



## Locational Guidelines

# Development in the Vicinity of Operating Coal Seam Methane Wells

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# Foreword

Coal seam methane (CSM) is a natural gas by-product of coal formation and is becoming a significant energy source as a substitute for natural gas from petroleum sources. It is now being produced from coal seams within the Sydney Basin and elsewhere in NSW.

While existing gas wells are generally located in rural areas, there is a potential for residential and other development in the vicinity of both existing and future operating CSM wells. As such, there is a need for locational guidelines on the siting of such development to ensure an appropriate balance between development on the land, community safety and a gas utility system using a locally produced source of energy.

The publication of technical and locational guidelines is an integral part of the Department's approach to the assessment and control of potentially hazardous development and the minimisation of land use safety conflicts.

These guidelines include separation distances between existing CSM wells and proposed development. Depending on the well configuration and operating conditions, separation distances for residential development range from 5 to 10 metres. Similarly, for sensitive use development, separation distances range from 8 to 20 metres.

I am pleased to be associated with these guidelines, which will strengthen the assessment and approval process leading to more effective land use safety planning.



Diane Beamer  
Minister for Juvenile Justice  
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# Executive Summary

Coal seam methane (CSM), also known as coalbed methane, a natural gas formed during the coalification process<sup>1</sup>, is now being produced from coal seams within the Sydney Basin and elsewhere in NSW. In 2001, Sydney Gas Ltd commenced production of CSM in the Camden/Wollondilly area. The existing wells are located in primarily agricultural/grazing land zoned rural.

The area is undergoing change as pressure for rural-residential development increases. In view of the potential for residential and other development in the vicinity of existing and future operating CSM wells and the desirability of developing a locally produced source of energy, there is a need for locational guidelines on the siting of such development to ensure an appropriate balance between development on the land and community safety.

These guidelines provide advice to consent authorities across NSW in assessing proposals for development in the vicinity of existing and future operating CSM wells.

The guidelines are based on systematic hazard identification and quantified risk assessment of typical existing and future operating CSM well installations. The application of the guidelines' land use and technical controls should ensure that development in the vicinity of existing and future operating CSM well installations having design and operational controls consistent with the configurations described in these guidelines will not be exposed to an unacceptable level of risk.

The guidelines describe the use of separation distances to ensure an appropriate buffer between a development and an existing or future operating CSM well and its associated equipment. Separation distances result in circular areas around the existing and future operating CSM wells, within which controls should apply to development.

Table 1 summarises the extent of the separation distances (measured from the centre of the well head, as shown in Figure 4) to residential and sensitive uses (i.e. dwellings or places of regular occupancy, as described in sections 1.2 and 2.2) during early/intermediate operation (typically less than two years) and for established wells (typically after two years).

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<sup>1</sup> *Coalification* is the term given to the process by which organic matter is transformed into coal.

**Table 1: Separation Distances**

Well Configuration	Separation Distance (m)	
	Residential Use	Sensitive Use
<b>Early/Intermediate Operation Wells (Typically up to 2 years)</b>		
Manual	10	20
Automatically Controlled (With Separator/Optional Pump)	10	20
Automatically Controlled (No Pump/Separator)	5	10
<b>Established Wells (Typically after 2 years)</b>		
Manual	10	15
Automatically Controlled (With Separator/Optional Pump)	10	15
Automatically Controlled (No Pump/Separator)	5	8

The guidelines also describe the technical and operational controls applicable to existing and future operating CSM well configurations that have been used in the preparation of these guidelines.

When considering rezoning or residential or sensitive use development in the vicinity of existing and future operating CSM wells, councils should confirm that the existing and future operating CSM well equipment configurations, controls and operating conditions are consistent with those set out in section 2 of the guidelines before applying the separation distances. Section 2.4 summarises how the guidelines should be implemented.

In situations where existing or future operating CSM well equipment and/or operations differ significantly from the guideline assumptions, development or rezoning proposals in their vicinity should be subject to a case-specific assessment in accordance with the principles in section 1.3.

Section 3 and Appendix 2 provide additional explanation of the technical basis of the guidelines but are not required for application of the locational and technical controls.

# 1 Introduction

## 1.1 Coal Seam Methane Production

Traditionally, natural gas used in New South Wales has been piped in from South Australia and the Bass Strait. Coal seam methane (CSM), also known as coalbed methane, is now being produced from within the Sydney Basin and elsewhere in NSW. CSM is a natural gas formed during the coalification process. Methane is the major constituent of both CSM and conventional natural gas from petroleum sources. The Sydney Basin, covering Sydney, Wollongong and Newcastle, holds large coal resources containing CSM. Unlike conventional natural gas found within sandstone and limestone formations, CSM is typically found in coal at depths of 200 – 1,000 metres.

Sydney Gas Ltd has operating CSM wells in the Camden/Wollondilly area and has been producing CSM from this area since May 2001. The existing wells are located in primarily agricultural/grazing land zoned rural. They are on properties (owned by others), which are mainly used for rural pastoral activities such as dairy farming or grazing. The physical infrastructure comprises wells, a gas gathering system, gas treatment facility and steel pipeline connected to the gas reticulation grid. While the wells are located on private property, the pipeline and the gas gathering system are located within local road reserves, wherever possible. The Company also operates a gas treatment facility, also located on private property.

