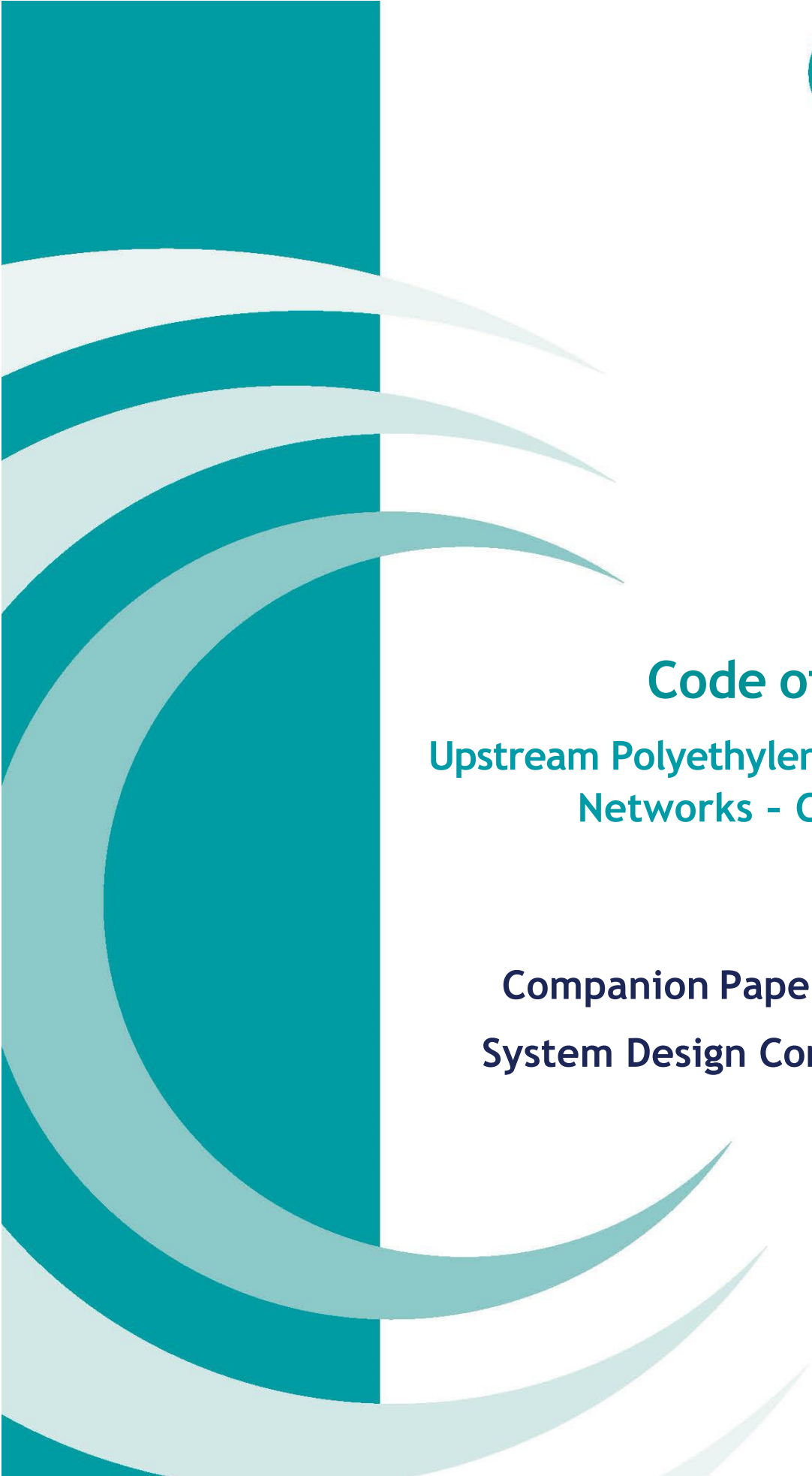


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Code of Practice

Upstream Polyethylene Gathering Networks - CSG Industry

Companion Paper CP-04-006
System Design Considerations

Revision 2
April 2025

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Feedback on this Companion Paper or recommendations for the preparation of other Companion Papers is encouraged.

A form has been provided to enable the submission of feedback. A link to the form can be found on the CSG Committee page on the APGA website here: <https://www.apga.org.au/code-practice-upstream-pe-gathering-lines-csg-industry>

If there are problems with the feedback form, please contact:

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Preface

Companion Papers have been developed by the Working Group responsible for the *APGA Code of Practice for Upstream PE Gathering Networks – CSG Industry* (the Code) as a means to document technical information, procedures and guidelines for good industry practice in the coal seam gas (CSG) industry.

Since 2008, the development of the LNG export industry based in Gladstone, Queensland, with its related requirement for a large upstream CSG supply network of pipelines and related facilities presented the impetus for significant improvements in design and best practice approach. Some of these are included in this paper

The principal motivation for the initial development of the APGA Code of Practice was safety and standardisation in design and procedures, and to provide guidance to ensure that as low as reasonably practicable (ALARP) risk-based requirements were available to the whole CSG industry. Accordingly, the Code is focused solely on this industry and the gathering networks and associated pipelines using locally-manufactured PE100 pipeline. The Code is a statutory document within Queensland.

