4

PROJECT DESCRIPTION

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4 Project Description

Arrow proposes to develop the CSG resource of the Project area for international markets, and potentially domestic sale. This will require exploration, field development, gas production, gas transport and export as outlined in Figure 4-1. The Project includes the field development and gas production stages of this process.

Development of the CSG field and production facilities will be progressive, extending over the Project life of approximately 40 years. Unlike conventional gas resources, CSG resources are extensive, requiring widespread field development to recover the resource. The yield from target coal seams is variable across the gas field. This leads to uncertainty about the precise number, timing and location of wells required to dewater the coal seams and extract the gas.

The lack of certainty about the preferred location of infrastructure is an issue for the EIS because the detailed impacts at any specific location cannot be fully determined at this time. However, they have been described based on the typical impacts of CSG project activities. With that knowledge, greater certainty about potential impacts has been achieved by identifying those areas that are not amenable to certain types of development and if they were developed, how development should proceed. This has been achieved through the identification of constraints to development and the establishment of environmental management controls that will apply to Project activities in constrained areas.

For these reasons, the EIS has not been able to identify the exact locations of all wells, pipelines and other associated infrastructure throughout the life of the Project. However, as required under the *Environmental Protection Act 1994* (EP Act), the EIS does provide enough information about the impacts of the Project to enable the administering authority to decide whether the Project should proceed and, for the purposes of the bilateral assessment for the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) process, to provide the Commonwealth Environment Minister sufficient information to make a decision about the Project.

The siting of CSG infrastructure for this Project is a process of progressive refinement informed by exploration, resource validation, gas field design and environmental assessment to optimise the recovery of economic reserves. It has commenced with the development of a reference case or conceptual layout that describes how wells, gathering systems and production facilities might be arranged to extract and process gas. The reference case, which is described in this EIS, is presented as areas in which facilities might be developed, with the arrangement of gathering systems and wells within a typical grid arrangement i.e. a grid of wells at nominally 800 m intervals. A preliminary development sequence is presented as part of the reference case to establish an indicative construction and drilling program. The reference case has informed the assessment of impacts given in this EIS, as it generally represents the worst case development scenario in terms of impact assessment.

The reference case will be updated after the Project's concept select phase. At this stage a concept will have been chosen to progress with into detailed design (front end engineering design (FEED)). This design process, which is expected to occur after the EIS process, will provide a greater level of detail about the number and capacity of production facilities, and will confirm equipment type selection, as well as functional layouts of wells and gathering systems. Constraints mapping and the findings of the EIS will inform design of the functional layout and site selection for facilities. The design process will be an iterative process that will be ongoing through the life of the Project as gas reserves mature and actual production is realised. Hence the reference case and development sequence will be progressively optimised through the Project life.

This section provides an overview of the Project's reference case for the construction, operation and maintenance, and decommissioning phases. Major infrastructure components associated with the Project, including the development process, sequencing and planning are also described.

It is important to note that the reference case for the EIS has been used as a worst case scenario and considers the greatest potential impacts to the values of the Project area that could occur under this scenario. As understanding of the Project evolves and the development scenario is optimised, impacts are likely to be less. Detail of the impact assessment methodology employed for the EIS is provided in Section 6.

A cross reference to the locations where each of the requirements of the ToR has been addressed is given in Appendix B which references both the study chapters (Sections 1 through 34) and/or Appendices (A through EE).

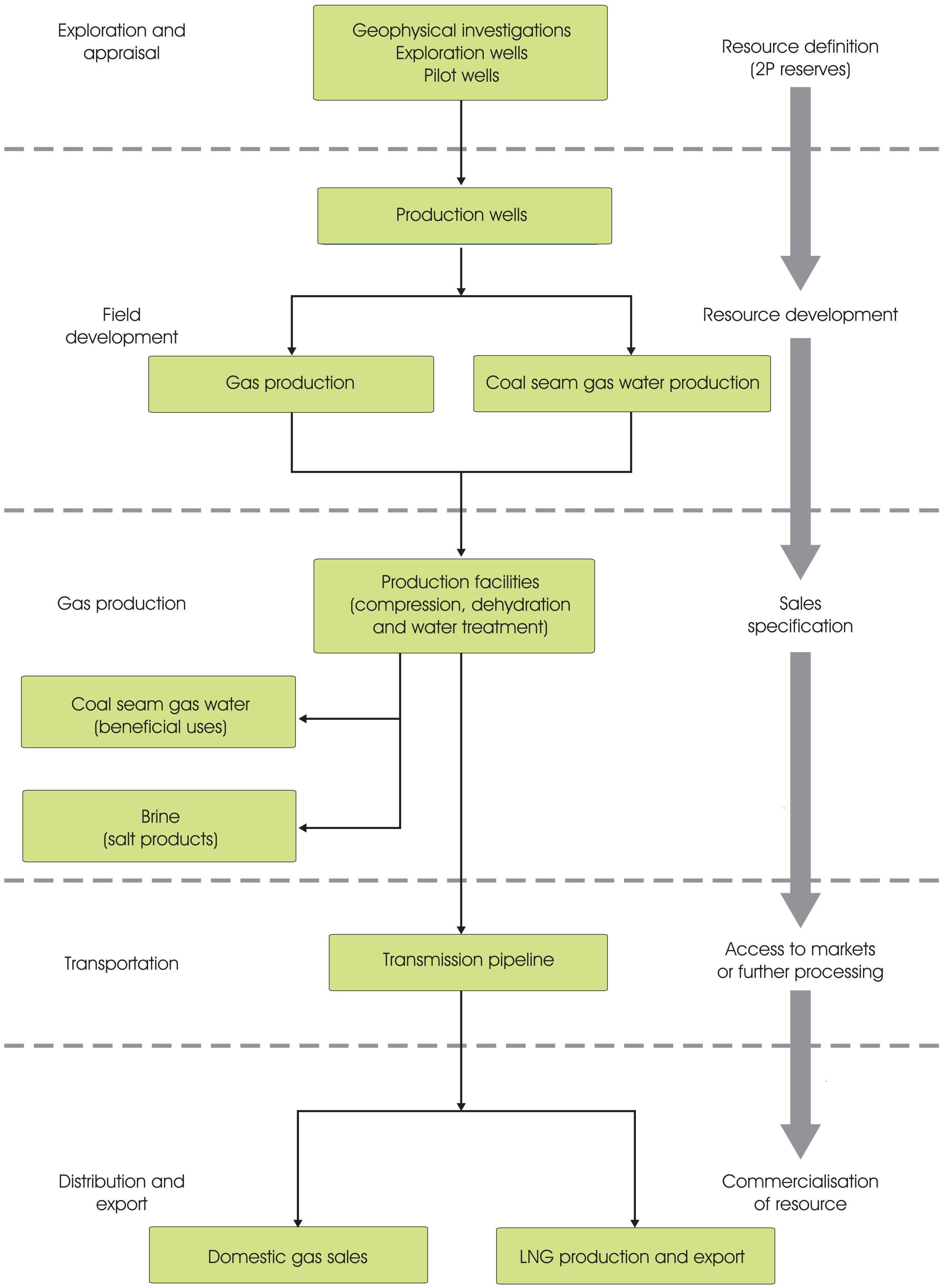
4.1 Background

The Project is located approximately 850 kilometres (km) north of Brisbane and 150 km south-west of Mackay, Queensland. The Project has been designed to assist in meeting the growing demand for gas supply for both domestic and global markets. It involves developing up to 6,625 production wells and associated CSG infrastructure over the approximate 40 year life of the Project

The Project area is approximately 8,000 km^2. The Project area extends north to south from Glenden to Blackwater, follows the Connors Range to the east and on the Denham Range to the west. It incorporates tributaries of the Suttor River and Bowen River catchments in the Burdekin Basin; and the Isaac River, Connors River and the Mackenzie River catchment in the Fitzroy Basin (Figure 4-2).

The Project area is predominantly used for grazing and agriculture, black coal mining, metals processing, gas development and forestry. Further detail on the land use of the Project area is provided in the Landuse and Tenure chapter (Section 19) of this EIS.

The topography is gently sloping and the geology is diverse though generally consists of fine grained sedimentary rocks, intersected by quaternary alluvium systems associated with creek and river flats, floodplains and alluvial plains. The characteristics of the superficial Quaternary deposits (alluvium) reflect the nature of the source rocks, weathering, transport and depositional conditions. Poorly sorted clay, silt, sand and gravel represents floodplain alluvium: and locally mottled, poorly consolidated sand, silt, clay and minor gravel, generally dissected by high-level alluvial deposits that reflect present stream valleys. These two types of alluvium make up a large majority of the surface geology of the Project area.



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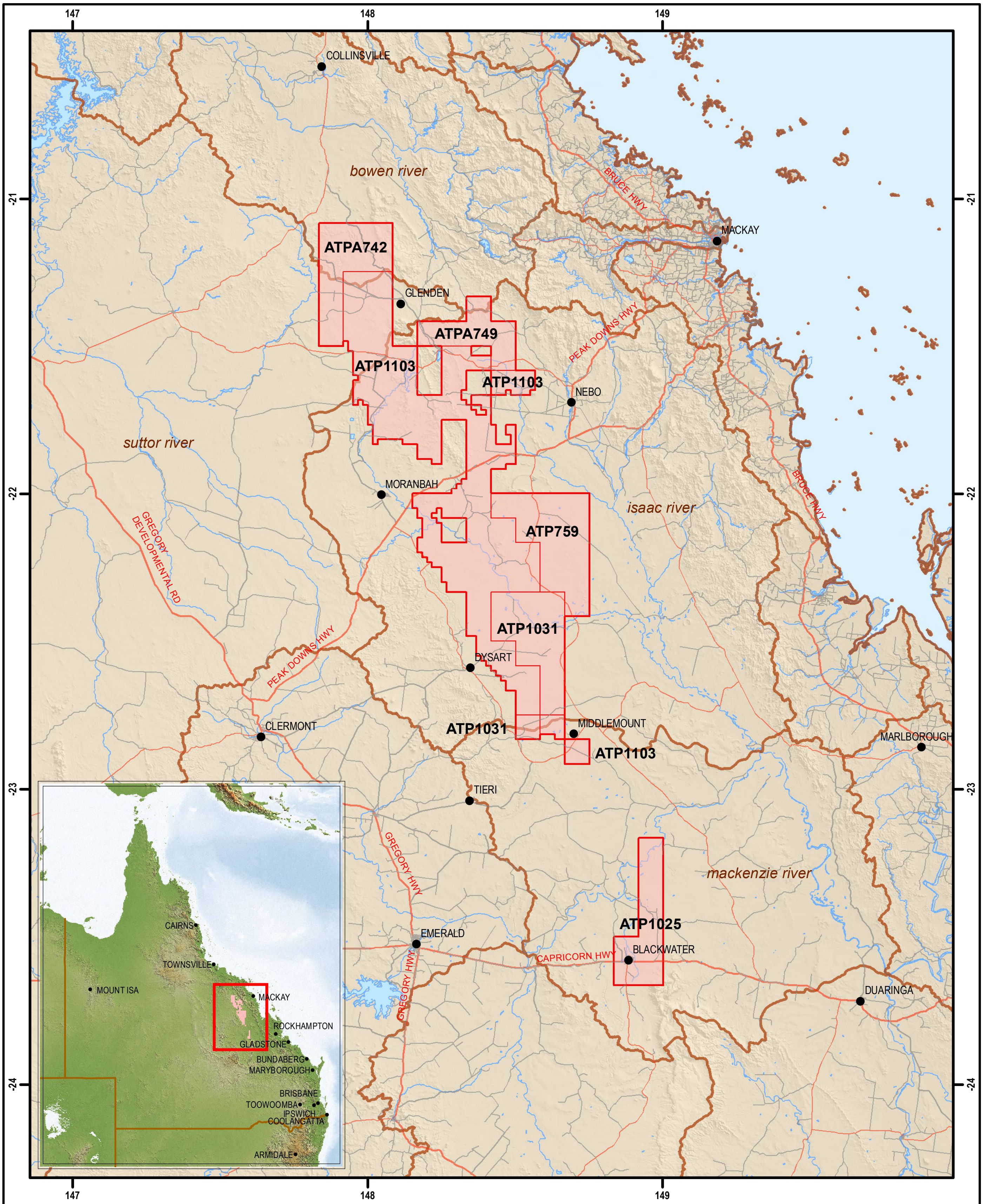
BOWEN GAS PROJECT EIS

PROJECT DEVELOPMENT ACTIVITIES

PROJECT DESCRIPTION

Figure: **4-1**

File No: **42626960-g-1114.cdr** Drawn: **MH** Approved: **DS** Date: **18-10-2012** Rev.**A** A4



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Projection: Geographic (GDA94)

Bowen Gas Project Tenements

Catchments

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BOWEN GAS PROJECT EIS

REGIONAL CONTEXT

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PROJECT DESCRIPTION

Figure: **4-2**

File No: **42626960-g-1094.mxd** Drawn: **MH** Approved: **DS** Date: **18-10-2012** Rev. **A** A4

Outcrops of consolidated formations are confined mainly to the northern portion of the Project area. The consolidated formations represented in surface outcrops include: the Late Permian Blackwater Group (Fair Hill Formation, Moranbah Coal Measures and Rangal Coal Measures) in the northernmost and north-eastern portion of the Project area; the mid-Triassic Moolayember Formation in the north-central portion of the Project study area, and the Early Triassic Rewan Group and Tertiary basalt outcrops which can be found the northern portion of the Project area. Further detail on the geological formations of the Project area is provided in the Geology chapter (Section 13) of this EIS.

The area experiences semi-arid and sub-tropical with summer-dominated rainfall that averages about 550 to 650 millimetres per year (mm/yr). Rainfall decreases from north to south and with distance from the coast. The area has mean maximum temperatures ranging from 34°C in January to 24°C in July. Mean minimum temperatures range from 22°C in January to 10°C in July. Heat wave conditions can be expected between October and March and frosts between May and August. The majority of precipitation falls in the warmer months of the year (November to February). Further detail on the climate formations of the Project area is provided in the Climate chapter (Section 8) of this EIS.

The Brigalow belt bioregion, in which the Project is located, is characterised by previously cleared and degraded grazing lands with patches of regrowth scrub (mostly brigalow (*Acacia harpophylla*) and eucalypt regrowth) and areas of remnant vegetation (forest woodland dominated by eucalypts, brigalow and paperbarks, and riparian vegetation associated with the Isaac River and grasslands). The extensive clearing in the Project area has resulted in remnant vegetation being largely confined to the riparian zones, escarpments and plateaus, protected areas and unallocated state land. Further detail on the biodiversity values of the Project area is provided in the Terrestrial Ecology chapter (Section 17) and Environmentally Sensitive Areas chapter (Section 18) of this EIS.

A number of towns and built up areas fall within or adjacent to the Project area. These include the towns of Moranbah, Glenden, Dysart, Middlemount and Blackwater. Project infrastructure, including CSG wells, gas gathering systems and production facilities will be located throughout the Project area but not in any of the towns. The Project will be staged and areas subdivided into development areas (gas fields) allowing a phased approach.

4.2 Description of the Gas Resource

The following sections provide an overview of the CSG resource and gas composition of the Bowen Basin.

4.2.1 Coal Seam Gas

Eastern Australia has large reserves of CSG, which occur within coal seams rather than in the sandstone reservoirs that typically hold conventional natural gas. CSG occurs when coal is formed underground by a process of heating and compressing plant matter. CSG then collects in the seam by bonding (or sorbtion) to the surface of the coal particles. The coal acts as a reservoir for the gas which is held in place by groundwater pressure. Target depths typically range between 150 m to 800 m. The CSG is desorbed once depressurisation occurs, and extracted via wells drilled through the coal seams.

The characteristics of CSG reservoirs differ from conventional gas reservoirs, as the coal is both the reservoir rock and the source rock for the gas. It is a heterogeneous and porous medium which is characterised by two distinct systems of different porosity: macropores and micropores. The macropores, also known as cleats, constitute the natural fractures common to all coal seams. Micropores, or the matrix within the coal, contain the vast majority of the gas.

In CSG and conventional gas reservoirs, both gas and water are produced. In a conventional oil and gas reservoir, the gas lies on top of oil, which in turn, lies on top of water. A conventional well typically draws only from the top layer of oil and gas without necessarily extracting the lower water layers. With CSG, the coal cleats are filled with water and the gas is sorbed to the coal matrix. Typically, groundwater must be pumped from the confined coal seam aquifers to reduce hydrostatic pressure. This reduction in pressure allows the CSG to desorb from the coal and mobilise into the production well. As a result, peak gas production is not reached until sufficient groundwater in the coal seam is removed (depressurising the coal seams). Coal seam groundwater production is, however reduced over time once target water pressures are met. This water is called CSG associated water (or produced water). Given the large volume of gas sorbed in the coal it generally takes a long time (up to 20 years) for the coal seam to deliver all its gas.

Much of the coal, and thus much of the gas, lies at readily accessible depths making wells relatively quick to drill. With greater depth, increased pressure closes the fractures (cleats) in the coal, which reduces permeability and the ability of the water and gas to move through and out of the coal.

4.2.2 Regional Context

The Bowen Basin represents a major rifting event that took place in the Late Permian along the eastern part of the current Australian continental landmass. The ‘rift valley’ extended from northern Queensland, south of Townsville, extending southward, approximately parallel to the current coastline, through Queensland and New South Wales, intersecting the current coast around Sydney.

This was an environment characterised by major coal measure development in several basins along the length of this large rift valley. During this time, the major Late Permian coal measure sequences were deposited in the Bowen Basin sequence underlying the Surat Basin in southern Queensland.

The Bowen Basin underlies the Duaringa and Surat Basins and extends across an area of approximately 160,000 km^2. The Bowen Basin is one of Australia’s major coal producing regions and contains much of the known Permian coal resources in Queensland, which are one of the coal measures targeted by the CSG industry. The gas resources associated with these deposits are significant and have the ability to supply large volumes of gas for development.