The area is undergoing change as pressure for rural-residential development increases. Many properties are being subdivided into lot sizes of less than 3 ha. Other major land uses in the surrounding area include the Elizabeth Macarthur Agricultural Institute, educational establishments (Camden High School and Cawdor Public School), Camden Park urban release area, and rural-residential development. The Camden urban area is located to the northeast of the project area.

In view of the potential for residential and other development in the vicinity of existing and future operating CSM wells and the desirability of developing a locally produced source of energy, there is a need for locational guidelines on the siting of such development to ensure an appropriate balance between development and community safety.

## 1.2 Purpose and Scope of the Guidelines

The purpose of these guidelines is to:

- assist councils across NSW with evaluating and determining development applications for residential and sensitive use development on land in the vicinity of existing and future operating CSM wells designed and operated in accordance with the technical basis of these guidelines;
- provide the basis for a consistent approach to preparing and determining development applications; and
- inform the public and other stakeholders of the basis for the assessment of development applications for residential and sensitive use development in the vicinity of an existing or future operating CSM well.

**Note 1: What is development?**

In the context of these guidelines, the term 'development', as defined in the Environmental Planning and Assessment Act 1979, includes:

- the use of land;
- the subdivision of land;
- the erection of a building; and
- the carrying out of a work.

The guidelines are particularly concerned with ensuring that appropriate separation distances are maintained between dwellings, and other places where vulnerable people may be concentrated, and existing and future operating CSM wells.

The guidelines provide risk-based separation distances between existing and future operating CSM wells and residential and other sensitive use development (including places of regular occupancy<sup>2</sup>), based on the Department of Infrastructure, Planning and Natural Resources' (Department) criteria for existing potentially hazardous facilities published in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 – *Risk Criteria for Land Use Safety Planning*.

The scope of the guidelines covers risks associated with existing and future well installations, starting from the well head through to the connection to the underground gas gathering system. It does not extend to risks associated with initial drilling and well construction, to risks from the gas gathering system and CSM treatment facilities or from subsequent re-fracing operations<sup>3</sup>.

The hazard identification and risk assessment underlying the guidelines is based on:

- typical maximum operating pressures, as described in Appendix 2;
- typical CSM well configurations, designed and operated as described in Appendix 2; and
- the technical controls described in section 2.3.

The guidelines cover the following well types and locational situations<sup>4</sup>:

1. The well is *manually operated with local instrumentation*. A pump and/or water separator are optional for this configuration.
2. The well has a water separator and is *remotely monitored and automatically controlled*. A pump is optional for this configuration.
3. The well is *remotely monitored and automatically controlled*. There is neither a pump nor a separator.

For convenience, the three configurations<sup>5</sup> are referred to in these guidelines as ***manually controlled, automatically controlled (with separator/optional pump) and automatically controlled (no pump/separator)***, respectively (Refer to Appendix 1).

## 1.3 Principles and Implementation

In considering applications for development in the vicinity of existing and future operating CSM wells, consent authorities across NSW should bear in mind that

<sup>2</sup> See Note 2:

<sup>3</sup> Re-fracing operations are considered unlikely and should be subject to case-specific assessment.

<sup>4</sup> It should be noted that at the time of writing the guidelines, the operating CSM wells in the Camden/Wollondilly area were a mixture of manually and automatically controlled wells (configurations 1 and 2). The automatically controlled well configuration 3 has been proposed as being representative of a typical future well configuration.

<sup>5</sup> These descriptions are provided solely for categorisation within these guidelines. They do not represent a formal definition of a particular CSM well type.

flexibility in the implementation of the guidelines may be warranted in some cases. In particular:

- These guidelines have been developed on the basis of a generalised risk analysis to facilitate assessment of site suitability. However, if a developer considers that a variation in the size of the separation distance may be justified, a case specific risk analysis may be undertaken to support any such variation from the guidelines. This may apply to situations in which the existing or future operating CSM well equipment and/or operations differ significantly from the guideline assumptions.
- Any such analysis should demonstrate that an equivalent level of safety to that provided by the guidelines will be achieved without there being a need to modify the CSM well design or operation.
- If a proposal does not entirely comply with the guidelines, it may be reasonable for the development to be approved if the consent authority considers that the associated risks are outweighed by the benefits of the specific development and additional mitigating measures to offset the risk are feasible.
- Because these guidelines are specifically for residential and sensitive use development on land in the vicinity of existing and future operating CSM wells, case specific analysis should be used for other types of development in the vicinity of the wells and for development in the vicinity of other CSM facilities, such as gas treatment facilities, that may pose a risk to surrounding development not addressed in these guidelines.

## 2 Locational Guidelines

### 2.1 General Approach

The guidelines describe the use of separation distances between development and existing or future operating CSM wells and associated equipment. Separation distances result in circular areas around existing or future operating CSM wells, within which controls should apply to development.

The guidelines also specify the technical and operational controls that must be present on each well configuration in order for the guidelines to be applicable.

Continued compliance with these guidelines may be affected by changes over time to the surrounding land uses. When considering an application for development on land in the vicinity of a gas well, consent authorities should take into account the likely future use of the land over the operating life of the gas well (which could exceed 15 years). This is of particular relevance when considering rezoning proposals.

### 2.2 Land Use Controls (Separation Distances)

There are two types of separation distances.

- A sensitive uses separation distance. Schools, hospitals, aged persons accommodation and other uses where vulnerable people are concentrated, should not be permitted within this distance from existing or future operating CSM wells.
- A residential separation distance. Dwellings or places of regular occupancy on residential properties or sensitive uses should not be permitted within this distance from existing or future operating CSM wells.