Companion Papers form part of the suite of documents which, together with the Code, and are intended to:

- a) be used in the design, construction and operation of upstream PE gathering networks;
- b) provide an authoritative source of important principles and practical guidelines for use by responsible and competent persons or organisations; and
- c) assist to leverage landholder legacy opportunities.

These documents should be read in conjunction with the requirements of the Code to ensure sound principles and practices are followed. These documents do not supersede or take precedence over any of the requirements of the Code.

A key role of the Companion Papers is to provide the flexibility to incorporate endorsed industry practices and emerging technologies expeditiously, as/when necessary.

A related benefit is that the Companion Papers can be referenced by the wider resources industry which uses similar PE gathering networks for gas or water handling, including coal bed methane (CBM) in underground coal mines; mine de-watering; or the emerging biogas industries (agricultural, landfill, etc.); or any development with similar characteristics (e.g. shale gas).

Other useful references to support CSG Field Development in Queensland include:

- Agreed joint arrangements between the Landholder and operating company as detailed in a Conduct and Compensation Agreement (CCA);
- Queensland Government Acts and Regulations, developed in association with the industry, covering the direct and indirect issues arising from the beneficial use of CSG produced water, to weed management, monitored by the GasFields Commission (under its own Act); and
- Safer Together publications which address many of the industry-wide issues, specifically standardised inductions, 4WD vehicle usage and monitoring, and heavy vehicle land transport, in particular drilling and construction water transfer and handling.

Note: This is revision 2 of this Companion Paper. It was updated to reflect V6 of the Code.

1 Scope

The scope of this Companion Paper covers the design considerations applied to the overall CSG field network generally as defined in Figures 1.2a (gas) and 1.2b (water) in the Code, and associated facilities. Additionally, provision is included for:

- gas networks operating up to 16 barg MAOP
- water networks up to 25 barg MAOP
- the use of the water gathering network for the transfer of drilling and workover water
- water delivery from external sources.

This revised paper extends the range of considerations which impact on the holistic network system design. As an example, from an operating company viewpoint, aspects of materials selection, procurement, fabrication and competencies of relevant personnel warrant attention.

Discussion related to the surface component aspects of the gas/water gathering system is included, despite the primary purpose of the Code being related to the PE gathering networks. Additionally, the influence of the proposed means of power supply to the facilities is discussed, as it specifically relates to field safety, optimisation and flexibility.

From a landholder perspective, issues include the use of grids and gates, traffic and weed management, and the beneficial use of CSG water including possible legacy benefits of repurposing the water gathering network and associated ponds.

2 Context

The development of a CSG field in Queensland involves an agreement to cover the simultaneous operation (SIMOPS) of agricultural and CSG extraction activities on a property, generally for a period up to, or exceeding three decades. This agreement is defined as a compensation and conduct agreement (CCA).

These agreements address the full range of current and proposed agricultural activities in parallel with the planned gas extraction aspects which may impact on these, including traffic activity (speed limits, gates and grids), weed management, and in particular the alignment of the roads and tracks co-located with the buried gathering networks.

A key learning from the initial CSG to LNG rapid expansion was the need to fully understand the significance of the ownership status of the local gas resources being vested in the Crown.

The GasFields Commission has reported that an effective CCA requires the participation of informed representatives of both parties. The Code uses the term ‘Competency’ to define this aspect from the operating company perspective, with full details defined in Competency CP-02-001. The Code mandates those stages in the development process when formal approval is required, implicitly by informed competent personnel.

Other learnings from the development activities to date are that the principal hazards identified are:

- driving
- SIMOPS
- water transfer by water trucks
- excavation near live gathering networks.

The majority of these hazards can be significantly reduced in scope by a well-considered field layout design and development plan, minimising implicit SIMOPS likelihood. The process design can then be subsequently optimised, sequentially and subordinately.

3 Introduction

While the CSG industry has operated in Queensland for almost three decades, during recent years the rate and intensity of field development has resulted in challenges associated with the industry's obligations or social licence to operate. Significant challenges exist related to various aspects of both the field layout and engineering design outcomes, including noise impacts; visual amenity; traffic and overall intrusion into community lifestyle.

This Paper references the GasFields Commissions report *On New Ground* issued in June 2017 which summarised lessons learned during the LNG expansion projects.

The risk-based design concepts initially advocated in Version 4 of the Code, with the parallel concepts of fully integrated optimised whole-of-life design have now been reinforced and extended.

Section 4.1 of the Code mandates that the design should use risk mitigation controls from industry (not just individual company) experience. As detailed in the Context section, local industry experience from recent years reinforces the paramountcy of field layout design over gathering network design chronologically. The design phases are inevitably linked to the integrated whole-of-life operations and can be considered often to commence in the pre-drilling stage, including optimisation of drilling water provision to the gas field well sites and ponds, and includes full corridor site rehabilitation.

