5 (Tertiary-early Quaternary plains with sandy or loamy soils). The dominant soil types in land zone 4 are Vertosols with gilgai microrelief, however sandy or loamy surfaced Sodosols and Chromosols derived from the same paleo-clay subsoil deposits can also be present. The dominant soil types in land zone 5 are usually Tenosols and Kandosols, also minor deep sandy surfaced Sodosols and Chromosols.

Strict soil handling and reuse practices will be adopted in areas of ground disturbance activities which will then be progressively rehabilitated soon after infrastructure installation. Further, topsoil and subsoil will be stripped according to profile depths and stockpiled separately. Stripping depths for disturbance areas will be subject to further field investigations during stripping activities to ensure the necessary controls are in place to minimise the potential for sediment runoff from the site. Also, the stabilisation and revegetation of long-term stockpiles will be undertaken as soon as practicable to reduce the potential for erosion.

The tower sites will be designed with careful consideration of the potential impact of overland flow during rainfall and flood conditions. This includes reducing the flow concentration and gully creation by minimising disruption to natural overland flow paths through the re-establishment of natural surface drainage lines where required.

Air quality

Potential impacts to air quality may arise from emissions of particulate matter (i.e. dust) generated during the construction activities. Potential impacts will be managed by the use of a construction environmental management plan that will be developed for the project. Mitigation methods include:

- Application of water by water trucks on exposed areas including stockpiles;
- Visual observation of dust emissions (particularly during dry and windy conditions) and increasing the water application frequency if required;
- Vehicle loads that may generate nuisance dust will be covered;
- Vehicle speed restrictions will be imposed at the construction site to minimise wheel generated dust.

Visual amenity

Visual amenity nuisance caused by the height of the towers will be mitigated by locating the tower in areas with surrounding vegetation and / or with an adequate separation distance from sensitive receptors. This will be discussed with the landholders at the time of siting the towers and Arrow will seek to preferentially locate the towers as per the feedback from the landholder. Including the landholders in the decision-making process for tower locations also reduces the potential for noise nuisance that may otherwise be caused during the construction of the towers. It is noted that there is no audible noise omitted during the operation of the towers.

(d) The applicant is seeking to amend the definition for Essential Petroleum Activities to allow disposal of residual drilling material to occur 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. Please provide the following:

- **a. Quality characteristics of the drilling material, including an assessment of whether the material constitutes a regulated waste;**
- **b. Method for undertaking the disposal of drilling material;**
- **c. A risk assessment prepared by a suitably qualified person that identifies the possible impacts due to the proposed activity and all associated risks (including contamination risks) to environmental values. This is to include:**
  - **i. An assessment of any additional risk in undertaking disposal of drilling material within primary protection zones of Category B and Category C environmentally sensitive areas;**
  - **ii. An assessment of any additional risk associated with shallow groundwater, and potential for any seepage or contamination to occur based on the soil structure and quality within the project area;**
  - **iii. Details of additional rehabilitation requirements;**
- **d. Consideration of the waste and resource management hierarchy in the Waste Reduction and Recycling Act 2011 and describe why all other strategies (avoid, recycle, reuse or recover) would be unsuitable; and**
- **e. Strategies to monitor and mitigate any identified risks to environmental values, including land and groundwater contamination.**

Note: Mix-bury-cover of residual drilling materials may trigger Notifiable Activity 20: Landfill—disposing of waste (excluding inert construction and demolition waste) as listed in Schedule 4 of the Environmental Protection Act 1994.

RESPONSE

Overarching approach

Arrow undertakes land application of residual drilling material (RDM) in accordance with Arrow's Land Application of Residual Drilling Material Work Method Statement (ORG-ARW-HSM-WOI-00046) (WMS). The WMS, which was prepared by a suitably qualified person, provides the management techniques required for the successful application of RDM to land in a manner that minimises and prevents environmental impacts in the short and long term.

The suitability of sites for land application of RDM application are assessed using desktop screening methods and onsite assessments. The following constraints are applied unless otherwise approved by a suitably qualified person:

- General site and hydrogeological conditions: These are important considerations as they mitigate the potential for runoff and the risk of sediment migration through avoiding slopes greater than 5% and potential for impacts to groundwater by avoiding areas with shallow (<5 mbgl) unconfined groundwater.
- Avoid unsuitable soils which are: <30 cm deep; where erosion has exposed subsoils; have noticeable (>50% by volume) coarse particles (>2 mm diameter gravel); and / or rocks, or

other large obstructions such as tree stumps or boulders that would impede RDM spreading.
- Locate sites at least 100 m from a surface water body to prevent the potential for direct entry into surface water or infiltration and discharge into surface-water.
- Locate sites at least 200 m from any natural wetland.
- Locate sites at least 100 m from any Environmentally Sensitive Areas (ESAs).

A response to each of the points raised in the DES request is provided below.

Quality characteristics of the drilling material, including an assessment of whether the material constitutes a regulated waste

Prior to land application, baseline soil sampling for targeted soil quality parameters is undertaken in conjunction with the site selection ecological assessment. Baseline soil data is collected in the proposed application areas and/or an analogue site/s if appropriate to facilitate a testing program. The following occurs:

- Validation and/or development of site-specific application rates considering soil salinity and cumulative contaminant loading (CCL) limitations for the proposed application areas;
- Provision of data against which post application soil quality data can be compared;
- Assessment of soil amendment (e.g. gypsum) and fertiliser requirements (by a suitably qualified person) to facilitate robust rehabilitation and plant growth and management of soil structure.

To account for the differences in physical and chemical properties that RDM may exhibit, Arrow characterises the RDM using the Land Application Calculator (which has been developed from historical results including the EHS Support 2016: Theten Land Application Trial) to confirm that the application and potential amendment rates provided in the proposed testing program are appropriate. This occurs prior to the application of the RDM.

Post-application, sampling is also undertaken and compared to the environmental screening levels in the WMS to confirm that no adverse impacts have occurred as a result of the land application.

Guidelines on sampling depths and frequency are including in the WMS. The analytes that are analysed at each stage in the process or shown in the following table.

Analyte	Sampling event
pH	Baseline/RDM/Post
Electrical Conductivity (EC)	Baseline/RDM/Post
Moisture Content	Baseline/RDM/Post
SAR, ESP	Baseline/RDM/Post
Soluble Major Ions (Na, Ca, Mg, K, in mg/l) plus Cl, SO_4, Alkalinity, carbonate, bicarbonate and total	Baseline/RDM/Post
Exchangeable Major Cations (Na, Ca, Mg, K) plus CEC (meq/100g)	Baseline/RDM/Post

Analyte	Sampling event
Particle Size Analysis	Baseline/RDM/Post
Metals (Al, Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Mo, Ni, Se, Ag, Th, Sn, U, V, Zn)	Baseline/RDM/Post
Hydrocarbons (TRH/BTEXN-plus F1/PAH) (for RDM samples: Silica gel cleanup)	Baseline/RDM/Post

Method for undertaking the disposal of drilling material

Land application of RDM is undertaken as follows, in accordance with the WMS:

- Stockpiled RDM is screened if required to ensure that unsuitable rock is removed prior to land application;
- The moisture content of the RDM is visually assessed to ensure that it is suitable for spreading (e.g. in consideration of avoiding run off, dust generation and clumping)
- Mixing of RDM is undertaken to provide the required homogeneity of material so that it can be applied to land for more consistent incorporation. Trench void walls and floors are excavated to remove RDM as far as practicable without over excavation of potential dispersive subsoils.
- Amelioration occurs to amend the SAR/ESP levels of RDM during or post application where required.

A risk assessment prepared by a suitably qualified person that identifies the possible impacts due to the proposed activity and all associated risks (including contamination risks) to environmental values. This is to include:

- **An assessment of any additional risk in undertaking disposal of drilling material within primary protection zones of Category B and Category C environmentally sensitive areas;**
- **An assessment of any additional risk associated with shallow groundwater, and potential for any seepage or contamination to occur based on the soil structure and quality within the project area;**
- **Details of additional rehabilitation requirements.**

Arrow's WMS was developed by a suitably qualified person to comply with legislation and EA conditions regarding land application and the sampling and methodology is based on Arrow's and other CSG proponents methods for the application of RDM in addition to the experience gained by Arrow in the trial of land application of RDM at the Theten Farm (Land Application Management Plan – Theten Trial Application Site, Arrow 2014 and Theten Land Application Trial Site – Phase 1 Review, EHS 2016).

Specific to the risk assessment for RDM proposed in areas of environmentally sensitive areas, the following points extracted from the WMS are of relevance:

- Land application of RDM does not occur within 100m of an ESAs (including secondary protections zones and the outer half of the primary protection zones)
- Land application of RDM does not occur in areas with shallow (<5 mbgl) unconfined groundwater

- Site selection must also include consideration of landholder constraints and applicable EA conditions which may limit types of activities permitted within certain distances of potential sensitive receptors such as ESAs, watercourses and wetlands.
- Initial screening of sites will be undertaken based on desktop data to ensure that no ESAs, protected plants or animals or other sensitive receptors are likely to be impacted if land application of RDM is undertaken.
- Based on the findings from this baseline assessment, adjustments to the location of the proposed land application area (if required) will be undertaken to avoid identified ESAs.

Consideration of the waste and resource management hierarchy in the *Waste Reduction and Recycling Act 2011* and describe why all other strategies (avoid, recycle, reuse or recover) would be unsuitable

Consistent with the *Waste Reduction and Recycling Act 2011* (WRR Act) hierarchy, Arrow has developed an integrated program of drilling fluid reuse, recycling, beneficial use and lastly disposal which avoids, recovers and treats drilling fluids and cuttings and ultimately minimises the volumes requiring disposal to landfill.

As per the Arrow Energy (Arrow) Health, Safety and Environment Management System (HSEMS) Procedure – Waste Management (ORG-ARW-HSM-PRO-00066), a Site Waste Management Guide (SWMG) has been prepared to guide the operations of Arrow's Well Delivery team. The guide is intended to achieve the following outcomes:

- minimise waste volumes and disposal costs;
- minimise the risk of causing harm to the environment that may arise due to waste management;
- improve operational efficiency;
- improve environmental performance; and
- meet environmental authority and other legislative requirements.

The majority of waste is expected to be generated from the following activities:

- Drilling activities;
- Workover activities;
- Completion activities; and
- Plug and abandonment activities.

The SWMG identifies:

- types and estimated volumes of waste streams generated
- potential environmental risks associated with waste management
- waste storage and handling requirements for different waste types that reflect the waste hierarchy and risks associated with each
- waste transport and disposal requirements
- assurance requirements
- record keeping and reporting requirements

Roles and responsibilities in regard to waste management are included in Arrow's HSEMS Procedure – Waste Management and Guide – Waste classification and tracking. General waste management principles to follow to ensure compliance with EAs include:

- All waste must be removed from the site and sent to a facility licensed to accept the waste unless otherwise authorised under the EA to be disposed of or re-used on site or supplied to a third party.
- All regulated waste must be removed from the site by an authorised transporter, sent to a facility licensed to accept the waste and be accompanied with completed waste tracking certificates.
- Waste must not be burned or allowed to be burned on the licensed site unless otherwise authorised under an EA.
- Waste fluids and cuttings must be appropriately contained in accordance with applicable standards prior to disposal, remediation or reuse where applicable.
- Coal seam gas (CSG) water must be contained and only used for purposes specifically authorised under an EA or other beneficial use approval.

Individual EAs may contain additional EA-specific conditions relating to waste, e.g. application of the waste and resource management hierarchy and management principles, management of pipeline wastewater, authorised uses of produced water, supply of CSG water to third parties, sewage treatment, management of residual drilling material, onsite waste disposal and record keeping requirements. EA conditions can differ between ATPs and PLs therefore any persons making decisions regarding waste disposal, management or reuse must ensure that the relevant EA for that tenure is understood, communicated and adhered to.

Arrow has also identified a detailed list of waste types anticipated for Well Delivery activities, waste management options and specific management strategies for each within the SWMG. Where more than one waste management option is indicated, the option highest up the waste hierarchy is to be selected where practicable. The order of preference is included within the SWMG.

The SWMG contains the following information with respect to drilling fluids and residual drilling material:

Drilling fluids are used to maintain primary well control in the well and are pumped down the drill pipe to lubricate and cool the drill bit and flush out the drill cuttings. Arrow uses water-based drilling fluids which contain small amounts of potassium chloride (2 – 3%), clay stabilisers (e.g. potassium chloride), cement additive (e.g. bentonite and calcium sulphate), disinfectant (biocide) and foaming agent (anionic surfactant similar to detergent). Arrow does not use any synthetic polymers in its drilling fluids. Onsite disposal of drill fluids are not permitted in the EA and must be disposed off-site as regulated waste.

Residual Drilling Material (RDM) is defined as muds and cuttings or cement returns from well holes and which have been left behind after the drilling fluids are pumped out. Conditions relating to land application or disposal of RDM differ between EAs. Some EAs permit RDM to be disposed of on-site via mix-bury-cover or a land application method where EA conditions can be satisfied.

A management plan or procedure approved by an environmental representative is required for all activities involving land application as a disposal method for RDM. It is to include how works will

be conducted to ensure all EA conditions will be met, including any sampling required to verify that contaminant concentrations in the drill fluid/cuttings do not exceed permitted values.

The following documents have been developed, and where necessary certified by a suitably qualified third party. These documents detail the Arrow's regulatory requirements when disposing of residual drilling materials:

- Work Method Statement - Application of RDM (ORG-ARW-HSM-WOI-00046)
- Work Instruction - Land Application (ORG-ARW-HSM-WOI-00049)
- Guide - Residual Drilling Material Sampling (ORG-ARW-HSM-GUI-00114)

Arrow will always reuse and recycle materials including drilling fluids and cuttings as long as it is safe and appropriate to do so. It is only once materials become unsuitable for reuse that Arrow will propose the option of disposal to land. Once this has been determined, these materials will only be spread where it has met the parameters explained earlier and were there will be no harm to environment values.

Strategies to monitor and mitigate any identified risks to environmental values, including land and groundwater contamination.

Note: Mix-bury-cover of residual drilling materials may trigger Notifiable Activity 20: Landfill—disposing of waste (excluding inert construction and demolition waste) as listed in Schedule 4 of the Environmental Protection Act 1994.

Soil sampling of the parameters defined in the WMS are undertaken to assess the soil post application. The results of the soil sampling and analysis is compared with baseline soils at relevant soil depths as per the WMS.

In the event that monitoring identifies signs of vegetation stress, key soil criteria are compared between the pre and post application (in addition to Arrow's rehabilitation criteria, which include vegetation cover and soil surface erosion) and additional soil sampling may be undertaken to identify if:

- ESP and EC in shallow soils are not near background levels, or not excessively elevated (as there is likely to be an initial increase following application of RDM)
- Corrective actions are identified on a site by site basis and determined by the success or failure of rehabilitation of the area where land spreading has occurred. These actions may include:
    - Additional testing of soils to determine potential cause of plant stress and lack of growth. On the basis of this testing, additional amendments and fertilisers for soils and vegetation can be applied in land application areas
    - Amending the surface soils (post land application of RDM) to mitigate potential impacts on soil structure.

Should it be identified that land application is unviable (based on sampling and even with treatment of the RDM), Arrow will dispose of the RDM to landfill. However, in accordance with the WRR Act hierarchy, this is the least preferred management option.

(e) The applicant has applied for the inclusion of streamlined model conditions (SMCs) for petroleum activities waste conditions 5, 6, C1, C2, 11, 12, 13, 14, 18, 19, 20, 21 and the Waste management schedule, Table 1—Assessment procedures for water quality criteria. The applicant has not provided a site-specific risk assessment that details the impacts to environmental values that may occur should the activities be authorised, for example, burning of vegetation waste and construction of a landfill facility. Provide the following:

- **i. Risk assessment that identifies the possible impacts due to the proposed activities and all associated risks to environmental values;**
- **ii. Strategies to mitigate identified risks to environmental values;**
- **iii. Rehabilitation requirements for the activities being applied for;**
- **iv. A consideration of whether additional environmentally relevant activities (ERAs) are required, for example, ERA 60 – waste disposal. This includes details of the type and quantity of waste intended to be disposed of.**

RESPONSE

Vegetation waste burning (Waste 5)

Arrow's Site Waste Management South Guide (ORG-ARW-HSM-GUI-00105) specifies that waste storage and handling requirements reflect the waste hierarchy contained in the *Waste Reduction and Recycling Act 2011* and risks associated with each. The guide requires that waste must not be burned or allowed to be burned unless otherwise authorised under the EA.

Pipeline wastewater (Waste 6)

Arrow has considered the risk to surface and groundwater quality and soil quality of transmission of CSG water via pipelines. Mitigation controls include regular monitoring and maintenance in accordance with Arrow's asset integrity and maintenance plan and inclusion of process safety in design with the measurable criteria being no reportable unplanned releases of CSG water (Section 5.2 of supporting report).

Additionally, the risk and mitigation of pipeline wastewater at low point drains is identified as a low residual risk in EHP risk assessment that supported the development of the SMC (Appendix D of the supporting report).

Irrigation of produced water (Waste C1 - C2)

Arrow has developed a Coal Seam Gas Water Management Plan (CSG WMP) for the Surat Gas Project with the purpose of:

- Addressing the requirements of section 126 of the EP Act as required for a site-specific EA application[1];
- Addressing Arrow's commitment under the Surat Gas Project Environmental Impact Statement (EIS) to produce a CSG WMP; and

- Describing how SGP's CSG water will be managed in a way that protects and maintains environmental values whilst balancing social and economic considerations.

The CSG WMP was prepared in accordance with the following Queensland Government regulatory guidance documents:

- The *Environmental Protection Act 1994* (Qld) (EP Act) – specifically Section 126 (1) and 126 (2); and
- The Department of Environment and Heritage Protection Coal Seam Gas Water Management Policy[2] – specifically its prioritisation hierarchy for managing and using CSG water and for managing saline waste.
- The CSG WMP is included in Arrow's supporting report and addresses the questions in the information request.

Sewage treatment (Waste 11-14)

Arrow has considered and included the residual risk of sewage treatment impacts and Arrow's procedures include the mitigation controls as included in the EHP risk assessment that supported the development of the SMC (Appendix D of the supporting report). Additionally, we will include the following in the SMC.

Consistent with Arrow's ongoing operational practices on existing PLs, if temporary camps are required, sewage will be treated onsite in packaged mobile sewage treatment plants. The treatment plants used by Arrow include settlement, digestion, aeration, clarification and disinfection equipment.