The separation distances are based on consideration of the level of risk to which individuals located closer than this distance may be exposed (see Table 6 and the discussion on page 25). They also take into account the need to ensure that the wells are adequately separated from potential ignition sources and from activities that could have a physical impact on the well and its equipment.

**Note 2: Places of Regular Occupancy**

A place of regular occupancy is an area, not necessarily a building, where people may be present on a regular basis.

There may be cases where separation distances extend onto properties or premises, but the areas are not judged to be places of regular occupancy. In such cases, development is not necessarily precluded but it may be necessary for conditions of consent to be imposed to ensure separation distances are maintained.

Consent authorities should use their judgment and may need to visit areas to assess if they are places of regular occupancy.

Development for recreational/commercial uses has not been specifically assessed in preparing these guidelines. Conservatively the residential separation distances should be applied. Alternatively, a case specific risk assessment may be carried out.

As previously noted, where existing or future operating CSM well equipment and/or operations differ significantly from the guideline assumptions, development or rezoning proposals in the vicinity should be subject to a case-specific assessment in accordance with the principles in section 1.3. In such instances, the guideline separation distances may not be appropriate.

The maximum pressures associated with CSM wells reduce over the first two years of a well's operating life. Two sets of separation distances are shown. The first is for wells in the early/intermediate stages of operation (typically up to 2 years), where the shut-in pressure can be up to 3790 kPa and the second is for established wells, in which the shut-in pressure is 1038 kPa or less (typically after two years' operation).

Table 2 shows the separation distances. They should be measured from the well head, as shown in Figure 4.

**Table 2: Separation Distances**

Well Configuration	Separation Distance (m)	
	Residential Use	Sensitive Use
<b>Early/Intermediate Operation Wells (Typically up to 2 years)</b>		
Manual	10	20
Automatically Controlled (With Separator/Optional Pump)	10	20
Automatically Controlled (No Pump/Separator)	5	10
<b>Established Wells (Typically after 2 years)</b>		
Manual	10	15
Automatically Controlled (With Separator/Optional Pump)	10	15
Automatically Controlled (No Pump/Separator)	5	8

## 2.3 Technical Controls

The hazard analysis for these guidelines was based on facilities designed and operated as described in this section and further detailed in Appendix 2. Any proposal for development in the vicinity of existing or future operating CSM wells, which are operated other than in accordance with these design features and operating controls, may be exposed to higher risk levels than those on which the guidelines are based, so that the guidelines would not be applicable. In such cases it would generally be appropriate to require a case-specific risk analysis. Alternatively, an agreement may be reached with the CSM well operator to modify the well's configuration and/or operation to achieve consistency with the guideline parameters.

As part of the development application, the applicant should provide written, specific advice that the relevant gas well has been designed and is being operated within the guideline parameters. Councils need to be satisfied that this is so before determining an application for residential or sensitive use development. Alternatively the application may be determined on the basis of a case-specific assessment of the risks, in accordance with the principles of section 1.3.

### 2.3.1 All Well Types

Irrespective of location, existing and future operating CSM wells are assumed to have the following design features and operational safeguards:

#### 2.3.1.1 Well Configuration

The basic well configuration is set out in Figure 1. Equipment, piping and instrumentation are assumed to meet the characteristics detailed in Appendix 2 (page 19 and following). In a number of cases, design pressure ratings are significantly above expected operating pressures. This reflects a degree of conservatism in the existing designs on which the risk assessment underlying these guidelines has been based.

In particular, to be consistent with the assumptions used in the guidelines:

- The well head collar should have a pressure rating of at least twice the maximum shut-in pressure.
- The separator, if fitted should have a design pressure rating at least equal to the maximum operating pressure of the gathering system (typically 850 kPag).
- The pump, if fitted, should have an automatic pump shutdown device fitted to stop the pump running in the event of it becoming “dead headed”.
- A Blow-Out Preventer (BOP) should be fitted to the well head during workover operations.
- A PSV (Pressure Safety Valve) should be installed on the separator, if fitted (as shown in Figure 1 and Figure 2), or otherwise directly on the pipeline (as shown in Figure 3). It should be set to relieve at a pressure that will protect the downstream gathering system. Its capacity should be sufficient to relieve full flow from the well. The vent line should be vertical and at least 2 m above the top of the vessel (or enclosure if it is enclosed), or 3 m above ground level or any platform on which a person can stand, whichever is the higher.
- A choke valve should be fitted to limit the maximum flow from the well and reduce the likelihood of over pressurisation of the gathering system.
- A non-return valve should be installed at the end of the meter run to prevent backflow from the gathering line in the event of a major leak at the well installation.
- All electrical equipment installed at the CSM well is appropriate to the hazardous area classification.
- Appropriate protection (eg. Bollards) should be provided for all wells that are vulnerable to impact (eg. wells located adjacent to a road).

### **2.3.1.2 Procedural Controls**

Procedural controls are generally common to all well configurations, except to the extent that telemetry and automatic local or remote valve actuation is employed. In each instance, the safety management system described below must include procedures for the maintenance and regular testing of the local, remote and automated systems.

The main procedural requirement is that operation of the wells should be covered by a safety management system (SMS) prepared in accordance with *Hazardous Industry Planning Advisory Paper (HIPAP) No 9: Safety Management*. The SMS should encompass all equipment and personnel relevant to the operation of the CSM facilities. A common SMS may be appropriate to several wells.