Additionally, based on current operating experience clear evidence has emerged that a principal impediment to safe and efficient field operations has in some instances been attributed to previous design approaches. SIMOPS criteria would normally ensure a sequential field development approach over the average 25- to 30-year period on each property, as follows:

- Pre-CCA preliminaries: identify and agree local sources for water and gravel. Negotiate CAA based on agreed road/track and gathering network. Three to five years (10 per cent) duration.
- Phase 1: construct and commission gathering networks, water transfer pipelines, well leases and agreed water ponds. One year (3 per cent) duration.
- Phase 2: drilling & completion of wells: 25-30 days (0.5 per cent) duration.
- Phase 3: installation and connection of wellhead facilities and buried services (water, gas, power, fibre optic, panel fencing and site rehabilitation (10 days).
- Phase 4: operations activities (including commissioning, maintenance, surveillance, suspension as required): 75-80 per cent duration.
- Phase 5: abandonment and rehabilitation, as per negotiated CCA conditions. Three to five years (10 per cent) duration.
- SIMOPS: agricultural activities: 100 per cent duration.

Accordingly, during CCA negotiations with the Landholder, the negotiating team should ensure that the layout and detail of the gas extraction operations reflects that 80 per cent of the SIMOPS will be between Operations and the Landholder, and that the civils infrastructure for access tracks and roads should reflect this, with drilling being users, not designers, of the well leases and tracks.

Integrated design may often require the identification and optimisation of manifold or nodal locations, with orphan wells reduced to a minimum. These nodes can often provide the location of new water bores and the initial produced water aggregation and boost pump transfer (often with associated degassing and solids removal) in addition to later-life gas boost compression. Such activities may involve noise generation and maintenance activity, and accordingly their location in relation to community infrastructure, especially residences, needs to be optimised.

Centralised electrical power supply should be considered due mainly to the ability to reduce noise levels. On a whole-of-life basis this could be seen to represent a coordinated ALARP approach to noise mitigation from a total field perspective. Electrical power also provides flexibility for the operation of high power usage downhole pumps such as beam or rod pumps. An associated benefit can be a significant reduction in field maintenance visits.

Similarly, communications by buried fibre optic cable has proven more reliable than alternatives.

The industry has recognised simplicity in facilities normally provides the safest, least cost and least intrusive long-term outcome.

Section 4.3.1 of the Code requires that the principles and philosophies to be applied are documented as prime determinants in satisfactory safety performance in both operations and maintenance, but specifically in design. Implicitly, this also highlights the need for system design decisions to be undertaken with cross function input from design, asset and operations personnel. Third parties possessing the critical operating or specialist technical expertise can assist (e.g. resin and pipe technology).

In summary, there will always be variances between individual wells and fields. Hence, fit-for-purpose designs should be based on the same best-practice principles, although differing good practice outcomes may result due to various design conditions and/or landholder requirements.

One-size-fits-all for any aspect or component is generally considered contradictory to such optimised fit for purpose (FFP) design.

4 Technical Considerations

4.1 Layout design

A CSG gas field is designed to safely and effectively extract the highest percentage of identified gas in place. The initial principal determinant is based on the assessment by the operator's asset technical personnel concerning the optimum spacing of wells required to maximise gas recovery in a specific field or block, within a petroleum lease area. Generally captured in a field development plan (FDP), the initial location and spacing of these wells are influenced by:

- sub-surface characteristics and the intended drilling methods used to extract the CSG;
- existing surface facilities associated with agricultural activities; and
- location of preferred water source for development activities.

The FDP should also define the proposed surface facilities concept which includes the location and type of gas compression for the life of the development within the gas gathering network (although only about 10 per cent of properties have such surface facilities), power and communication infrastructure, water transfer/treatment facilities, proposed beneficial use, type and location and links to the water gathering network, source of drilling and construction water and the access tracks necessary to drill, complete and operate the wells effectively over the field's lifetime.

The gas compression and water management philosophy is key to the layout of the gas and water gathering network. For gas, this determines design pressures and the acceptable pressure loss from the wellhead to the main compression facilities. Wells are connected through a network of increasing sized pipelines. The FDP defines the commissioning schedule to achieve the de-watering processes to achieve the gas forecast, generally radiating from the compression facilities. The water gathering network is co-located with the buried gas network and often provides more extensive surface facilities including ponds and pump stations

With the ideal well layout identified, constraints other than technical sub-surface are applied to the field, with an appropriate recognition of stakeholder requirements, including but not limited to:

- land usage (current and future) and ownership
- environmentally sensitive areas
- location of residences
- topography
- existing infrastructure-roads, railways, pipelines, fences, etc.
- location of proposed future infrastructure-mining activities, electrical power corridors, etc.
- source of water for drilling and construction
- environmental licence obligations
- legislative requirements (e.g. Petroleum & Gas Act and Regulations, Environmental Protection Act, Regional Planning Act, Strategic Agricultural Land Usage Regulations, GasFields Commission Act, Waste Reduction and Recycling Act, etc.).

Environmental licence obligations. Large developments require an Environmental Impact Statement which nominates controls to be put in place. These can vary between fields, subject to land use and other factors. In recent years, legislation now enables CSG water to be used for beneficial use.

Key undertaking. The CSG industry has collectively undertaken in discussions with the Queensland GasFields Commissioner representing numerous community stakeholders, to “minimise the footprint” of wells and associated infrastructure tracks, roads, etc. and to generally rehabilitate (or “make good” in GFC terms) the land area affected by development on each property.