The mobile sewage treatment plants if required would treat and then release treated effluent to land only after meeting or exceeding secondary treated class C standards (as per the relevant EA SMCs - Waste 11 and Waste 12) (Section 6.5 of Supporting Reports). All sewage sludge and residues associated with these mobile facilities will be collected in a closed system and taken to an appropriately licensed facility for further treatment or disposal.

Arrow has committed to appropriately siting mobile sewage treatment plants associated with mobile camps. Siting considerations include:

- 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.

As per the management hierarchy from Section 14 of the Environmental Protection (Water and Wetland Biodiversity) Policy 2019, the following will occur:

- Appropriate treatment and release to a waste facility or sewer: All sewage sludge and residues associated with these mobile facilities will be collected in a closed system and taken to an appropriately licensed facility for further treatment or disposal.

[2] Queensland Department of Environment and Heritage Protection (2012*), Coal Seam Gas Water Management Policy*.

- Appropriate treatment and release to land: treated effluent will only be released to land after meeting or exceeding secondary treated class C standards (as per the relevant EA SMCs - Waste 11 and Waste 12) should there be excess treated effluent that is not recycled, it will be released to land (as per the relevant EA SMCs - Waste 11 and 12).
- Appropriate treatment and release to surface waters or groundwater: no release to surface waters or groundwaters is proposed.

Residual Drilling Material – general waste (Waste 18-21)

Refer to response for item 2(d), above.

Onsite waste disposal – general waste (Waste 18-21)

An onsite dedicated landfill facility is not proposed to be constructed on PL253.

(f) The applicant has applied for the inclusion of streamlined model conditions (SMCs) for petroleum activities noise conditions to authorise blasting. The applicant has not provided justification for the activity, or a site-specific risk assessment that details the impacts to environmental values that may occur should the activities be authorised, including whether the applicant can comply with the existing noise and air conditions. The applicant should also detail the proposed locations for blasting, and include a consideration of proximity to the former Linc Energy site (Lot 40 DY85).

RESPONSE

Arrow Energy has never undertaken blasting for any of the activities authorised by the Hopeland EA and has no plans of undertaking blasting for any future activities on PL253. As such, Arrow does not require any conditions within the EA related to blasting. If this position changes, Arrow will prepare and lodge an amendment application.

(g) Appendix C of the Amendment Application Report contains a Terrestrial Ecology Report (Ecosmart Ecology, June 2017) for the entire Surat Gas Project area. This appears to be a summary only. Please provide further details of the ecological assessment relevant to PL253 that includes, but is not limited to:

i. Methodology of ecological surveys undertaken;
ii. Details of how the ground-truthed biodiversity values differ from Queensland government mapping e.g. locations, amount (hectares), composition, habitat features;
iii. Detailed assessment results; and
iv. A thorough, evidence-based, justification for any presence/absence determinations for matters of State environmental significance (MSES), particularly where that deviates from the Queensland government records.

RESPONSE

Methodology of ecological surveys undertaken

The Terrestrial Ecology Report (Ecosmart Ecology, 2017) is a thorough document outlining the methods and results of a detailed, seasonal flora and fauna survey covering 202,915 ha, including the PL253 tenement. The methods applied across the entire survey area are the same and resulted in detailed, ground-verified mapping incorporating survey sites, vegetation communities and threatened species and their core habitat. The methods are outlined in detail in Section 3 of Ecosmart Ecology (2017) and cover desktop analyses, field survey methods, survey techniques and survey effort.

The flora field survey was consistent with Queensland Herbarium standards (Neldner *et al*., 2012) and included secondary, tertiary and quaternary sites. In total 218 secondary, 17 tertiary and 2,223 quaternary flora survey sites have been sampled throughout the Surat Gas Project study area. The location of these sites was selected using aerial photograph analysis, or opportunistically during traverse, to ensure that the field survey targeted a representative range of habitats. Six flora ecologists completed two 12-day surveys, one during the wet season and one during the dry season, totalling over 1,440 person hours in the field.

The terrestrial fauna surveys used a variety of recognised survey methods consistent with relevant federal and state survey guidelines. These included trapping (Elliot, pitfall, funnel and Harp), observation (spotlighting, bird survey, and active search), remote sensing (Anabat ultrasonic bat detection and camera trapping), and targeted methods (i.e. Koala [SAT], Glossy Black Cockatoo ort searches, microbat tripline over water bodies and reptile artificial shelter). Eight fauna ecologists completed two 12-day surveys, one during the wet season and one during the dry season, totalling over 2,304 person hours in the field.

In addition to the above, the two lead ecologists (David Stanton and Mark Sanders) conducted a five-day 'pilot study' to visually inspect the SGP study area, identify survey constraints, and locate possible detailed fauna trap sites; and, a three-day 'follow-up' survey to sample fragmented habitats (including habitats for Squatter Pigeon, Painted Honeyeater and Yakka Skink), habitats not subject to effort during the detailed surveys (e.g. wetlands), or areas which may not have been otherwise inspected.

Focusing on PL253, Figure G1 shows the survey area covering the entire tenement, Figure G2 shows the flora survey sites and Figure G3 shows the fauna survey sites as representative of vegetation communities and habitats across PL253.

Details of how the ground-truthed biodiversity values differ from Queensland government mapping e.g. locations, amount (hectares), composition, habitat features

Ground-verified mapping (Figure G4) did differ from that supplied by the Queensland Government (Figure G5) in some cases in terms of extent (area) and Regional Ecosystem (RE) classification. See Figures G4 and G5, and below (iii.) for detailed assessment results.

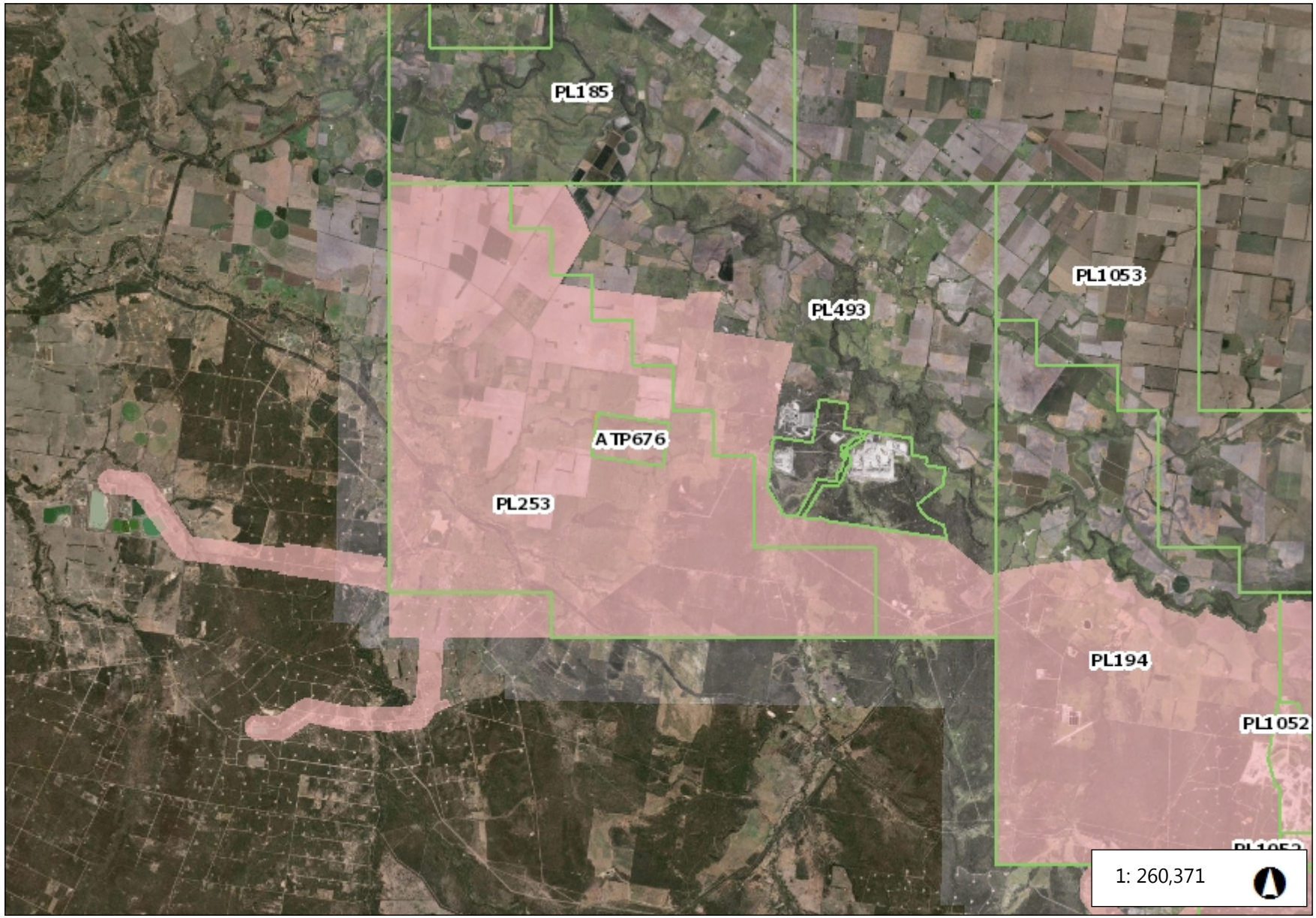
Detailed assessment results

Across the PL253 tenement there are 15 ground-verified REs (Table G1).

Figure G1

arrow energy
go further

Terrestrial Ecology Report (Ecosmart Ecology, June 2017) - Survey Area



Legend

- Actual PL Boundary
- Actual ATP Boundary
- Survey Boundary
- SB Imagery AAM 2014
- BB Imagery AAM 2014
- BB Imagery Fugro 2012

Notes

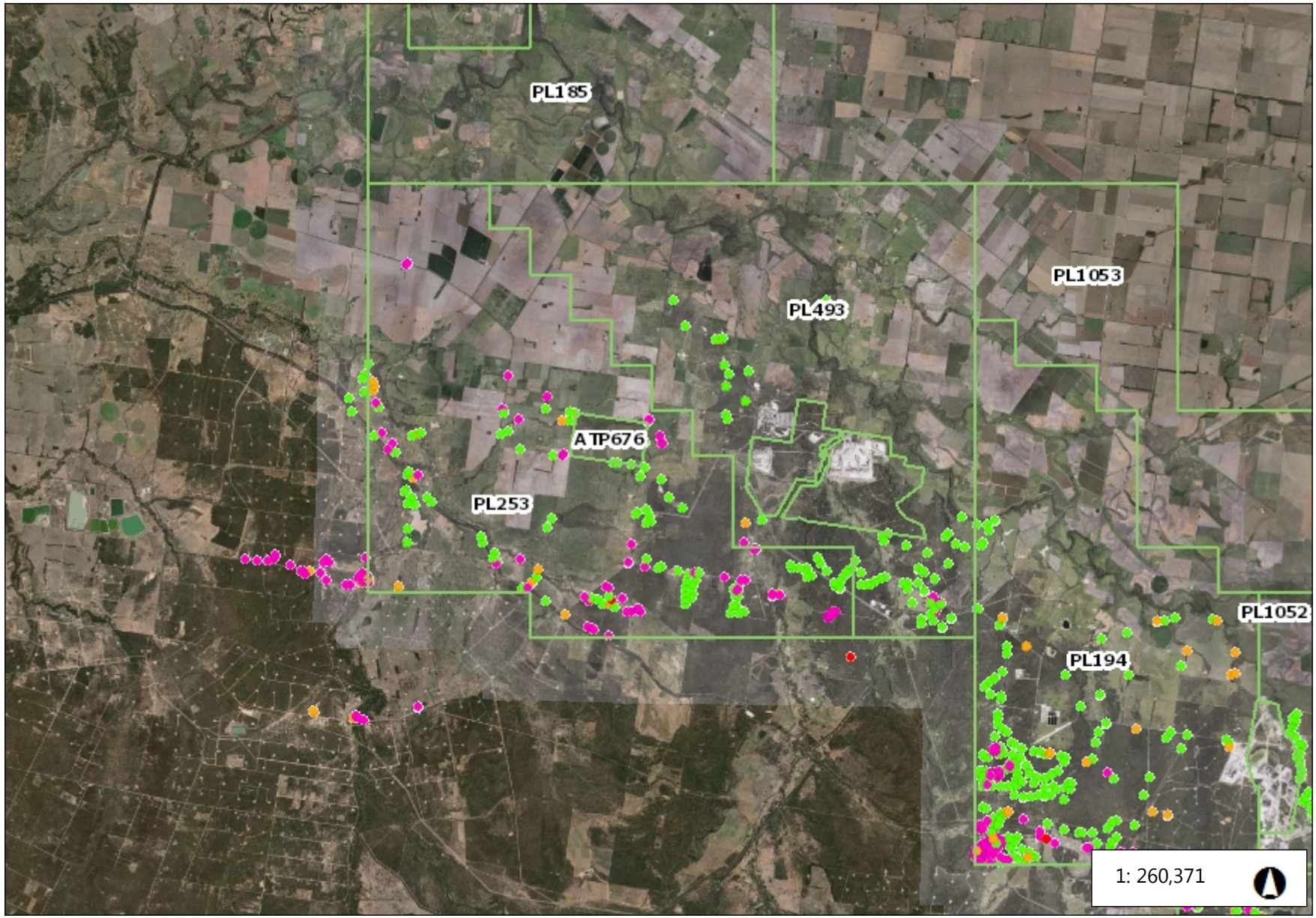
13,226.8 0 6,613.41 13,226.8 Meters

Print Date: 4/9/2020

Figure G2

arrow energy
go further

Terrestrial Ecology Report (Ecosmart Ecology, June 2017) - Flora Survey Sites



Legend

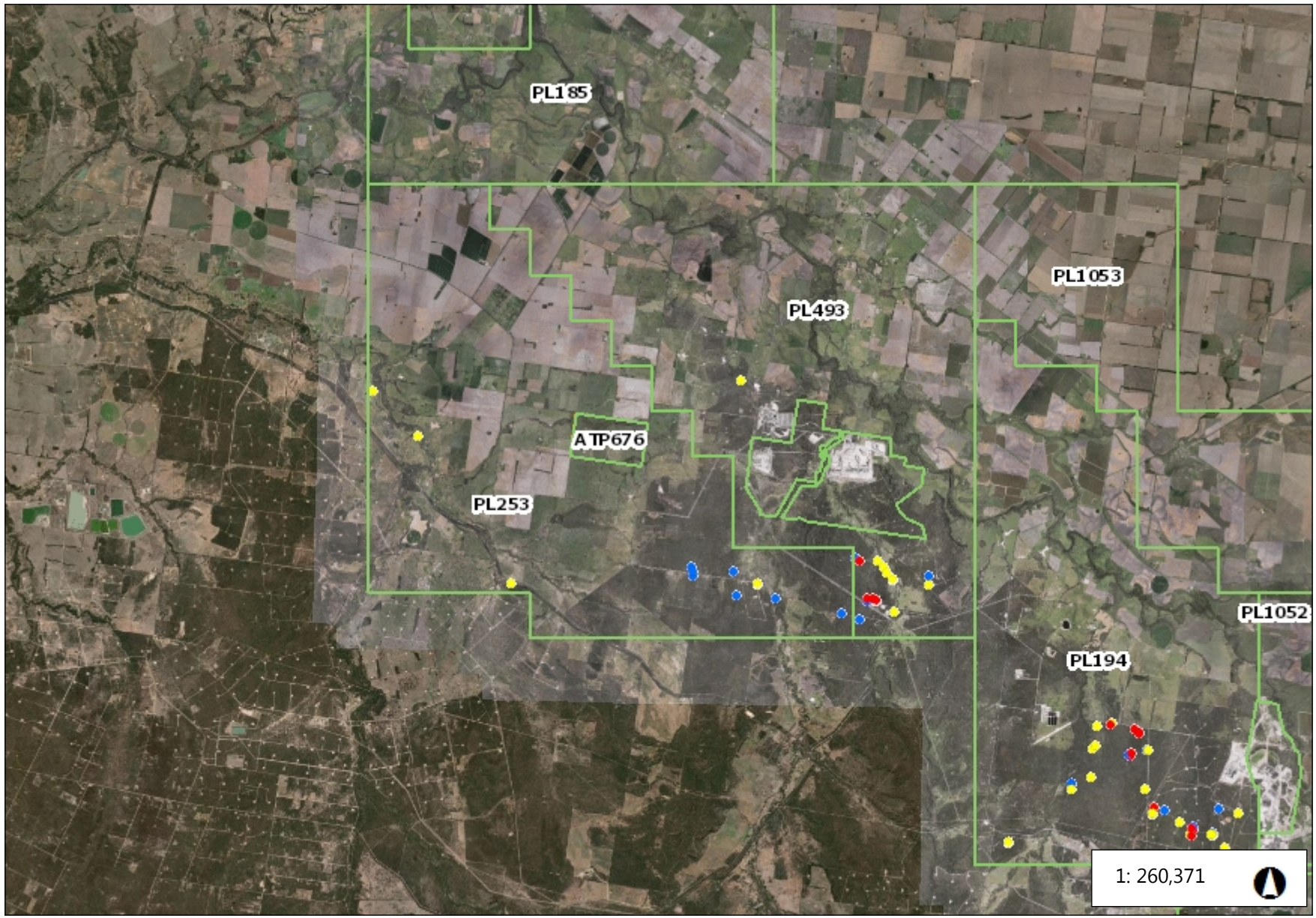
- Actual PL Boundary
- Actual ATP Boundary
- Flora Survey Sites
  - Observaton (Linear)
  - Observation
  - Observation (Watercourse Crossing
  - Quaternary
  - Road Crossing
  - Secondary
  - Tertiary
  - Watercourse Crossing
- SB Imagery AAM 2014
- BB Imagery AAM 2014
- BB Imagery Fugro 2012

Notes

13,226.8 0 6,613.41 13,226.8 Meters

Print Date: 4/9/2020

Figure G3



Terrestrial Ecology Report (Ecosmart Ecology, June 2017) - Fauna Survey Sites

Legend

- Actual PL Boundary
- Actual ATP Boundary
- Fauna Survey Sites
  - Observation
  - Obs incl harp trap
  - Detailed Trapping SIte
- SB Imagery AAM 2014
- BB Imagery AAM 2014
- BB Imagery Fugro 2012