The Bowen Basin contains 23% of Australia’s 2P (proven and probable) CSG reserves (DEEDI, 2012 in Geoscience Australia, 2012).

CSG exploration and production within the Bowen Basin has been predominantly associated with the coal measures of the Blackwater group, which have established the Bowen Basin as an important gas resource.

4.2.3 Regional CSG Composition

The composition of CSG extracted from the Project area has been characterised based on CSG composition from Arrow's existing exploration and production. This is presented in Table 4-1.

Table 4-1 Typical CSG Composition for the Project Area

Component	Typical Quantity (%)
Methane	98.75
Ethane	0.01
Carbon dioxide	0.19
Nitrogen	1.05

4.3 Major Infrastructure Components

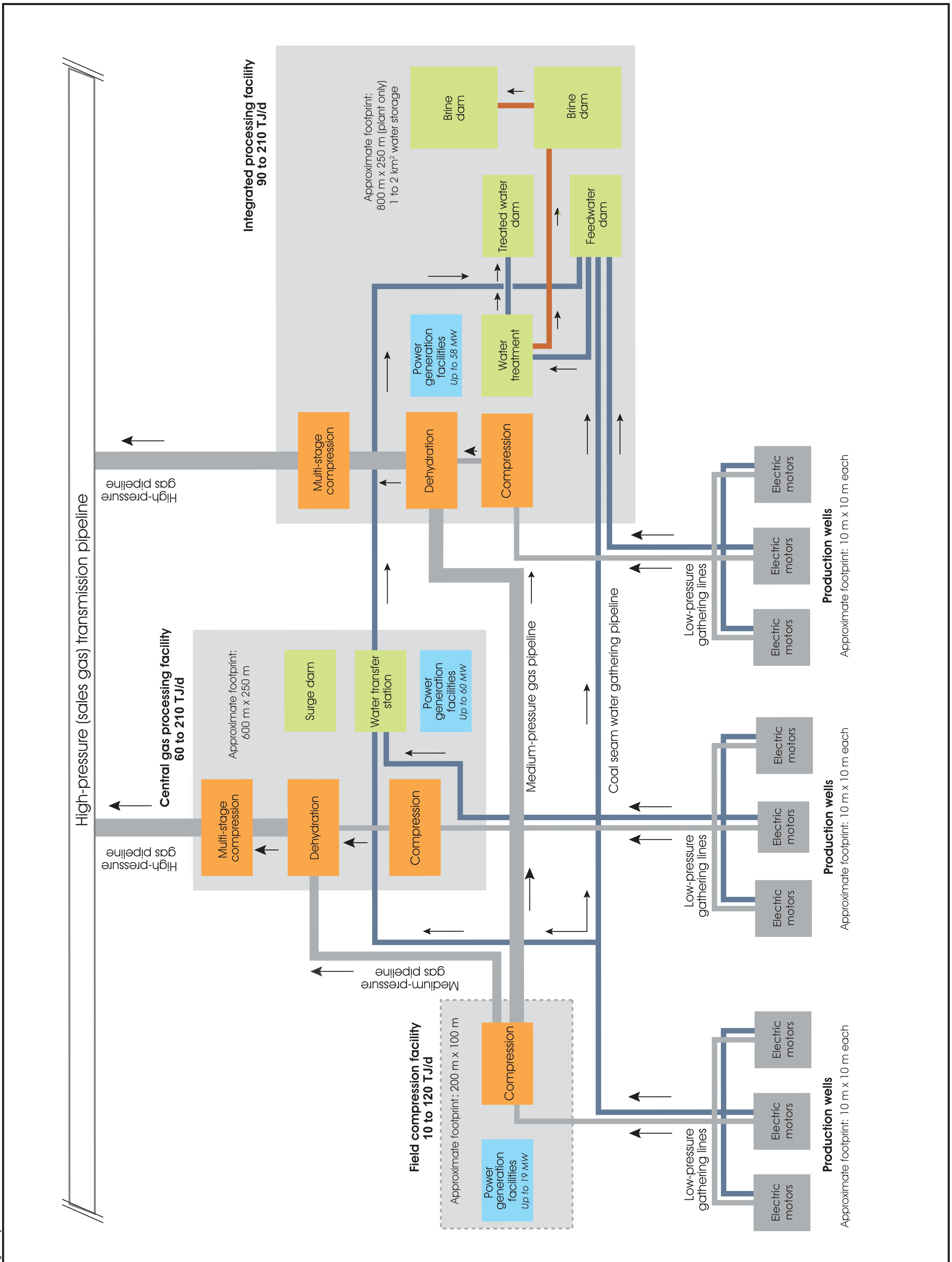
Arrow will divide the Project area into a number of development areas, with timing of the development of each of these areas sequenced to meet production targets. Each development area will include:

- A production facility - which may be a:
  - field compression facility (FCF) – a gas pressure boosting station to allow onward transport of remotely located gas to a CGPF or an IPF;
  - central gas processing facility (CGPF) – to treat (dehydrate) and compress the gas to export pressure, and pump water to the nearest integrated processing facility; and
  - integrated processing facility (IPF) – to treat (dehydrate) and compress the gas to export pressure, and treat water for beneficial use;
- Production wells – to access the coal seams and evacuate in-situ water and CSG;
- Field gathering systems – low and medium pressure pipeline networks to gather water and gas to a production facility;
- Access roads;
- Power generation and distribution facilities; and
- Monitoring and telecommunication facilities.

Further details on major infrastructure components are provided in the following sections. A schematic diagram illustrating the key Project components and the process of gas and water production and treatment is provided in Figure 4-3.

4.3.1 Production Facilities

The three types of production facilities described above (FCF, CGPF and IPF) are proposed with location selection dependent on environmental and social constraints, and final optimised development timing. The number of production facilities to be built across the Project area is expected to be optimised during the FEED process; however indicative locations for the reference case are depicted in Figure 4-4.



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BOWEN GAS PROJECT EIS

GAS AND WATER PRODUCTION AND PROCESSING

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PROJECT DESCRIPTION

Figure: 4-3

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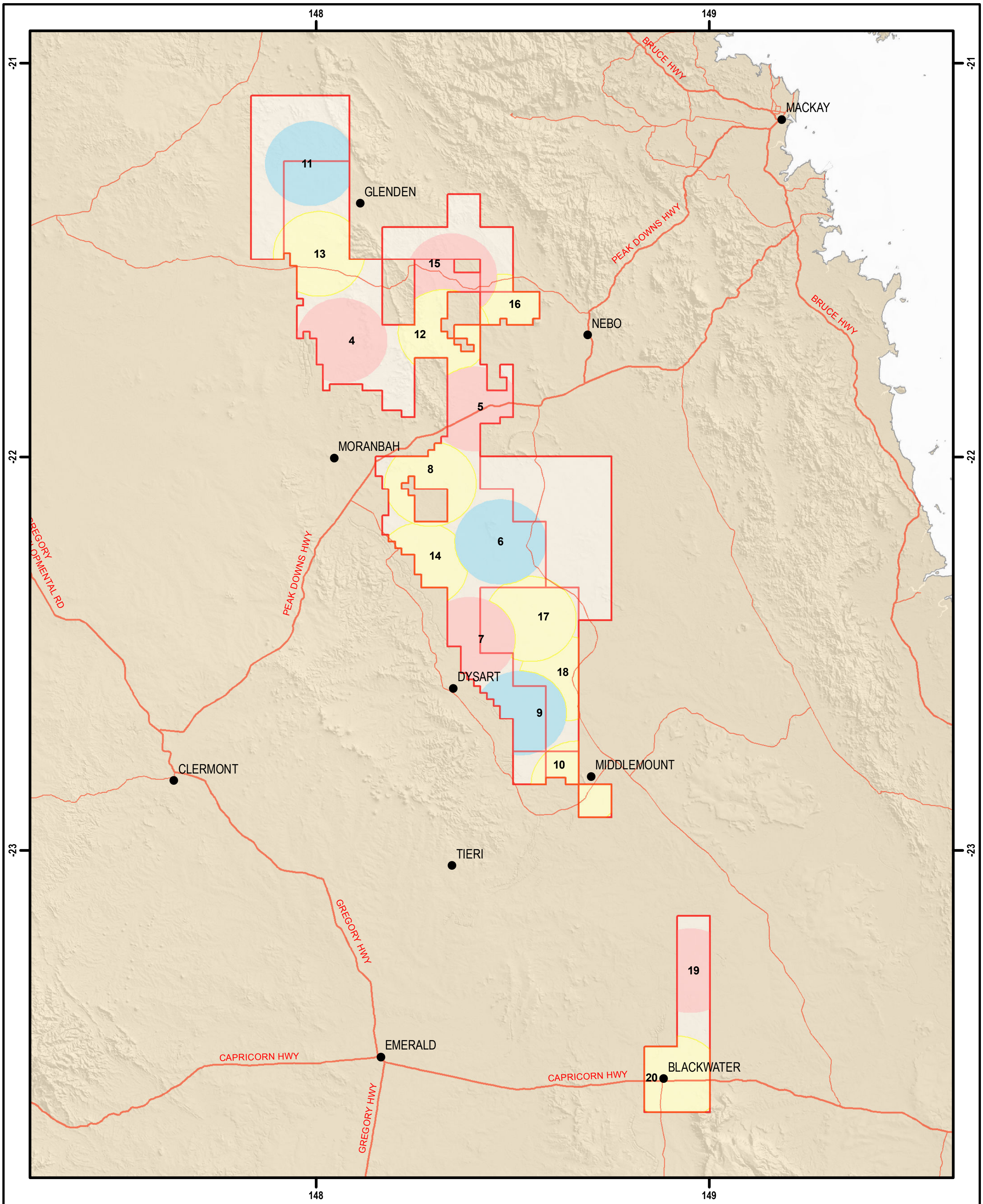

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Projection: Geographic (GDA94)

Bowen Gas Project Tenements

4 Development Area ID

Field Compression Facility Development Area

Central Gas Processing Facilty Development Area

Integrated Processing Facility Development Area

Source: Client Supplied Data; Roads and Locations from MapInfo Streets Pro, 2011; Topography sourced from Hole-filled seamless SRTM data V4, CIAT

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BOWEN GAS PROJECT EIS

INDICATIVE FACILITIES LAYOUT

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PROJECT DESCRIPTION

Figure: **4-4**

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For the purpose of this EIS production facility locations are assumed to be located somewhere near the centre of each development area of 12 km radius, allowing flexibility for the final location to be sited within environmental and social constraints. The proposed reference case development sequence of production facilities is further outlined in Section 4.5.

Gas and water collected in the gathering systems will be transported to the production facilities. Production facilities will primarily perform the following functions:

- Receive gas from wells located within reasonable proximity to the facility;
- Remove any bulk water remaining in the gas through a slug catcher;
- Compress gas through multiple stages to achieve sales gas pipeline pressure;
- Dehydrate gas to sales gas pipeline quality;
- Meter and control gas flow from the wells and to the sales gas pipeline;
- Provide a control centre for activities in the facility and the associated gas fields;
- Flare gas in the event of plant upset conditions or control failure; and
- Vent process gas in emergency situations.

4.3.1.1 Range of Facility Sizes

The following equipment size ranges have been adopted as a worst case scenario for the conceptual field layout. Proposed equipment sizes for gas compression and water management are outlined in Table 4-2. The approximate land area likely to be required by proposed facilities is outlined in Table 4-3.

Table 4-2 Production Facility Compression Types

Facility Type	Forecast Flow Range (TJ/d)	Compression Type	Comp. Train Count Screw[1]	Comp. Train Count Recip. Compressors[2]	Total Comp. Power (MW)[3]	Discharge MAOP (kPag)	Gas Dehydration
FCF	9 to 120	Screw and reciprocating, or centrifugal	1 to 12		1 to 14	1,000 to 2,000	No
CGPF	60 to 210	Screw and reciprocating, or centrifugal	5 to 21	2 to 7	10 to 51	10,200 to 15,000	Yes
IPF	90 to 210	Screw and reciprocating, or centrifugal	8 to 19	3 to 7	21 to 44	10,200 to 15,000	Yes

Note 1: Assessment based on 10 TJ/d capacity screw compressors.
Note 2: Assessment based on 30 TJ/d recip. Compressors.
Note 3: Direct compression power only – excludes ancillaries.

Table 4-3 Production Facility Area Requirements

Facility Type	Approximate Land Area
FCF	200 x 250 m
CGPF	600 x 250 m
IPF	800 x 250 m + up to 1 km x 1 km for dams

4.3.1.2 Field Compression Facilities

Where there is insufficient pressure within low pressure flow lines or trunklines to move gas from the wells directly to a CGPF or IPF, FCFs will be installed to boost the gas pressure to enable to transportation of the gas over longer distances.

Gas will be received at an FCF from the low pressure gathering lines, compressed to medium pressure, and discharged to medium pressure infield pipelines which will transport the gas to a CGPF or IPF.

An FCF may contain one compression train or multiple compression trains depending on the quantity of gas being delivered from wells in the area.

It is currently anticipated that an FCF will be operated remotely with manning on a maintenance basis only.

FCFs consist of compression trains that are made up of:

- Drive engines and/or motors;
- Compressors;
- Cooling fans;
- Separators;
- Control and safety systems;
- Electrical panels;
- Pipework;
- Pig launcher;
- Water pumping facilities
- Supervisory control and data acquisition (SCADA); and
- Flare and/or vent.

FCFs will most likely be of skid based modular construction to minimise onsite construction and periods of disturbance. A closed reclamation system is located on site to receive any oily water stream resulting from the compression process. It is envisaged that oil suitable for re-use will be recovered in this process, and any other separated water or other waste streams will be contained and stored on site in tanks, with periodic pump-out by road tanker for off-site disposal / recycling at a registered recycling facility.

It is currently expected that electrical power will be reticulated to an FCF from the nearest CGPF or IPF. At an FCF, water can be received from the local production area gathering systems, collected in a storage tank, and pumped to the closest IPF.

4.3.1.3 Central Gas Processing Facilities

CGPFs are high pressure compression facilities where gas is received from either medium pressure infield pipelines or directly from low pressure gathering systems, dehydrated to sales specification and compressed to reach a high pressure (10,200 to 15,000 kPag) to allow export to the Arrow Bowen Pipeline via a pipeline lateral.

The CGPFs will be manned during the day and remotely operated / controlled at night from a central 'Control Room' in the HQ building in Brisbane. The CGPFs will still have the ability for local control to be taken for machine trouble shooting and commissioning.

CGPFs are expected to have multiple compression trains that will consist of:

- Drive engines and/or motors;
- Integrated Power plant (or grid connected substation);
- Compressors;
- Cooling fans;
- Separators and gas dehydration;
- Control and safety systems;
- Electrical panels;
- Station pipework;
- Pig launcher / receiver;
- SCADA;
- Control rooms;
- Ancillary systems; and
- Flare and/or vent.

A combination of screw and reciprocating compression is assumed as the reference case for this EIS. CGPFs will have one or more dehydration facilities that operate for multiple compression trains.

A closed reclamation system on site will be used to collect any oily water streams that may result from the compression process. Any oil suitable for re-use will be recovered in this process, and any separated water or other waste streams will be collected and stored on site in either tanks or a utility dam, with occasional pump-out by road tanker for off-site disposal, or recycling at a registered recycling facility. Further detail on the management of operational waste of is provided in the Waste Management chapter (Section 28) of this EIS.

Gas flows at the Project's CGPFs are likely to range between 60 to 210 terajoules per day (TJ/d). Onsite sparing will increase the installed capacity.

The gas is received at the facility at a controlled pressure of approximately 40 kPag at the inlet manifold and 30 kPag at the suction to compression. A slug catcher will separate any bulk water in the gas before it is directed to the first stage of compression.

Gas is received by the first stage of compression via separators that remove any water droplets down to a size aligned with the allowable tolerance of the compressor. The first stage of compression will compress the gas to approximately 1,000 to 1,200 kPag.

The gas is heated during the compression cycle and then flows through air coolers where the gas is cooled to approximately 50°C to remove entrained water. The cooled compressed gas is then directed to the next stages of compression which will compress the gas up to pipeline export pressure (10,200 to 15,000 kPag).

It is currently envisaged that the gas dehydration will be comprised of Tri-ethylene Glycol units.

At a CGPF, water can be received from the local production area gathering systems, or from gathering systems of adjacent production areas via low pressure trunklines. This water will be collected either in a utility dam or tank and pumped, via a water transfer station to an IPF.

CGPFs may be co-located with Integrated Power Generation Facilities which will provide power to the facility and to a local area power grid. Alternatively, CGPF power could be supplied from an IPF (see Section 4.3.5.2). Connection to the electricity transmission network is also being investigated as an alternative.

4.3.1.4 Integrated Processing Facilities

IPFs will contain the same gas compression and processing equipment as the CGPFs, but will also contain a Water Treatment Facility (WTF) to treat associated water. The term 'integrated' is used as the facility contains both gas and water processing facilities.

Preliminary assessments indicate that the approximate volumes of water production could vary over time between 15 and 30 ML/d allowing that some areas will produce more water than others.