Route selection. At the commencement of the gathering network routing process, there is a considerable level of uncertainty due to a number of variables - for example land holder, environmental and cultural heritage constraints. Accordingly, the preliminary routing should be performed by competent personnel with an understanding of the project obligations, and input from the various stakeholders. Each project has its own unique characteristics that require interactive coordination of potential routes. Participation in the desk-top scouting process should include all key operating company (OPCO)] stakeholders, including asset, operations, environmental, drilling, cultural heritage, health and safety, etc.

Primary considerations are whole-of-life safety including, both implicit and explicit SIMOPS challenges, topography, geology, environmental impact, noise, visual amenity, existing infrastructure and minimising major crossings. Priority should be accorded in the first instance to corridors which align generally with existing landholder roads, fence lines, etc. As such the initial corridors are selected to avoid key constraints and the gathering and related infrastructure route alignment is supplemented by a preliminary safety management study and discrete aerial survey work and should normally be submitted to teams representing preliminary asset/wellheads and gathering operations for approval prior to proceeding to detailed design.

As the design matures, an initial corridor of interest (nominally 100 metres wide) is positioned to allow for deviations and constraints. This corridor is then narrowed to an approved right of way (ROW) width taking into account all land holder, environment, construction and operations considerations. A consistent narrowing of the corridor should be expected and is encouraged to reduce visual impact and disturbance.

A desktop route selection approach should be formulated according to a primary set of rules and guidelines that can include, but are not limited to, the following:

- SIMOPS: agricultural and gas extraction.
- Reduce impact to landholders and co-locate with existing property tracks, roads and fence lines.
- Nodal/manifold locations.

- Ponds and pump stations.
- Surveillance and abandonment.
- Shortest point-to-point routing and optimised headings.
- Safety, including driving tasks.
- Hydraulic considerations.
- Align common interest infrastructure.
- Interface considerations.
- Optimise crossings and avoid overlapping tenure.
- Environmental licence commitments.
- Elevation and land cover.
- Additional area requirements along the ROW.
- Allow for cross-connects to adjoining fields.

Technology is available in unmanned aerial vehicles, light detection and ranging (LIDAR) and 'imagery capture' that allows for the project team to perform a virtual site visit from the office. This technology can increase the accuracy of desktop routing, certainty of cost estimates and defers or minimises the need for previous historic field site surveys until detailed design. The above constraints can therefore be accurately identified from a detailed assessment assuming adequate LIDAR, imagery and GIS data sets have been acquired.

NOTE: A comprehensive and efficient GIS system would likely be required to analyse and display the vast amount of data now available.

The gathering system layout and design should give consideration for the whole-of-life operational requirement, including asset monitoring, 4WD vehicle access to facilitate both network surveillance patrolling purposes and maintenance access to isolation valves, high point vents, air release valves and low point drains.

For both gas and water systems, the holistic design for each CSG field should incorporate the following:

- operations and maintenance philosophy and principles
- isolation philosophy
- commissioning plans and processes
- segregation plans (3D where appropriate) for constructability
- inter-connects between compression facilities, with redundant systems to allow low- pressure gas to migrate between gas plants
- cross-connections between adjoining blocks (only for fields or blocks with satellite compression)
- nomination of exclusion zones for pressure testing.
- drilling and construction water sources.
- beneficial use of CSG water.

4.2 Design considerations

CSG gathering systems are generally comprised of separate CSG and produced formation water (PFW) gathering networks. CSG producers have various methods for well completions and for separating gas and liquid phases at the well head, beyond which there are a number of aspects that need to be considered in the design of the gathering network.

The Code does not formally differentiate between sub-groupings of pipe within either the gas or water networks. In practice the networks contain at least two groups of pipes with differing design and operational requirements.

- Group 1: Consists of the small diameter pipes that connect the well to nodal or manifold connections. These are typically less than DN160 in size. Whilst there is no formal naming convention applied in the Code, pipes in this part of the network are often referred to as spurs or flow lines.
- Group 2: Consists of pipe that transports gas or water from a number of wells beyond manifold, isolating valve or flow switching facilities to nodal or hub CSG Gas processing facilities or in the case of the water network to treatment facilities or dams. These are larger pipes typically DN160 and larger. Pipe sizes in this group regularly exceed DN630 and future developments will likely see the use of sizes of DN1000 and perhaps beyond. This group of pipes within the network are often referred to as spine, lateral, header or trunk lines.

Note: refer Section 4.5 for specialised gathering system commentary.

The design of such gas and water gathering networks need to be considered separately due to differing aspects of their design. However, the two systems are normally run in parallel in the same trench adjacent to the wellsite access tracks until diverging to separate gas and water processing facilities.

Using single phase assumptions for the whole gathering network is not advisable.

4.2.1 Basis of Design

This normally provides the basic data for both gas and water in the specific field, including forecast flow rates, pressures, temperatures, quality, in addition to overall basin characteristics e.g. shut in well head pressure. Predicted decline curves for both products based on both production testing and, if available, data from adjoining fields with similar completion techniques to provide key inputs.

Landholder preference for proposed beneficial use of produced water should be included, as this would be a major determinant in the use of nodal ponds which if used normally influence the operating envelope of the water network.