The following procedural controls, which have been assumed in carrying out the risk assessment that forms the basis of these guidelines, need to be present in the form of written, verifiable procedures:

- retesting of each relief valve after it has been activated and, as per AS/NZS 3788:2001 (Section 4.6.6.2 – Scheduled Testing and Maintenance), at periods not exceeding the internal inspection period of the vessel;
- scheduled visual inspection of pressure piping and fittings;
- 6-monthly soap leak testing;
- an ultrasound thickness testing program for fittings;
- external inspection via non-destructive test (NDT) of the separator, where fitted, as per AS/NZS 3788:2001 (Table 4.1 (10.2));
- a systematic pump inspection and maintenance program, where fitted, paying particular attention to pump seal integrity;

- a systematic maintenance and testing program for all local and remote monitoring and control systems;
- pre-startup purging of all lines and equipment to eliminate the presence of oxygen;
- safe work practices (e.g. hot work permit system) to ensure that ignition sources are appropriately controlled during maintenance, equipment testing, etc.; and
- a job safety analysis (JSA) or equivalent must be performed before carrying out each workover operation.

### **2.3.2 Manually Controlled Wells**

The basic well configuration and procedural controls should be generally as set out in section 2.3.1. Specific configuration features and control requirements of this configuration are:

- a manual shutdown valve to isolate the well; and
- local pressure and flow indication.

The wells may optionally be fitted with a pump and/or separator, depending on need. Fittings are as shown in Figure 1. Pumped wells operate at significantly lower pressures than free flowing wells.

### **2.3.3 Automatically Controlled Wells (With Separator/Optional Pump)**

The basic well configuration and procedural controls should be generally as set out in section 2.3.1. Specific configuration features and control requirements of this configuration are:

- remote and local pressure and flow indication;
- a water separator;
- remotely and automatically actuated shutdown valve to rapidly isolate the well under defined emergency or abnormal operating conditions; and
- fire detection (fusible loop) linked to the emergency isolation valve.

As noted above, there must be documented procedures for the maintenance and testing of all parts of the monitoring and control system.

These wells may optionally be fitted with a pump, depending on need. Fittings are as shown in Figure 2.

### **2.3.4 Automatically Controlled Wells (No Pump/Separator)**

The basic well configuration and procedural controls should be generally as set out in section 2.3.1. Specific configuration features and control requirements of this configuration are:

- no pump or separator;
- remote and local pressure and flow indication;
- remotely and automatically actuated shutdown valve to rapidly isolate the well under defined emergency or abnormal operating conditions; and
- fire detection (fusible loop) linked to the emergency isolation valve.

As noted above, there must be documented procedures for the maintenance and testing of all parts of the monitoring and control system. Fittings are as shown in Figure 3.

## 2.4 Implementation

### 2.4.1 Initial Evaluation

In considering rezoning for future residential development or an actual development application, a consent authority should use the categorisation basis described in section 1.2 to determine which category (stage of operation and well configuration) would apply to any relevant existing and future operating CSM wells, whose separation distances would extend into the development area.

Once this has been done, it will be necessary to gather information about any CSM wells so identified. It is the proponent's responsibility to identify possibly impacted areas of the development and to gather the information from the CSM well operator needed to establish compliance of the proposed rezoning or development with these guidelines.

### 2.4.2 Rezoning or Development Application Requirements

As part of their submission to consent authorities, applicants should provide the following information.

- An appropriately scaled land use plan showing the area proposed for development or rezoning, together with the proposed or actual location of any residential buildings or places of regular occupancy. It should show the location of any relevant operating CSM well installations and outlines of all buildings and other places of regular occupancy within the minimum guideline separation distance(s) of the well(s). The existing use of the buildings should be shown on the drawings. Separation distances, which should be measured from the well head (as shown in Figure 4) to relevant places of regular occupancy, should be shown on the drawings. Plans and associated documentation should clearly show the category of well on which the separation distances are based.
- A schematic diagram should be provided of all operating CSM wells whose separation distances extend into the area or property proposed for rezoning or development. The diagram(s) should show the arrangement of piping, valving, instrumentation and equipment as well as clearly identifying the type of configuration. Any aspects of the installation which differ significantly from the typical configurations shown in Figure 1, Figure 2 and Figure 3, as appropriate, should be highlighted.
- The application should confirm that the operating CSM wells in proximity to the proposed development have configurations and controls consistent with the technical controls on which this guideline is based.
- It may be appropriate to impose conditions of development consent to ensure that places of regular occupancy do not extend to within the relevant separation distances from the operating CSM wells.

## 3 Guideline Basis

These guidelines are based on systematic hazard identification and quantified risk assessment of typical existing and future operating CSM well installations. The application of the guidelines' land use and technical controls should ensure that development in the vicinity of existing and future operating CSM well installations having design and operational controls consistent with the configurations described in these guidelines will not be exposed to an unacceptable level of risk.

Wherever quantities of flammable gases such as CSM are stored or handled, there is the possibility of a hazardous incident.

While technical controls, engineering safeguards, design standards and operating procedures are used to limit the likelihood and consequences of incidents, it is impossible to entirely eliminate risk.

The types of incidents which are of concern for CSM installations are those involving fire or explosion. In order for these events to occur there are two requirements - loss of containment of CSM and ignition. Gas can be released due to equipment failure or maloperation.