1: 260,371

Notes

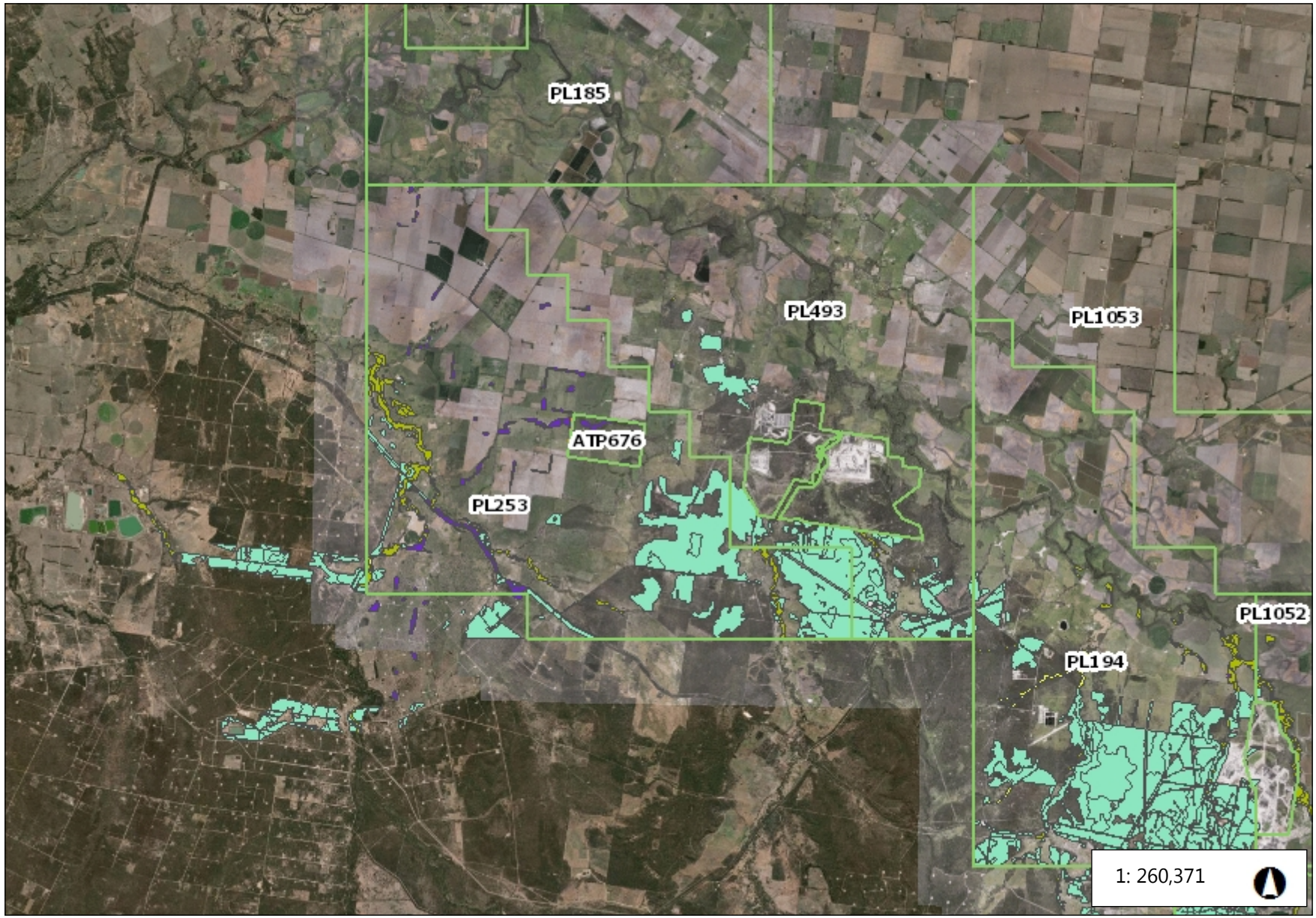
13,226.8 0 6,613.41 13,226.8 Meters

Print Date: 4/9/2020

Figure G4

arrow energy
go further

Terrestrial Ecology Report (Ecosmart Ecology, June 2017) - Remnant



Legend

- Actual PL Boundary
- Actual ATP Boundary
- Remnant BD Status
  - End.
  - OC dom.
  - OC sub_dom.
  - NCAP
  - Cleared
  - Non remnant
- SB Imagery AAM 2014
- BB Imagery AAM 2014
- BB Imagery Fugro 2012

Notes

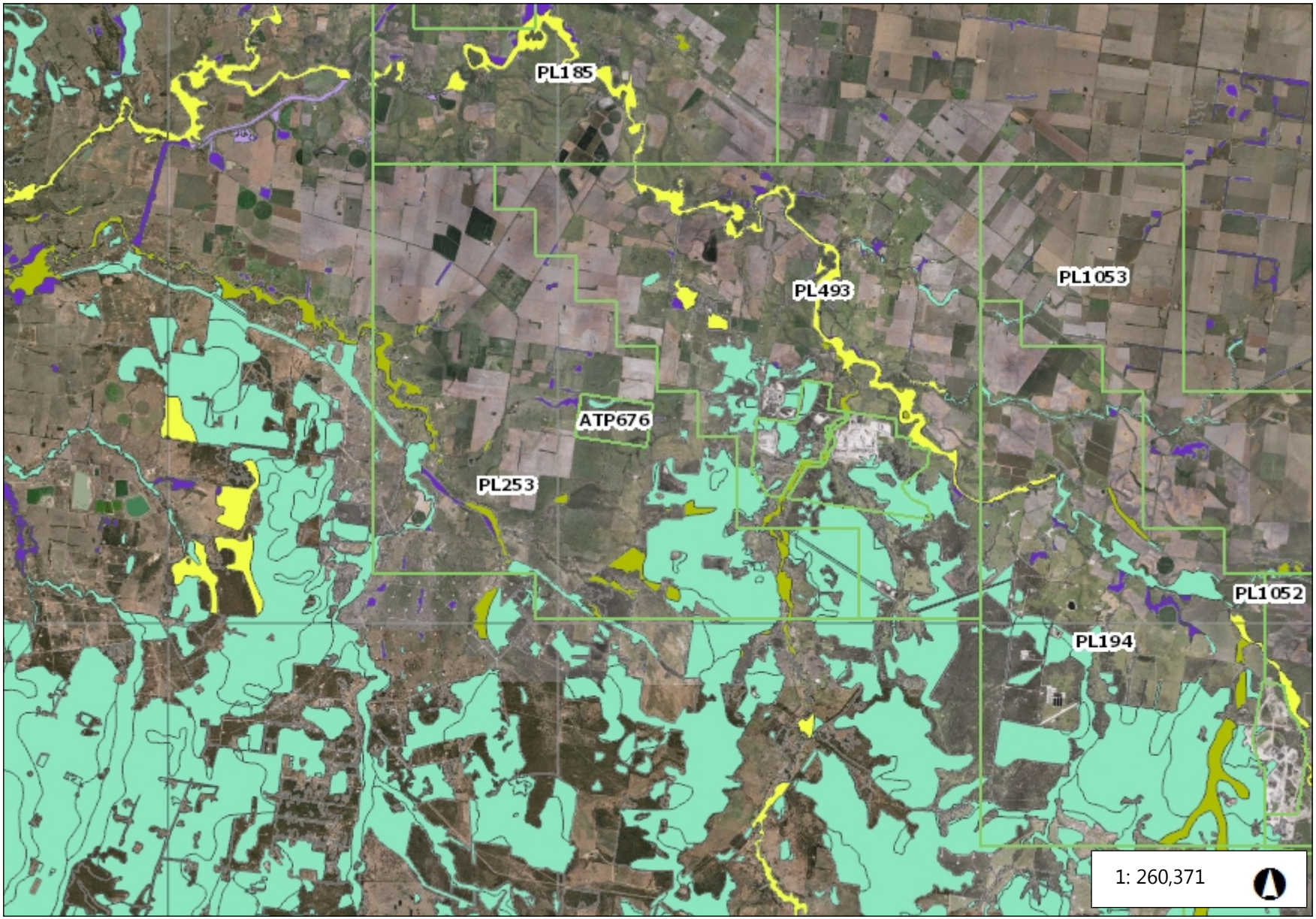
13,226.8 0 6,613.41 13,226.8 Meters

Print Date: 4/9/2020

Figure G5

arrow energy
go further

QLD Government - Remnant



Legend

- Actual PL Boundary
- Actual ATP Boundary

Regional Ecosystems Version

- Endangered - Dominant
- Endangered - Sub-dominant
- Of Concern - Dominant
- Of Concern - Sub-dominant
- Least Concern
- 1, non-rem/; Non-remnant, regrowth
- Plant
- Estuary
- 253, ocean
- 253, shallow
- 253, water

SB Imagery AAM 2014
BB Imagery AAM 2014
BB Imagery Fugro 2012

Notes

13,226.8 0 6,613.41 13,226.8 Meters

Print Date: 4/9/2020

Table G1: Ground-verified Regional Ecosystems (REs) present within PL253

Regional Ecosystem	Description	VM Act Status	BD Status
11.3.1	Acacia harpophylla and/or Casuarina cristata open forest on alluvial plains	E	E
11.3.2	Eucalyptus populnea woodland on alluvial plains	OC	OC
11.3.4	Eucalyptus tereticornis and/or Eucalyptus spp. woodland on alluvial plains	OC	OC
11.3.14	Eucalyptus spp., Angophora spp., Callitris spp. woodland on alluvial plains	LC	NCAP
11.3.18	Eucalyptus populnea, Callitris glaucophylla, Allocasuarina luehmannii shrubby woodland on alluvium	LC	NCAP
11.3.25	Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines	LC	OC
11.3.27f	Eucalyptus coolabah and/or E. tereticornis open woodland to woodland fringing swamps.	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 populnea woodland with Allocasuarina luehmannii low tree layer	LC	NCAP
11.5.4	Eucalyptus chloroclada, Callitris glaucophylla, C. endlicheri, Angophora leiocarpa 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
11.7.4	Eucalyptus decorticans and/or Eucalyptus spp., Corymbia spp., Acacia spp., Lysicarpus angustifolius woodland on Cainozoic lateritic duricrust	LC	NCAP
11.7.6	Corymbia citriodora or Eucalyptus crebra woodland on Cainozoic lateritic duricrust	LC	NCAP
11.7.7	Eucalyptus fibrosa subsp. nubilis +/- Corymbia spp. +/- Eucalyptus spp. woodland on Cainozoic lateritic duricrust	LC	NCAP

Vegetation communities (REs 11.3.1 and 11.4.3) consistent with the federally Threatened Ecological Community (TEC) Brigalow (*Acacia harpophylla* dominant and co-dominant), listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), were present in a number of small, isolated and edge-effected patches of remnant vegetation, typically along roadsides (Figure G6).

Endangered, Vulnerable and Near Threatened (EVNT) flora species known to occur within the tenement include only the Kogan waxflower (*Philotheca sporadica*), listed as Near Threatened under the *Nature Conservation Act 1992* (NC Act) (Figure G7).

EVNT fauna species known to occur within the tenement include the Endangered grey snake (*Hemiaspis damelii*), Vulnerable koala (*Phascolarctos cinereus*) and pale imperial hairstreak (*Jalmenus eubulus*) and Near Threatened golden-tailed gecko (*Strophurus taenicauda*); as listed under the NC Act (Figure G8).

A thorough, evidence-based, justification for any presence/absence determinations for matters of State environmental significance (MSES), particularly where that deviates from the Queensland government records.

Ground-verified data is used to apply the 'avoid, minimise, mitigate' hierarchy for proposed infrastructure. Once final layout approval is reached for the proposed infrastructure, the significant residual impacts (SRI) to MSES is determined. This is completed by comparing government mapped MSES with ground-verified data. All reliable Queensland Government flora and fauna records (post 1980) are included as well as any further records obtained from the above-mentioned studies or collected by Arrow suitably qualified ecologists. Any SRI to MSES will be offset as required.

(h) Table 6-3 of the Amendment Application Report (page 72) lists the proposed significant residual impacts to prescribed environmental matters. To determine the appropriateness of these values, the department requests the following:

- **a. A GIS layer of proposed disturbance;**
- **b. Detailed justification of the significant residual impact (SRI) assessment on prescribed environmental matters, including connectivity areas;**
- **c. The scale and extent of the activity planned for those areas that would result in a SRI on prescribed environmental matters; and**
- **d. The status of the Offset Strategy under the Environment Protection and Biodiversity Conservation Act 1999 that may be relevant to the application.**

RESPONSE

A GIS layer of proposed disturbance

A map of PL253 showing the proposed significant residual impacts to prescribed environmental matters is presented at Attachment B. Shape files have also been provided along with this response to the information request.

Detailed justification of the significant residual impact (SRI) assessment on prescribed environmental matters, including connectivity areas

As noted in section 6.2 of the Hopelands EA amendment application, the total footprint for the proposed development is 1,100 ha. Of that, proposed impacts to Category A Environmentally Significant Areas (ESAs) is 0; Category B ESAs is 5 ha (or 0.45% of the total disturbance area); and

Category C ESAs is 60 ha (or 5.45% of the total disturbance area). These low percentage impacts compared to the total area to be impacted demonstrate the success of the above-mentioned impact assessment process.

The processes adopted by Arrow to minimise impacts to prescribed environmental matters and to determine significant residual impacts are comprehensive. The assessments were first described in the Queensland and Australian governments' approved Surat Gas Project Environmental Impact Statement (EIS) (October 2013 and 19 December 2013 respectively) and Supplementary Report to the EIS (19 December 2013). Subsequently, the process has been refined and detailed in the Australian Government approved SGP Species Impact Management Plan (14 December 2018) and in each of the three main Environmental Authority applications approved by the Department of Environment Science (DES) for the SGP (being the EA North – 7 August 2018 date; EA South – 16 January 2019; EA Kogan East – 8 August 2018).

Furthermore, the same method to assess and minimise impacts was applied and described in the Australian Government approved SGP Off-Tenure Pipelines Preliminary Documentation (28 May 2020) and the two DES approved Environmental Authorities for the Kenya Brine Ponds (7 November 2018, amended on 9 April 2020) and David Pipeline (21 September 2018).

Section 6.2 of the Hopelands EA amendment application describes this same process.

Fundamentally, the assessment process includes the following:

- desktop and geospatial analyses of all relevant Government mapping;
- ground verification of all vegetation communities across the entirety of PL253 by third party suitably qualified ecologists – the full report of which was provided in Appendix C to the Hopelands EA amendment application;
- updating of Arrow geospatial database layers to capture the ground truthed information and to ensure the accuracy and currency of Arrow data;
- overlay of the proposed field development layout on top of the Government layers and ground verified layers to understand potential impacts on prescribed environmental matters;
- iterative and detailed constraints analyses of Arrow's proposed field layouts against the ecological values;
- relocating infrastructure and optimising field layouts to reduce impacts to matters such as MSES as much as practicable;
- GIS analysis to determine the proposed areas of impact when the datasets are overlain;
- Table 5.7 and Table 6.3 of the Hopelands EA amendment application detail the outcomes of this assessment process against Matters of State Environmental Significance and Prescribed Environmental Matters respectively.

Arrow's Ecologists and Development Planning Teams worked closely to place infrastructure to avoid impacts to MSES as much as possible and to apply the avoid, minimise, mitigate hierarchy for proposed infrastructure. Further information about this has been provided earlier in response to question G(iv).

To determine SRI to MSES, the following analyses of values were undertaken:

Value	Government Mapping	Ground Verified Data
Fish waterways for waterway barrier works (stream and estuaries)	✓	
Habitat for an animal that is special least concern wildlife	✓	✓
Protected Plant (high risk trigger) NC Act 1992	✓	✓
Areas of essential habitat for endangered or vulnerable wildlife prescribed under the NC Act 1992	✓	✓
Wildlife habitat (endangered and vulnerable wildlife)	✓	✓
Regulated vegetation (defined watercourse)	✓	✓
Category B Regulated Vegetation	✓	✓

The Queensland Government's Landscape Fragmentation Connectivity Tool was used to determine impacts to connectivity communities. The Tool determined that Arrow's proposed development on PL253 will not result in significant residual impacts to connectivity areas. This was not a surprising result given that Arrow preferentially avoids dissecting vegetation areas with our infrastructure.

The scale and extent of the activity planned for those areas that would result in a SRI on prescribed environmental matters; and

As noted in section 6.2 of the Hopelands EA amendment application, the total footprint for the proposed development is 1,100 ha. Of that, proposed impacts to Category A Environmentally Significant Areas (ESAs) is 0; Category B ESAs is 5 ha (or 0.45% of the total disturbance and area); and Category C ESAs is 60 ha (or 5.45% of the total disturbance and area). These low percentage impacts compared to the total area to be impacted demonstrate the success of the above-mentioned impact assessment process.

To more fully understand the biodiversity values to be impacted and offset, Table 6.3 provided a complete breakdown of maximum disturbance areas to each PEM listed in the DES Streamlined Model Conditions (SMCs). The scale and extent of activities planned across PL253 that would result in a SRI on prescribed environmental matters is included in the PEMs table that was included within the EA amendment application. The draft PEMs table has been included below for reference:

Protecting biodiversity values, Table 2—Significant residual impacts to prescribed environmental matters

Prescribed environmental matter	Location of impact	Maximum extent of impact	Maximum extent of impact – Stage 1 (Years 2019 – 2023 inclusive)
REGULATED VEGETATION			
Endangered regional ecosystem	NA	NA	NA
Of concern regional ecosystem	NA	NA	NA
Regional ecosystems (not within an urban area) that intersect a wetland on the vegetation management wetlands map	NA	NA	NA
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	NA
Essential habitat (not in an urban area) for endangered wildlife			
Hemiaspis damelii (Grey Snake)	PL253	5 ha	2 ha
Essential habitat (not in an urban area) for vulnerable wildlife			
Jalmenus eubulus (Pale Imperial Hairstreak)	PL253	5 ha	4 ha
Connectivity areas			
Connectivity area that is a regional ecosystem (not in urban area)	NA	NA	NA

Prescribed environmental matter	Location of impact	Maximum extent of impact	Maximum extent of impact – Stage 1 (Years 2019 – 2023 inclusive)
Wetlands and watercourses			
A wetland in a wetland protection area shown on the Map of referable wetlands (HES wetlands in GBR)	NA	NA	NA
A wetland of high ecological significance shown on the Map of referable wetlands	NA	NA	NA
Designated precincts in strategic environmental areas			
Designated precinct in a strategic environmental area	NA	NA	NA
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	NA	NA	NA
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	NA
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	NA
Habitat for an animal that is endangered wildlife			
Hemiaspis damelii (Grey Snake)	PL253	15 ha	15 ha

Prescribed environmental matter	Location of impact	Maximum extent of impact	Maximum extent of impact – Stage 1 (Years 2019 – 2023 inclusive)
Habitat for an animal that is vulnerable wildlife			
Acanthophis antarcticus (Common Death Adder)	PL253	125 ha	120 ha
Calyptorhynchus lathami (Glossy Black Cockatoo)	PL253	10 ha	8 ha
Jalmenus eubulus (Pale Imperial Hairstreak)	PL253	5 ha	5 ha
Habitat for an animal that is special least concern wildlife			
Tachyglossus aculeatus (Echidna)	PL253	5 ha	4 ha
Protected areas			
National park	NA	NA	NA
Regional park	NA	NA	NA
Nature refuge	NA	NA	NA
Highly protected zones of State marine parks			

Prescribed environmental matter	Location of impact	Maximum extent of impact	Maximum extent of impact – Stage 1 (Years 2019 – 2023 inclusive)
Conservation park zone	NA	NA	NA
Marine national park zone	NA	NA	NA
Preservation zone	NA	NA	NA
Other zones	NA	NA	NA
Fish habitat areas			
A declared fish habitat area	NA	NA	NA
Waterway providing for fish passage			
Fish passage (not in an urban area)	PL253	15 ha	12 ha
Marine plants			
Marine plant (not in an urban area)	NA	NA	NA
Legally secured offset area			

Prescribed environmental matter	Location of impact	Maximum extent of impact	Maximum extent of impact – Stage 1 (Years 2019 – 2023 inclusive)
Legally secured offset area	NA	NA	NA

The status of the Offset Strategy under the *Environment Protection and Biodiversity Conservation Act 1999* that may be relevant to the application.