Section 4.3.1 of the Code requires that the design basis is reviewed throughout the detailed design and adjusted as required. Normalisation or averaging techniques are commonly used. These assume that for a particular node or section of the field not all wells are operating simultaneously at peak forecast production but are at different stages of de-watering and related gas production. On average only 85 - 90 per cent of the wells are operating, typically at an average of 75 per cent of peak forecast production. Such techniques can reduce the design flow significantly for lateral, spine or header lines by as much as 25 per cent. Downstream water network allocations to beneficial use can further reduce design flows.

4.2.2 Large diameter PE pipe

Design techniques have evolved to eliminate the requirement for satellite boost compressors, replaced by large (>DN700) PE pipe which reduces friction losses adequately to maintain and optimise gas flow for most designs. Field compression, either nodal or wellhead can be provided if required. Very significant capital and operating expenditure whole-of-life savings can be achieved using such designs.

At present for these larger pipe sizes there are no endorsed flow-stopping methodologies for purposes of emergency response and to assist commissioning and testing. Hence current designs for these large sizes include DN 630 PE ball valves to achieve suitable full life isolation capabilities. The pressure/friction loss across these valves is relatively minor and should not inhibit effective design for sizes up to DN1000.

Experience has shown that produced gas and water from several fields across the main producing basins in Queensland contain bacteria, either acid-producing or sulphate-reducing or both. While this can be addressed by dosing at the well head, from an engineering design approach, the use of inert PE 100 valves, fittings, couplings and risers is recommended.

Flowlines generally represent 50 per cent of the gathering network total length. In almost all locations a standardised design approach can be adopted, as detailed in the following sub-sections.

4.3 Network design

Most flowlines are of less than 2000 metres in length, often less than 1000 metres. Detailed hydraulic design is rarely required.

Each Operating Company normally adopts a standard diameter PE100 pipe, often DN 125 for both products for ease of construction. A minimum SDR 13.6 is recommended for weldability, although terrain conditions may require a thicker walled pipe for sections of the water network.

4.3.1 Gas spur/flow line design

CSG gas networks contain water in the form of vapour or free liquid. This is subject to the well completion design and well head separator efficiency. Normally a single simple low point drain is installed in each flow line to permit the removal of this water. In situations where exceptional length or terrain exist supplementary drains maybe required. All such drain locations can be located from modern GIS data, and field surveys are rarely required. As detailed below, the main consideration in flowline design is to provide an appropriately sized pipe to support the whole-of-life production flow. Operating flexibility (commissioning, emergency response, suspension and abandonment) should be provided by appropriately located isolation valves, preferably buried PE valves at the nodal manifold or connection to lateral/spine line.

4.3.2 Water spur/flow line design

Water networks contain entrained gas in many situations, while solids, bacteria and other contaminants are carried into the water gathering network from the well borehole. Water flowlines are recommended to be designed for high velocity to carry any impurities downstream into nodal ponds or other collection points. Each PFW flowline design should include at least one high point vent, appropriately located. Specialised valves are available which assist in the de-gassing of the PFW without leaks.

Some CSG fields PFW has a tendency to cause internal scale lining the pipe walls, while other water can on occasion produce algae if stored in open tanks or ponds. While chemical dosing options exist as remedies the design engineer needs to be aware that the primary objective is to facilitate the beneficial use of the PFW once de-gassed, which is discussed further in Clause 4.5.

4.4 Gas Network

Gas flows from the well as it is de-watered. Entrained water from wellhead carry-over or from condensation as the gas stream cools can accumulate and if not removed from a gas gathering network has the potential to form slugs which may inhibit the flow of gas and may require additional equipment such as an inlet separator or slug catcher at the compression facilities to ensure that these facilities work optimally and are not damaged. Accordingly, it is important that any significant quantities of water are removed from any network low points by low point drains.

In order to remove water from the gas gathering network, a series of low point drains (LPDs) are generally used throughout the network. Designs for LPDs should be as simple as possible and in-line with operating philosophies. Their design will vary depending on the volume of water anticipated to be collected, the design pressure and velocity of the gas network. Separation of the water from the gas may occur by the installation of a larger diameter pipe section with a sump to collect the water. Designs then vary according to the operating philosophy to discharge to a local tank for later collection or possibly re-injection into the adjoining water line using a boutique solution. Other options, including siphons, can be considered.

4.4.1 Modelling

Based on the experience gained from more than 8,000 CSG wells, each CSG Operating Company needs to decide whether the approximately 50 per cent of gathering network length represented in spur/flow lines warrant detailed modelling or whether standardised design should be adopted.

Downstream of the spur/flow line junctions or manifolds the network design intent is to minimise friction loss and any other impediment to flow. Isolation valves represent a design challenge and while a key operating requirement the incorporation of these will often be a key design decision guided by the isolation philosophy. PE ball valves do not normally present a significant friction loss (refer 4.2.2 above).

Several advanced modelling packages are available which can provide guidance to the efficient transfer of gas to final compression facilities using large diameter PE pipe with appropriate support facilities.

Historically in many fields water transfer quantities have been over estimated with resultant over-sized water transfer and storage facilities. In part this is due to the variable rate of decline during the initial years of field de-watering. Similarly, models can be used for calculations related to the pumped water transfer network although in future the likely principal determinant will be the reduced quantities available after beneficial use offtakes and normalisation techniques.