Typical examples of initiating release scenarios are:

- leaks during routine operation from fixed piping, valves, pumps or the separator vessel due to equipment failure, mechanical damage or pressure fluctuations; and
- leaks during maintenance or workover operations.

Depending on the circumstances of the release, the following outcomes could occur:

- Jet fires: these result from the ignition of a continuous release of CSM, producing a long stable, high temperature flame. Jet fires are the main risk contributors.
- Flash fires: this occurs when a cloud of CSM vapour is ignited, resulting in a flame travelling through the cloud.
- Vapour Cloud Explosion (VCE): If, prior to ignition, the released cloud is large or there is a high degree of confinement, an explosion may occur, although this is very unlikely. While the effects of the flash fire are largely limited to the area within the cloud, an explosion can have far reaching effects. Because mass release rates from a CSM well are relatively low, the potential for formation and ignition of a large gas cloud is limited. Although theoretically possible, analysis has shown that a VCE associated with a CSM release from a gas well is not a credible event.

The worst case event considered in the risk assessment is a flash fire from a release of gas from a large hole at the well head before the choke valve, during a period of well shut-in. In the near field, jet fires are the main risk contributors.

The methodology used in the development of these guidelines involved:

- a review of the design, layout and operating procedures currently in use within the industry;
- a review of CSM well studies previously carried out in NSW;
- an identification of the possible hazardous incidents;
- modelling and analysis of incident consequences;
- analysis of safeguards and controls;
- analysis of the likelihood of initiating events and of outcomes;
- the quantification of risk levels, and

- the assessment of the tolerability of the resultant risk.

To assess the acceptability of a particular development, the risk imposed by an installation can be quantified and compared with established risk criteria. These levels of risk represent the limit of acceptability for various situations.

They are set to ensure that additional risks imposed upon development on surrounding land are negligible compared to the risks of everyday life.

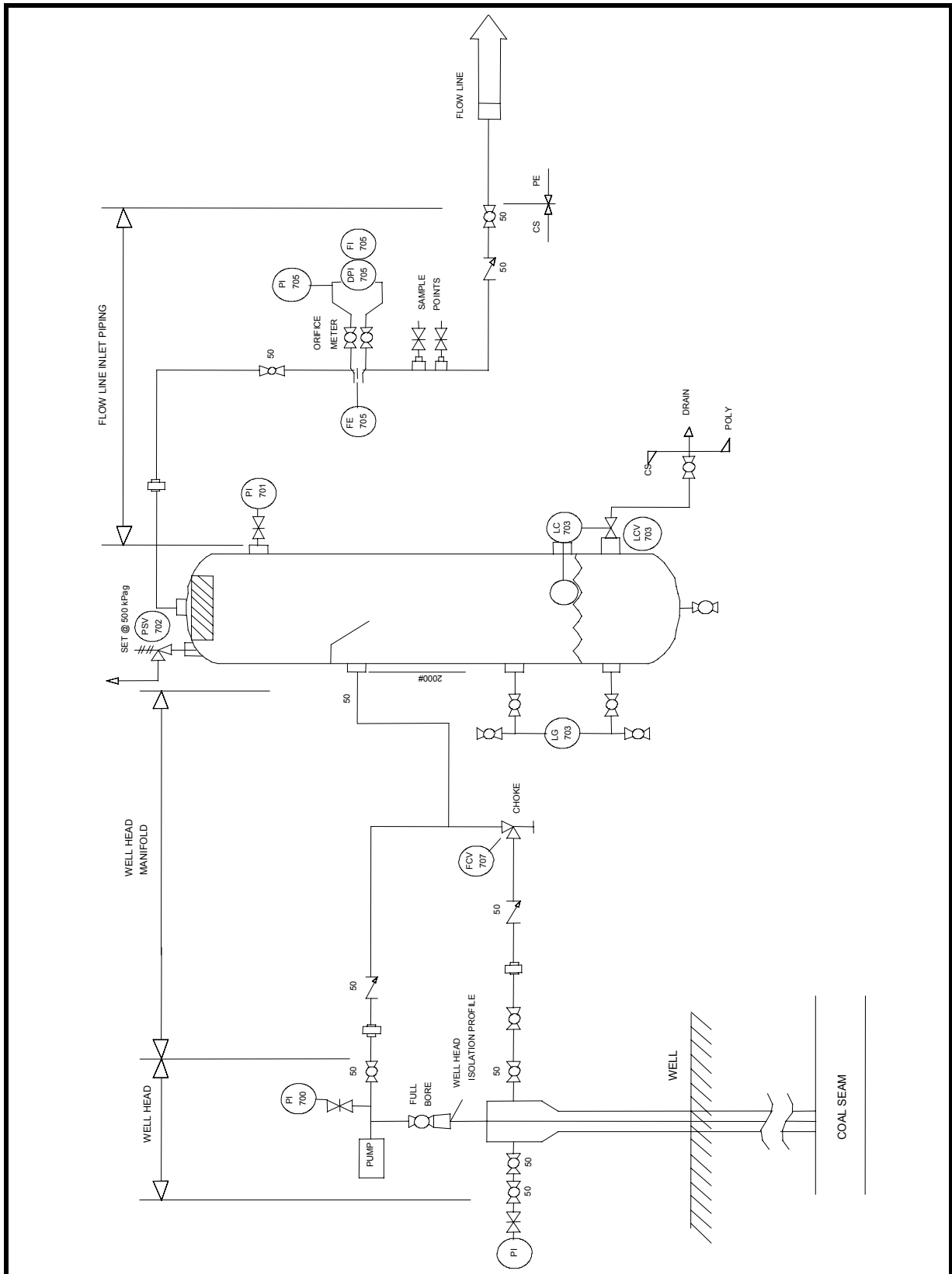
A general description of the methodology used is given in *Hazardous Industry Planning Advisory Paper (HIPAP) No. 6: Guidelines for Hazard Analysis*. A more detailed description of the assumptions used and the outcome of the analysis are given in the Technical Supplement to this guideline (Appendix 2).