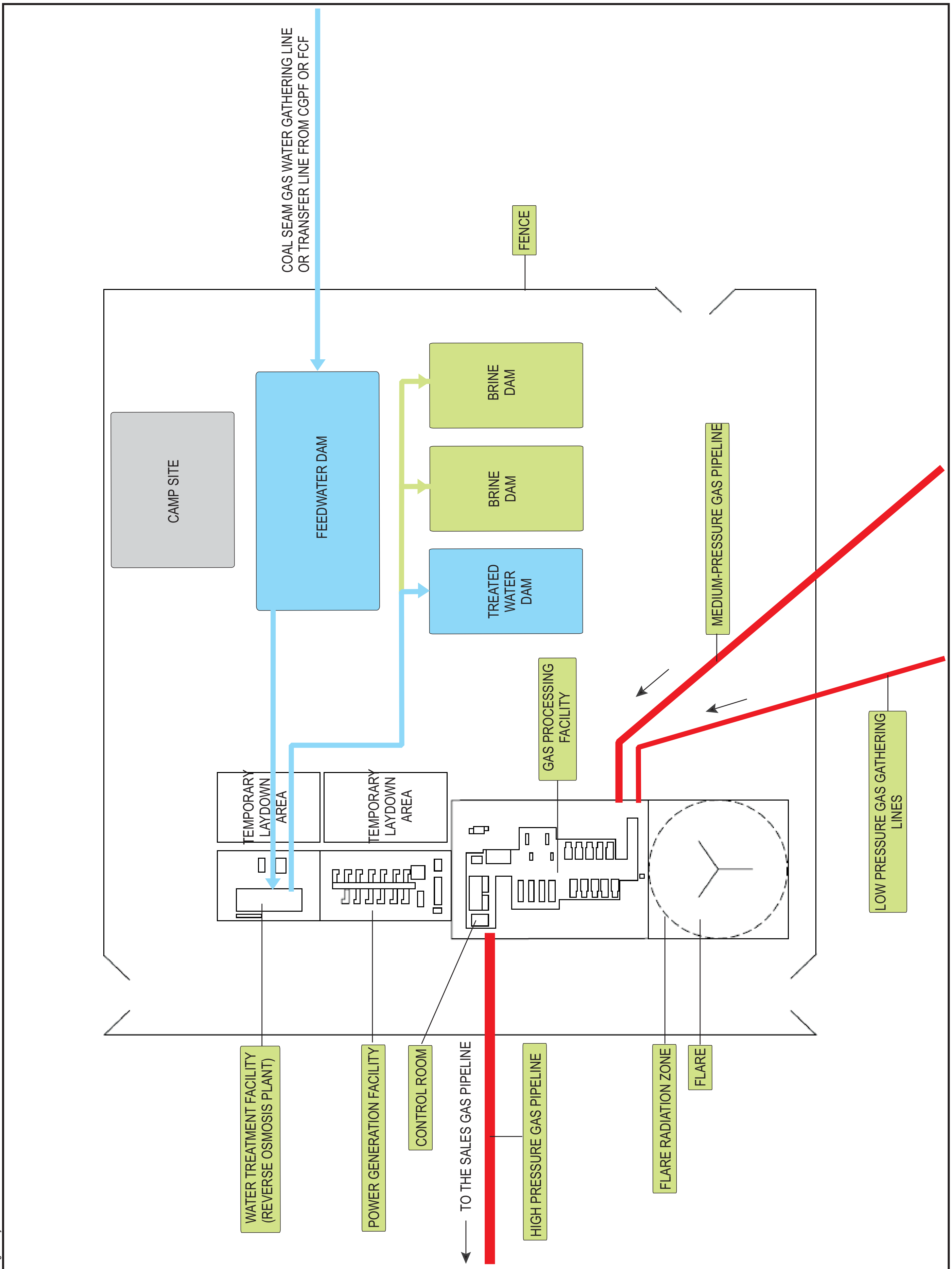
Gas flows at the IPFs are likely to be between 90 and 210 TJ/d. With use of onsite sparing, the installed capacity will be higher.

IPFs will be co-located with Integrated Power Generation Facilities which will provide power to the facility and to a local area power grid. Connection to the electricity transmission network is also being investigated as an alternative. It is proposed that IPFs will be manned during the day. Figure 4-5 provides a conceptual depiction of an IPF.

4.3.2 Production Well Development

Up to 6,625 production wells are expected to be drilled throughout the Project area over the approximate 40 year Project life to maintain gas supply to the LNG plant. Generally, wells will be designed for a 15 to 20 year life with production expected to decrease after the peak rate is achieved following initial dewatering. Once depleted, it is expected that the wells will be decommissioned in line with Arrow standards (see Section 4.8.1), with new wells drilled at predetermined locations to sustain production needs.

Current development plans comprise a number of well types that are under review and it is possible that a variety of well types will eventually be installed. In the reference case development scenario for this EIS, surface-in-seam (SIS) chevron wells in a dual lateral configuration will be used on a nominal 800 m grid pattern, with a potential range of between 700 and 1,500 m. A typical SIS production well is depicted in Figure 4-6.



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BOWEN GAS PROJECT EIS

TYPICAL INTEGRATED PROCESSING FACILITY ARRANGEMENT

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PROJECT DESCRIPTION

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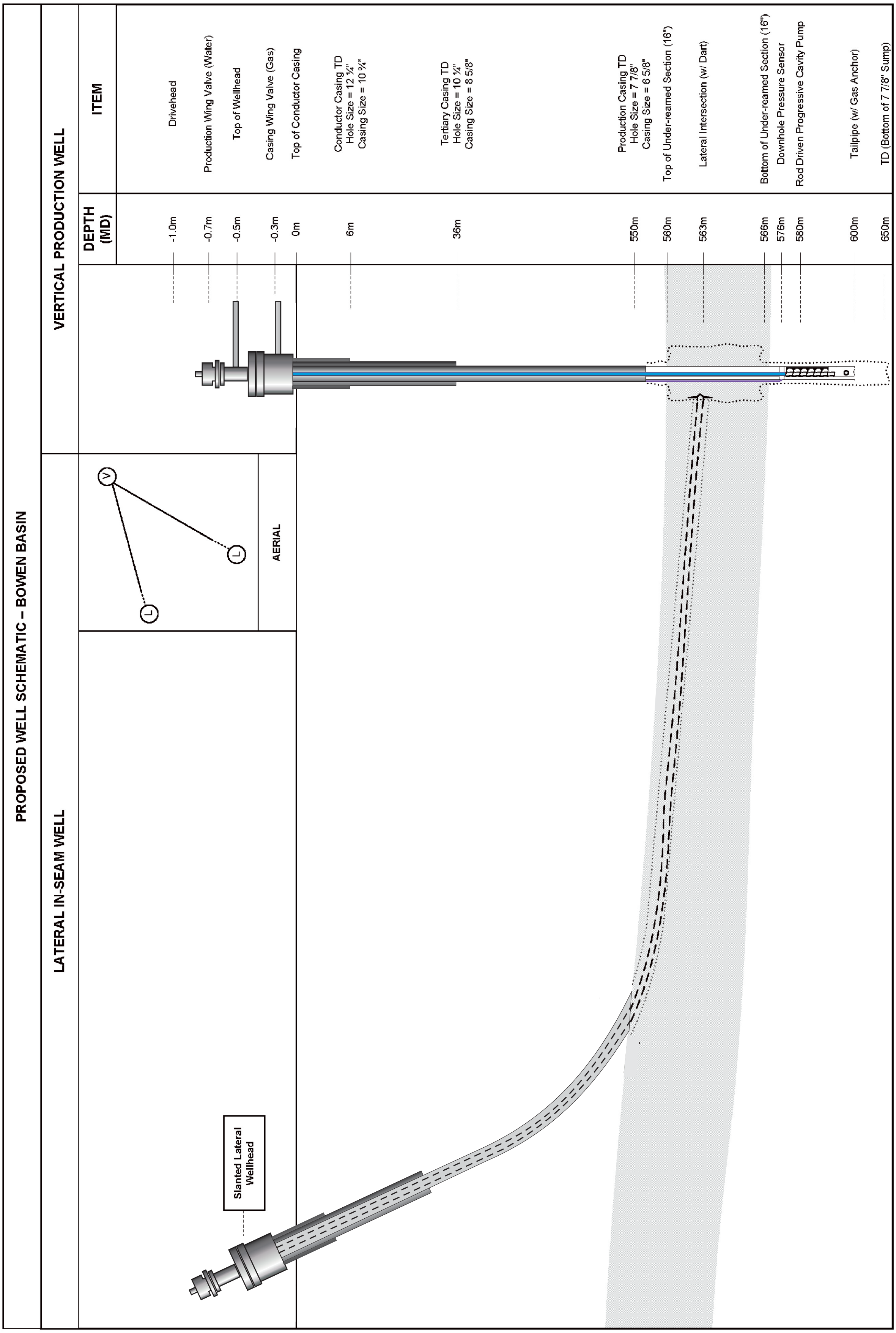

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BOWEN GAS PROJECT EIS

INDICATIVE SIS WELL SCHEMATIC

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PROJECT DESCRIPTION

Figure: 4-6

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Wells do not need to be placed on a precise grid and their spacing will depend on constraints such as environmental and social values, economics, reservoir characteristics and existing land use. As gas production ramps down, in-fill wells may be drilled between existing well locations to improve gas recovery and production.

Prior to drilling a well, a temporary drilling site will be prepared. Preparation will involve construction of temporary pits to hold the fluids used for drilling. In some locations, vegetation trimming may be required. To ensure safe operation of the drilling rig and associated equipment, drilling sites are normally up to 90 by 90 m.

Once the well is installed, the footprint is reduced to approximately 10 by 10 m as this area is sufficient to house the wellhead and associated equipment. The larger drilling site footprint is then partially rehabilitated. Workover rigs will re-establish a temporary 90 by 90 m footprint on a periodical basis (typically every three years) over the well's lifespan.

Production wells are typically drilled to between 150 to 800 m in depth. To prevent the loss of water from any upper groundwater aquifers that may be intersected, the top section of each well is cased with steel and cement.

Artificial lift (most likely a variable speed electric motor driven progressive cavity pump) is usually installed into the production tubing to allow removal of water released from the coal seam, via the well bore. The removal of water from the well removes the static pressure on the coal seam, thereby releasing gas from the coal seam.

During the well production phase, gas from the well will flow up the annulus (between the liner and the tubing) before exiting the wellhead and entering the metering and control skid. The metering and control skid will comprise gas and water metering, a gas control valve (throttling and pressure management), a control and communications unit, and power to the well. Where downhole well separation proves to be insufficient, surface separators are installed to separate the water from the gas.

The surface facilities will also have telemetry equipment for the transmission of signals to a central control room. Operational data such as water flow, gas flow and valve positions will be transmitted such that the well can be observed, controlled and optimised remotely.

4.3.3 Well Designs

4.3.3.1 Surface-in-seam Chevron Wells

In the Bowen Basin, (SIS wells are often used in a Chevron pattern where two SIS wells are drilled to intersect a vertical production well. This method increases the surface area of the coal seam exposed to the well to increase production (DEEDI, 2012).

The Arrow reference case design is a horizontal, SIS, dual-lateral in a Chevron configuration (Figure 4-6). This design includes two production laterals per well (and therefore requires that three holes are drilled, from three separate surface locations, to provide one “dual lateral producer”).

In the development scenario, on a nominal 800 m grid pattern, an indicative density of one producer well per 160 to 320 acres (65 to 130 ha) is typically expected.

During the drilling phase each well pad will occupy an area of 8,100 square metres (m^2) (90 by 90 m)[1] such that for each SIS dual-lateral producer, the required collective well pad area (for the three separate pads) will be 24,300 m^2.

4.3.3.2 Multi-seam Hydraulically Stimulated Vertical Wells

Hydraulic stimulation through cemented casings is the most widespread completion technique employed in vertical CSG wells globally. This well type is ideally suited to regions with more complex geology, typically characterised by faulted, deeper, thinner and multiple target seams, and may be employed in such areas as an alternative to SIS wells.

In such development scenarios, on a nominal 600 m grid pattern (potential range is 350 to 1,000 m), an indicative density of one well per 30 to 250 acres (12 to 100 ha) is typically expected.

During the drilling phase each well pad would occupy an area of approximately 8,100 m^2 (90 by 90 m).

Hydraulic stimulation is a process used in areas where the character of a coal seam impedes gas flowing readily into a gas well. In these areas, the coal may need to be stimulated to enhance the flow of gas. During this process a fluid is pumped at high pressure down the cased well and into the coal seam. This creates fractures in the coal seam in a horizontal plane up to 100 m or so around the well, which are then held open by sand.

About 99.5% of the material pumped into a well comprises water and sand. The remaining 0.5% is made up of minor quantities of additives used to:

- Enhance fracture initiation;
- Help lubricate the flow of the sand into the fractures;
- Prevent microbial or chemical reactions following introduction of surface water; and
- Prevent formation of scale deposits that may affect the well or pumps.

Depending on the location and geological formation being hydraulically stimulated, different additives may be used in different wells. In general, the additives used in hydraulic stimulation fluids are made of substances commonly found in many household products.

Arrow will ensure that any hydraulic stimulation fluids that are used are free of benzene, toluene, ethylbenzene and xylene (BTEX) chemicals. Despite this prohibition, it is still possible for small traces of BTEX to be detected in associated water as these chemicals can be found in petroleum-based products used in the well drilling process, and can also occur naturally in coal and petroleum.

Hydraulic stimulation processes are highly regulated by regulatory agencies and strict guidelines and risk assessment protocols are adhered to wherever this process is undertaken. Further detail on this is provided in the Groundwater chapter (Section 14) and Groundwater and Geology Technical Report (Appendix L) of this EIS.

[1] In some areas the disturbed areas could extend beyond this pad area (up to 130 by 130 m).

4.3.3.3 Innovative Well Designs

A number of alternative well design concepts are being trialled in order to complement and improve upon the reference case development well designs for the Project. These include:

- Standalone horizontal production wells (no vertical producer);
- Multi-seam horizontal production wells; and
- Multi-branched lateral wells.

In combination with these innovative well designs, Arrow is developing methods to review the potential for drilling multiple wells from a single surface location

4.3.4 Gathering Systems

Gas and water will be transported via separate flow line and trunklines from the wells to the compression and treatment facilities. Well head pressure (approximately 100 kilopascal gauge (kPag) for gas and between 200 kPag and 600 kPag for water) is used to transport the gas and water through the gathering system. The types of pipelines required to manage the production, treatment and distribution of CSG water are:

- Water gathering lines – a low pressure water gathering system installed from each well head to aggregation tanks or dams at each treatment facility;
- Transfer pipelines – a transfer pipeline, including associated pumps and controls constructed to connect tanks and dams within and between project treatment facilities to ensure that variations in CSG water production and field development phasing can be managed; and
- Distribution pipelines – a network of distribution pipelines, including associated pumps and controls, to convey treated and/or untreated water to end users in the region

The gas and water gathering lines are constructed of high-density polyethylene pipe. The minimum depth of burial to top of pipe will be 0.75 m, the final depth of burial will be agreed with the landowner to minimise disruption to other land uses and risk of damage to infrastructure. Gas gathering lines will include low point drains to manage any water not separated from the gas at the wellhead. These points will require regular draining to ensure unrestricted gas flow. Similarly, water gathering lines will include high point vents to allow the removal of trapped gas.

4.3.5 Power Generation and Distribution

Power is required for the extraction, transport and production of CSG and water. The reference case assumes power generation facilities are required at both the production wells and production facilities. These facilities are expected to generate electricity continuously 24 hours a day, 365 days a year, except during scheduled and unscheduled maintenance.

The power supply options being investigated for the supply of electrical energy to the Project are as follows:

- Production facilities:
  - grid connection (at high voltage and/or medium voltage); or

  - infield integrated electrical power generation at compression facilities (multiple gas-fired reciprocating engine units).
- Wellheads:
  - stand-alone generators; or
  - distributed power from production facilities.

Key criteria which will be considered for the supply of power will be safety considerations, environmental considerations, land use considerations, availability, reliability and integrity of power supply, economics, operability and maintainability.

The following sections outline the basis of each option and how each option may be adopted to a particular situation. However, the reference case to be adopted for this EIS is a combination of infield integrated electrical power generation for the facilities and stand-alone generators for the wellheads. The infield integrated electrical power generation facilities will be co-located at the IPFs and/or CGPFs, supplying power to that facility and where possible to adjacent facilities (such as FCF) via a local power grid.

4.3.5.1 Grid Connection

It is expected that bulk electricity supply will be achieved at either 132 kilovolts (kV) or 66 kV with the preferred option being to connect to existing transmission grid and/or distribution infrastructure. Arrow will work with the network service providers to establish, subject to availability and location, suitable 132 kV or 66 kV connections at new zone or local substations on Arrow’s petroleum leases (PLs) in the vicinity of the major facilities to be developed.

4.3.5.2 Integrated Power Generation

Use of integrated power generation to provide electrical power is the preferred method to be adopted for the supply of power to each IPF or CGPF and, where possible, to a wider area grid to power other facilities.

For the reference case a power generation facility will likely comprise a series of high-efficiency, CSG-fired reciprocating engines with lean burn technology, which will achieve high efficiency generation (greater than 40%) with reduced emissions (low nitrogen oxide combustion technology). Each engine will be coupled to alternators generating directly at 11 kV. Power generation facilities will be located within or in close proximity to production facilities. An estimated 80 by 150 m footprint will be required to accommodate a power generation facility, dependant on the capacity of the facility. These facilities will supply power for gas compression, dehydration and water treatment.

The number of electrical generators for each production facility will be based on the facility load requirements, the size of each generator and the required redundancy sparing (normally expected to be one engine). Power generation requirements will range from a minimum of 2 MW for an FCF to a maximum of 60 MW for a CGPF.

4.3.5.3 Stand Alone Generators

Individual local gas powered electrical generators may be used to provide electrical power to the wellheads. In each case the generator will supply electrical power to drive the water pump and control systems. The technology selected for this application is expected to be a high efficiency gas engine or microturbine with low emissions.

4.3.5.4 Distributed Power

The distribution of power from the production facilities to each individual wellhead via individual overhead and/or underground lines will be investigated to determine if there are practical, economic and environmentally acceptable alternative solutions to the use of local generation for each wellhead.

4.3.6 Pipelines

4.3.6.1 Medium Pressure Infield Pipelines

Medium pressure infield pipelines receive gas from an FCF at medium pressure and the gas is routed through the infield pipeline to either a CGPF or an IPF.