4.5 Water Network

In recent years very significant changes have occurred among all stakeholders in relation to the beneficial use of produced formation water (PFW). Treated PFW is now recognised as a valuable resource available for use by landholders for agricultural use. PFW is also required for the gas field development: construction, drilling, testing, etc. activities. Progressively, government legislation has supported these initiatives.

. From a system design aspect, there are three main outcomes:

- Significantly reduced water quantities to be transferred offsite from a new development;
- Encourages the installation of a two-way flow water gathering network to optimise the transfer and use of CSG water for the workover, flush-by, etc. of wells and other similar activities; and
- Encourages the use of nodal ponds.

Produced water associated with CSG can have significant quantities of entrained gas which should mainly be removed by separation downhole or at the wellhead but remaining entrained gas can be evolved during flow or transportation through the network.

Commentary in notes related to Section 4.5 of the Code should be referenced if significant additional gas is present.

Solids may be removed from the base of the separator, either by regular dumping to an on-site collection trough or by using irregular direct collection by vacuum truck or a phased transition between these options.

In an optimised design, water spur/flow lines are collected into an in-line in-field storage system (IFS), either a pond or a tank. Storage in the pond or tank allows the release of most entrained gas, solids and bacteria, and oxygenation of the water to occur. Thereafter, the de-gassed CSG water surplus to local beneficial use can be transferred through the water gathering network to a centralised pond in a less turbulent flow status, with vent locations accordingly being less critically sensitive longitudinally which can alleviate community concerns near residences.

NOTE 1: The IFS can often use an adapted pond or tank from earlier exploration and appraisal activities, and be either an open pond or a prefabricated tank. The location could also act as a future gas boost compression station site.

NOTE 2: Water handling facilities at an IFS normally comprise an open pond or tank into which the node flowlines (normally from 6 to 10 wells in number) free flow, at which time impurities-solids, fines and gas are removed. A small fit-for-purpose water pumping manifold comprising two pumps suitable for single phase flow transfer the de-gassed CSG water to any existing legacy water handling and treatment infrastructure using larger diameter PE 100 water lines to major ponds and centralised water treatment facilities. Electricity to power the pumps may be supplied by electrical cable or dual fuel gas/diesel generator sets. These IFS facilities, if installed prior to drilling preliminaries team mobilisation, can often provide a safer, lower net cost means of transferring drilling water to each well lease thus minimising or eliminating water delivery by trucks.

Such practices have been used in the past decade in the US shale oil and shale gas field development for the transfer of the considerable quantities of water required for well stimulation operations over distances up to and exceeding 20 kms. This is often achieved by using re-usable on-ground PE 100 pipe. Locally, similar transfer methodology may require the consideration and adaption of such processes, for full or partial lengths.

In a non-nodalised system, by contrast, the entrained gas will likely accumulate at high points and, if not removed, can increase the operating pressure of the water gathering network and potentially form a gas lock or eventually impact the operation of the wellsite equipment. Therefore, the water gathering system will need to have sufficient vents to vacate gas from these locations. Selection and design of vents is well-understood. Riser fabrication and pre-testing prior to installation is recommended as retrofitting normally would require a hot-tapped saddle design.

Specialist designs have been developed to vent entrained gas and air from a water gathering network into the adjacent gas network (and the reverse for the gas network). Such designs are appropriate to address specific challenges rather than for general purpose use (including topographical, hot and wet gas, etc., often for restricted periods).

For water networks, “Open Path” design may be adopted, whereby it is designed such that the water network cannot be closed in the impact of hydraulic head can be neglected. Such design shall only be implemented on sections where blockages are not credible, or a risk assessment has deemed that the risk of blockages is ALARP.

4.6 Operational considerations

4.6.1 Travel within gas field

As a guideline for CCA agreement, the following criteria are normally adopted for travel within landholders' property:

- Access roads to nodal, compression or major pond locations: 40km/hr speed limit.
- Five to six metres wide gravel roads, shared with existing landholder roads or along fence lines, with 95 per cent weather access.
- Wellsite access tracks: 10 km/hr speed limit.
- Four-metre wide lightly-graded tracks.
- Wherever possible install grids not gates.

4.6.2 Surveillance

A significant amount of the whole-of-life surveillance obligations can be met by normal observations and recording by Operations field staff from transiting vehicles during scheduled activities, provided that the gathering network is within three metres from edge of track or access road.

4.6.3 Emergency response

Prevention of damage to PE pipe from excavation activities (by first or third parties) is aided by the use of marker posts, procedures, etc.

While the main header and spine gas lines have relatively few isolation valves in the large diameter lines, most spur/flow lines should have small buried DN 100 PE isolation ball valves at the spur/header line junction which can assist in early response.

The water gathering network may have isolation valves to assist water transfer throughout the field, often bi-directional- refer CP-04-007 for further details.

4.6.4 Out-of-service operations

While CSG wells can cease de-watering for various reasons, the gas flows normally continue for a reasonable period of time unless halted by intervention. Surveillance requirements accordingly continue. Operational procedures, as defined in Section 11 of the Code should provide guidance as to when the relevant network section should be suspended.

4.6.5 Suspension and abandonment

CP-11-008 provides details on specialised purging, isolation valves and line pressure monitoring for spur/flow lines.