*Hazardous Industry Planning Advisory Paper (HIPAP) No. 4: Risk Criteria for Land Use Safety Planning* sets out the risk criteria adopted for determining the acceptability of risks to surrounding land uses from potentially hazardous facilities. These criteria are generally applicable to both existing and proposed facilities and were considered in setting appropriate development controls for these guidelines, as noted in the Technical Supplement (Appendix 2).

# Appendix 1

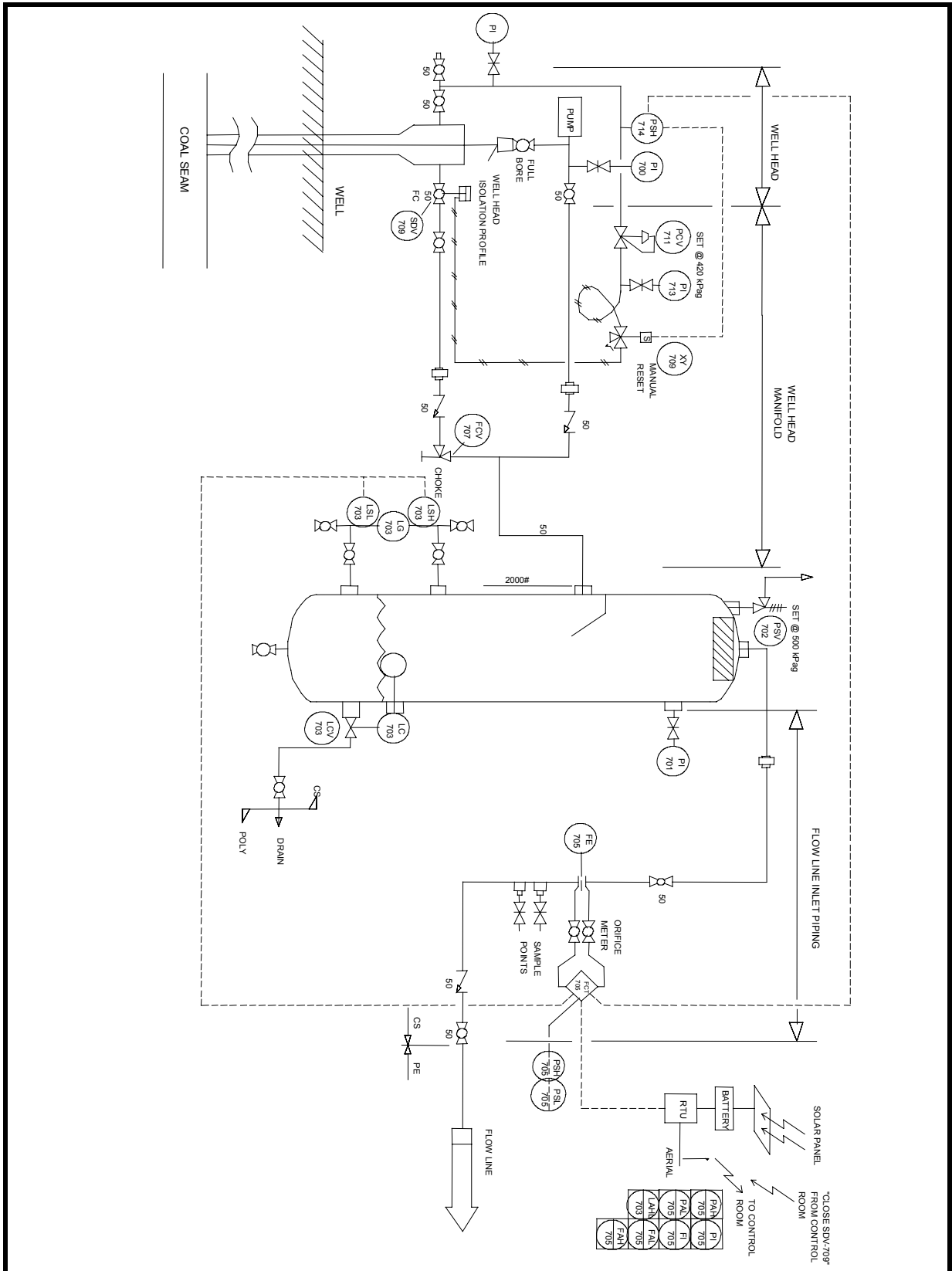
Figures

Figure 1: Manually Controlled Well



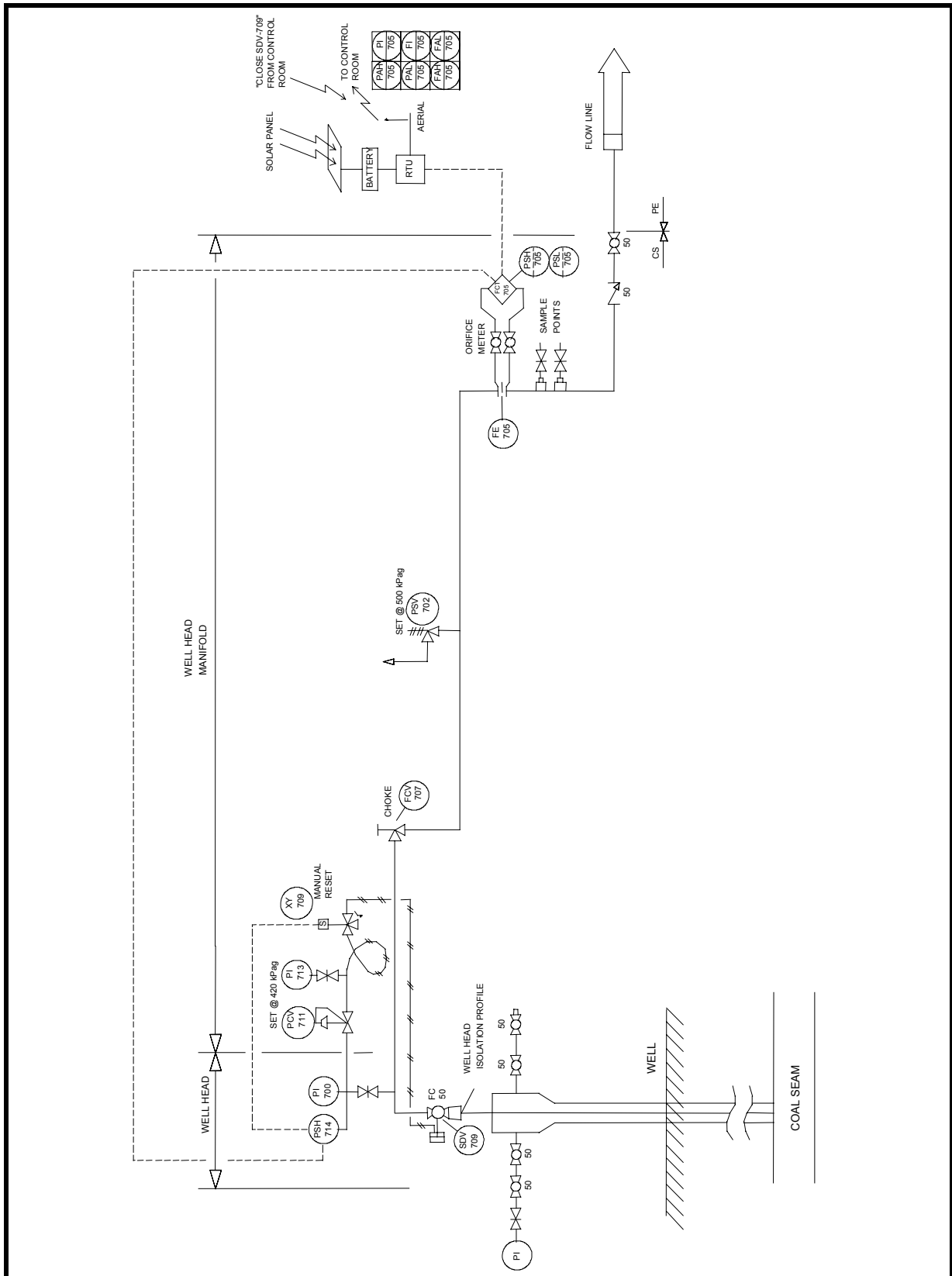
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Figure 2: Automatically Controlled Well (With Separator/Optional Pump)



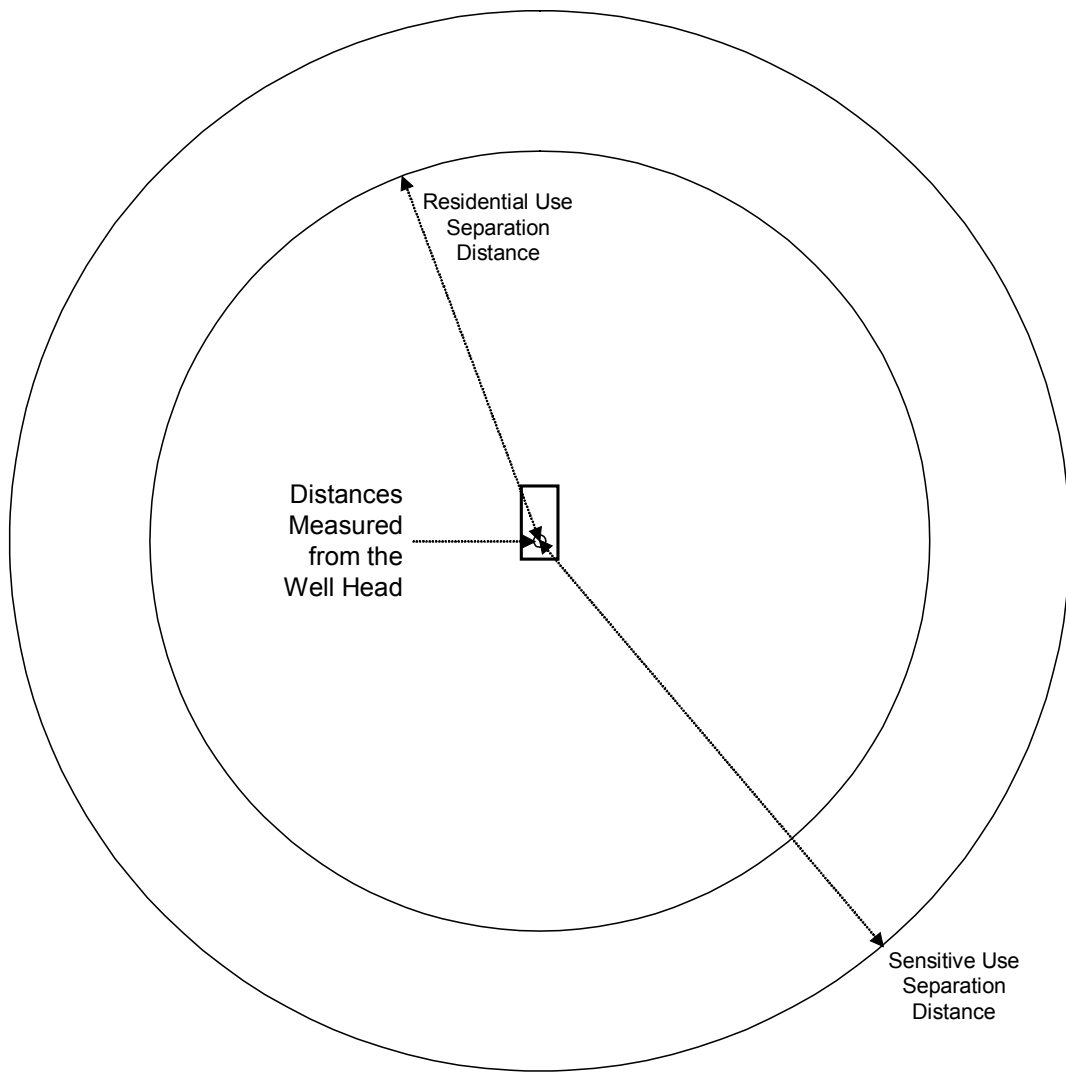
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Figure 3: Automatically Controlled Well (No Pump/Separator)