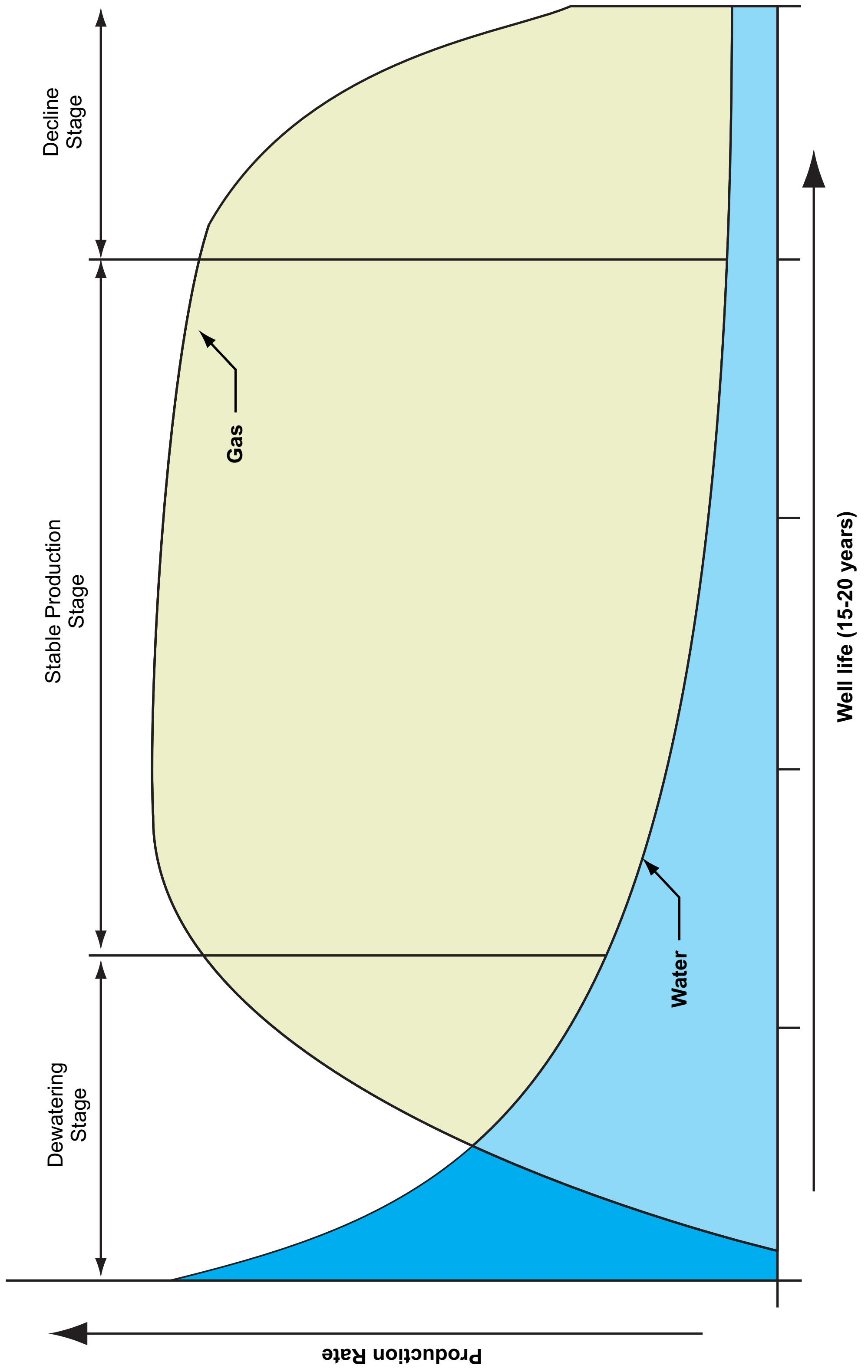
Medium pressure infield pipelines will be constructed of a lightweight strong plastic composite; glass reinforced epoxy (GRE) or lined steel. They will have a minimum depth of burial to top of pipe of 1 m. The final depth of burial will be agreed with the landowner to ensure disruption to other land uses and risk of damage to infrastructure is minimised.

Gas from FCFs is saturated with water and this water often collects in low points along the infield pipelines. This pooling of water requires the trunklines to be pigged (cleaned) on a regular basis to ensure the flow of gas is unrestricted.

4.3.7 Water Treatment and Storage Facilities

CSG production often requires the removal of large quantities of water to depressurise coal seams to allow the gas to flow. Dewatering can take weeks or up to several years, depending on the characteristics of the coal seam. Arrow has typically observed a six-month timeframe to dewater a production well before gas will flow and 18 months for a well to reach peak gas production. A typical gas versus water production curve is shown in Figure 4-7.

Total associated water volume to be extracted over the life of the Project is estimated at approximately 264.3 GL, or an average of about 18.6 ML/d over a 40 year Project life (approximate). The associated water produced is expected to vary from 2.9 GL to 9.9 GL per year depending on CSG field development.



Source: Client supplied data

BOWEN GAS PROJECT EIS

TYPICAL WELL GAS AND WATER PRODUCTION CURVE

PROJECT DESCRIPTION

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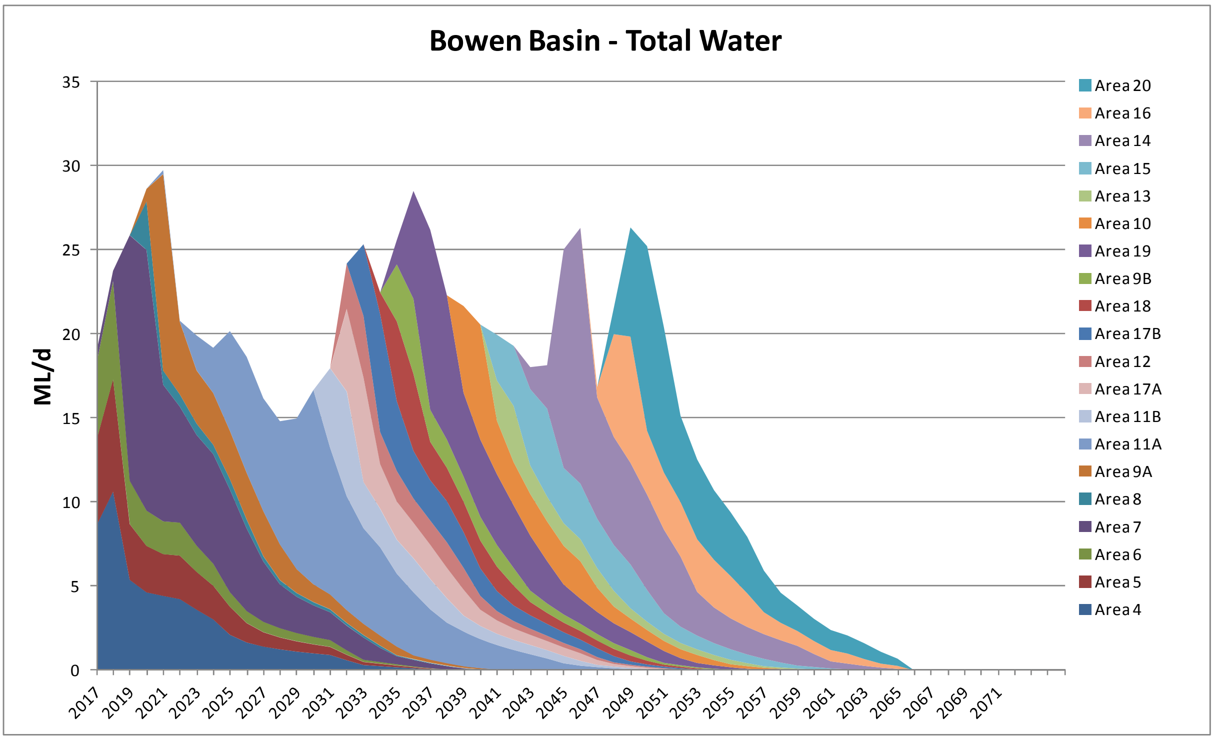
Figure: **4-7** Rev.**A** A4

The estimated annual CSG water production rates over the life of the Project are illustrated in Figure 4-8.

Figure 4-8 Indicative Annual Average CSG Water Production



Arrow maintains water balance models for long-term planning and management of CSG water in connection with its existing production wells in the target coal seams. The modelling is reviewed and updated quarterly in alignment with the production-forecasting schedule. Such models and modelling will be applied to the planning and management of CSG water across the Project area.

Further detail on groundwater monitoring is provided in the Arrow CSG Water and Salt Management Strategy (Appendix AA).

4.3.7.1 Water Quality

CSG water can vary in quality from slightly brackish to saline. It usually contains a mix of various elements and can have variable turbidity. CSG water from the Bowen Basin typically has the following characteristics:

- pH of approximately 7 to 10;
- Salinity, measured as total dissolved solids (TDS) in the range of 3,000 to 8,000 mg/L (i.e., brackish), including chloride, sodium salts, carbonate salts, and others;
- Significant amounts of suspended solids from the well that will usually settle out in aggregate dams over time;
- Other ions including calcium, magnesium, potassium, fluoride, bromine, silicon and sulphate (as SO_4); and

- Trace metals and low levels of nutrients.

The quality of the CSG water will be monitored as the Project progresses. However development is planned with the assumption that similar water quality and salt concentrations will be observed across the Project area.

Associated water characterisation studies are ongoing using pilot well data in advance of treatment facility design.

4.3.7.2 Water Treatment Infrastructure

Arrow has undertaken a comprehensive marketplace evaluation of the various technologies available for the treatment of CSG water. Reverse osmosis is the treatment technology of choice based on experience, economics, energy consumption, brine recovery, regulations and operational and environmental footprint of the associated technology.

Infrastructure required for CSG water treatment and storage of includes:

- WTFs;
- Water transfer tanks or dams;
- Aggregation dams;
- Treated water dams;
- Brine storage dams;
- Waste water dams;
- Transfer pipelines and associated pumps and controls to provide interconnection between the production facilities and WTFs; and
- A network of distribution pipelines to convey treated water to end users.

Water Treatment Facilities and Associated Dams

Water produced from each gas region will be directed, after degassing, to a 600 ML aggregation dam at each IPF. The aggregation dam is an important part of the treatment process as it allows for surge capacity, sediment settlement, homogeneous mixing, liberation of residual volatile compounds and oxidation of some organics and metals. From the aggregation dam, water will be transferred into the pre-treatment stage of the WTF.

At a CGPF, water will be received from the local production area gathering systems and pumped to the closest IPF.

Reverse osmosis technology is currently being considered as the most appropriate treatment process coupled with some form of suitable pre-treatment such as membrane or media filtration and hardness removal.

WTFs may be designed in a modular configuration to enable the size of each facility to better match local demand. A modular approach provides the ability to relocate facilities during the Project life to accommodate changing water production volumes as the field develops. This will prevent significant over design and capitalisation of total water treatment capacity. Some excess capacity will be unavoidable and will be assessed and quantified during the Concept Select stage.

The reverse osmosis treatment will produce water which will be stored in treated water dams prior to being distributed to customers in the local area. The treated water will be amended to ensure that the quality meets the requirements for the end use or disposal option. Each IPF is expected to contain one 600 ML treated water dam

Brine produced from the WTF will be contained in brine dams where salt will concentrate through evaporation before it is beneficially used or disposed of in registered landfills. To facilitate evaporation, each IPF facility is expected to contain two 960 ML brine dams. Options will be investigated to enhance crystallisation to reduce the proposed footprint of the dams and facilitate beneficial use.

Alternatives to brine evaporation are being investigated, with Arrow's preference being for mechanical or thermal concentration with selective product recovery. Other options under consideration include re-injection to the aquifer, and disposal to the ocean. Waste lubricants and chemicals used in the water treatment process and the compression systems will be stored in relatively small waste water dams. Not all locations will require waste water dams.

Further, dam sizes will be examined in more detail to account for optimisation, specific site conditions and parameters for each region.

Buffer storage will be provided in each dam to allow variation in:

- Daily flows from the field;
- Gas to water ratio - controlled by automated level control at each well;
- Development of the field to accommodate new wells as required for initial field development and future maintenance wells;
- Availability of off-takes and/or downstream processes due to maintenance and other factors; and
- Levels due to long periods of rain and/or evaporation.

Disposition of Salt

Options for the management and disposal of salts produced in the reverse osmosis treatment process are being considered. Crystallisation or enhanced evaporation options include:

- Conventional solar evaporation in storage dams; and/or
- Enhanced evaporation using thermal, chemical and/or mechanical assistance.

For the disposal of salt, options include the recovery of processed products including conventional salt (NaCl), bicarbonate and carbonate salts (Bi-carb Soda, Soda Ash, and Calcium Carbonate).

Arrow is consulting commercial enterprises to investigate viable opportunities for the beneficial use of brine through selective salt precipitation. Infrastructure required to convert brine to salt for beneficial use typically includes a salt storage area with a concrete apron, process building, bunding and roof.

Distribution Infrastructure

Transfer infrastructure will be installed to allow the transfer of raw or treated water between the WTFs, aggregation dams, brine dams, and between facilities and irrigation dams, or for transportation to end users. This infrastructure may comprise:

- Interconnection between the WTFs linking facilities to provide additional flexibility to cope with variations or spikes in water production across the development areas.
- A network of distribution pipelines to transport treated water to end users (for beneficial use, disposal or for make-good measures to ensure ongoing water supply to landholders with impaired bore capacity). The network location and its extent will be dependent upon the location(s) of the end user market.
- A connection to a selective salt precipitation plant.

4.3.8 Access Roads and Tracks

Existing roads will be utilised as far as practicable to minimise disturbance to the surrounding areas and all Project-related movements will be restricted to existing public roads and approved access tracks. Access tracks design and planning will include consultation with relevant landholders and regulatory authorities to determine the exact location of the access, and if the access points are to be permanent or temporary. New access tracks will be sited to minimise disturbance to landholders. All temporary access tracks will be rehabilitated in accordance with the statutory approvals and landholder requirements.

4.3.9 Existing Infrastructure

Use of existing infrastructure will be investigated for possible reuse as part of the Project’s initial field development. For example, use of spare processing capacity may be available at Arrow’s adjacent Moranbah Gas Project facilities and other new facilities developed under separate Environmental Authority (EA) applications (preceding the scope of this EIS).

4.3.10 SCADA and Telecommunications

A SCADA system will be employed to monitor and remotely control all wellheads and facilities by a single integrated process control and information system.

For telecommunications, it is proposed that the following systems be deployed in the field:

- Well site telemetry systems;
- Access to Arrow’s corporate voice and data network from manned locations, remote offices, etc.;
- Mobile (wireless) communications, e.g. mobile phones and two way voice communications such as handheld radios and vehicle mounted radios;
- Vehicle tracking (vehicle location, speed, braking force, etc.);
- Man down alarms;
- Closed circuit television (CCTV) for security and site monitoring, e.g. water dam levels; and
- Intruder detection systems – either perimeter (fence-line) mounted or sub-surface “listening” devices.

These systems will be supported by a combination of a High Speed Backbone Network (HSBN) and Secure Wireless solutions. The HSBN will interconnect the FCFs, CGPFs and the IPFs as well as extending where required into the well fields. The HSBN will be implemented by either buried fibre optic cable or microwave links. Fibre optic cables will also be assessed for use within upstream facilities to reduce site cabling installations.

A Secure Wireless System will be used to cover the gas fields and specifically to provide telecommunications to the wellhead sites for telemetry and possibly CCTV applications.

Consideration will be given for the early installation of the wireless network to facilitate communications during the Project's construction phase.

4.3.11 Supporting Infrastructure and Logistics

The development of the Project, which will require supporting infrastructure to construct and operate the various extraction, gathering and production facilities, will occur over a large and diverse area. Where existing infrastructure is not in place, additional supporting infrastructure will be constructed to facilitate Project development requirements.

The main supporting infrastructure for the Project is expected to include depots, borrow pits, accommodation facilities, telecommunications facilities and potable water supplies.

Arrangements for the transport of plant, equipment, products, wastes and personnel will be required over the full life cycle of the Project. A logistics plan will be developed during the FEED process when potential locations of the major Project infrastructure are identified. Traffic movements will be planned to take place as efficiently as possible, with minimal handling, such as bulk transport. The frequency of trips to Project facilities will be minimised where possible.

4.3.11.1 Depots

For the reference case, depots are proposed to be located at four IPF facilities in Figure 4-9. These depots will accommodate administration, engineering and production, supervisory support, occupational health and safety management, stores, workshops, laboratories and associated personnel.

4.3.11.2 Accommodation Facilities

Accommodation for the construction and operation workforce of the Project is expected to include a combination of temporary workforce accommodation facilities (TWAFs) and permanent housing.

The construction workforce will be accommodated in self-contained TWAFs that contain a canteen, fitness facility, laundry, vehicle parking, fuel handling and storage area, and a camp waste management and storage area. These accommodation facilities are expected to be located in the vicinity of an IPF.

Small mobile camps to house drilling staff may also be required in a location central to any drilling activities that are taking place a considerable distance from the IPF based TWAF's. These camps would contain a small canteen, vehicle parking areas, and waste collection and storage areas.

Operations staff are expected to be primarily accommodated in TWAFs, with locally sourced personnel accommodated in permanent housing. Additional details on the construction and operation of accommodation facilities are provided in Section 4.6.7 and Section 4.7.8 respectively.