The Surat Gas Project Stage 1 Offset Strategy was forwarded to the then Commonwealth Department of the Environment and Energy on 28 June 2019 and approved by the Minister on 7 July 2019.

(i) In relation to offsets for PL253, provide further information as follows:

i. Details of whether suitable offsets exist for the proposed impacts to prescribed environmental matters, including the endangered *Hemiaspis damelii* (Grey Snake);

RESPONSE

Yes, suitable offsets exist for all species including *Hemiaspis damelii* on Arrow's Offset property (Killara).

ii. If already determined, the proposed offset delivery mechanism, i.e. land-based, financial payment or a combination of both. Where financial payment is proposed, the values to which the financial payment relates and the quantity (as determined by the offset financial calculator). Where land-based offsets are proposed, provide an assessment of 'habitat quality' of the impact area and offset area; and

RESPONSE

The offsets delivery method has not been determined as yet. Appropriate offsets will be delivered in accordance with the Qld Offsets Policy 2020 (V1.9) and EA as required.

iii. Details of whether the proposed impacts / offsets will be undertaken in full prior to the impacts occurring, or whether they will be staged over the life of the project. If staged impacts / offsets are proposed, identify what those stages are, which impacts are proposed for each stage and the anticipated timeframe for each stage.

RESPONSE

The proposed impacts/offsets will be staged over the life of the project. At present it is difficult to determine the number of stages and timeframe for each stage. This detail will form part of the Notice of Election with Arrow's first offsets.

(j) Subsidence has been cited as an indirect impact of coal seam gas activities. Provide further information regarding the potential impacts to land and its use that may occur as a result of the activities. This should include mitigation measures to manage the impacts to land and details of any current or planned subsidence monitoring.

RESPONSE

Arrow Energy has undertaken considerable research and monitoring of land subsidence. This work was first discussed in the Surat Gas Project Environmental Impact Statement (EIS) that was approved by the Australian and Queensland governments in 2013.

A condition of approval from the Australian Government was to develop a monitoring program to better understand subsidence in the area of the SGP. This subsidence monitoring program was included within Arrow's Stage 1 CSG Water Monitoring and Management Plan (CSG WMMP) and the Updated SCSG WMMP. These plans were approved by the Australian Government in 2018 and 2020 respectively and are publicly available at: https://www.arrowenergy.com.au/environment/groundwater/water-monitoring-management-plans

Appendix K to the Stage 1 CSG WMMP provides particularly useful information with regards to subsidence monitoring that was conducted at that time. Of note, monitoring of subsidence was carried out by Altamira (Altamira 2016) comparing data obtained from Radarsat-2 satellite images covering 10,736 km^2 of Arrow's SGP leases. Comparisons were made of 34 images over the period July 2012 to December 2015.

As such, Arrow's primary tool for monitoring potential subsidence is satellite-borne interferometric synthetic aperture radar technology (InSAR). InSAR can be used to interpret changes in relative position and indicate subsidence for different regions within areas potentially affected by CSG drawdown. The InSAR data provides a baseline from which future data can be assessed to determine changes in vertical ground elevation and provides a snapshot of current vertical ground movement. InSAR methodology can identify ground movement in excess of 8mm per year.

In addition to the InSAR monitoring, permanent ground movement monitoring stations are proposed to be installed at four locations within Arrow's Surat Gas Project tenure to ground truth the results of satellite monitoring. Arrow also uses LiDAR technology, extensometer monitoring stations, on-ground survey and aerial photography to investigate specific instances of potential subsidence.

Arrow is seeking ground movement data from agriculture-related entities to better understand the dynamics of non-CSG related ground movement across cropping land. This will also be used to inform and update Arrow's modelling and monitoring.

A presentation developed to help inform the community of subsidence and to summarise the results of the more detailed technical studies conducted to date is available at Arrow's website at

the following link:
https://www.arrowenergy.com.au/__data/assets/pdf_file/0016/32803/Kupunn-landholder-webinar-Subsidence-6-July-2020.pdf

The following provides a summary to address the DES question raised above.

Potential impacts

Coal seam gas occurs within coal formations through adsorption to the surface of the coal under hydrostatic pressure. Depressurisation of the coal seams below a threshold (by groundwater extraction) reduces hydrostatic pressure and liberates the gas from the formation. At any point below the ground surface, the weight of overlying strata is supported partly by water pressure and partly by the fabric of the rock mass. A reduction in water pressure therefore results in an increased proportion of the load being carried by the rock mass, leading to compression of the rock. The combined compression over the thickness of rock strata affected by reduced water pressure results in subsidence at the ground surface.

Therefore, CSG induced subsidence is markedly different to coal mining or UCG induced subsidence where a void is generated that can result in collapse of the overlying roof strata. CSG induced subsidence occurs as a broad downward warping of strata rather than acute subsidence due to physical collapse of structures.

A conservative assessment of potential subsidence from Arrow activities indicates predicted subsidence of less than 100 mm within PL253, with the modelling indicating that trigger thresholds are unlikely to be exceeded (see below for discussion of trigger thresholds).

The discussions occurring with landholders with regards to subsidence are related to the potential impacts on land use and farming practices predominantly in areas of Intensively Farmed Land (IFL) where laser-levelled paddocks are more common. Arrow's position is that the predicted subsidence, being a gradient change of 0.0002% reflecting 65mm over a distance of 35km or a surface elevation change of 5mm over a 1km long paddock, is considered to represent a minor impact to land use practices.

Monitoring and mitigation

Arrow Energy has monitored subsidence since 2006 using data collected and processed by Altamira, a specialist ground movement monitoring company using satellite borne Interferometric Synthetic Aperture Radar technology (InSAR). This subsidence monitoring will continue.

In addition, this monitoring program is being expanded to include an extensometer array of initially four locations within Arrow Energy tenure in areas of predicted subsidence impact from Arrow activities.

The monitoring program is part of an assessment process including screening levels, investigation levels and trigger thresholds. These are described in the CSG WMMP and summarised below.

Trigger threshold exceedance response actions are dependent on the evaluation of the cause of the exceedance, and if the potential for detrimental impacts is confirmed, a mitigation (action) plan will be developed and implemented within 90 days to minimise impact. The mitigation plan will:

- Identify potential mitigation measures and response actions;
- Select suitable response actions, tailored to site-specific conditions, impact cause, timing and magnitude;
- Evaluate timeframes within which impacts would be expected to occur and within which mitigation actions would need to be successful;
- Schedule mitigation implementation, with consideration for the anticipated timing of the indicated impact; and
- Contain procedures to evaluate the effectiveness of the mitigation measures.

The subsidence monitoring program has been subject to peer review and addressed the Australian Government approval conditions relating to the assessment, management and mitigation of surface and groundwater impacts as a result of project development. It also delivers against relevant commitments in Arrow's SGP Environmental Impact Statement (EIS) (Arrow Energy 2012) and Supplementary Report to the EIS (SREIS) (Arrow Energy 2013) approved by the Australian and Queensland governments in 2013.

(k) The AGE 2020 report contained within Appendix E of the Amendment Application Report states on page 4 that, "Only very limited information relating to historic activities on the former Linc Energy site has been available to date."

Please note, investigative works are on-going at the former Linc Energy Site, including the installation and sampling of on-site monitoring bores. DES will provide this data to the applicant when available.

Arrow are to determine the additional information (i.e. that may be attainable by DES about the former Linc Energy Site), that would be required to further refine the contaminant fate and transport modelling and estimations associated with the potential extent/propensity for contamination to migrate from the site.

RESPONSE

Arrow has undertaken modelling based on the data provided by DES and collected by Arrow and appreciates that the DES will provide additional information when available. Arrow has continued to refine our groundwater model to not only improve our ability to predict changes in groundwater direction and speed, but more importantly to undertake fate and transport tracking of contaminants. By way of context, Arrow has modelled data from a number of sources for several years including observed data and unless future data shows significant differences, Arrow believes that material difference to predicted impacts of our proposed activities within PL253 is highly unlikely.

To ensure that this response to the Information Request included all available information at this time Arrow requested the following of the DES on 19 October 2020:

Clarification sought for DES question (k).

The above request notes that investigative works are ongoing and that DES will provide this data when available.

Could you please confirm that all available data in this regard has been provided to Arrow. The following is provided as examples of the type of data that would be of benefit:

- *Number of data points for which on-site information has been collected and whether all data from each data point has been provided*
- *Data from pump tests, DST or other permeability data or data on fracture aperture size at the site*
- *Data on the composition of the free phase and the fraction of the composition comprising the most prevalent contaminants (i.e. benzene and naphthalene)*
- *Calculations or data showing contaminants above aqueous solubility limits or effective solubility limits in the Macalister or Springbok for the primary contaminants of concern*
- *Information on the potential void size.*

The following response to the above clarification was provided by the DES on 17 November 2020:

In relation to the below email, apologies again for the time it's taken to respond, we were confirming the information that was held by the department and whether this could legally be released. Unfortunately, I can confirm that the department is unable to provide any additional information for Arrow to utilise within their current amendment application.

(l) The AGE 2020 report referred to above states on page 9 that the Office of Groundwater Impact Assessment (OGIA) Surat Underground Water Impact Report (UWIR) and the Arrow Hopeland Groundwater Modelling Report (prepared by GHD, October 2019) groundwater models may underestimate lateral migration of particles. The structure of the contaminant fate and transport model was therefore altered to add a coal layer at the top of each Walloon Coal Measures sub-unit. It is noted that vertical hydraulic conductivity (Kv) was altered immediately above each gasifier, but horizontal hydraulic conductivity (Kh) does not appear to have been amended within the bounds of the site. The implications of this approach is not known, against assigning an increased Kh to relevant cells for example, within the boundary of the site (to reflect likely localised horizontal fracturing within the Springbok Sandstone and within the Macalister Seam).

Please provide an explanation of the limitations of the adopted approach and its impact on the contaminant fate and transport modelling. Provide results for a contaminant fate and transport model in which Kh is locally altered.

RESPONSE

The reference to the groundwater models was in relation to previous models, not the most recent Arrow Hopeland groundwater model. As described in section 3.2.1, the 2020 AGE model report was updated to address this specific issue.

In summary, the AGE model included further delineation of upscaled coal packages (which consist of coal and interburden) to separate explicit layers for coal and for interburden. Figure L1 shows the separate coal and interburden layers in the site area.

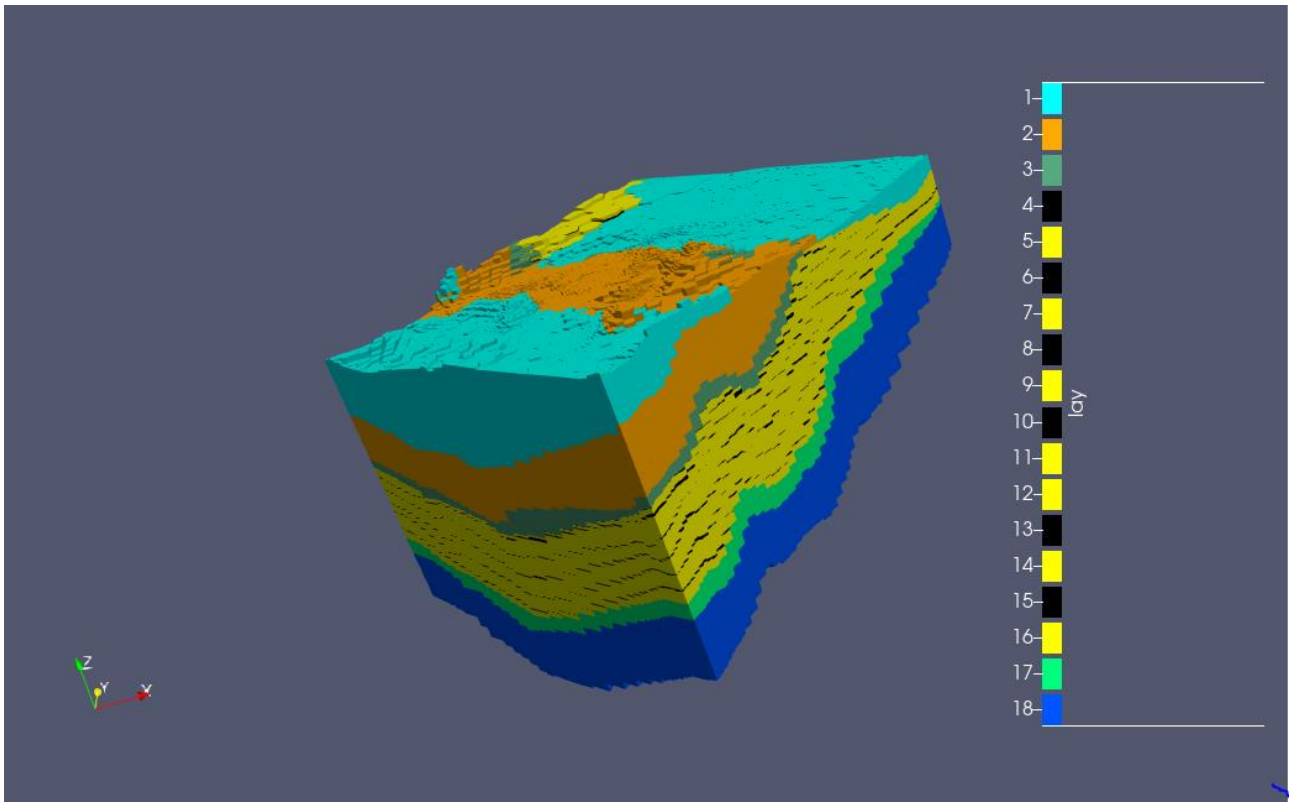


Figure L1: Block Model with layer index showing coal layers in black (1:25 Vertical Exaggeration)

The variability in horizontal (Kh) and vertical (Kv) hydraulic conductivity was enabled in the model through use of 'pilot point' calibration, which provides a variable distribution of these parameters, including in the vicinity of the gasifiers. In addition to the calibrated model, uncertainty analysis using the null space monte carlo (NSMC) method provided 200 scenarios of variable distribution of these parameters.

This provided a calibrated variable Kh distribution (Figure L2) in the Macalister coal seam in the immediate site area ranging from a P05 of 0.02 m/day to a P95 of 0.04 m/day with a P50 of 0.03 m/day.

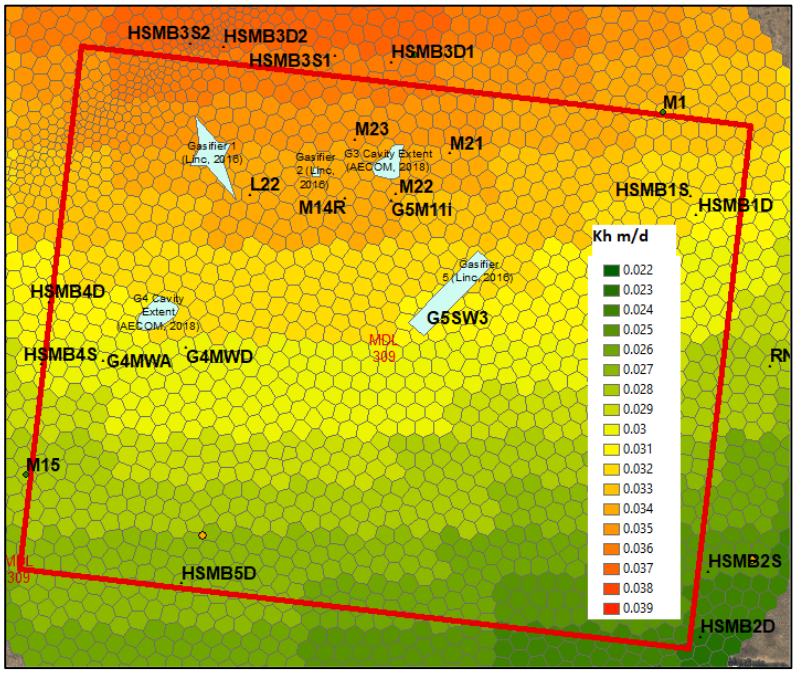


Figure L2: Kh parameter distribution from 0.02 m/day to 0.04 m/day for MDL309 in the calibrated case.

This provided a higher range of values than the OGIA model, which had a median value of 0.00012 m/d, and was in the range of the DST tests from drilling of 0.045 m/d for this unit.

The NSMC uncertainty analysis using 200 realisations that all approached the calibration criteria was able to show that the Kh range could extend up to 0.28 m/day. It should be noted that this measurement refers to the upper limit of hydraulic conductivity and not the rate of movement of groundwater.

Hence, the current simulation and uncertainty analysis explores parameter variability, in line with the Australian Groundwater Modelling Guidelines, up to an order of magnitude higher than observed values. The current simulation also assumes continuous coal seams are present allowing for pressure to be conducted without interruption through coal seams that in actuality pinch out, and thus provides a scenario that is likely to over-estimate impact.

In all models, from the 2018 submission (using the OGIA model) through the 2019 model to the current 2020 model, we have proven consistently, that regardless of the variation in predictions, the incremental impact of Arrow's proposed FDP compared to a background case with no Arrow development is negligible. Arrow's proposed FDP does not appreciably change the risks posed by the site contamination compared to the background case with surrounding development from other operators as shown in the model reports.

The exploration of uncertainty shows that even with the upper range of values of horizontal and vertical hydraulic conductivity that are consistent with observed data there is minimal additional impact to the site. Therefore, the risk posed by the site can be managed under an adaptive management regime as proposed by Arrow in the EA amendment application.