4.7 Construction considerations

Each individual property and landholder has unique aspects which need to be addressed and agreed during the CCA process. These can relate to land use and bio-security aspects.

For construction, the following considerations need to be addressed during the internal OPCO design and approval process, based on the agreed CCA:

Landholder views:

Property access points & emergency evacuation routes. Gates or grids preference. Noise from 24-hour gensets for security, drilling or well operations.

Overland water flow.

Location of construction crew base:	Staff amenities with parking and security.
Sequencing of construction:	Exclusion zones for pressure tests.
Communications:	Mobile coverage or radio.
Locations of stockpiles:	Onsite storage for PE pipe, fittings,

Note: Where possible for large diameter PE pipe make deliveries direct to ROW corridors

Typical gathering network corridor width requirements:

- spur/flow lines: 8-10 metres maximum
- spine/header lines: 10-12 metres maximum
- immediate rehabilitation after construction (GasFields Commission recommendation).

For connections maximise the use of prefabricated and tested spools and manifolds.

4.7.1 Design drawings

Piping and Instrumentation Diagrams remain essential but alignment sheets are no longer expected to be used. The latest GPS technologies appear appropriate to be used to prepare the 'as constructed' drawings and records.

Further details are provided in CP-05- 001 Safety in Construction.

4.8 Optimisation considerations

As stated previously, the gathering network design is defined by the FDP which is based on predicted performance of the wells in operation and on standardised calculations and sensitivity checks. Once in regular operation, the field may perform at less than predicted flows. Proven options to enhance production include wellhead or nodal boost compression or blowers, possibly twinning or looping pipelines. The initial design should make provision for such brownfield plant changes or modification to the gas network.

4.8.1 Emerging alternate gathering design options

Subsequent to the MAOP rating equivalence for gas or water service, design opportunities exist for single dual phase (gas/water) PE pipeline usage under several circumstances, including:

- Minimal water-producing CSG fields which may adapt beam or rod pump wellhead technology.
- CSG fields where downhole separation using electrical submersible pumps (ESG) pumps and separator systems is used e.g. possibly for 'tight gas' CSG fields.

Optimised design in such situations may possibly require the involvement of specialists (e.g. resin or pipe specialists) and an alternative risk-based fit-for-purpose approach.

4.9 Power supply and communications considerations

Many CSG developments have included high voltage power supply and communications cable, either overhead or buried cable, connected to all major compression or water transfer facilities for the following reasons:

- Whole-of-life economic savings.
- Noise mitigation/ alleviation.
- Reliability.
- Simplified maintenance regimes

For such fields, often the majority of wells similarly have electrical power and related data collection by buried fibre optic cable, either connected to the high voltage power supply or provided by nodal power generation sources. Historically a range of wellsite power options have been used including generators and micro turbines or HPU's. The collected data over recent years indicates that these wells have lower reliability and availability compared to those with a discrete cabled power supply.

Note: Historic data indicates that poor well reliability can generate more workovers and reduced nett gas recovery.

In relation to overhead power and communications to nodes or well sites, often CCA concerns related to visual amenity may limit such deployment, especially in cultivated paddocks. Also risk concerns in some regional locations from possible storm damage further lessen the use of this lower capital cost option. Mine site locations with an overhead power distribution network for other purposes) are an exception.

4.10 Process safety considerations

Endorsed design approaches require a detailed understanding of the visco-elastic properties of polyethylene. PE 100 and associated resins continue to evolve but key benefits centre on their inert non-corrosive nature and at normal operating temperatures their resilience and ability to withstand short-term over-pressure excursion events.

CSG networks normally operate for the majority of their working life at lower flows and pressures compared to initial start-up.

Similarly, CSG fields possess inherent pressure in the coal seams. Once initial production wells are drilled this retained pressure (often characterised in design as shut in well head pressure) progressively reduces over the initial 1200-1500 days of operation. Overpressure protection requirements for above ground upstream well site and downstream compression facilities are generally more than adequate for the protection of the gathering network.

Most CSG networks operate in locations where there is a low likelihood or low consequence risk associated with leaks. This enables ALARP to be readily assessed and appropriate controls to be implemented. This has been demonstrated by the gathering networks associated with the more than 8000 wells currently being successfully operated. Full compliance with relevant Codes of Practice is mandatory.

These operating envelopes and industry experience commend the use of risk based fit-for-purpose design (as advocated in Section 4.5 of the Code) to produce safer, more cost-effective and efficient gas and water networks, supporting the objective of maximising gas recovery from each CSG field.

4.11 Procurement

Some significant beneficial legacies resulting from the major export projects remain and continue to support the ongoing gas field development and LNG export over coming decades. Some of these beneficial legacies include:

- Two modern state-of-the-art PE pipe extrusion plants located on the Darling Downs with the capability to:
 - provide quality PE100 pipe across the required range of SDRs and DN's
 - provide other specialised PE pipe grades using specific resins.
- Strong supplier support base for full range of PE valves and fittings in size range DN50 to DN1000.
- Local Queensland and NSW based PE100 spool and manifold fabricators.

- Experienced contactors, capable of designing and constructing gathering networks, including specialised ploughing and coiling expertise.
- Teams of experienced PE welders, inspectors and supervisors.