4.3.11.3 Borrow Pits

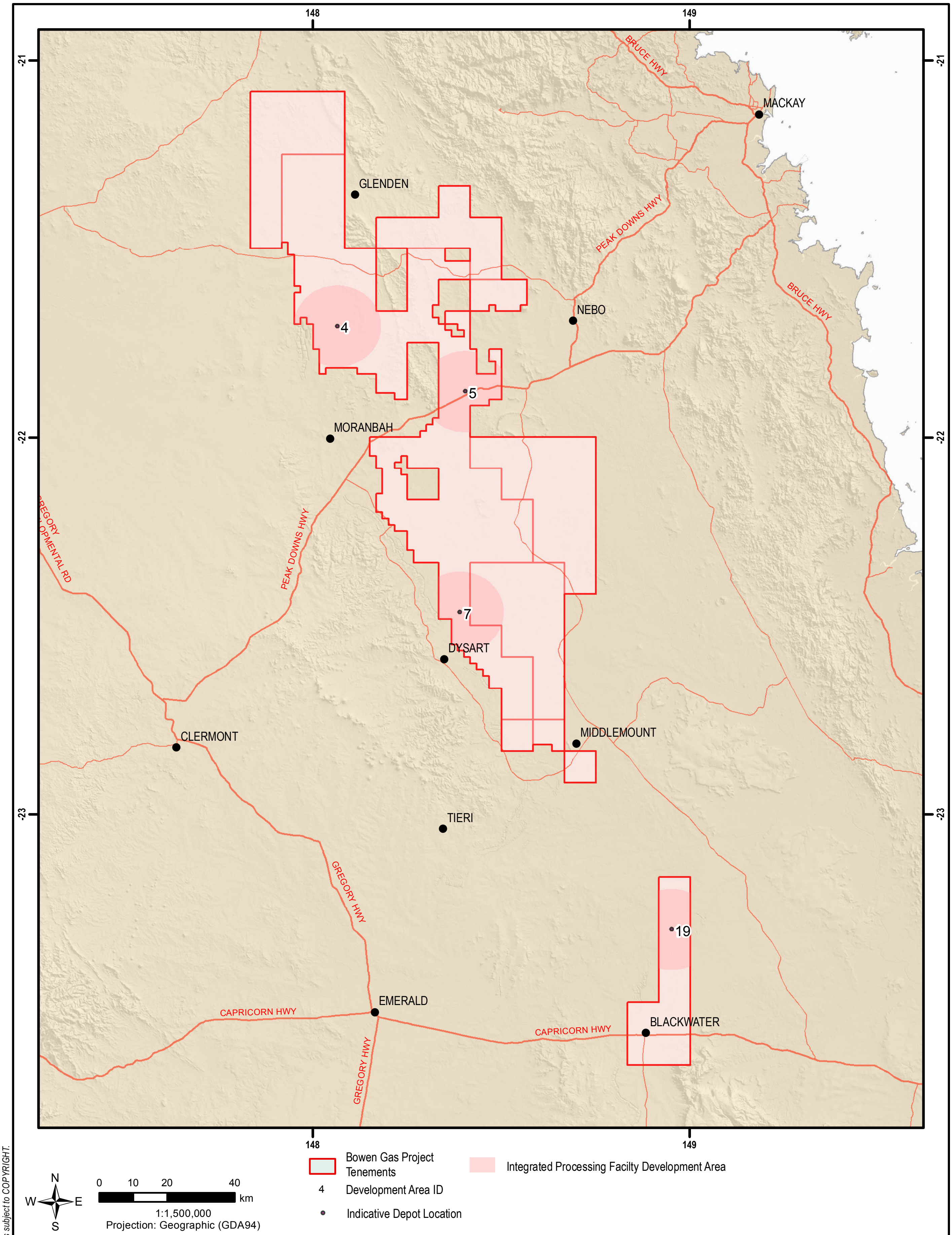
The Project construction and operations activities will require foundation aggregate for construction of camps, roads and production facilities.

Where approved by the relevant government agency, existing quarries and borrow pits will be used for rock, gravel, sand and soil. If unavailable, alternative sources of quarry and borrow pit materials will be sought from more remote sources or through the identification and development of new borrow pits. Proximity to production facilities will be a key factor in investigating alternative borrow pit sites. Borrow pit site selection will primarily be informed by quality of material, access to resource, environmental and social constraints and consultation with landowners and relevant government agencies.

4.3.11.4 Potable Water

Potable water required during construction and operational activities will be sourced and trucked from existing town water supplies, groundwater bores, or treated CSG water depending on the location of the activities and production facilities.

The expected volume of potable water consumed during construction and operations will be approximately 7 ML per annum and 12 ML per annum, respectively.



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BOWEN GAS PROJECT EIS

INDICATIVE LOCATIONS OF DEPOTS

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PROJECT DESCRIPTION

Figure: **4-9**

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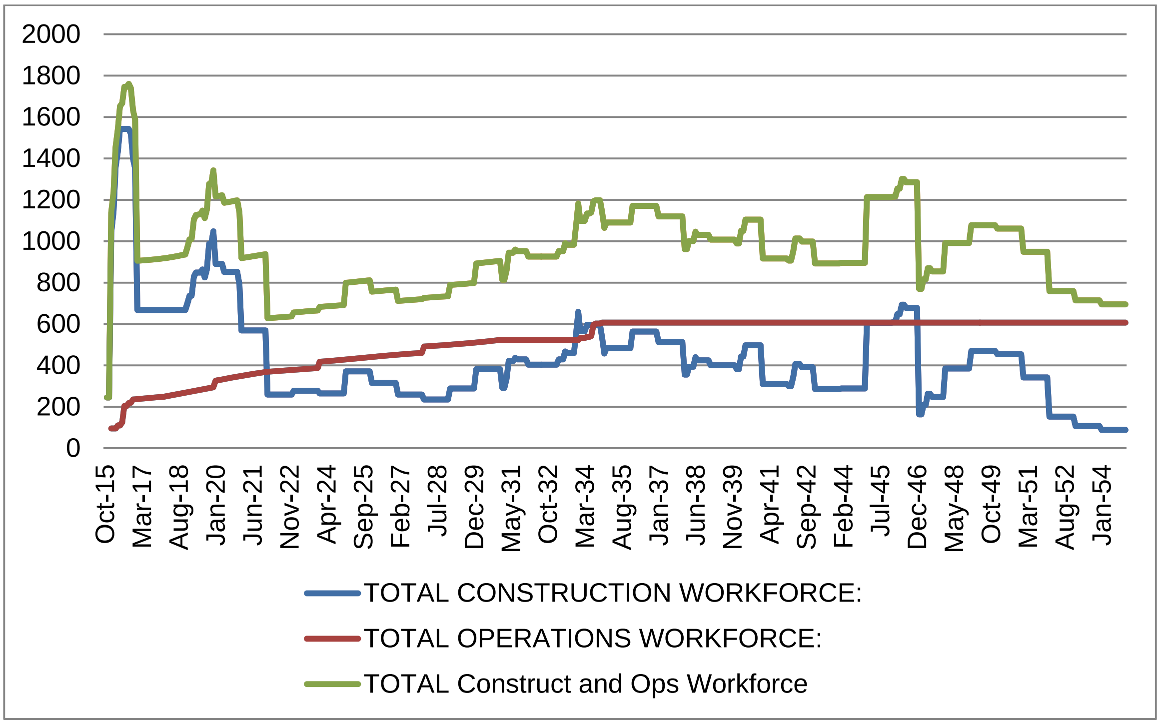
4.3.12 Workforce

A significant workforce will be required for the development of the Project. Workforce numbers will be made up of the following:

- Construction:
  - facilities (including compression, power generation, water treatment, support staff and earthworks); and
  - drilling and gathering lines (including support staff).
- Operations:
  - facility operations;
  - workover crews;
  - field staff (wells and gathering lines); and
  - depot-based support staff.

The components of the total Project workforce over the approximate 40 year Project life are illustrated in Figure 4-10.

Figure 4-10 Total On-Site Project Workforce over the Life of the Project



Source: Arrow, 2012

Peak total Project workforce for the EIS development scenario is expected to occur in September 2016 with 1,760 personnel. Two smaller peaks are expected to occur in December 2019 with 1,342 personnel and in May / June 2046 with 1,300 personnel. Other total Project workforce peaks are represented in Table 4-4 and generally coincide with the construction of facilities.

Table 4-4 Total Project Workforce Peaks

Peak Year	2016	2019	2025	2031	2034	2036	2040	2042	2046	2049
Total workforce numbers	1,745	1,342	812	959	1,198	1,170	1,104	1,013	1,300	1,077

Source: Arrow, 2012

Wherever possible, Arrow prefers to recruit its workforce from the local Project region. An overview of Arrow's staff training and community development programs are outlined in the Social chapter (Section 24) and the Social Impact Management Plan (Appendix V) of this EIS.

4.3.13 Workforce Accommodation

Workforce accommodation is assumed to be co-located with IPFs for the reference case scenario.

Occupancy rates of TWAFs are likely to fluctuate according to development timing. Peak TWAF occupancy will occur during construction of production facilities. Once these production facilities have been commissioned, TWAFs may be downsized to accommodate the smaller well and gathering system installation crews, and operations staff.

Estimated TWAF sizes for each of the four IPF locations are shown in Table 4-5 below. The TWAF location selection process will satisfy regional council requirements while minimising the impact on local residents and the environment.

Table 4-5 Estimated Temporary Worker Accommodation Facility Sizes for Each Development

TWAF Location	Maximum TWAF Capacity Requirements (pax)	Year Maximum TWAF Capacity Requirements Expected
IPF Area 4	291	2020
IPF Area 5	259	2016
IPF Area 7	298	2016
IPF Area 19	386	2034

4.4 Development Planning

As discussed at the beginning of this chapter, development of the CSG field and production facilities will be progressive, extending in a phased approach over the life of the Project. This is because the yield from the target coal seams is variable across the gas field leading to uncertainty about the precise number, timing and location of wells required to dewater the coal seams and extract the gas.

The Project's assessment and approval process reflects this phased approach to the CSG field development. It progressively demands more detailed information to inform decisions about the

Project's ongoing development, under what controls, whether requisite environmental authorities and permits should be granted, and under what conditions.

An EA under the EP Act is required to commence construction and operation on a PL. The EA sets out the detailed conditions under which a project must be constructed and operated within a PL. Detailed information is required to enable an application to be assessed and is typically presented in an Environmental Management Plan.

Arrow will need to have a valid EA before a PL can be granted by NRM. An initial development plan, which typically covers the first five years of development, must be submitted with the application. The initial development plan will contain detailed information about the nature and extent of activities to be carried out under the lease within the specified time period. Subsequent development plans will be required to provide detailed information about the development of further PLs.

Arrow proposes to stage its applications for PLs and the associated environmental authorities (or amendments to existing environmental authorities) throughout the Project life, as additional PLs are required to support ongoing gas field development. Development plans will be prepared for each stage of the Project and will be guided by the results of exploration, previous operational experience, and environmental and social constraints.

A typical development plan will include (but not be limited to) the following:

- The exploration and appraisal history and status;
- Geological and reservoir modelling and subsurface development schemes;
- The number of wells to be drilled, their location, sequencing and spacing to meet the required production rates;
- The location, quantity and size of production facilities;
- The quantity of water produced and subsequent treatment and storage requirements;
- The pipeline networks needed to transport gas and water;
- The high-level operations philosophy for the field layout;
- Capital and operating expenditures as well as schedule estimates; and
- Risk and opportunity register.

Environmental and social design specifications relevant to the Project have been included in Constraints Mapping (Appendix BB), which forms the basis of the framework established by Arrow to address the current uncertainty about the location of infrastructure. The framework approach allows Arrow to analyse potential constraints during detailed planning and consists of constraint maps and environmental controls that will inform site selection and the preparation of development plans, as well as the environmental management of construction, operation and decommissioning activities. Further details on the framework approach and constraints mapping are provided in the Environmental Framework chapter (Section 7) of this EIS.

4.4.1 Exploration

Arrow is currently conducting significant exploration across the Project area. Exploration activities are governed by existing approvals covering tenures across much of the Project area.

The majority of work being undertaken is part of a de-risking exercise that delineates geological anomalies and reduces geological uncertainties surrounding coal seam extent, gas content and permeability. These results will influence the sequence of field development and inform the regional development plan.

Exploration typically begins with seismic geophysical that characterise the geologic environment and identify potential coal seams. Drilling is then required to verify the geologic setting, determine coal seam properties such as thickness, permeability, gas content and gas quality, and test the production potential of the target reservoir.

The location of exploration wells is flexible and is guided by physical, environmental, social and landowner constraints.

As stated in the Introduction chapter (Section 1) of this EIS, exploration activities throughout the Project area are governed under existing approvals and are not within the scope of this EIS.

4.4.2 Environmental and Social Constraints

Development planning within the Project area is also guided by potential environmental and social constraints. Environmental and social constraints have been considered in the preliminary design of the Project from which potential impacts were assessed in this EIS. Arrow's health, safety and environmental management system (HSEMS) includes a number of design specifications (Table 4-6) that aim to minimise environmental and social impact, and hence inform the development plans.

Table 4-6 HSEMS Design General Requirement

Aspect	Design Specification
Air Quality	• Reduction of nitrogen dioxide emissions through selection of low NOx gas engines for power generation. • Minimisation of flaring by selling ramp up gas to domestic markets.
Greenhouse gas	• Reduction of greenhouse gas emissions through selection of high-efficiency drivers for compressors. • Minimisation of greenhouse gas emissions through the use of flares rather than venting at facilities.
Geology, landform and soils	• Avoid unstable slopes where possible, or design to address slope and soil stability issues.
Groundwater	• Avoid natural springs. • Construct dams using material capable of containing the water and brine and any contaminants.
Surface water	• Avoid wetlands.
Terrestrial ecology	• Avoid Category A* environmentally sensitive areas. • Avoid national parks. • Avoid wetlands (e.g., Lake Broadwater). • Minimise construction footprint through centralisation of WTFs. • Minimise construction footprint through placement of gas and water gathering lines within the same trench.

Aspect	Design Specification
Social	• Manage impacts on local communities through the construction phase by using fly-in, fly-out workforces and accommodating them in camps. Maximise employment of local people and minimise fly-in fly-out arrangements for operations. • Avoid locating wells and infrastructure within 200 m of sensitive receptors.
Cultural heritage	• Avoid significant heritage sites.
Hazard and Risk	• Fire and gas detection systems; • Emergency shutdown systems; • Emergency pressure release systems; and • Fire suppression systems in high-risk locations.

*Category A environmentally sensitive areas are all areas designated as national park under the *Nature Conservation Act 1999* as well as conservation parks, forest reserves, and the Wet Tropics World Heritage areas.

4.5 Development Sequence

Arrow will stagger the development of each resource area to sustain the required production rate, and may vary the rate of development subject to the LNG Plant demand. Production well installation, facility construction, operation, decommissioning and rehabilitation will therefore occur concurrently at different locations throughout Project life.

The life of a production well will vary in accordance with the density of wells, the gas extraction rate and the production performance of the well. Modelling of well life is based on probabilities and averages and Arrow's current modelling suggests an average well life of 15 to 20 years. Once the wells cease production, the well sites will be decommissioned and rehabilitated and new wells will be established either in the same gas field or in a new development area.

4.5.1 Development Areas

The EIS reference case depicts 17 development areas of 12 km radius each, staged for progressive development as shown in Figure 4-11. The first stage of the Project is expected to involve the development of the first four development areas coming online in 2017 (most likely at Red Hill, South Walker, Coxendean and Saraji, to be confirmed) with up to approximately 600 production wells likely to be drilled in the first two years.

This information is indicative of the likely development sequence, based on Arrow's current understanding of the Project. As more understanding from exploration and appraisal becomes available, the sequence of development may change and the number, location, and construction timing of development areas may be amended during the design process.

The location and scheduling of facilities in the conceptual preliminary layout was influenced by the following considerations.

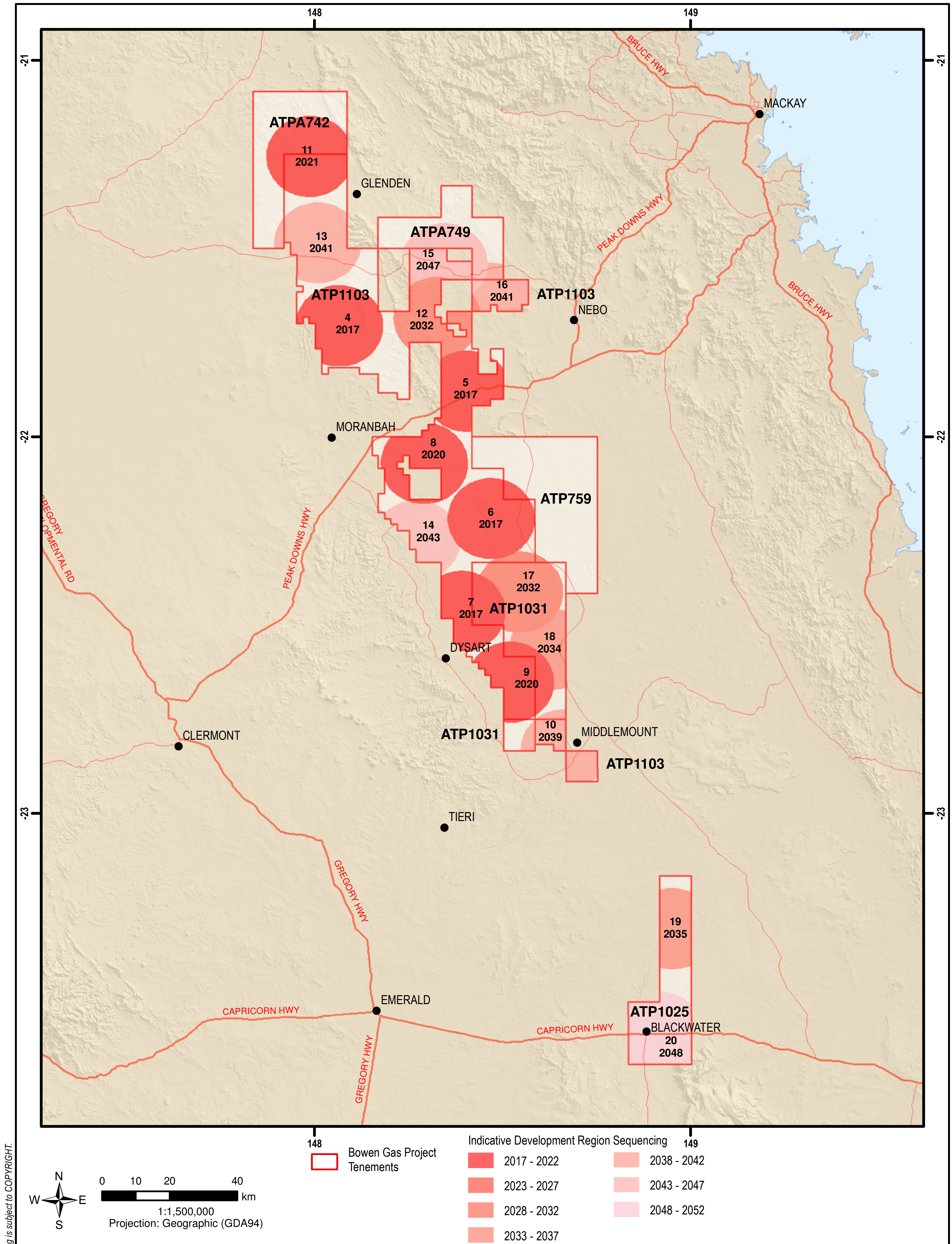
- Major facilities, such as CGPFs and IPFs will generally be located as near as possible to the areas with the highest resource density (and/or highest current level of subsurface understanding) which will be developed during the first stage of development.