(m) The AGE 2020 report referred to above states on page 33 that "Benzene and Naphthalene have reduced at nearly all monitoring points since the commencement of monitoring in June 2018" and "the available groundwater level data suggest ongoing flow towards, rather than away from the site which would tend to promote gradual adsorption and dispersion of the contaminant plume in situ rather than advective transport of contaminants outside of the lease area".

When considering the current hydrogeological dynamics of the former Linc energy site, it is noted that due to UCG activities, groundwater in both the Springbok Sandstone and the Macalister Seam surrounding the site are currently flowing towards the UCG gasifiers as a cone/s of depression appears to have formed in aquifer/s beneath the site. Therefore, DES does not agree with the interpretation as outlined above regarding contaminant dispersion because the groundwater contamination being referred to, which originated at the source site, is flowing back towards the source site. That is, it is concentrating, not dispersing. DES asserts that the dispersion of contaminants would refer to the distribution of those contaminants from the source to a larger area however, in this circumstance the contaminants are flowing back towards their point of origin and concentrating due to temporary circumstances.

Based on the foregoing, impacts associated with Linc Energy's former UCG project have resulted in the generation of cavities within the Macalister seam, which is considered highly likely to contain free phase petroleum hydrocarbons. With groundwater reporting back towards the site and making contact with the primary impact source (i.e. free phase petroleum hydrocarbons), it is agreed that advective transport may not be occurring at the site presently as groundwater is flowing towards it. DES asserts however, if regional depressuration occurs in the future and/or if the aquifer beneath the site recovers and groundwater flows in its original regional direction, the future advective transport of contaminants at saturation (maximum solubility limits) cannot be discounted. The future migration of contaminants at maximum solubility limits reporting from the site does not appear to have been considered in the AGE 2020 report. DES considers that the modelling may have underestimated the potential contaminant transport risks.

The applicant is required to undertake and provide DES a contaminant fate and transport model using maximum solubility limits at the source area.

RESPONSE

Summary

Arrow has used groundwater data from and on the boundary of the former Linc site as well as groundwater data obtained by Arrow's GCMP bores to inform the company's groundwater model. This is in line with industry practice, including the Australian Groundwater Modelling Guidelines, and thus Arrow has correctly based its modelling upon available data. Our work in this regard has shown that the observed data is inconsistent with the DES' statement and further that the numerical modelling does not simulate observed data in a way that supports the statements from DES about contaminant fate and transport.

To assess the statements presented by the DES, Arrow reconfirmed with DES that it had all available site data to be considered in the numerical model (see below). In the absence of any new information, Arrow then developed a conceptual groundwater model to consider DES's statements and applied this within the numerical model. To achieve this in the numerical model Arrow simulated a constant free phase source of hydrocarbons in a char/ash zone around each of the gasifiers starting at the date of the end of each gasifier's operation and assessed the contaminant fate and transport.

The outcomes from this modelling generated a modelled pattern of high concentrations in and around the gasifiers and low concentrations at the site periphery as shown below in Figure 4.1 for benzene and Figure 4.2 for naphthalene which is inconsistent with observed data. This is detailed further below.

The observed data is inconsistent with the DES' statements and therefore the outcomes from the modelling undertaken does not support the DES view that there is significantly mobile phase petroleum hydrocarbons (napl source). This is because

- Site and boundary groundwater data indicate a current cone of depression at the site, and;
- If the napl was acting as a constant source of dissolved phase contaminants, concentrations on-site would be expected to remain constant. The data provided to Arrow shows reducing concentrations of napl in groundwater from monitoring bores proximal to the former Linc Energy site gasifiers.

In the absence of any further site data (current or historic) that may support views detailed in question (m), Arrow continues to support the conclusions drawn from our current modelling undertaken with all available data. That is:

- Arrow's groundwater model and uncertainty analysis indicate that groundwater particle from the gasifiers will not reach the site boundary during Arrow's 20-year production period.
- Arrow's contaminant and fate transport model is supported by site and boundary data.

Arrow has proposed a monitoring, assessment and adaptive management process in line with our groundwater modelling, which is updated annually as part of our GCMP. In the unlikely event that early warning indicators are exceeded, Arrow has proposed processes and activities to prevent contaminant migration from the former Linc Energy site which is detailed in question (o).

Available information

To ensure that this response to the Information Request included all available information at this time, Arrow requested the following of the DES on 19 October 2020:

Clarification sought for DES question (m).

Could you please confirm that all available data in this regard has been provided to Arrow. The following is provided as examples of the type of data that would be of benefit:

- *Data on the composition of the free phase and the fraction of the composition comprising the most prevalent contaminants (i.e. benzene and naphthalene)?*
- *Calculations or data showing contaminants above aqueous solubility limits or effective solubility limits in the Macalister or Springbok for the primary contaminants of concern?*
- *Data/opinion on the extent and composition of potential napls?*

The following response to the above clarification was provided by the DES on 17 November 2020:

In relation to the below email, apologies again for the time it's taken to respond, we were confirming the information that was held by the department and whether this could legally be released. Unfortunately, I can confirm that the department is unable to provide any additional information for Arrow to utilise within their current amendment application.

In the absence of any new information, Arrow built a conceptual model based on the statements provided by DES above. The following describes the modelling undertaken and concludes that with the information available to Arrow at this time, the numerical modelling does not simulate observed data in a way that supports the statements from DES about contaminant fate and transport.

Movement of groundwater

In line with standard practice, including the Australian Groundwater Modelling Guidelines, Arrow Energy has correctly based its modelling upon available data. The hydraulic data clearly indicates a current cone of depression at the site. The hydraulic model and uncertainty analysis show that, under a case with the proposed Arrow development, the rates of movement indicated a groundwater particle does not reach the site boundary from the gasifiers during Arrow's 20-year production period.

Factors affecting free phase product migration

Review of available literature (CSIRO 2012, LLNU 2017) indicate that any napl material will most likely be immobile tars from which dissolved phase contaminants may leach.

If the napl was acting as a constant source of dissolved phase contaminants, concentrations on-site would be expected to remain constant as they are replenished by the napl. Data provided to Arrow at on-site sample locations proximal to gasifiers show reducing concentrations. Therefore, in the absence of any further DES data that may support DES' proposed conceptual model, Arrow upholds the conclusions drawn from our current modelling undertaken with all available data.

Arrow simulation of napl and contaminants at maximum solubility limits

Literature on UCG (LLNU 2017) suggests that, depending on the "clean up" process undertaken after a UCG burn, the gasifier comprises a void, charred coal, ash and further out unaffected coal. Potential non-aqueous phase liquids (napl) may occur in cleats in the charred coal and ash.

An initial simulation providing a constant free phase source of hydrocarbons in a char/ash zone around each of the gasifiers starting at the date of the end of each gasifier's operation is described below.

Ongoing non-aqueous phase liquid source

The contaminant transport scenario has been undertaken assuming that each gasifier represents an historic and ongoing source of naphthalene and benzene at maximum solubility limits to investigate whether or not the available historic observations are consistent with such a scenario; and to predict future naphthalene and benzene concentrations in this scenario.

Source term

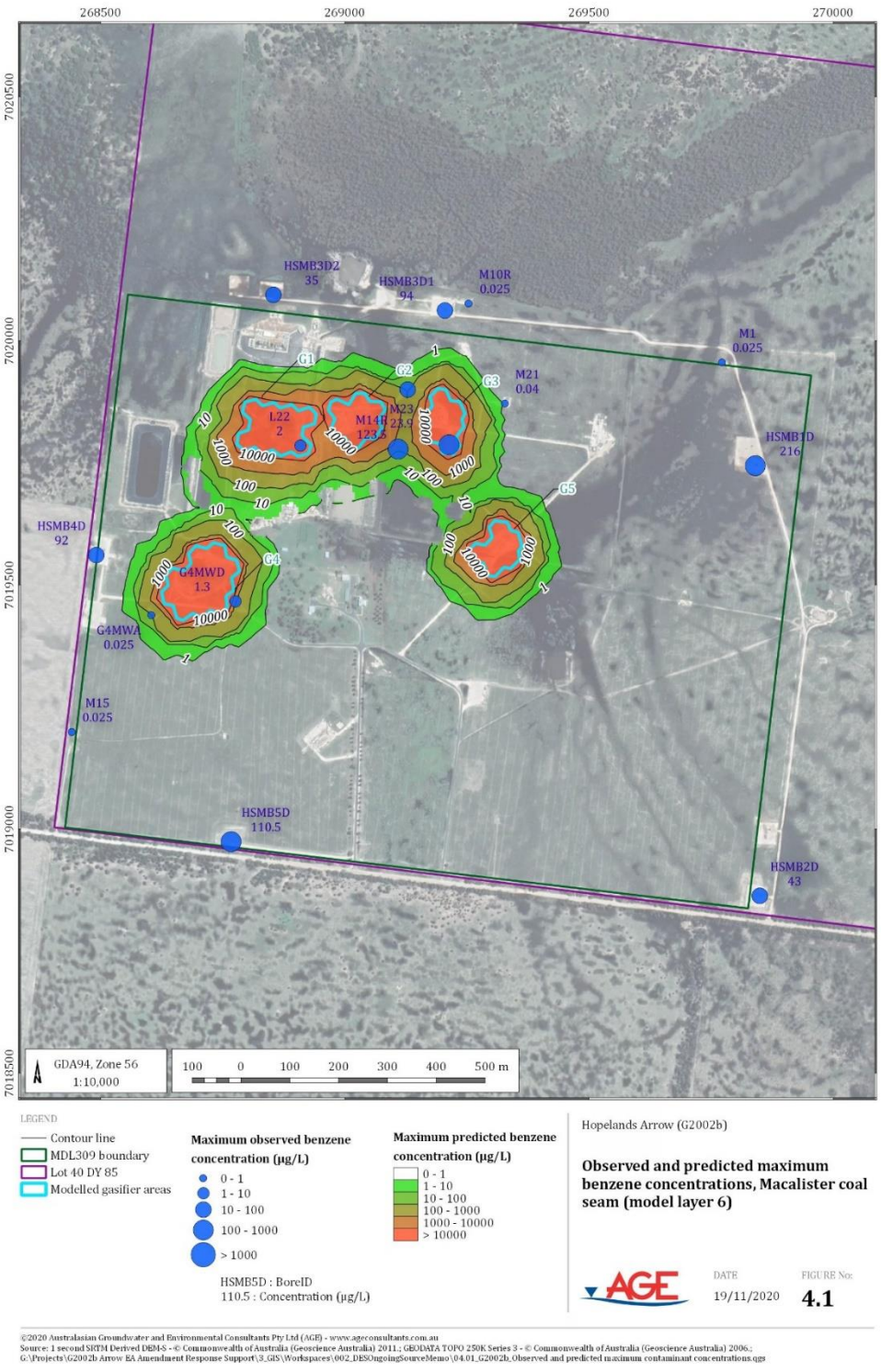
The United States Environmental Protection Agency (US EPA) state that whilst the aqueous solubility of pure benzene is around 1,750 mg/L (or 1,750,000 µg/L), typical maximum benzene concentrations resulting from equilibrium between gasoline and water are in the range 20 to 40 mg/L (i.e. up to 40,000 µg/L) as benzene forms a proportion of the total napl composition. In the absence of any data indicating napl presence or composition, the initial concentrations of benzene was set at 40,000 ug/L. Following the same process, the source term for Naphthalene was set at 1,200 ug/L. These concentrations started when gasifier operation ceased and continued through the entire model run.

Transport Parameters

As requested by DES, for the purposes of the ongoing source scenario, the first order decay term (Foc) for benzene was reduced to 25 days (i.e. at the centre of the 20-30 day range quoted in the literature for anerobic conditions).

Conclusion

The model outcome generated a modelled pattern of high concentrations in and around the gasifiers and low concentrations at the site periphery as shown below in Figure 4.1 for benzene and Figure 4.2 for naphthalene. These scenarios are not supported by the site and boundary data (i.e. observed data).

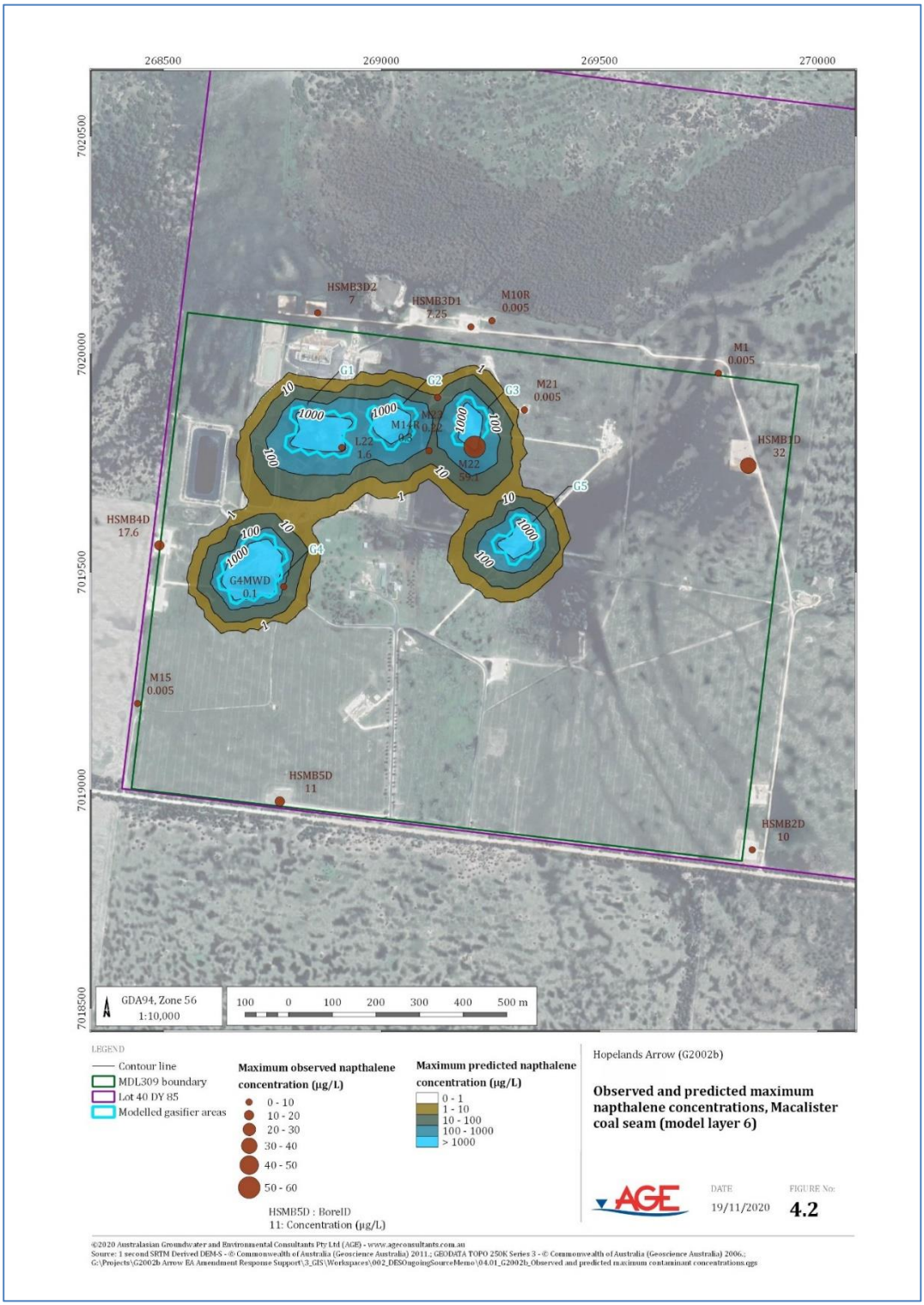


In the scenario with a high concentration source at the gasifiers the bores closest to gasifiers are predicted to have very high concentrations.

Table m4.1 below shows the monitoring points closest to the gasifiers and the observed concentration compared to the predicted concentration for the scenario where a napl is present. This indicates the observed data does not support a large, mobile napl source.

Bore ID	Distance to nearest gasifiers	Observed maximum benzene concentration (µg/l)	Predicted maximum benzene concentration (µg/l)	Observed maximum napthalene concentration (µg/l)	Predicted maximum napthalene concentration (µg/l)
L22	59m south east of G1	2.0	40,000	1.6	1,200
M14R	103m south east of G2	123.5	102.9	0.3	39.7
M21	125m east of G3	0.04	0.17	0.005	0.12
M22	48m south of G3	335	40,000	59.1	1,200
M23	100m north west of G3	23.9	31.9	0.22	11.8
G4MWD	77m south east of G4	1.3	1,155	0.1	84.4

Table m4.1 Observed and Predicted concentrations at bores adjacent to gasifiers.



As discussed above, the modelled pattern of high concentrations in and around the gasifiers and low concentrations at the site periphery is almost the inverse of the observed data and the simulation's predicted concentrations are incompatible with observed data.

The Australian Groundwater Modelling guidelines recommend experimenting with numerical model conceptualisation to compare how well they reproduce reality. The modelling undertaken based on the DES statements has explored the potential for napl and found it to be inconsistent with observed data.

(n) DES also notes that the current volume and extent of the petroleum hydrocarbon source area (i.e. tars and concentrated organics resulting from the gasifiers) is not currently well documented, but free phase petroleum hydrocarbons in the cavity are understood to exist. These source areas are considered highly likely to be an ongoing source of groundwater contamination as long as groundwater is in contact with the petroleum hydrocarbons within the cavity. As groundwater levels recover and/or when the aquifer/s is influenced by regional depressurisation from CSG activities, DES considers ongoing migration of elevated contaminants arising from the former Linc Energy site highly likely. For the purpose of modelling the fate and transport of these contaminants, DES does not consider that the observed reducing concentrations in the periphery wells an adequate indicator of the contamination plume behaviour. Nor is the data considered suitable to be used in a modelling scenario (i.e. that the groundwater is flowing towards the source, not away). or enough to establish degradation coefficients.

DES asserts that the reduction in contaminant concentrations is not currently considered to be dominated by natural attenuation/degradation or sorption of the contaminants as indicated in the AGE 2020 report. Rather, DES considers that dilution and flushing of the wells resulting from the current hydraulic gradient is causing non-impacted groundwater further from the source flowing past the periphery monitoring bores and towards the site, as onsite groundwater levels continue to recover from the UCG activities.

The AGE 2020 report states that it is recognised that the upper bound of the range of values adopted for the first order decay coefficient (Foc) for Benzene is somewhat higher than typical ranges identified in the literature. DES considers the values adopted in the contaminant fate and transport model incorrect as the data used for calibration is considered to have been established based on observed groundwater conditions, whilst not considering a site conceptual model including the source location versus the direction of groundwater flow at this site. DES believes that the data obtained from any monitoring bore surrounding the site may be anomalous if used for the purposes stated in the model.