5 Best practice engineering example

The CSG province has numerous proven producing basins throughout Queensland with very different coal seam characteristics requiring different extraction techniques and processes. While there are best principles in gas field design methodologies there is no single best practice applicable. The example below demonstrates (from Version 5) an application of the risk-based design methodology applicable to the majority of gathering networks. It is provided as a thought provoker for engineers unfamiliar with the complexity of integrated design.

The major change is that the entire gathering network, both buried and above-ground, including all valves, fittings, manifolds, risers may now be constructed from PE components.

Below provides additional guidance to best practice engineering:

<u>Commentary</u>	<u>Criteria</u>
A 'standard' 100 well CSG field, based on an integrated optimised field development.	1
Assume 90 wells are systematically gathered through 8-10 nodes, with 10 -20 'orphan' wells.	2
<u>Water flowline design:</u> Small [DN110 or 125] PE, equivalent size to gas flowline size (where appropriate). Black pipe, SDR11/13.6 (subject to topography)	3
Pre-fabricated water riser, integral with gas release valves (GRV); coiled PE pipe if suitable. High point vent (HPV) if required on water gathering.	4, 5
Flowing to a nodal in-field storage (IFS), potentially using former exploration and appraisal ponds. Flowline tested to SDR level above designated SDR; over pressure protection (OPP) set to operate at higher SDR level. DN100 PE isolation valve with purging capacity fitted at nodal manifold or, for orphan wells, at spur/spine line junction, preferably pre-fabricated.	6,7
IFS pond facilitates the removal of the gas, most contaminants (solids and bacteria) and oxygenation. Water is now then normally available for beneficial use (BU). Buried PE manifold located at node pond. If no centralised power, use a small bank of dual/fuel powered standardised water pumps.	Info.
Beneficial Use (BU) water is now available for drilling, construction or agricultural purposes. Any excess CSG water can be transferred to centralised water treatment plant storage via DN 315/450 PE pipeline fitted with GRV at appropriate 1000-2000 metre intervals, (or as required).	9
<u>Gas flowline design:</u> Small [i.e. DN 110/125] PE, equivalent to gas flowline size (where practical). Black pipe (gas on left, water on right in direction of away flow), SDR 13.6. Coiled PE pipe if suitable.	3
Pre-fabricated riser with buried DN100 PE ball valve as main isolation (XV) at/near base, supplemented by DN100 PE ball valve with purging capability at junction with nodal manifold or main spine line. LPD only if required (topography or flow).	10, 11
Flowlines join/link at designated node, with buried PE manifold/spools [pre-fabricated] blanked to link to future nodal gas compression.	Info.
DN 315/450 lateral, thence to DN 630/700+ header/trunk line to field or main compressor station.	12
<u>Well head design:</u> Outside of CoP Scope, however main requirement is a simple, effective and efficient separator; optimum height for access – ease of maintenance/modification/plant change. Solids/contaminants drainage line from separator base requires consideration. If warranted, connect to solids trough, otherwise evacuate by occasional collection by vacuum suck truck.	8, 14

5.1 Criteria and commentary

Criteria	Commentary
1.	Integrated design = sub-surface coal seam(s) to inlet compression. Optimised design = gas system design to allow first stage compression. FCS/nodal) outlet pressures (12.5 bar @ 50° Celsius) to permit PE pipe to be used downstream of any (FCS-type) boost compression.
2.	Nodes = node locations for a cluster of wells to be selected on the topographic basis so that PFW can be normally transferred by wellhead back pressure control valve (BPCV).
3.	Flowlines equal sized = safer, quicker, lower cost installation.
4.	Prefabricated and pressure-tested PE riser is safer, quicker, lower cost installation.
5.	HPV = only if required by elevation/length.
6.	Flowline higher SDR pressure test (both gas and water) facilitates higher OPP settings = wider effective range of BPCV operation; reduces incidental OPP relief events (LOCs).
7.	IFS pond type depends on forecast life [turkey's nest/prefab types are preferred designs]. Pond role is to remove contaminants, especially solids and bacteria, AND entrained gas. Water quality to Beneficial Use (BU) standard to facilitate local use. Normalises water quantities, provides some evaporation, ensures downstream mainly single-phase laminar flow.
8.	The laminar flow is ensured by using appropriate water pumps. Sizing = $[N/2 + 1]$. N is normalised, based on approximately 85 per cent of wells operating at about 75 per cent of peak flow rate, with (portable) redundancy. Volumes reduced by estimated local BU offtake. Where needed, powered by dual gas/diesel fuel generator sets, (if practical).
9.	GRVs= HPV model [at present], used in different role.
10.	PE100 ball valve included at (buried) base of gas riser, as XV.
11.	Flowline LPD only if required by topography/elevation or flow volumes. Nodal gas connections provision.
12.	DN 315 and larger PE lateral/header/trunk lines.
13.	LPDs sized and installed as required; Simplify design. Drop to grade, except where automated design requirements are mandated.
14.	SIMPLICITY = minimal rotating equipment. Various power sources-electricity preferred as normally lowest whole-of-life cost.

6 References

CP-02-001	Competency
CP-03-001	PE Material Selection and quality
CP-05-001	Safety in Construction
CP-11-004	Safety in Operations