- FCFs will in general be placed in later stages of development, except where the initial development requires a relatively small facility which does not justify a stand-alone CGPF or IPF.
- All IPFs will be developed first due to the need to treat water and will be sized to accommodate water from that production area and the immediately surrounding FCFs and CGPFs.

Environmental constraints mapping (Appendix BB) produced during this EIS is being utilised by the Project development team for planning and site selection activities of all facilities and infrastructure beyond the conceptual stage.

Section 4.5.2 provides more specific details regarding the production areas and production facilities. It should be noted that the 12 km radius development areas are indicative, and development may occur outside of these circles in accordance with ongoing changes in project design.

Facilities are expected to be designed and constructed such that their capacity can be altered if required in accordance with the resource extraction rates in the area.



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BOWEN GAS PROJECT EIS

INDICATIVE DEVELOPMENT SEQUENCE

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PROJECT DESCRIPTION

Figure: **4-11**

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4.5.2 Facility Timing

In order to achieve the required production rate of 520 TJ/d, approximately 1,450 wells will be required in the first five years of development. As the gas production of early wells decreases and wells are decommissioned, additional wells will be drilled to maintain the required production rate.

Production wells will be located geographically close to each other with common access and/or gathering systems where possible. Parcels of wells within a development area will be developed concurrently (i.e. wells drilled and gathering systems installed) with the construction of production facilities. More than one development area is expected to be developed at a time.

Based on these proposed production areas and early field development planning work (Section 4.4), a potential configuration for production facilities (types and timing) has been developed.

Current proposed timing for sequential development of the development areas is provided in Table 4-7. These Development areas are shown in Figure 4-11. Note that development areas 1, 2 and 3 relate to the Moranbah Gas Project and do not form part of the proposed Project.

Table 4-8 provides further detail on the expected production facility type, peak annual gas and water flow, production station capacity and power demand, and main equipment counts (compressors and power generation units) for each development area.

Table 4-7 Production Facilities Timing

Year	Development Area																
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
2017	■	■	■	■													
2018																	
2019																	
2020					■	■											
2021								■									
2032									■					■			
2033																	
2034															■		
2035																■	
2039							■										
2040																	
2041										■		■					
2042																	
2043											■						
2047													■				
2048																	■

Table 4-8 Expected Production Facilities Definition and Timing

Production Area	Peak gas flow from Production Area TJ/d	Peak water flow from Production Area ML/d	Production Station Type	Station Peak Forecast Gas capacity TJ/d	Station Peak Forecast Water capacity ML/d	Station nominal Peak Power demand MW	Nominal compressor count (10 TJ Screw) Based on Station forecast	Nominal compressor count (30 TJ Recip) Based on Station forecast	Power Generator count (3MW) Based on Station Load	Onstream Date (1st Jan)
4	100	11	IPF	100	14	31	10	4	11	2017
5	76	7	IPF	81	10	25	8	3	9	2017
6	33	6	CGPF	53	6	16	5	2	6	2017
7	176	15	IPF	191	22	58	19	7	20	2017
8	9	3	FCF	9	3	2	1	-	1	2020
9	91	12	CGPF	104	12	31	9	4	11	2020
10	68	7	FCF	68	7	11	7	-	4	2039
11	206	13	CGPF	206	13	60	21	7	21	2021
12	36	4	FCF	36	4	6	4	-	2	2032
13	28	3	FCF	28	3	4	3	-	2	2041
14	119	15	FCF	119	15	19	12	-	7	2043
15	83	5	FCF	83	5	12	8	-	5	2041
16	77	8	FCF	77	8	12	8	-	5	2047
17	106	10	FCF	106	10	17	10	-	6	2032
18	46	5	FCF	46	5	7	5	-	3	2034
19	80	11	IPF	132	12	40	13	5	14	2035
20	97	11	FCF	97	11	15	10	-	6	2048

4.6 Construction

Project construction activities will essentially occur over the life of the Project at a rate that maintains plateau gas production. The peak construction period will be during the initial infrastructure construction period in 2016 with a construction workforce of approximately 1,540.

Sections 4.6.1 outlines the typical construction schedule for a development area, while Sections 4.6.2 to 4.6.9 describe the planning requirements, construction methods for major infrastructure, workforce required to construct the infrastructure, and associated accommodation to house the workforce. Construction generated waste is also discussed.

4.6.1 Construction Schedule

It is currently proposed that the Project commences production from the first phase of facilities in January 2017, with facilities construction required in the 2015 to 2016 period, and initial well drilling commencing in 2016.

Figure 4-12 illustrates an indicative timescale for the development of a typical field (wells and gathering system) and corresponding production facility.

4.6.2 Production Wells

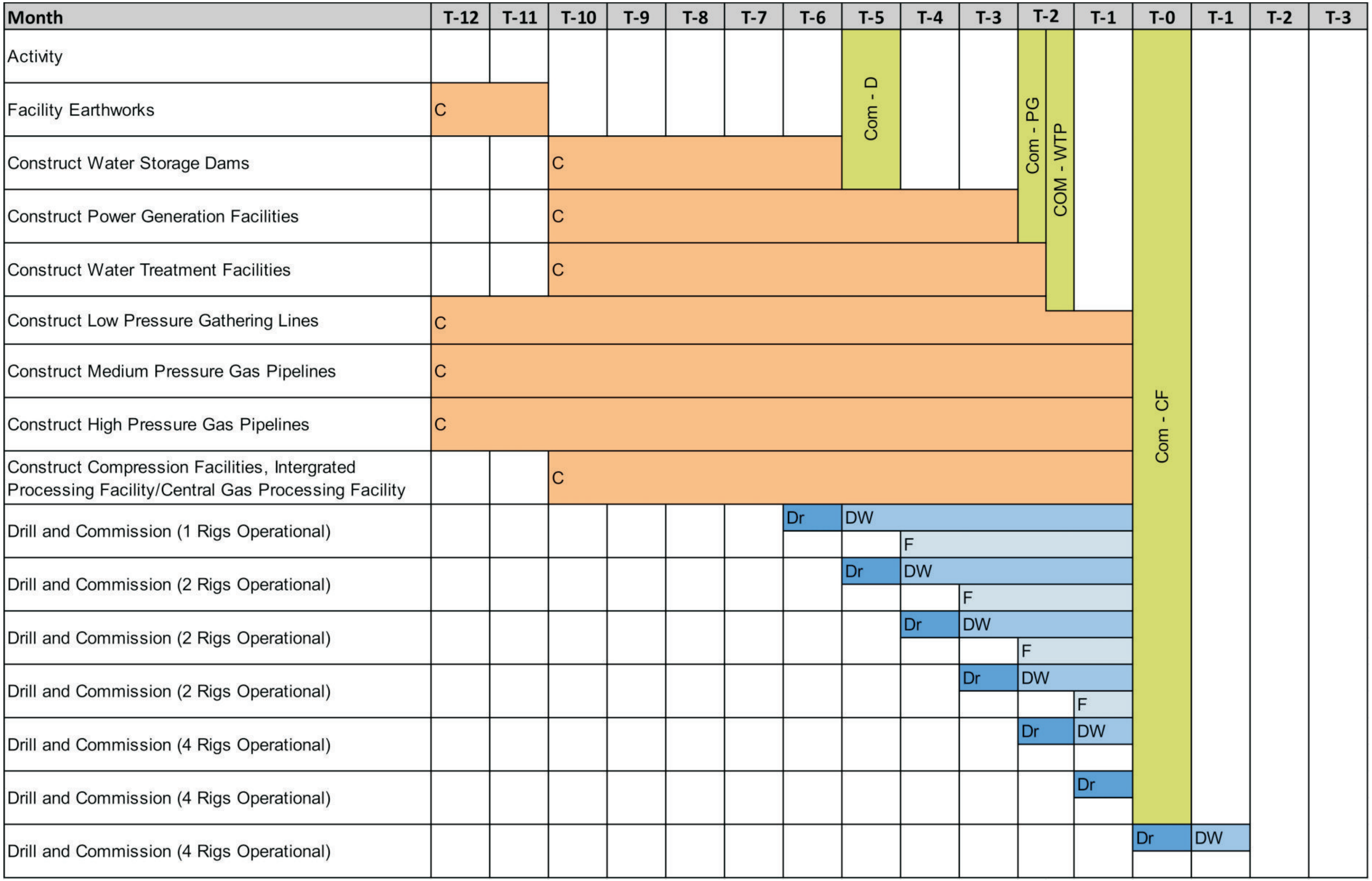
Production wells will be installed progressively throughout the Project life, starting in 2016. It is expected that up to 18 drilling rigs will be used to install up to 6,625 wells. The short-term construction footprint for each production well is approximately 90 by 90 m, equating to a total maximum footprint of approximately 5,300 ha for up to 6,625 planned wells for the reference case. This footprint will significantly reduce following construction, with an estimated 0.01 ha (10 by 10 m) required per well during operations, resulting in a total operational well footprint of approximately 66.5 ha.

Production well construction is undertaken in three broad stages:

1). Site Preparation: Where possible, well sites will typically be accessed via existing tracks; otherwise, a new track will be cleared and graded. A drilling area of approximately 90 m x 90 m will be prepared, including vegetation removal, stripping and stockpiling of topsoil, grading and compaction, fencing, and excavation of small pits for drilling fluids and ground flares.

Where wells are constructed on intensively farmed land, surface tanks will be utilised for drilling fluids instead. Site preparation works will be carried out using earthmoving equipment such as graders, excavators and bulldozers.

2). Production Well Drilling and Well Site Completion: Arrow intends to use truck mounted drilling rigs or hybrid rigs to drill wells. A completion rig will be used to install a downhole pump and stimulate the well as required. The top section of each well between the targeted coal seam and the surface will be cased and cemented through the non-gas producing strata to prevent cross-contamination between aquifers. To promote gas and water flow in the well, a special rotating blade will be used to ream out the producing coal seams. Drilling fluids will be used in the rotary drilling process during the construction of production wells.



LEGEND

C - Construction activities
CF - Compression facility
CGPF - Central gas processing facility
Com - Commissioning
D - Dam
Dr - Drilling
DW - Dewatering
F - Flaring (1 flare per pod of 5 to 10 wells)
PG - Power generation
WTP - Water treatment plant

Source: Coffey Environments Drawing No. 7040_04_F069_GL

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BOWEN GAS PROJECT EIS

TYPICAL CONSTRUCTION SCHEDULE

URS

PROJECT DESCRIPTION

Figure: **4-12**

File No: **42626960-g-1111.cdr** Drawn: **XL** Approved: **DS** Date: **18-10-2012** Rev.**A** A4

The production zone will be lined with alternating slotted and blank steel casing. An electric, top-drive, variable-speed pump will be installed to extract water though an 80 mm tube installed inside each well casing. This limits the amount of water entrained with the gas. In some cases, Arrow will construct wells with more than one production zone, enabling production from multiple coal seams. Approximately 200 cubic metres (m^3) of drilling fluid will be used for drill each production well. Drilling fluids (also known as mud or drill mud) will be pumped down the drill pipe to lubricate and cool the drill bit and flush out drill cuttings.

Arrow's preference is to use an inert, water-based drilling fluid largely comprised of fresh water and 2% to 3% salt. This increases the mud weight and prevents the natural clay in the formation from swelling. A small amount of bentonite (a clay-based product) may be added to coat the bore hole to stabilise the formation and prevent the loss of fluid.

Drilling fluid will be collected in surface tanks or pits and will either be removed from site for disposal at a licensed facility or stored in purpose-built containment structures on the property. Arrow's current activities use drilling fluids comprised of clay stabilisers (calcium chloride, calcium chloride anhydrous and potassium chloride), cement additive (bentonite and calcium sulphate), disinfectant (biocide), viscosifier (FS2000, XCD polymer and NIF 20 liquid), foaming agent (Tuff-Foam Ultra) and fluid loss prevention (Tuff-Loss).

3). Progressive Rehabilitation: Following completion of drilling, the rig and pits will be removed and the well site footprint reduced to a sufficient size to accommodate the surface equipment. Typically this is less than 10 by 10 m. The construction site footprint outside the 10 by 10 m area will no longer be used and will be rehabilitated and contoured as soon as practicable to pre-existing conditions or to a standard agreed with the landowner.

The operational well site will be fenced to exclude stock and unauthorised access. A two metre safety exclusion zone within the fence will be implemented.

Additional well workovers may be required during the well life, necessitating a rig to replace or repair the downhole pump. Any disturbance during workover operations will be progressively rehabilitated as soon as practicable.

Wastes generated during the construction of production wells will include:

- Solid wastes, including general trash, scrap metal, cleared vegetation, cut and fill material, empty drums and containers, timber, drill cuttings, cardboard and other packaging materials, wood pallets and soil contaminated with chemicals / oils.
- Liquid wastes, such as drill fluids, residual drilling mud, CSG water, filters and filter media, used lubricating oil and filters, acids and caustics, unused or spent chemicals / oils / solvents, grey water and stormwater.
- Gaseous waste (CSG and engine emissions)

With the exception of drilling mud, waste liquids will typically be removed by a tanker to nearby IPFs for treatment. Solid wastes will be removed offsite to an appropriate waste facility.

Additional details of the expected waste types, quantities and waste management practices are provided in the Waste Management chapter (Section 28).

4.6.3 Gathering Systems

Low-pressure gathering lines will be used to deliver gas and CSG water from production wells to production facilities. Medium-pressure gathering lines will deliver gas from FCFs to both CGPFs and IPFs.

The location of the gathering pipelines will be informed by technical, environmental, social and landowner constraints.

Construction of the gathering lines will incorporate, but not be limited to, the following activities:

Site Preparation: A right-of-way (RoW) of up to 25 m wide will be prepared including vegetation removal and stockpiling, topsoil stripping and stockpiling and grading where required. In environmentally sensitivity areas, the RoW may be narrowed for short distances. Markers will be placed along the route. Temporary fencing may be established around sensitive areas occurring along the RoW to ensure they are not disturbed during construction.

Prior to vegetation removal the RoW be subjected to a preconstruction clearance survey by a team of environmental specialists, Project engineers and surveyors to identify site-specific technical, environmental, social and cultural heritage sensitivities and develop measures to avoid or mitigate the potential impacts on these sensitivities.

Trenching and Laying Pipe: Separate gas- and water-gathering pipelines will be buried below ground in a commonly excavated trench to minimise surface land use disturbance. Trench spoil will be stockpiled for backfilling.

Breaks in the trench will be installed to facilitate stock and wildlife crossings. There will be locations where trenching is not a suitable construction method, for example, due to river or road crossings or potential environmental constraints.

The depth of pipeline burial will conform to acceptable industry practices but will ultimately depend on the existing land use. As a minimum, the pipeline depth will be 750 mm from the top of the pipe. Landowners will be consulted to determine land use practices and pipelines will be buried to a depth that minimises risk of damage.

The pipe will be lowered into the trench using side-boom or all-terrain vehicles. Other equipment used to trench and lay the pipelines may include graders, excavators, tip trucks, low loaders, ploughs, trenchers, backhoes, fuel delivery trucks, and 4WD coaster buses.

Hydro-testing: Gathering pipelines are integrity tested by hydro-testing or pneumatic pressure testing prior to commissioning. Pipelines are filled with water and subjected to higher than normal operational pressures. Water used for hydro-testing will be diverted to holding dams for re-use or treatment and/or discharge. Water quality will be tested prior to release.

Progressive Rehabilitation: Once the gathering system is installed, the trench will be backfilled and the ground compacted to a level consistent with the surrounding land use. The surface will be stabilised using the stockpiled vegetation and the disturbed area will be contoured, topsoil respread and revegetated to a standard consistent with the surrounding land use. In most instances, gathering lines will be capped with a crown of topsoil to compensate for settlement. Breaks in the crown will be constructed to prevent channelling of surface drainage. Marker posts, marker tape, trace wire and 'as-built' surveys will be used to identify the location of the buried gathering lines.

Wastes generated during the construction of gathering pipelines include:

- Solid wastes (general trash, scrap, cleared vegetation, excess trench soils and rock, empty drums and containers, timber, plastic pipe, steel pipe offcuts, cardboard and other packaging materials, soil contaminated with chemicals / oils, x-ray film).
- Liquid wastes (hydrostatic-test water, filters and filter media, used lubricating oil and filters, unused or spent chemicals / oils / solvents, paints and paint wastes, grey water).
- Gaseous waste (vehicle air emissions).

Waste liquids will be removed by a tanker for treatment at nearby integrated processing facilities. Solid wastes will be removed offsite to an appropriate waste facility.

Medium pressure infield pipelines will be located and constructed similar to those described for construction of gathering system.

4.6.4 Production Facilities

All production facilities will be designed and constructed to minimise disturbance and limit the size of the footprint. The proposed location, positioning and layout of the production facilities will be based on site-specific technical, environmental and social features (i.e. ground stability, remnant vegetation, topography, proximity of sensitive receptors and landowner consultation).