On the basis that there is currently no oxygen supply within the cavity or the aquifer, DES believes that degradation rates adopted for the model should reflect anaerobic conditions and literature based degradation values from a source that is at solubility limits. The applicant is required to undertake and provide to DES a contaminant fate and transport model that takes these considerations into account.

RESPONSE

The additional contaminant fate and transport modelling undertaken by Arrow to assess the DES statements is discussed above in the response to question m. As detailed in question (m), the statements provided by DES were used by Arrow to build a numerical model and once tested against the observed Groundwater data, it was shown that it does not support the DES view that there is a significantly mobile phase petroleum hydrocarbons (napl source). This is because

- Site and boundary groundwater data indicate a current cone of depression at the site, and;

- If the napl was acting as a constant source of dissolved phase contaminants, concentrations on-site would be expected to remain constant. This is in direct contrast to the observed data which shows reducing concentrations of napl in groundwater from proximal to gasifiers.

The processes affecting contaminant concentration reduction are:

- Advective dilution (flushing)
- Sorption
- Degradation
- Dispersion (diffusive processes).

The Foc in the 2020 AGEmodel used for the Macalister was higher than that typically found in contaminated land studies because it is for a coal which is 80-90% organic carbon and for which references have been provided.

This does not indicate the Foc is erroneous, just that it is not typical of shallow surficial deposits that are the subject of most contaminated land scenarios. As such the sorption parameters used are considered suitable for the simulation.

As such, it is noted as shown in Figure n1 below that in the model submitted to DES in support of this amendment application, the initial conditions for the simulation did not assume zero concentrations in or around the site, as such contaminants in boundary wells were not being flushed by 'unimpacted' groundwater, but groundwater with existing concentrations of contaminants from the coals.

Advective dilution (flushing) of contaminant concentrations is calculated based upon a combination of groundwater flow rate and the concentrations in the model cells. Therefore, advection is included in both the original simulation (AGE 2020 model) submitted where dispersed concentrations flow into the site, as well as in the new simulation which was undertaken in response to this information request with a napl source, where high concentrations from a napl source mix with groundwater as it migrates from the gasifiers.

Anaerobic conditions have been simulated and compared to observed contaminant concentrations as reported above for information request item (m). This indicates that the proposed conceptual model based on the DES statements which included a large, high concentration, mobile napl source term is inconsistent with the observed data.

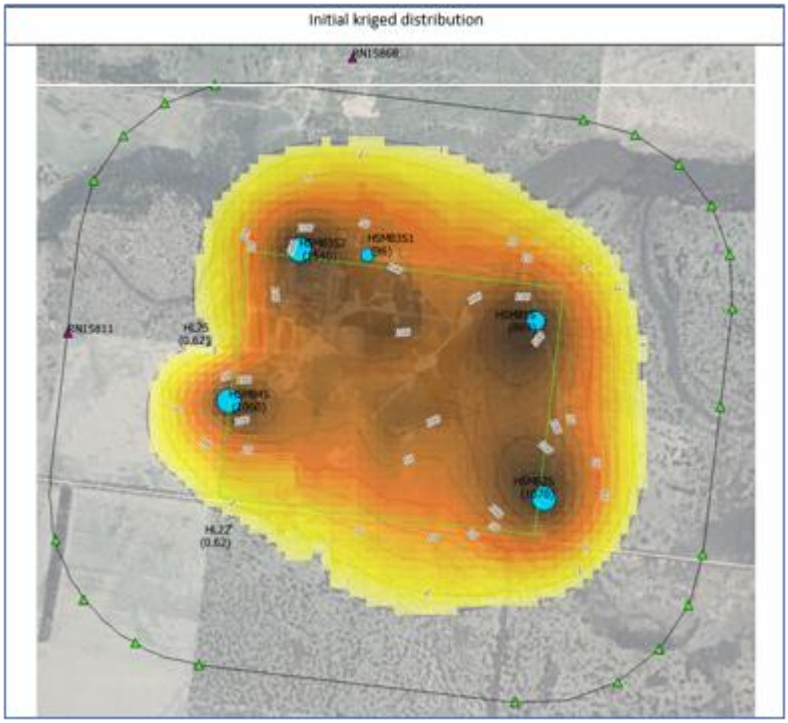


Figure n1 – Initial Condition of plume indicating contamination levels entering the site in groundwater

(o) Provide additional information on the monitoring/identification and mitigation measures proposed to prevent contaminant migration from the former Linc energy site. Include details on the early notification measures that will be implemented to inform DES on potential contaminant migration.

RESPONSE

Data Quality Objective Process for Management

The conceptual model, observed data and the numerical modelling of potential outcomes shows that potential impacts from the site to potential receptors is unlikely, however to ensure controls are implemented, a process of monitoring, assessment and adaptive management is proposed which will allow risks at the site from groundwater to be managed.

Consistent with its existing GCMP, Arrow proposes a system based upon the National Environment Protection Assessment of Site Contamination (ASC NEPM 2013) which lists the design components as:

- Establishing the objectives of the investigation (problem statement)
- 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 provided below.

Problem Statement

A rigorous adaptive management regime is 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."

Identify the goal and principal question

In order for monitoring data to be used in an adaptive management regime the questions that the monitoring data address must be clear, as must the outcomes that the data seeks to inform. These are provided below:

Principal Study Question

- Does the monitoring data show a significant[3] change in contaminant impact at Arrow monitoring wells?
- Does the monitoring data show a significant[1] change in hydraulic gradient?
- If not, what is the appropriate response?

Identify the alternative outcomes or actions that could result from

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

Form the Decision Statements

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

1. If the contaminant concentrations are not detected off-site and the hydraulic gradient remains within predicted levels, continue monitoring.
2. If hydraulic gradients change and contaminants are detected off-site at levels below trigger criteria conduct formal risk assessment and update predictions to assess the source of the impact to the hydraulic regime.
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.

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

Identify the information inputs, trigger criteria and study bounds

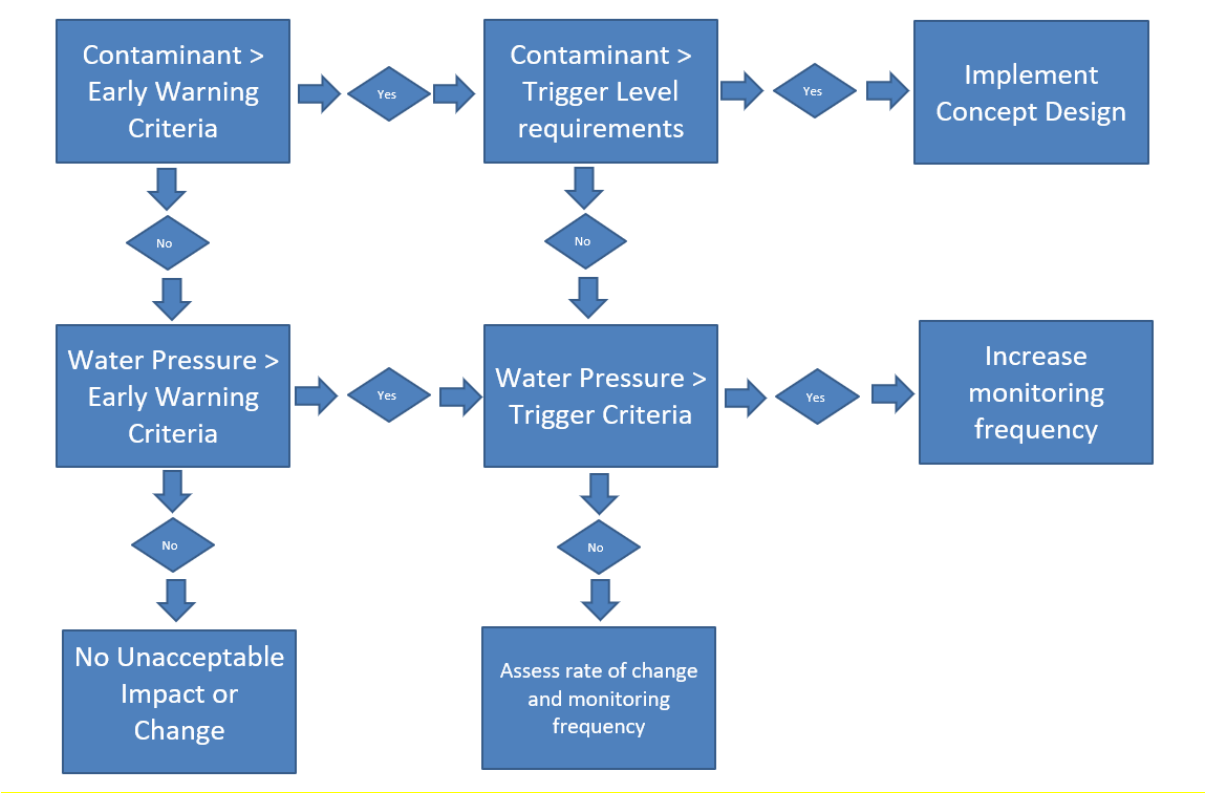
The data to be collected in order to inform the above decision structure is clearly identified, as well as forming the basis for the derivation of action levels that drive decisions.

These will be monitoring points included in the GCMP and criteria sourced from Australian Guidance documents including the NHMRC and site-specific risk assessment 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.

Develop the analytical approach

A pre-determined approach that assesses background concentrations, early warning 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 and agreed decision tree for adaptive management. A proposed flow chart for this is shown below.



Management and Contingency Measures

Assessment of impact in terms of "risk" to human health and environment can provide a hierarchy of responses. Some examples are provided below:

1. Risk Assessment
    a. Assessment of rates of change in groundwater pressures against predictions are assessed by testing the impact of the observed change against the uncertainty of that rate of change in the model. When observed rates of change result in a 90% probability of a predicted contaminant trigger exceedance within 12 months due to Arrow Energy activity then risk assessment of contaminants could proceed.
    b. This includes implementation of assessment of receptors, and risk based levels for those receptors; and
    c. implementation of assessment of magnitude and sources of change in hydraulic regime.

Risk assessment and sources of change in the hydraulic regime could include both quantitative site specific risk assessment to human health and the environment from the contaminants of concern and quantified uncertainty analysis and hypothesis testing to assess the source of stresses to the hydraulic regime resulting in the change in groundwater movement leading to the observed contaminant impact.

2. Options for physical intervention – Contingency measures

In the unlikely event that the trigger criteria from the risk assessment are exceeded and the risk assessment indicates that physical intervention is required due to Arrow Energy's activities, contingency measures will be investigated, including but not limited to.

- Enhanced insitu remediation
- Interception system
- Containment system

Investigation of the above contingency measures would be based upon the contaminants detected and the concentration of those contaminants.

(p) Undertake a dual phase model that incorporates groundwater and gas movement that will demonstrate how gas movement may influence groundwater movement. Model gas movement, including up dip movement (Condamine bubbles), given that gas is more actively moving due to fracturing.

(q) The application material has not addressed the liberation of gas and its impact to environmental values, specifically on sensitive receptors and the suitability of land for its current and future use. Additional information is required on:

i. How this will impact the suitability of the land for current and future land uses;
ii. The management/mitigation practices to be implemented to prevent impacts to land from the liberation of gas;
iii. Additional remediation/rehabilitation measures required due to the liberation of gas; and
iv. Details of expected emissions associated with the liberation of gas and whether a flare will be required due to the impurity of the gas. Provide further details as to the requirements of the flare.

RESPONSE

Arrow commissioned The University of Queensland Centre for Natural Gas to undertake the modelling required to address these further questions. The results of the UQ modelling, demonstrate that the proposed Arrow development has a low potential to s impact sensitive receptors or the suitability of land for its current and future use by the liberation of gas. In particular:

- the risk of change to the movement of free gas at the former Linc Energy site by the proposed activities on PL253 is low;

- gases will be re-adsorbed into the coal thereby reducing volumes of free gas;
- residual gas will become trapped, either by adsorption, or due to small structures (traps) within the coal whether the Arrow development is included in the models or not;

In particular, the proposed development is unlikely to:

- require additional management/mitigation practices to be implemented to prevent impacts to land from the liberation of gas;
- require additional remediation/rehabilitation measures due to the liberation of gas; and
- require a flare due to the impurity of liberated gas.

The following summarises the modelling and the information response developed by the team led by Associate Professor Phil Hayes. It should be noted that UQ relied upon hydraulic outputs from the AGE 2020 model to develop the dual phase model.

Due to the overlap in the questions posed, a single response is provided. Also, due to the unique nature of the questions posed (i.e. combining UCG and CSG influences on subsurface gas), a brief description of the model development is provided before answering the questions.

Linc Energy (Linc) undertook Underground Coal Gasification (UCG) activities on the site between 1999 and 2013 which have left residual gases within the upper seams of the Walloon Coal Measures and the lower Springbok Sandstone.

The questions have been addressed with multi-phase numerical simulations of free gas movement using the Computer Modelling Group's (CMG's) GEM compositional simulator. The approach to modelling was to represent a 3.5km x 3km domain around the former Linc Energy site in detail, incorporating site specific data where available. The model has 8 layers, representing the interval from surface, through the Springbok Sandstone to the Wambo Coal of the Walloon Coal Measures, which allowed representation of individual seams targeted by UCG operations.

The structure of the model was based on a geological/structural model provided by Arrow Energy. A 'gasification' period (i.e. 1999 to 2013) was simulated, then models were run from 2013 until 2019. Models were rejected as unrealistic if they were unable to replicate a key observation: that pressures at the Linc site have not recovered by 2019, with 30 to 40 m of residual drawdown remaining. This is a key observation because it represents the status of the former Linc Energy site as determined by data provided to Arrow from the DES.

For this dual phase modelling, the boundary conditions applied around the model perimeter and at the base replicated the pressure heads of the larger scale PL253 groundwater modelling developed by AGE (2020). Two versions of these boundary conditions were used, representing the difference between two main scenarios:

1. current baseline conditions with no further Arrow production in PL253
2. current baseline conditions with the proposed Arrow development on PL253.

An inert tracer was added to the free gas phase in the model to allow 'contaminant' gases remaining after gasification to be identified. The sensitivity of multiple parameters that control gas movement was tested. This included models with enhanced permeability (horizontally and vertically into the Springbok), transmissive or sealing faults, higher saturation (adsorbed gas content) of the coal, and models with an enhanced pressure gradient across the model.

Figures 1 and 2 show the results of this modelling. The pressure head plots in Figure 1, corresponding to 2013 and 2019, show gradients oriented inward toward the site with

groundwater flow inward toward the gasifier locations. This inflow causes pressures to increase over time with residual gas being compressed and within coals, methane will be adsorbed into the coal matrix becoming trapped. This is the opposite of the behaviour seen in Coal Seam Gas operations, where pressures are reduced (by dewatering) to cause desorption and release trapped gas. This adsorption leads to the apparent increase in tracer concentration in the simulations as methane adsorbs, and the non-adsorbing tracer remains in the free gas phase.

In Figure 2, showing the results for 2043, the pressure head plots differ by approximately 10 m of water pressure due to Arrow development. The predicted gas saturations are low, due to adsorption and there is little to no difference in distribution of remaining gas between the development scenarios. The modelling indicates the potential for Arrow Energy's proposed activities to change the movement of free gas at the site is low.

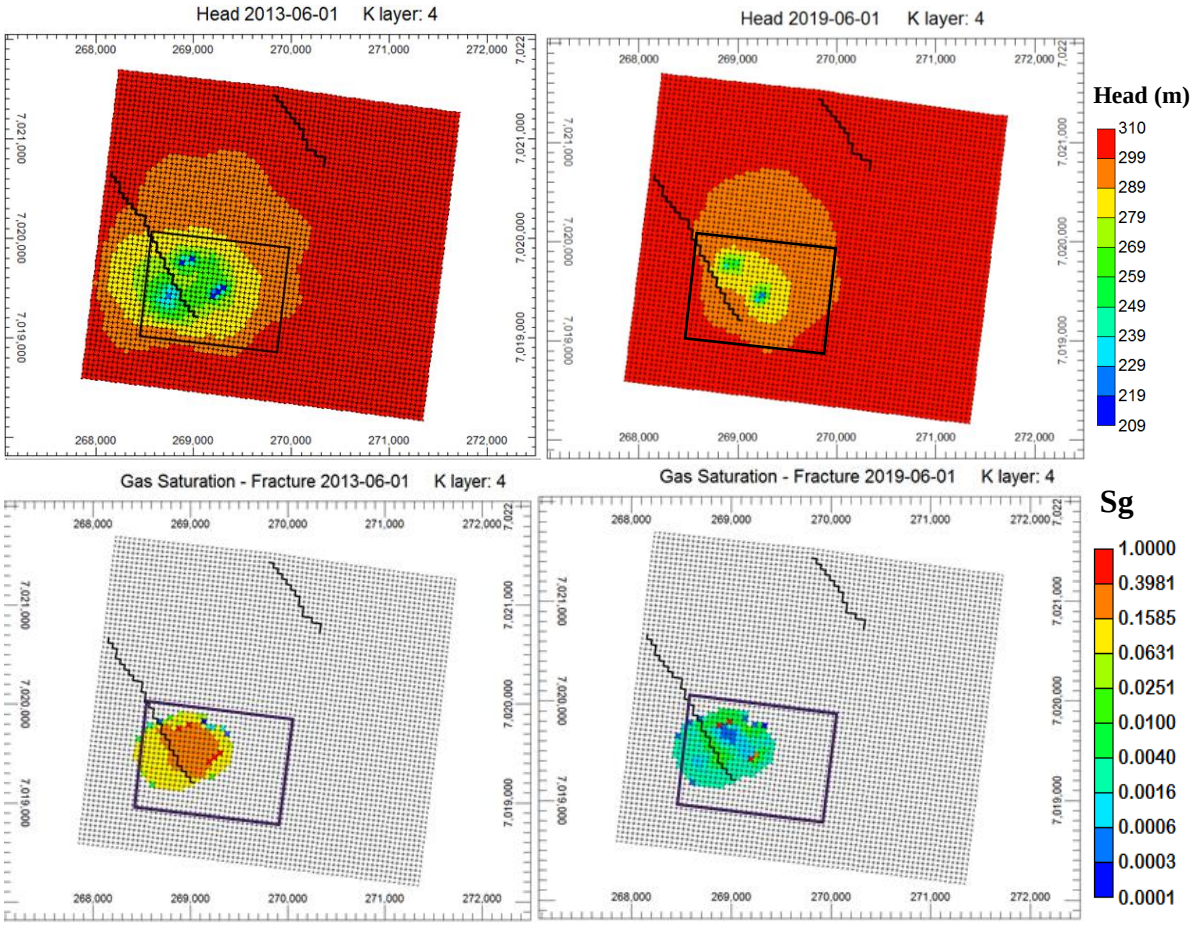


Figure 1 Groundwater pressure head (top), and gas saturation, Sg, (bottom) in Macalister seam A in 2013 (left) and 2019 (right)

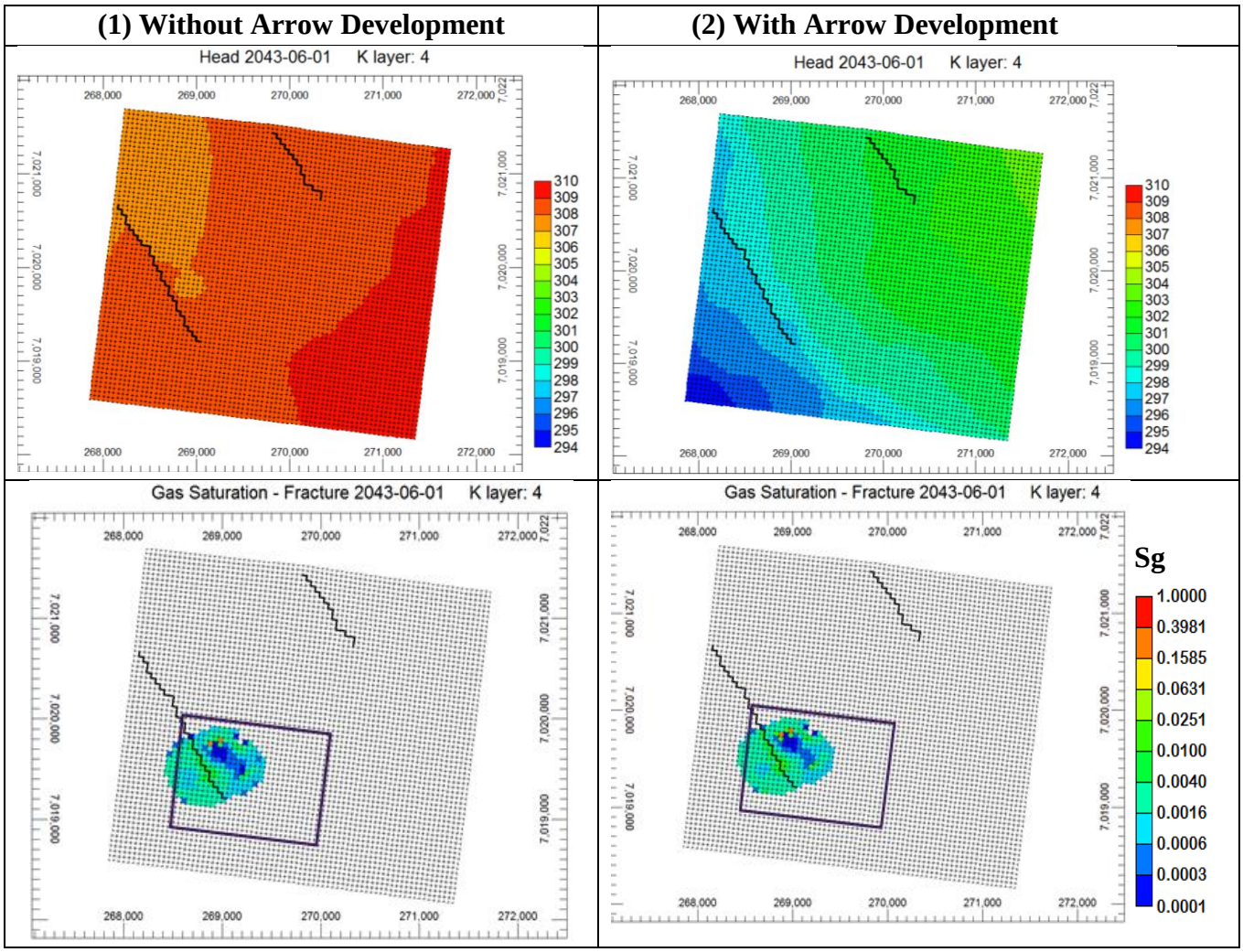


Figure 2 Groundwater pressure head (top), and gas saturation (bottom) in Macalister Seam A for without (left) and with (right) Arrow development in 2043

The result can be understood by considering the physical processes that occur around the site. Initially, the area around the gasifiers is depleted compared to the surrounding area with an inward pressure gradient mostly towards the gasifiers. Actual groundwater flow is at very low rates due to a combination of the low intrinsic permeability of the rock and the low relative permeability to water or gas. This behaviour is consistent with the site observations in 2019, which indicate the site remains depleted as pressures had not recovered in the six years since gasification operations ended.

Buoyancy does cause some gas movement in the models. However, this is limited by the low permeability, or low relative permeability, around the site. Note that conceptually, gasifiers would be 100% gas saturated at the end of gasification whilst coals in the far field, at sufficient distance from gasification, remain 100% water saturated. Between these end members, coal cleats will be partially saturated with both gas and water, and the relative permeability to each fluid may act to impede flow.

This means that whether the Arrow development is included in the models or not, the majority of residual gas in the models becomes trapped, either by adsorption, or due to small structures (traps) within the structure of the Macalister A seam.

Simulation and sensitivity results indicate that free gas that is not trapped by these mechanisms is still unlikely to move (again due to low permeability, or low relative permeability), even if subjected to the increased pressure (groundwater head) gradient predicted to occur due to Arrow's development.

The modelling result of very minor future gas movement, with or without Arrow development, may appear counter-intuitive when considered in the Surat Basin context of gassy groundwater bores, bubbles in rivers and recent coal exploration hole fluxes. However, in the context of CSG development, the number and spacing of CSG wells and the very low bottom hole pressures applied to produce gas, the results are more in line with expectation.

The major CSG projects typically have permitting for many thousands of production wells, with typical initial spacings of 750 m. Infill drilling frequently reduces this to 350 to 400 m. To rapidly produce gas, wells are typically dewatered with bottom hole pressures 200 to 300 m lower than hydrostatic. Effective gas production means gas migration to wells, and this requires high pressure gradients and close well spacing. The pressure gradients acting at the former Linc Energy site, with or without further Arrow development are insufficient to promote horizontal gas migration.

Groundwater movement is predicted to be inward toward the site for a further 10 or more years as pressures recover. After this time, groundwater movement is predicted to be influenced by Arrow development (AGE 2020). But with low residual gas saturations at this time, there is likely to be little influence of gas on groundwater flow.

Figure 3 shows the evolution of gas saturation in the lower Springbok for 2013, 2019 and for 2043 with and without Arrow development. These results are for a sensitivity case that considers higher vertical permeability between the Macalister coal seam and the Springbok. This case could be considered analogous to considering enhance connectivity between these units. Results show gas migration into the Springbok, and that in the absence of coal, no adsorption occurs, and the gas remains effectively static. There is no difference in predicted Springbok Sandstone gas occurrence between the development and non-Arrow development scenarios. This again confirms that, even with uncertainty analysis, Arrow's proposed development has a low potential to significantly alter the behaviour of residual gases around the former Linc Energy site.

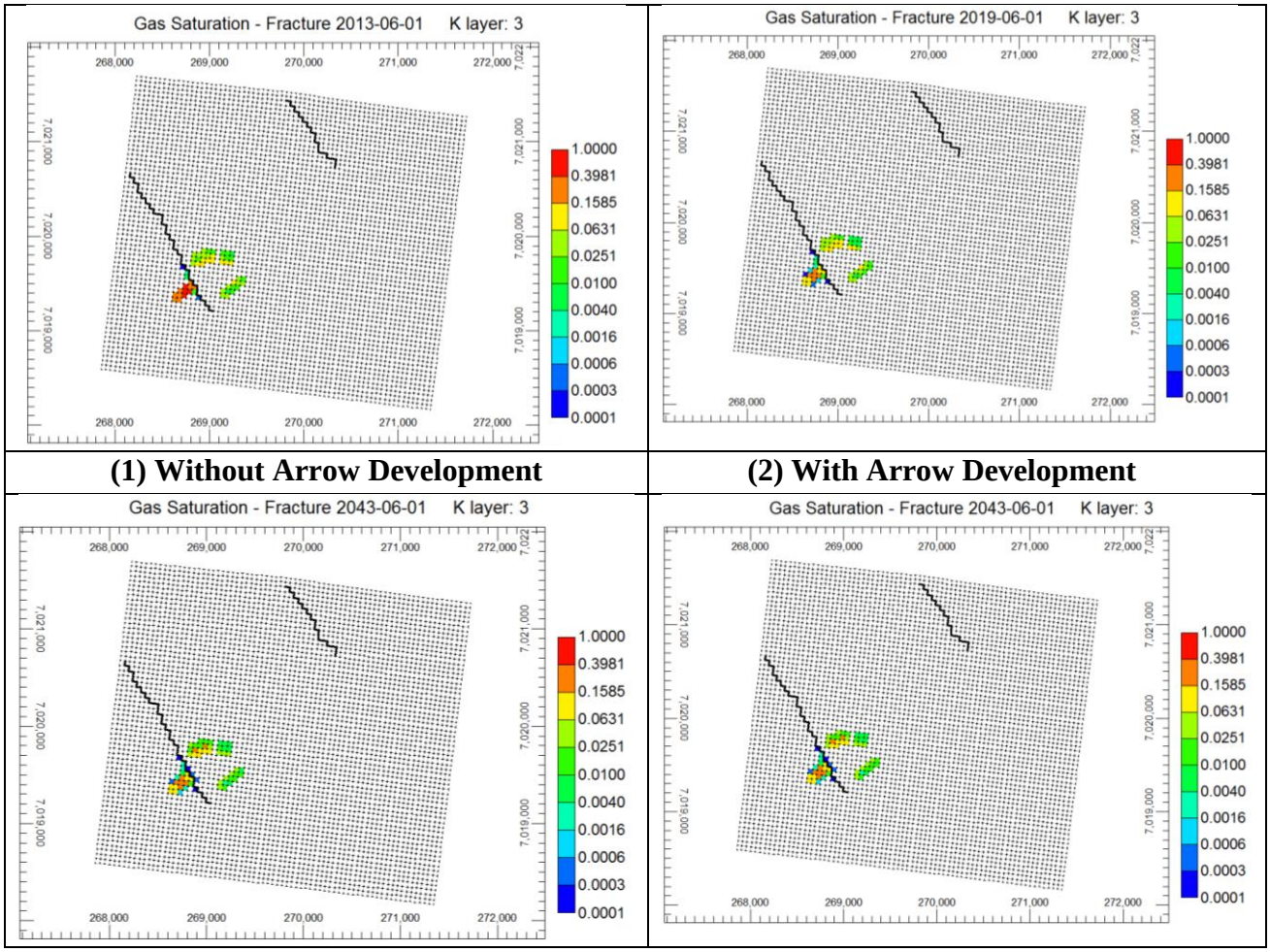


Figure 3 Evolution of gas saturation in 2013, 2019 (upper figures) and 2043 within the lower Springbok Sandstone for the sensitivity case with high vertical permeability (without and with Arrow development in lower figures).

Notice

Environmental Protection Act 1994

Information request

This information request is issued by the administering authority under section 140 of the Environmental Protection Act 1994 *to request further information needed to assess an amendment application for a site-specific environmental authority.*

To: Arrow CSG (Australia) Pty Ltd
Level 39
111 Eagle Street
BRISBANE CITY QLD 4000

ATTN: Andrew Hall, andrew.hall@arrowenergy.com.au

Our reference: EA0001401

Further information is required to assess an amendment application for a site-specific environmental authority

1. Application details

The amendment application for a site-specific environmental authority was received by the administering authority on 6 July 2020.

The application reference number is: APP0056458

Land description: PL253

2. Information request

The administering authority has considered the abovementioned application and is writing to inform you that further information is required to assess the application (an information request).

The information requested is provided below:

(a) The current environmental authority (EA) (effective date of 25 June 2020) details the authorised activities in EA condition General 1. The activities listed in Table 1 of General 1 includes the scale and intensity of gathering pipelines, raw water pipelines, access tracks, a borrow pit, and sediment ponds. The proposed table in section 5.1 of the EA Amendment Application Report does not detail what increases in scale and intensity are being sought for the previously mentioned items. Please provide a revised table of proposals that aligns with the current details prescribed in EA condition General 1.

(b) The applicant proposes that 440km of gas and water gathering pipelines are required, however in section 4.3 (page 22) of the EA Amendment Application Report, it states that approximately 220km of gathering lines will be constructed across PL253. Please confirm the correct value each of gas and water gathering lines being applied for.

(c) The applicant proposes to amend the definition of Essential Petroleum Activities to include communications towers. Please provide an indication of how many communications towers are required, what infrastructure is involved, the maximum size of disturbance/footprint required for each and what impact this may have on environmental values.

(d) The applicant is seeking to amend the definition for Essential Petroleum Activities to allow disposal of residual drilling material to occur 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. Please provide the following:

i. Quality characteristics of the drilling material, including an assessment of whether the material constitutes a regulated waste;

ii. Method for undertaking the disposal of drilling material;

iii. A risk assessment prepared by a suitably qualified person that identifies the possible impacts due to the proposed activity and all associated risks (including contamination risks) to environmental values. This is to include:

a. An assessment of any additional risk in undertaking disposal of drilling material within primary protection zones of Category B and Category C environmentally sensitive areas;

b. An assessment of any additional risk associated with shallow groundwater, and potential for any seepage or contamination to occur based on the soil structure and quality within the project area;

c. Details of additional rehabilitation requirements;

d. Consideration of the waste and resource management hierarchy in the *Waste Reduction and Recycling Act 2011* and describe why all other strategies (avoid, recycle, reuse or recover) would be unsuitable; and

iv. Strategies to monitor and mitigate any identified risks to environmental values, including land and groundwater contamination.

Note: Mix-bury-cover of residual drilling materials may trigger Notifiable Activity 20: Landfill—disposing of waste (excluding inert construction and demolition waste) as listed in Schedule 4 of the *Environmental Protection Act 1994*.

(e) The applicant has applied for the inclusion of streamlined model conditions (SMCs) for petroleum activities waste conditions 5, 6, C1, C2, 11, 12, 13, 14, 18, 19, 20, 21 and the Waste management schedule, Table 1—Assessment procedures for water quality criteria. The applicant has not provided a site specific risk assessment that details the impacts to environmental values that may occur should the activities be authorised, for example, burning of vegetation waste and construction of a landfill facility. Provide the following:

i. Risk assessment that identifies the possible impacts due to the proposed activities and all associated risks to environmental values;

ii. Strategies to mitigate identified risks to environmental values;

iii. Rehabilitation requirements for the activities being applied for;

iv. A consideration of whether additional environmentally relevant activities (ERAs) are required, for example, ERA 60 – waste disposal. This includes details of the type and quantity of waste intended to be disposed of.

(f) The applicant has applied for the inclusion of streamlined model conditions (SMCs) for petroleum activities noise conditions to authorise blasting. The applicant has not provided justification for the activity, or a site specific risk assessment that details the impacts to environmental values that may occur should the activities be authorised, including whether the applicant can comply with the existing noise and air conditions. The applicant should also detail the proposed locations for blasting, and include a consideration of proximity to the former Linc Energy site (Lot 40 DY85).

(g) Appendix C of the Amendment Application Report contains a Terrestrial Ecology Report (Ecosmart Ecology, June 2017) for the entire Surat Gas Project area. This appears to be a summary only. Please provide further details of the ecological assessment relevant to PL253 that includes, but is not limited to:

i. Methodology of ecological surveys undertaken;

ii. Details of how the ground-truthed biodiversity values differ from Queensland government mapping e.g. locations, amount (hectares), composition, habitat features;

iii. Detailed assessment results; and

iv. A thorough, evidence-based, justification for any presence/absence determinations for matters of State environmental significance (MSES), particularly where that deviates from the Queensland government records.

(h) Table 6-3 of the Amendment Application Report (page 72) lists the proposed significant residual impacts to prescribed environmental matters. To determine the appropriateness of these values, the department requests the following:

i. A GIS layer of proposed disturbance;

ii. Detailed justification of the significant residual impact (SRI) assessment on prescribed environmental matters, including connectivity areas;

iii. The scale and extent of the activity planned for those areas that would result in a SRI on prescribed environmental matters; and

iv. The status of the Offset Strategy under the *Environment Protection and Biodiversity Conservation Act 1999* that may be relevant to the application.

(i) In relation to offsets for PL253, provide further information as follows:

i. Details of whether suitable offsets exist for the proposed impacts to prescribed environmental matters, including the endangered *Hemiaspis damelii* (Grey Snake);

ii. If already determined, the proposed offset delivery mechanism, i.e. land-based, financial payment or a combination of both. Where financial payment is proposed, the values to which the financial payment relates and the quantity (as determined by the offset financial calculator). Where land-based offsets are proposed, provide an assessment of 'habitat quality' of the impact area and offset area; and

iii. Details of whether the proposed impacts / offsets will be undertaken in full prior to the impacts occurring, or whether they will be staged over the life of the project. If staged impacts / offsets are

proposed, identify what those stages are, which impacts are proposed for each stage and the anticipated timeframe for each stage.

(j) Subsidence has been cited as an indirect impact of coal seam gas activities. Provide further information regarding the potential impacts to land and its use that may occur as a result of the activities. This should include mitigation measures to manage the impacts to land and details of any current or planned subsidence monitoring.

(k) The AGE 2020 report contained within Appendix E of the Amendment Application Report states on page 4 that, *"Only very limited information relating to historic activities on the former Linc Energy site has been available to date."*

Please note, investigative works are on-going at the former Linc Energy Site, including the installation and sampling of on-site monitoring bores. DES will provide this data to the applicant when available.

Arrow are to determine the additional information (i.e. that may be attainable by DES about the former Linc Energy Site), that would be required to further refine the contaminant fate and transport modelling and estimations associated with the potential extent/propensity for contamination to migrate from the site.

(l) The AGE 2020 report referred to above states on page 9 that the Office of Groundwater Impact Assessment (OGIA) Surat Underground Water Impact Report (UWIR) and the Arrow Hopeland Groundwater Modelling Report (prepared by GHD, October 2019) groundwater models may underestimate lateral migration of particles. The structure of the contaminant fate and transport model was therefore altered to add a coal layer at the top of each Walloon Coal Measures sub-unit. It is noted that vertical hydraulic conductivity (Kv) was altered immediately above each gasifier, but horizontal hydraulic conductivity (Kh) does not appear to have been amended within the bounds of the site. The implications of this approach is not known, against assigning an increased Kh to relevant cells for example, within the boundary of the site (to reflect likely localised horizontal fracturing within the Springbok Sandstone and within the Macalister Seam).