Construction of the proposed production facilities will incorporate, but not be limited to, the following activities:

- **Preconstruction Clearance Survey**: All sites proposed for development of production facilities will be subjected to a preconstruction clearance survey by a team of environmental specialists, Project engineers and surveyors. The purpose of the survey will be to identify site-specific technical, environmental, social and cultural heritage sensitivities, and to develop measures to avoid or mitigate the potential impacts on these sensitivities once the preferred location of the facility has been identified. Preconstruction clearance surveys will be conducted during detailed design and prior to ground disturbance.
- **Surveying**: All sites will be surveyed and pegged to demarcate the construction footprint and ensure avoidance of any site-specific sensitivity that was noted during the preconstruction surveys.
- **Geotechnical Investigation**: The physical and chemical properties of the subsurface materials will be assessed to determine suitability and type of facility foundations.
- **Vegetation Clearing**: The site will be cleared and grubbed within the surveyed and demarcated footprint. The cleared vegetation will be used for stabilisation or rehabilitation works.
- **Grading and Foundation Excavation**: Sites will be graded, excavated and compacted to the designed level and slope to provide a base for the infrastructure. Excavated cut material will be used to fill where suitable. Surplus soil will be deposited in designated areas and used for bunding and landscaping as required.
- **Erosion Control**: Surface water drainage systems and stormwater diversions will be constructed to reduce the potential for soil loss and degradation and to limit the discharge of sediment-laden water to local watercourses. Clean surface water run-off will be diverted away from disturbed

areas, while runoff from the disturbed areas will be collected and transferred to Arrow's water treatment facilities, if necessary.

- **Progressive Rehabilitation**: Any temporary areas cleared for construction will be contoured, topsoil respread and revegetated. This progressive rehabilitation will occur not only within the footprint but any surrounding areas that may have been disturbed during construction activities. Production facilities will be fenced to maintain a secure site.

Construction equipment is likely to include:

- Graders;
- Dozers;
- Excavators;
- Tip trucks;
- Low loaders;
- Trenchers;
- Backhoes;
- Heavy lift cranes 80 to 150 t;
- Fuel delivery trucks;
- Concrete trucks and concrete pumps;
- Welding machines;
- Portable generators;
- Piling rigs; and
- 4WD coaster buses and passenger buses.

Some of this equipment will also be used for progressive rehabilitation of the area surrounding the site. Construction will involve the transportation of large items of plant and equipment to the site, such as compressors and gas-engine generators. Construction equipment will be moved to successive production facility sites as construction progresses.

Wastes generated during construction of a production facility could include:

- Solid wastes (filter cartridges, batteries, concrete, general trash, scrap metal, cleared vegetation, cut and fill material, empty drums and containers, timber, plastic pipe, sandblast grit, cardboard and other packaging materials, wood pallets, oily rags and sorbents, electrical cable and tyres).
- Liquid wastes (cleaning acids, domestic cleaners, fuel, greases, lube oils, glycol, paint waste, wash-out liquids, hydro-test water, sewage from amenity blocks, contaminated stormwater runoff, radioactive wastes from integrity testing, pesticides and herbicides).
- Gaseous waste (vehicle air emissions).

4.6.5 Water Treatment and Storage Facilities

WTFs will be located within integrated processing facilities using similar construction methods as for production facilities.

Construction of water storage facilities includes dams for CSG water (treated and untreated) and brine. Dams will be constructed in accordance with EHP guidelines using equipment such as graders, dozers, excavators and tip trucks. All untreated CSG water and brine storage dams will contain impermeable liners to prevent potential impacts on groundwater. Wastes from the construction of WTFs are similar to that of the production facilities.

4.6.6 Power Generation Facilities

Power generation facilities will be located within the production well sites and production facility sites and the subsequent construction methods are similar to those described for construction of production facilities (see Section 4.6.4, Production Facilities).

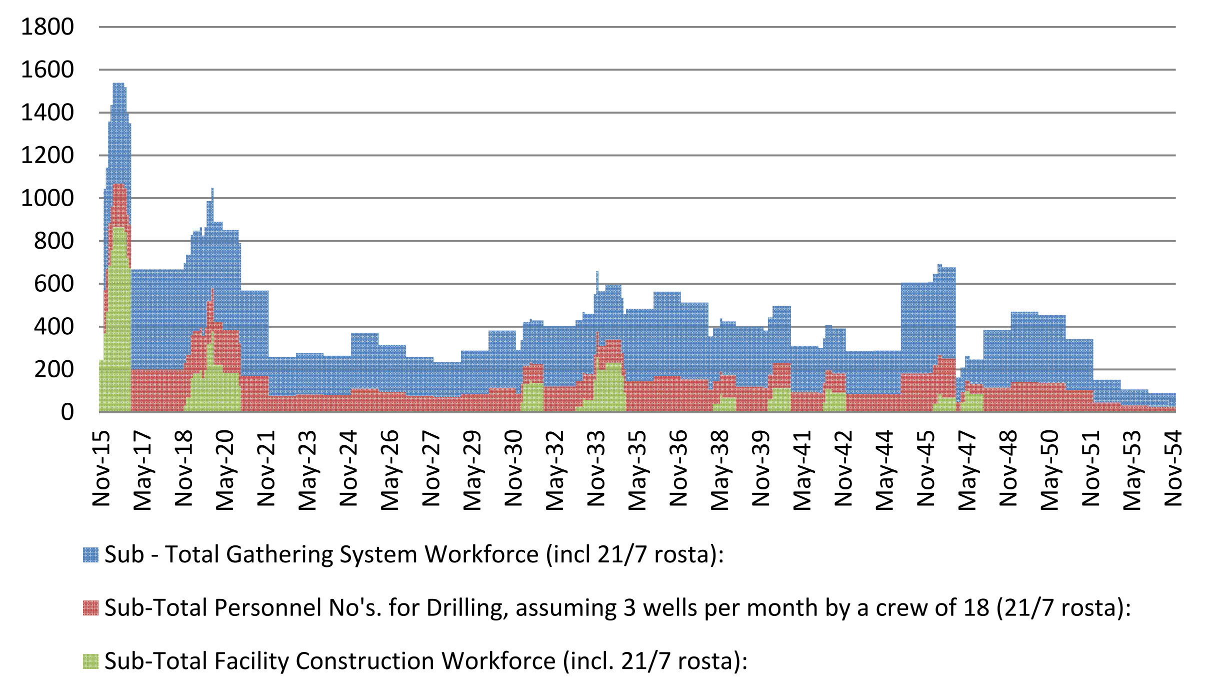
4.6.7 Construction Workforce

The development of workforce numbers has assumed that similarly configured infrastructure will be constructed where possible. Major components including compressors, power generating units, gas metering equipment and water treatment units, will typically be supplied as modules assembled on skids to facilitate quick construction and easy relocation to other sites. The roles required for the construction component of the Project include (but are not limited to):

- Project management;
- Human resources;
- Health and Safety;
- Engineering;
- Supervision;
- Administration;
- Superintendents;
- Field staff;
- Technicians;
- Leading Hands;
- Skilled labour and operators; and
- Maintenance contractors.

Construction is due to commence in 2015, with drilling to commence in 2016. Figure 4-13 presents total indicative construction workforce requirements over the life of the Project.

Figure 4-13 Total Indicative Construction Workforce Numbers



Source: Arrow, 2012

A peak construction workforce of approximately 1,540 personnel is expected to occur in 2016, when three IPFs in Area #4, Area #5 and Area #7 and one CGPF in Area #6 will be constructed. The total construction workforce will have multiple peaks associated with the construction of production facilities. Table 4-19 indicates the key anticipated peaks in total construction workforce numbers during the Project.

Table 4-9 Key Peaks in Indicative Construction Workforce

Peak Year	2016	2019	2025	2033	2036	2040	2042	2046	2049
Total construction workforce	1,542	1,048	371	659	563	497	406	693	470

Source: Arrow, 2012

Arrow's preference is to provide employment to people sourced locally; however, due to the high demand by other CSG proponents, mining and low unemployment rates, Arrow recognises that labour may need to be also sourced from further afield. Arrow's aim is to implement a hierarchy of preferred employment and contractor candidates based on the employees' / contractors' home or source location. Arrow's hierarchy of preferred employment and contractor candidates is as follows:

- Local:
  - Moranbah, Blackwater, Dysart, Glenden, Middlemount;

- Regional:
  - Nebo, Emerald, Clermont, Mackay, Rockhampton;
- State / Interstate:
  - Other regions of Queensland and Australia;
- Overseas.

4.7 Operations and Maintenance

4.7.1 Production Wells

Production wells generally will be remotely operated and monitored from central locations at the production facilities. Wells will be remotely monitored for pressure as well as gas and water flow rates. Regular visits will also be conducted by field operators and maintenance personnel to inspect and maintain surface facilities. Regular maintenance of production wells will include:

- Wellhead engine, gas wellhead generator or electric motor maintenance - daily field operator visits will occur until such a time that production stabilises and telemetry is established, after which visits will be weekly.
- Downhole water pump maintenance- downhole pumps, which usually require flushing, will be maintained as necessary throughout the Project.
- Well workover - generally required every three years, with some wells requiring more frequent maintenance. Workovers involve the cleaning the production zone by high-velocity air or water jetting, maintaining or replacing the pump and, if necessary, replacing the well tubing and rods to ensure continued flow of gas and/or water from the coal seam. A workover drilling rig is required for well maintenance.

With the exception of a small safety exclusion zone, farming and grazing activities can continue around established well sites.

Operation and maintenance waste associated with the production wells will be limited to well workover drilling fluids.

4.7.2 Gathering Systems

Operation of gas and water gathering pipelines will be limited to remote flow rate monitoring. Regular inspections and maintenance will be conducted by field operators. Gathering system maintenance includes:

- Regular inspections will be conducted along the gathering line routes to observe and manage vegetation, subsidence, erosion and to ensure appropriate bushfire protection.
- Maintenance of valves, vents and drains. Valves periodically require inspection and maintenance to ensure effective and safe operation. Water pipelines contain high-point vents to release

accumulated gas and low-pressure gas pipelines have low-point drains to allow the accumulated water to drain. Inspection and maintenance of the vents and valves are required to maintain flow.

The operation and maintenance of the gas and water gathering pipelines will generate negligible volumes of waste.

4.7.3 Production Facilities

The operational life of a production facility is expected to be approximately 30 years and will be operated 24 hours a day, 7 days a week. Production facilities will be fully automated and designed for minimal operator intervention. They will be controlled and monitored by a computer-based integrated control system that includes process and safety controls as well as a fire and gas systems. Operators will be notified through warnings and alarms of changes in key operating parameters.

It is expected that both IPFs and CGPFs will be manned however FCFs will be operated remotely with manning for maintenance purposes only. Typical operational tasks for all production facilities will include:

- Regular operation and maintenance;
- Major shutdowns in the order of eight hours per year for servicing critical equipment (e.g., gas compressors);
- Monitoring activities; and
- Emergency repairs if required.

Wastes generated during the operation and maintenance of a production facility could include:

- Solid wastes, including filter cartridges, activated carbon, membrane modules, batteries, general trash, scrap metal, empty drums and containers, sandblast grit, cardboard and other packaging materials, wood pallets, oily rags and sorbents, electric cable, spent filter media bulk bags and tyres.
- Liquid wastes, such as cleaning acids, domestic cleaners, fuel, greases, lube oils, glycol, paint waste, water treatment chemicals, sewage from amenity blocks, triethylene glycol, brine, CSG water, contaminated stormwater runoff, pigging waste, pesticides and herbicides.
- Gaseous waste from air emissions.

The Waste Management chapter (Section 28), details production facility waste types, quantities and management measures.

4.7.4 Water Treatment and Storage Facilities

As described in Section 4.3.7, the removal of groundwater is required to depressurise coal seams and allow gas to flow at production rates. CSG water management is addressed in the Coal Seam Gas Water and Salt Management Strategy (Appendix AA) of this EIS. The strategy addresses aspects of Arrow's operations that extend beyond the Project. The aspects of the strategy that are directly relevant to the Project are presented below.

4.7.4.1 CSG Water Management Strategy

Arrow's water management strategy has been developed in line with the Queensland EHP's *Coal Seam Gas Water Management Policy* (DERM, 2010). This policy is supported by recent legislative changes and is implemented through the EA conditions imposed upon Arrow's operations and projects.

Arrow's water management strategy seeks to maximise beneficial use of CSG water and minimise the environmental impacts associated with water use and disposal. It also seeks (where possible) to manage CSG water in such a way as to mitigate the impacts of groundwater depressurisation on groundwater users.

In order to achieve these objectives, the CSG water produced as a result of undertaking CSG extraction activities will be managed through a hierarchy of management options.

4.7.4.2 CSG Water Management Options

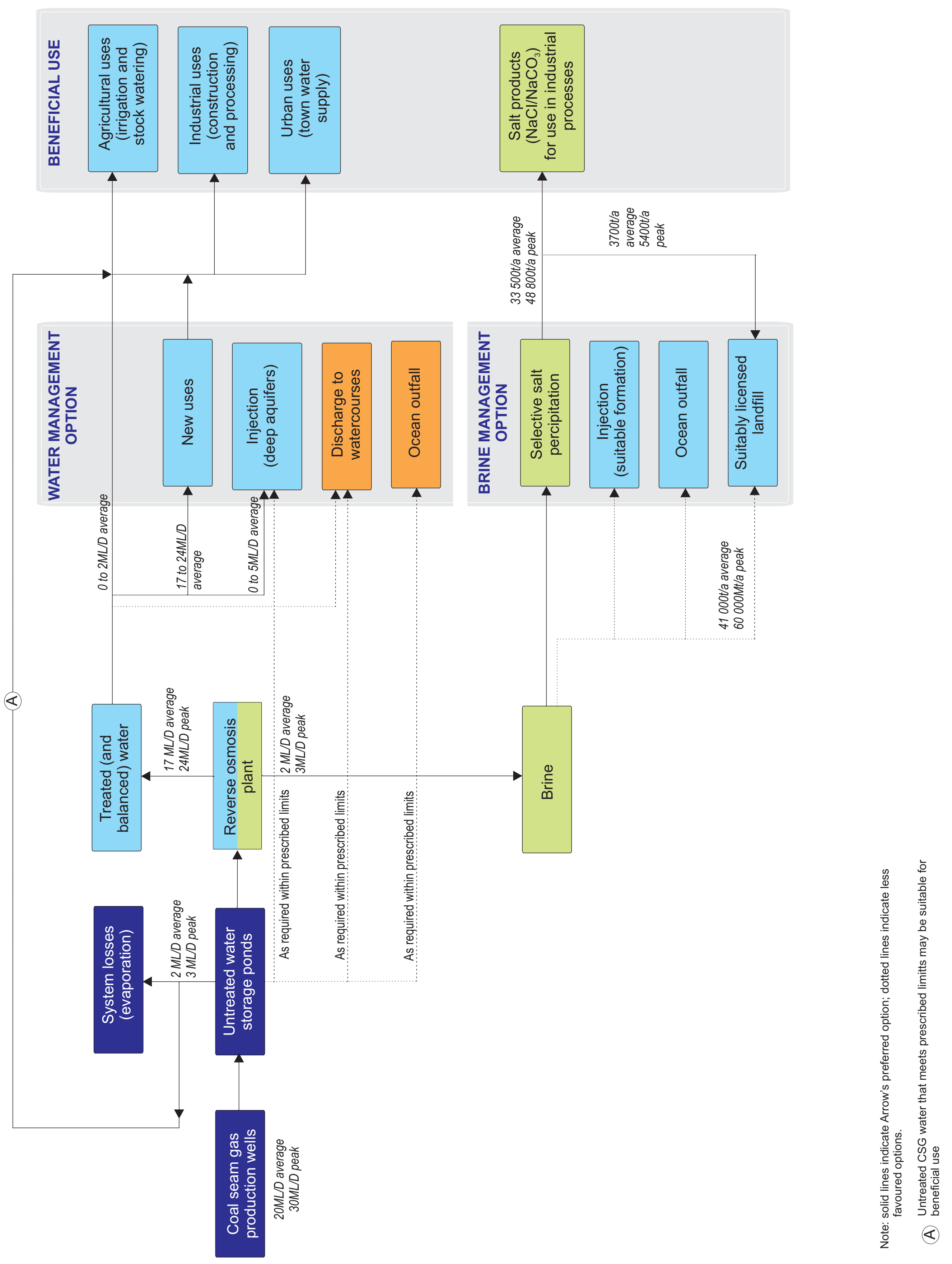
An overview of the CSG water management strategy proposed during operations is given in Figure 4-14, which illustrates the preferred and potential management options for CSG water and associated brine / salt, including treatment, storage, beneficial use and disposal.

Although CSG water is considered a waste under the EP Act, the government may approve its use as a 'resource' on a case-by-case basis if the water has a beneficial use that would negate the need for its disposal. When used in accordance with a Beneficial Use Approval, CSG water ceases to be defined as a waste.

The management options presented below apply to treated and untreated water. Untreated water may be suitable for any of the beneficial use options identified in Figure 4-14, depending upon the water quality requirements of the end user. Investigations indicate that there is limited demand for the beneficial use of untreated CSG water in the Project area.

The following risks and uncertainties are considered when determining Arrow's hierarchy of CSG water management options:

- **Production profile** – water volume forecasts differ across basins and the confidence in predictions also varies depending upon the extent of exploration and field development activities. The CSG water management options will consider basin-specific conditions, and in some cases, further observations of reservoir behaviour are necessary to better inform the model and increase confidence levels in forecast volumes. Timing and quantity of water production is highly dependent upon the timing and extent of CSG development within each development area. The water management options must be tailored to the development plans and have the flexibility to meet a range of outcomes.



Source: Client supplied data

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BOWEN GAS PROJECT EIS

CONCEPTUAL CSG WATER MANAGEMENT OVERVIEW

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PROJECT DESCRIPTION

Figure: **4-14**

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- **Commercial agreements** – to enter into contractual arrangements, a high level of certainty is required, specifically in terms of the following:
  - available water volumes;
  - the timing of water availability; and
    the ability to guarantee that water quality characteristics are fit for the intended application, for example for third-party irrigation, where the water quality must be suitable for the soil type and the intended crop.
- **Approvals** – the water management options must be continually revised to meet regulatory requirements into the future, while retaining flexibility to meet a range of outcomes.