Please provide an explanation of the limitations of the adopted approach and its impact on the contaminant fate and transport modelling. Provide results for a contaminant fate and transport model in which Kh is locally altered.

(m) The AGE 2020 report referred to above states on page 33 that *"Benzene and Naphthalene have reduced at nearly all monitoring points since the commencement of monitoring in June 2018"* and *"the available groundwater level data suggest ongoing flow towards, rather than away from the site which would tend to promote gradual adsorption and dispersion of the contaminant plume in situ rather than advective transport of contaminants outside of the lease area".*

When considering the current hydrogeological dynamics of the former Linc energy site, it is noted that due to UCG activities, groundwater in both the Springbok Sandstone and the Macalister Seam surrounding the site are currently flowing towards the UCG gasifiers as a cone/s of depression appears to have formed in aquifer/s beneath the site. Therefore, DES does not agree with the interpretation as outlined above regarding contaminant dispersion because the groundwater contamination being referred to, which originated at the source site, is flowing back towards the source site. That is, it is concentrating, not dispersing. DES asserts that the dispersion of contaminants would refer to the distribution of those contaminants from the source to a larger area however, in this circumstance the contaminants are flowing back towards their point of origin and concentrating due to temporary circumstances.

Based on the foregoing, impacts associated with Linc Energy's former UCG project have resulted in the generation of cavities within the Macalister seam, which is considered highly likely to contain free phase petroleum hydrocarbons. With groundwater reporting back towards the site and making contact with the primary impact source (i.e. free phase petroleum hydrocarbons), it is agreed that advective transport may not be occurring at the site presently as groundwater is flowing towards it. DES asserts however, if regional depressuration occurs in the future and/or if the aquifer beneath the site recovers and groundwater flows in its original regional direction, the future advective transport of contaminants at saturation (maximum solubility limits) cannot be discounted. The future migration of contaminants at maximum solubility limits reporting from the site does not appear to have been considered in the AGE 2020 report. DES considers that the modelling may have underestimated the potential contaminant transport risks.

The applicant is required to undertake and provide DES a contaminant fate and transport model using maximum solubility limits at the source area.

(n) DES also notes that the current volume and extent of the petroleum hydrocarbon source area (i.e. tars and concentrated organics resulting from the gasifiers) is not currently well documented, but free phase petroleum hydrocarbons in the cavity are understood to exist. These source areas are considered highly likely to be an ongoing source of groundwater contamination as long as groundwater is in contact with the petroleum hydrocarbons within the cavity. As groundwater levels recover and/or when the aquifer/s is influenced by regional depressurisation from CSG activities, DES considers ongoing migration of elevated contaminants arising from the former Linc Energy site highly likely. For the purpose of modelling the fate and transport of these contaminants, DES does not consider that the observed reducing concentrations in the periphery wells an adequate indicator of the contamination plume behaviour. Nor is the data considered suitable to be used in a modelling scenario (i.e. that the groundwater is flowing towards the source, not away). or enough to establish degradation coefficients.

DES asserts that the reduction in contaminant concentrations is not currently considered to be dominated by natural attenuation/degradation or sorption of the contaminants as indicated in the AGE 2020 report. Rather, DES considers that dilution and flushing of the wells resulting from the current hydraulic gradient is causing non-impacted groundwater further from the source flowing past the periphery monitoring bores and towards the site, as onsite groundwater levels continue to recover from the UCG activities.

The AGE 2020 report states that it is recognised that the upper bound of the range of values adopted for the first order decay coefficient (Foc) for Benzene is somewhat higher than typical ranges identified in the literature. DES considers the values adopted in the contaminant fate and transport model incorrect as the data used for calibration is considered to have been established based on observed groundwater conditions, whilst not considering a site conceptual model including the source location versus the direction of groundwater flow at this site. DES believes that the data obtained from any monitoring bore surrounding the site may be anomalous if used for the purposes stated in the model.

On the basis that there is currently no oxygen supply within the cavity or the aquifer, DES believes that degradation rates adopted for the model should reflect anaerobic conditions and literature based degradation values from a source that is at solubility limits. The applicant is required to undertake and provide to DES a contaminant fate and transport model that takes these considerations into account.

(o) Provide additional information on the monitoring/identification and mitigation measures proposed to prevent contaminant migration from the former Linc energy site. Include details on the early notification measures that will be implemented to inform DES on potential contaminant migration.

(p) Undertake a dual phase model that incorporates groundwater and gas movement that will demonstrate how gas movement may influence groundwater movement. Model gas movement, including up dip movement (Condamine bubbles), given that gas is more actively moving due to fracturing.

(q) The application material has not addressed the liberation of gas and its impact to environmental values, specifically on sensitive receptors and the suitability of land for its current and future use. Additional information is required on:

i. How this will impact the suitability of the land for current and future land uses;

ii. The management/mitigation practices to be implemented to prevent impacts to land from the liberation of gas;

iii. Additional remediation/rehabilitation measures required due to the liberation of gas; and

iv. Details of expected emissions associated with the liberation of gas and whether a flare will be required due to the impurity of the gas. Provide further details as to the requirements of the flare.

3. Actions

The abovementioned application will lapse unless you respond by giving the administering authority -

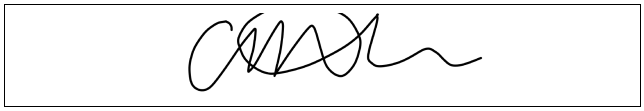
(a) all of the information requested; or
(b) part of the information requested together with a written notice asking the authority to proceed with the assessment of the application; or
(c) a written notice –
    i. stating that you do not intend to supply any of the information requested; and
    ii. asking the administering authority to proceed with the assessment of the application.

A response to the information requested must be provided by 26 March 2021 (the information response period). If you wish to extend the information response period, a request to extend the period must be made at least 10 business days before the last day of the information response period.

The response to this information request or a request to extend the information response period can be submitted to the administering authority by email to **EnergyandExtractive@des.qld.gov.au.**

If the information provided in response to this information request is still not adequate for the administering authority to make a decision, your application may be refused as a result of section 176 of the *Environmental Protection Act 1994,* where the administering authority must have regard to any response given for an information request.

If you require more information, please contact Amelia Sellars on the telephone number listed below.



Signature

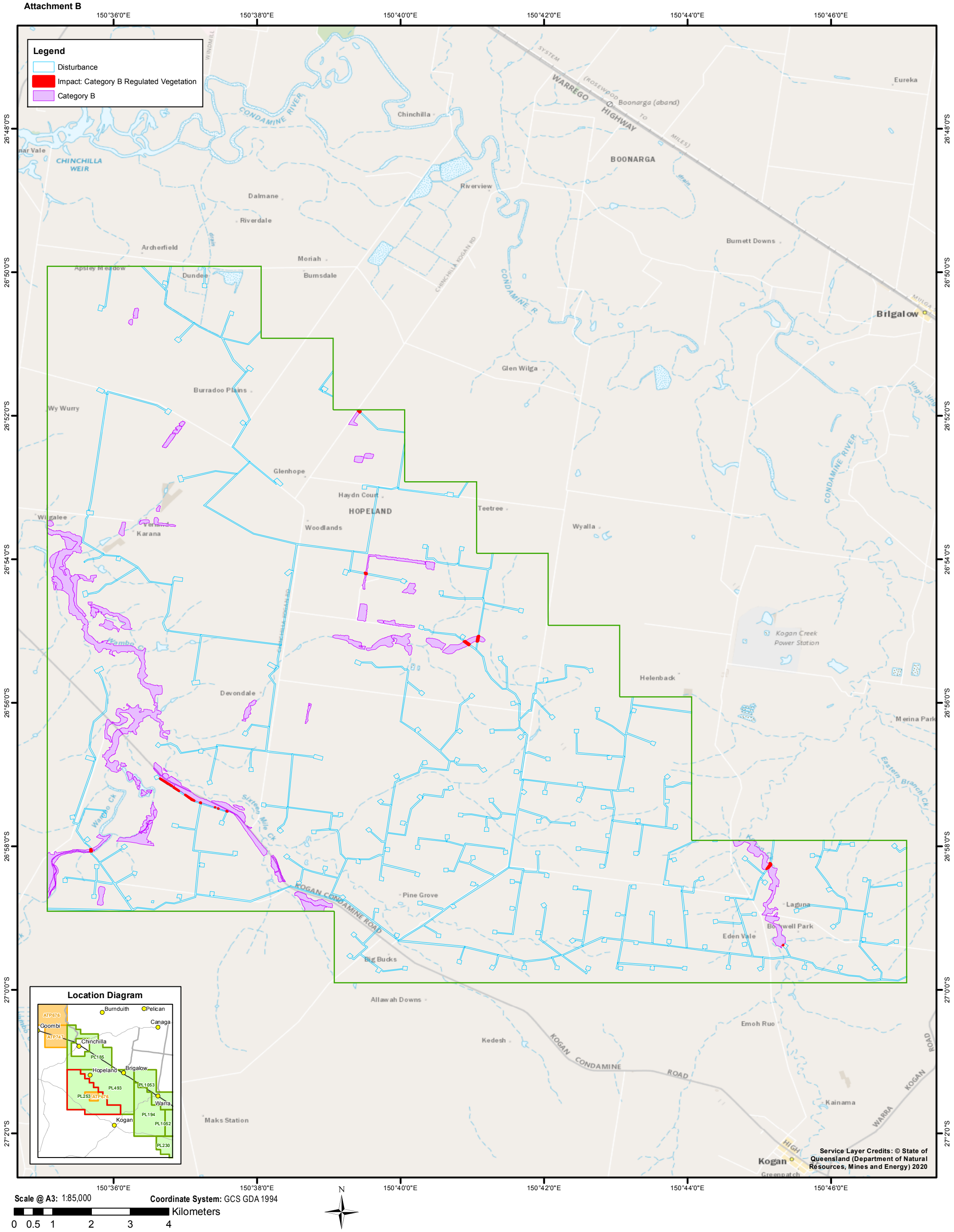
27 August 2020

Date

Clancy Mackaway
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Enquiries:
Energy and Extractive Resources
Department of Environment and Science
GPO Box 2454, Brisbane QLD 4001
Phone (07) 3330 5715
Email: energyandextractive@des.qld.gov.au

Attachment B



Rev	Date	Revision Description	Orig	Ckd	Eng	QA	App
A	25/09/20	Type here	XX	XX	XX	XX	XX

Source:
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Status: IFI
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Author: tstringer

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Reg Veg Cat B

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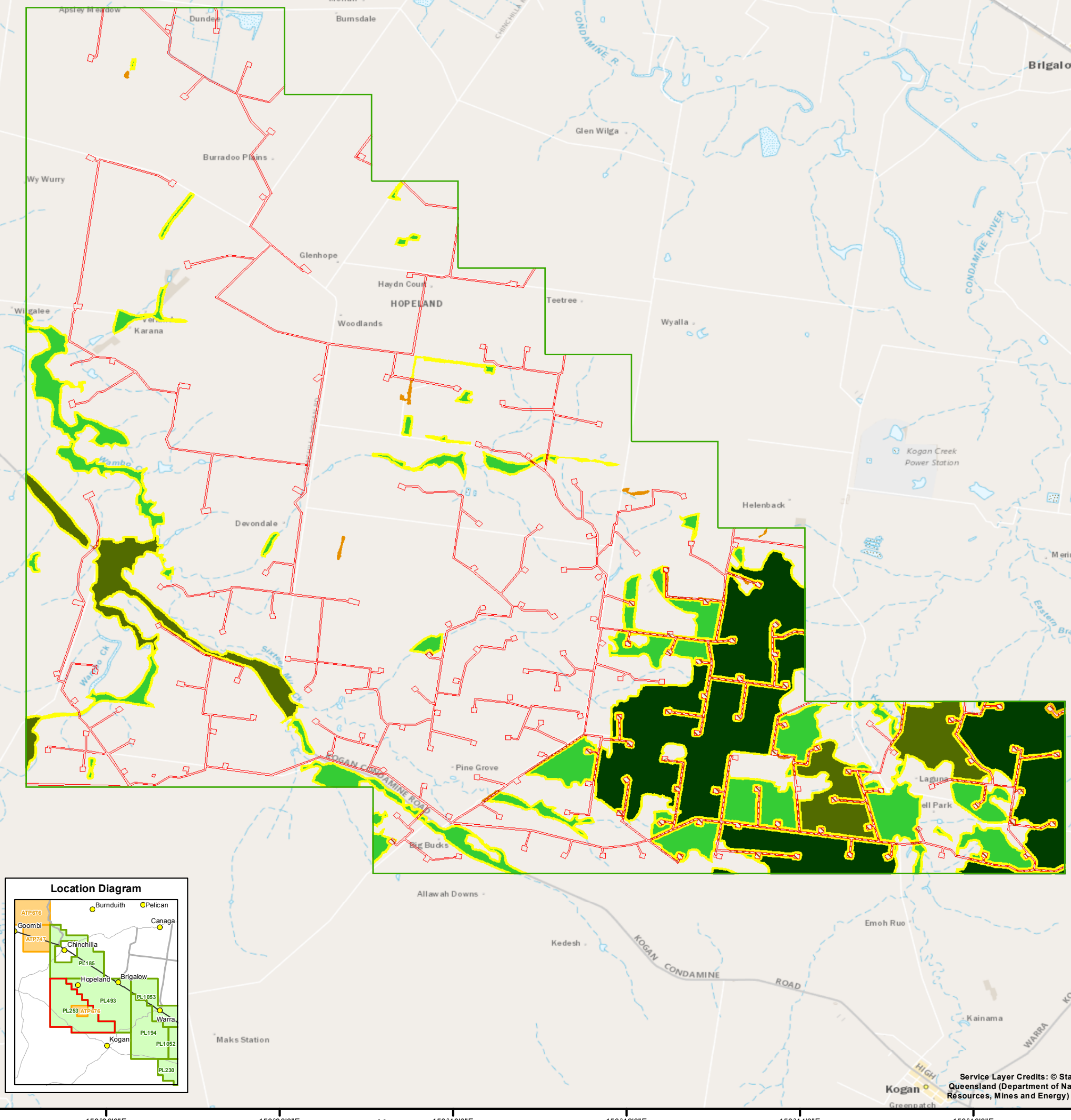
Legend

- impact site
- Cleared regulated vegetation (Cat. B)
- impact site local buffer
- impact site regional buffer

regional fragmentation post impact

- patch
- edge
- perforated
- core (< 100 hectares)
- core (100-500 hectares)
- core (> 500 hectares)



Location Diagram

Service Layer Credits: © State of Queensland (Department of Natural Resources, Mines and Energy) 2020

Scale @ A3: 1:85,000 **Coordinate System:** GCS GDA 1994

0 0.5 1 2 3 4 Kilometers

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Rev	Date	Revision Description	Org	Con'd	Eng	QA	Appr
A	25/09/20	Type here	XX	XX	XX	XX	XX

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LFC

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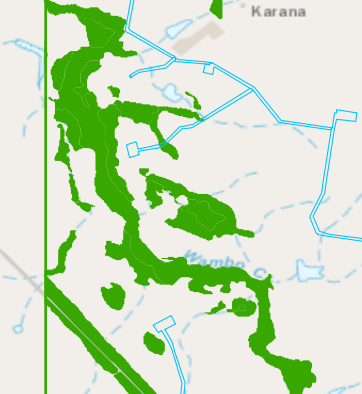
Legend

- Disturbance
- Impact: Protected Plants
- Protected Plants (high risk trigger)
- Groundtruthed Remnant Vegetation

Location Diagram



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 The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

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Protected Plants

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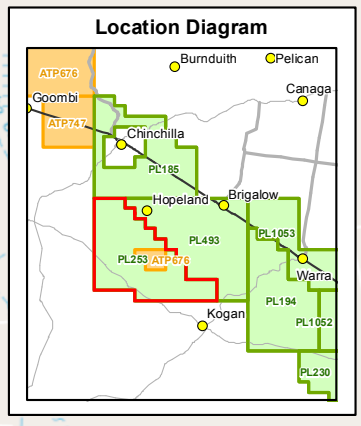
Legend

- Species
- Disturbance
- Wildlife habitat (Endangered and Vulnerable animal)
- Special Least Concern
- EssentialHabitat
- Impact: Essential Habitat
- Impact: Endangered Vulnerable
- Impact: Special Least Concern
- Groundtruthed Remnant Vegetation

Location Diagram



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Species

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Legend

Waterways Barrier Works-Risk of Impact

- 1 - Low
- 2 - Moderate
- 3 - High
- 4 - Major
- Impact: Fish waterways for waterway barrier works
- Impact: Defined WaterCourse (RegVeg)
- Regulated vegetation (defined watercourse)
- Disturbance

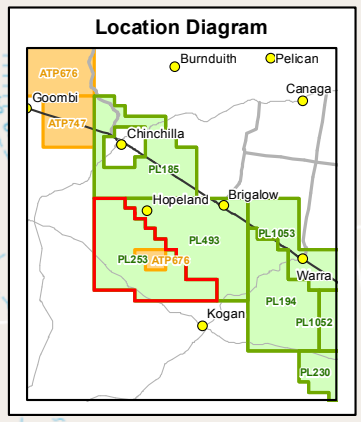
150°36'0"E 150°38'0"E 150°40'0"E 150°42'0"E 150°44'0"E 150°46'0"E

26°48'0"S 26°50'0"S 26°52'0"S 26°54'0"S 26°56'0"S 26°58'0"S 27°0'0"S 27°20'0"S

Chinchilla, Dalmane, Riverdale, Archerfield, Apsley Meadow, Dundee, Moriah, Burnsdale, Riverview, BOONARGA, Boonarga (aband), Eureka, Burnett Downs, Brigalow, Glen Wilga, Burradoo Plains, Wy Wurry, Glenhope, Haydn Court, HOPELAND, Teetree, Wyalla, Woodlands, Wigalee, Verland, Karana, Devondale, Helenback, Kogan Creek Power Station, Merina Park, Pine Grove, Laguna, Edin Vale, Big Bucks, Allawah Downs, Emoh Ruo, Kedesh, Kainama, Maks Station, Greenpatch, Kogan

CONDAMINE RIVER, WARREGO HIGHWAY, CHINCHILLA KOGAN RD, KOGAN CONDAMINE ROAD, KOGAN CONDAMINE ROAD, WARRA KOGAN ROAD, Eastern Branch Ck, Sixteen Mile Ck, Wambo Ck

Location Diagram



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Waterway Barrier Works

Defined Waterway (Reg Veg)

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