Agriculture

Potential beneficial uses could include stock watering and irrigation.

Industrial Uses

CSG water may be used for industrial purposes in Arrow's operations, e.g. dust suppression, drilling and construction water supply and power station cooling. Arrow will also continue to supply third party industrial users and look for further similar opportunities.

Urban Uses

Arrow will investigate potential for augmentation of urban water supplies such as the Moranbah town water supply.

Injection

The benefits of injecting water are to offset the impacts of groundwater depressurisation on users and to provide a disposal option for any water that cannot be accommodated through beneficial use.

Arrow will conduct an injection feasibility study and is preparing EA applications to conduct aquifer injection trials in the Project area. The purpose of the trials is to determine the suitability of the formations for injection, and to identify the volumes and rates of water that can be sustainably injected.

An injection trial would typically run for 12 months including preparation, data collection and data evaluation. Initial trials would involve drilling a single injection bore into each target aquifer. The bores will be used to collect geological data and characterise the water geochemistry of those aquifers.

Further work will be required to define the extent and feasibility of injection over the Project area. This EIS assumes that the legislative framework to enable CSG water injection into aquifers will be developed.

Disposal to Watercourses

Disposal to watercourses will be considered in future EA applications. A site specific impact assessment will be undertaken to determine the relevant parameters for discharge to the receiving environment. This assessment would be provided to the EHP as part of an EA amendment application which would be subject to public exhibition.

Disposal to watercourses will be considered in the event that beneficial uses of CSG water are temporarily unavailable, beneficial use approvals are not granted, significant or prolonged weather events or the demand for water decreases and alternative disposal options are required to maintain dam integrity and safety.

Ocean Outfall

Disposal of CSG water to the sea via an ocean outfall pipeline is recognised as a feasible option; however it is not the preferred option. In the event that preferred CSG water management options do not eventuate, the feasibility of an ocean outfall, as an alternative disposal option for CSG water, will be evaluated This evaluation would be conducted at the time of detailed design of the field and facilities.

New Uses

Over the course of the Project, it is anticipated that new opportunities for use of treated and untreated water will emerge and be investigated. These new uses may include any of the options outlined above or other use options that may be realised within the Project area.

Brine Management Options

Brine is a by-product of the water treatment process, which also requires specific measures to manage its storage, use and/or disposal.

Assuming an average salt concentration of 4,500 mg/L, Arrow expects that treatment of CSG water will generate in the order of 4.5 t of salt per ML of CSG water. Arrow will continue to monitor CSG water quality as the development progresses; however, development is planned with the assumption that similar water quality and salt concentrations will be observed across the entire Project area.

Although beneficial use is the preferred option for brine management, for the purposes of this EIS it is assumed that brine will be stored in dams and disposed to a suitably licenced landfill.

Selective Salt Precipitation

The concentrated brine produced through water treatment is comprised of sodium chloride (salt), carbonate and bicarbonate salts (soda ash). Arrow is consulting commercial enterprises to investigate viable opportunities for the beneficial use of brine in the Surat Gas Project.

4.7.5 Power Generation Facilities

Power generation facilities will be located at production wells and production facilities and will be operated and maintained as per the facilities described above in Section 4.7.1 and 4.7.3

4.7.6 Pipelines

Mandatory signage to identify the medium pressure pipelines and gathering line locations will be visible above ground. Regular patrols, inspections and maintenance will occur in order to ensure the management of weeds, ensure vegetation is not encroaching on the pipeline centreline, inspect for any subsidence or erosion, and conduct valve and integrity testing. Inspections will be conducted most frequently in the first 12 months post-construction as the right-of-way (RoW) rehabilitates. Intrusive investigations (excavation) to address pipeline coating defects or other upset conditions are not a common occurrence.

Pipeline pressure and gas volumes within the pipe will be monitored remotely. Pipelines will be constructed with automatic inlet valves that shut-off or isolate sections of pipe for inspection and maintenance if a large pressure change is detected.

4.7.7 Supporting Infrastructure

Operation of supporting infrastructure, such as depots and borrow pits, will be conducted during daylight hours only. Management of operational logistics from any borrow pits will be minimal as only small volumes of material will be shipped to production facilities.

4.7.8 Operations Workforce

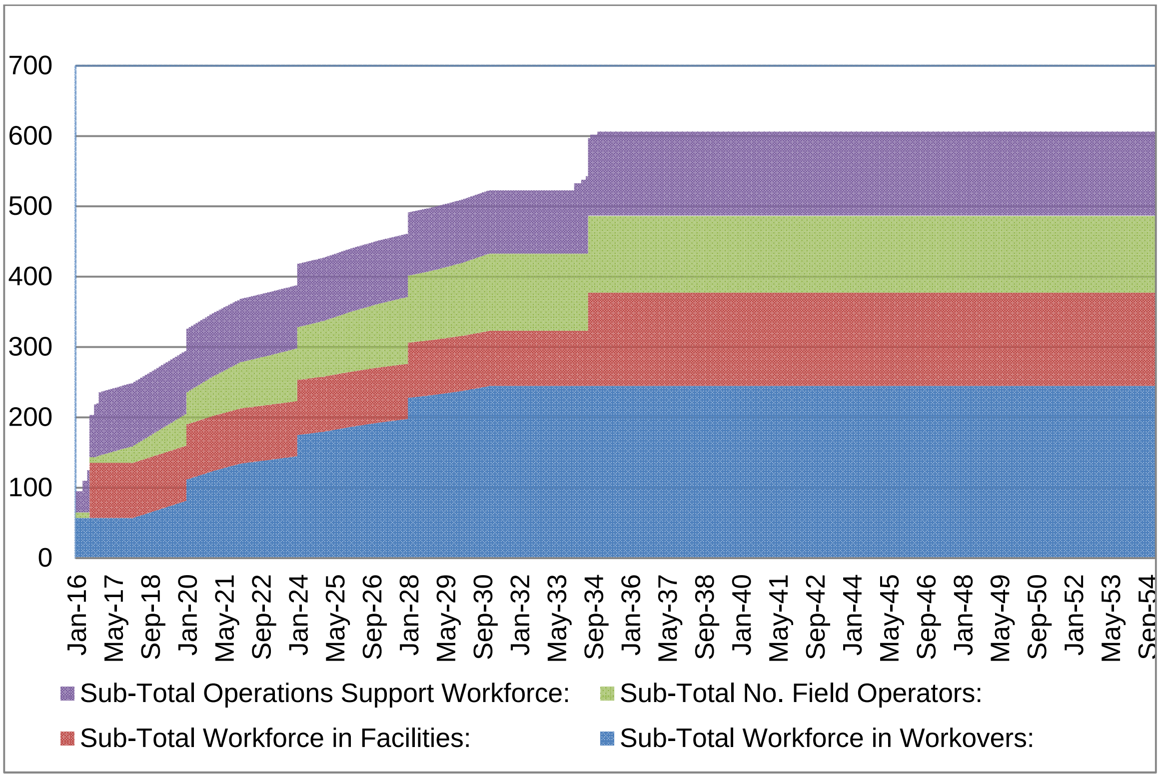
It is expected that operations workforce requirements begin in 2016. The forecasted operations workforce is expected to reach its peak of approximately 597 personnel in 2034. Ramp up in the operations workforce will occur in the years as indicated in Table 4-10. Figure 4-15 shows the estimated total operations workforce.

Table 4-10 Ramp Ups of Operations Workforce

Ramp Up Year	2016	2020	2024	2028	2034
Total operations workforce	203	326	418	492	597

Source: Arrow, 2012

Figure 4-15 Total indicative Operations Workforce Numbers



Source: Arrow, 2012

Roles within the operations roles will be in three main areas: support staff, field staff for commissioned production wells; and facility operations workforce. A further outline of broad roles within these groups is provided in Table 4-11.

Table 4-11 Positions Required for Project Operations

Support Staff
On-site staff: • Centralised administration, stores, four depots located at IPFs; • Land access: Includes land agents, cultural heritage agents and monitors, and environmental agents; • General support: Construction superintendents, field engineers, quality assurance engineers; • OH&S support; • Earthworks: Earthworks supervision; • Gathering lines: Pipeline supervision; and • Arrow supervision **Brisbane-based support staff:** • Access: Land access, cultural heritage and environment managers; and • Management and engineering: Project management, Project engineering, mechanical engineers, pipeline designers, cost controllers, schedulers, GIS managers, and contract administrators.

Well Workover Crew and Well Operations Staff for Commissioned Production Wells
• Well operators and workover crews develop and maintain the production wells, including recovering and redeploying down-hole equipment periodically over the life of a production well. • Workover personnel numbers will be added from 2016 at increments of around 30 until workforce numbers plateau at approximately 250 within 15 years.
Facility Operations Workforce
• IPF- 1 x manager, 6 x compression, 2 x water and 2 x power generation; and • CGPF- 1 x manager, 6 x compression and 2 x power generation

Source: Arrow, 2012

4.7.9 Operational Security and Safety

Arrow is committed to protection of assets. Workforce and public safety is paramount to Arrow's operations. Utilising qualified personnel and through implementation of Arrow's comprehensive and integrated health, safety and environmental management system, the potential security and safety risks will be minimised. Below is a brief summary of key security and safety features employed during operations.

A detailed discussion of security and safety is provided in the Preliminary Hazard and Risk chapter (Section 27), and Preliminary Hazard and Risk Technical Report (Appendix Y) of the EIS.

4.7.9.1 Site Security

Site-specific security measures will be risk-based and determined during FEED. Common security features include the following:

- Completed production well sites will be fenced to prevent access. The height of the fence will be dependent upon well location and risk of unauthorised access.
- Production facilities will be enclosed by a perimeter security fence, and will have 24-hour lighting and security monitoring equipment.

4.7.9.2 Safety

Production wells, pipelines and production facilities have numerous safety systems that maintain the integrity of the facilities. Systems include:

- Fire detection and fire suppression systems that consist of active and passive fire protection systems such as flame, smoke and heat detectors;
- Gas detection systems;
- Automatic alarm systems;
- Emergency shutdown systems in the event of an upset or emergency, which will be both:
  - automatic – through the integrated control system; and
  - manual – through operator call points and pushbuttons.

- Automated overpressure protection systems on high-pressure pipelines, remote-controlled isolation valves on medium-pressure gas pipelines and manual isolation valves on low pressure gas and water pipelines at each of the well heads.

In the event of an emergency, Arrow will implement their emergency response plans as described in the draft EM Plan (Appendix Z) of this EIS.

4.8 Decommissioning and Rehabilitation

Decommission and rehabilitation will occur progressively throughout the Project life, with final decommission and rehabilitation being undertaken at the end of individual infrastructure life in accordance with relevant approvals and regulatory requirements. The following provides a summary of these activities, while a detailed outline of decommissioning and rehabilitation is provided in the Decommissioning and Rehabilitation chapter (Section 29).

The goals of the decommissioning and rehabilitation of the Project will be to ensure that:

- Decommissioning and rehabilitation activities meet all stakeholder expectations and comply with relevant regulatory requirements and/or industry best practices;
- Above ground infrastructure developed for the purpose of the Project is decommissioned, safely removed and appropriately disposed of;
- Where appropriate, the progressive rehabilitation of disturbance areas will be undertaken throughout the life of the Project;
- The final landform is stable and an acceptable final land-use for the disturbance area is achieved;
- Where appropriate, and authorised by the regulator, infrastructure such as dams or roads are transferred to the landholder; and
- The potential for adverse environmental impacts is minimised, including but not limited to contaminated run-off into local waterways, air quality from dust, and soil contamination from hydrocarbons or other chemicals.

Prior to decommissioning, detailed objectives, criteria and performance indicators will be developed for each of the above goals in consultation with the appropriate regulatory agency and landowners.

Decommissioning and rehabilitation will involve three key tasks:

1. Progressive rehabilitation: this will be undertaken post construction, to stabilise the land and to reduce the size of the construction footprint. The period of time between construction and rehabilitation of disturbed land not required for operations will be minimised to prevent degradation and loss of exposed soils. Surface structures, equipment and waste materials from the construction area will be removed prior to rehabilitation.
2. Decommissioning: at the end of the Project infrastructure life, or when it is no longer required, infrastructure will be decommissioned by removal of surface facilities and waste from site. Subsurface infrastructure will generally remain in situ. Any contaminated soils present will be remediated or removed to a licensed disposal facility.
3. Final rehabilitation: where required, topography, re-profiling and revegetation of the site will be undertaken to return the disturbed land to as near as possible to its pre-disturbance state.

Compacted areas will be ripped or scarified and topsoil will be respread to encourage natural revegetation. In some cases, stabilisation measures will be used to ensure topsoil remains intact. Site-specific rehabilitation plans will be developed for areas where natural vegetation regeneration may be problematic. The final rehabilitation will be determined in conjunction with the landowner.

During decommissioning Arrow will aim to:

- Reuse TWAFs, offices, pumps, tanks and components of production facilities;
- Recycle steel, piping and fencing; and
- Dispose of general waste from camps, brine residue from dams and liners in accordance with the waste hierarchy described in the Waste Management chapter (Section 28).

Decommissioning and final rehabilitation methods for major Project infrastructure are described below.

4.8.1 Production Wells

As described in Section 4.6.2, once installed, the footprint required for the well site will reduce from approximately 90 by 90 m to 10 m by 10 m. The construction site footprint outside the 0.1 ha required for operations will be rehabilitated and contoured as soon as practicable to pre-existing conditions or to a standard agreed with the landowner.

Production wells will generally operate for approximately 15 to 20 years. Over time the gas production rates from individual wells decline. When they are no longer commercially viable, the wells will be decommissioned and rehabilitated in accordance with relevant regulatory requirements and industry best practice.

4.8.2 Gathering Systems and Pipelines

General Decommissioning of the Pipeline

It is anticipated that the buried pipelines will be used for between 15 and 40 years depending on their location. In general pipelines will be left in-situ to minimise the environmental disturbance associated with excavating pipelines.

Rehabilitation

After removal of all infrastructure developed for the pipeline, the disturbance area will be reshaped and trimmed to make a landform that is consistent with the surrounding topography.

4.8.3 Production Facilities

Arrow may undertake decommissioning of production facilities as a combined project, or may progressively decommission and rehabilitate individual components. The preliminary development schedule has been used to create a conceptual decommissioning schedule, as outlined in Table 4-12.

Table 4-12 Conceptual Decommissioning Schedule

Production Area	Production Station Type	Onstream Date	Projected Decommissioning Date
4	IPF	2017	2038
5	IPF	2017	2039
6	CGPF	2017	2037
7	IPF	2017	2041
8	FCF	2020	2039
9	CGPF	2020	2055
10	FCF	2039	2055
11	CGPF	2021	2051
12	FCF	2032	2053
13	FCF	2041	2055
14	FCF	2043	2055
15	FCF	2041	2055
16	FCF	2047	2055
17	FCF	2032	2054
18	FCF	2034	2055
19	IPF	2035	2055
20	FCF	2048	2055

Major production facility equipment such as compressors, electric motors and gas engines, as well as ancillary equipment such as flares, tanks, piping, electrical and other utility systems, will be isolated, drained, purged of gas and removed from site. Where practical, the major equipment will be re-used elsewhere in Arrow's developments.

4.8.4 Water Treatment and Storage Facilities

Water Treatment Facilities

Prior to the commencement of decommissioning activities, the water pipelines will be drained and isolated. In addition, tanks and vessels will be pumped dry and services that are not required for demolition will be disconnected.

All buildings and other surface infrastructure, including the reverse osmosis units, pre-treatment equipment and control rooms, will be demolished and disposed of in a suitable approved location. Opportunities for the sale and/or re-use of assets and recycling of scrap steel will be maximised where possible.

Water Storage Facilities

At the cessation of operations, CSG water storage dams will be drained, with the water preferably passing through the water treatment plant. Clean water dams will be drained using existing infrastructure where possible, or pumped out using a road tanker or similar and disposed of at an approved location.

In some instances an agreement may be in place with the landholder to transfer ownership of a dam following the removal of CSG water. Approval from the regulator is required to effect this transfer.

4.8.5 Power Generation Facilities

All buildings and other surface infrastructure (including the gas engine generating sets, gas metering facilities, gas treatment facilities, sub stations, switchgear, oil storage facilities, workshops and control / switch room) will be demolished and disposed of in an appropriate manner.

Opportunities for the sale and/or re-use of assets and recycling of scrap steel will be maximised where possible. All associated infrastructure, for example fencing and CCTV, will be removed.

If an alternative use for electricity transmission network infrastructure can be agreed with the relevant stakeholders it will remain in-situ. Alternatively it will be demolished and disposed of in a suitable manner. Opportunities for the sale and/or re-use of assets and recycling of scrap steel will be maximised where possible.

4.8.6 Supporting Infrastructure

Project TWAFs will be constructed in modules and therefore can be removed easily from any site and reused elsewhere.

Decommissioning and rehabilitation of borrow pits will involve ripping of the pit floors, slope stabilisation, contouring, respreading of topsoil and, if practicable, revegetation.

4.8.7 Decommissioning Waste

Wastes generated during decommissioning and rehabilitation may include:

- Solid wastes, including general trash, concrete, electrical cables, fencing, piping, gas compressors, scrap metal, production wellheads, power generators, pumps, sewerage, sludge, storage tanks and soil contaminated with chemicals / oils;
- Liquid wastes, such as brine, triethylene glycol, lube oil and spent chemicals; and
- Gaseous waste from vehicle air emissions.

Details on the expected waste types, quantities and waste management practices are provided in the Waste Management chapter (Section 28) of this EIS.

4.8.8 Financial Assurance

Financial assurance for the Project is required by EHP under the guideline *Financial assurance for chapter 5A activities* (EHP, 2012). It is a security held by the Queensland Government to meet any potential costs or expenses it may incur in taking action to rehabilitate or restore the environment.

Arrow will calculate the financial assurance required for the Project during EA applications and/or amendments. The financial assurance will be provided to EHP and reviewed throughout the life of the Project.