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**Figure 4: Representation of Separation Distances**



NOT TO SCALE

# Appendix 2

## Technical Supplement

This supplement gives further information on the basic assumptions used in carrying out the hazard analysis of typical CSM installations and formulation of the locational guidance. It covers the following aspects:

- General Process Description
- Design Assumptions and Operational Safeguards
- Hazard Identification and Risk Assessment

### General Process Description

#### Drilling and Commissioning

A well is drilled intersecting the target coal seam formations. Steel production casing is then installed and cemented in place, providing zonal isolation between the formations. The target coal seams are then perforated allowing access to the coal seam. Hydraulic fracturing (fracking) of the coal can now be accomplished by pumping water and sand down the production casing and into the coal seam.

This operation either produces new fractures or forces the pre-existing cracks and fractures in the coal seam to enlarge and extend. The coal is fractured in a number of directions for distances of up to several hundred metres from the well bore. These fractures deep in the coal seam are less than one centimetre wide, and have no effect on the ground surface.

The water is then pumped out, reducing the pressure and leaving the sand in the small fractures. The sand prevents the fracture from completely closing up, thereby acting as a conduit through which the gas flows to the well bore.

Once the drilling of the CSM well has been completed, a small amount of equipment is installed on the surface and the surrounding area is rehabilitated.

***These initial drilling and commissioning operations are excluded from the scope of the guidelines, as is any subsequent re-fracking of the well<sup>6</sup>.***

#### Ongoing Operation

CSM is allowed to flow from the well through the well head piping and equipment into underground gathering lines (low pressure pipes) to a treatment plant where any excess water is removed, the quality is regulated and the gas is compressed. ***The transfer of gas through the gathering lines and its subsequent treatment are excluded from the scope of the guidelines.***

Gas production is dependent on the thickness of the coal seam(s) intersected, gas content, permeability or ability for the gas to flow, depth of the coal seam and purity of the gas. CSM in the Camden region of the Sydney Basin typically contains over 95% methane. Therefore, it generally requires less processing than conventional natural gas.

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<sup>6</sup> Re-fracking is considered an unlikely operation. Any re-fracking operations should be subject to a case-specific assessment.

Depending on the nature of the well and its location, a different site layout and arrangement of equipment<sup>7</sup> is used. The various arrangements are shown on Figure 1, Figure 2 and Figure 3.

In a free flowing well without pump or separator, the gas passes from the well head through a shutdown valve then through a choke valve to limit the downstream pressure and flow. From the choke valve, the gas passes along a meter run containing an orifice plate and flow meter and finally through a non-return valve into the gathering line.

Figure 1 and Figure 2 show the flow path when a separator and optional pump are fitted. Figure 1 represents manually controlled wells, while Figure 2 shows the automatic controlled well arrangements.

Table 3 shows the typical pressures in various parts of the system. It may be noted that the operating pressures of pumped wells are significantly lower than those of free flowing wells.

### **Maintenance Activities**

In addition to ongoing daily monitoring of well operation (manually or by telemetry) there are a number of periodic maintenance activities designed to maintain the integrity of the equipment and systems. These include:

- regular visits by production personnel during the workover operations and additional drilling operations to monitor equipment operation, to record gas flow rates and pressures for locally monitored and manually controlled wells;
- retesting of each safety relief valve, as per AS/NZS 3788:2001;
- three-weekly visual inspection of the well if the technical parameters of the well can not be monitored remotely;
- 6-monthly soap leak testing of the pressure piping;
- inspection and pump maintenance (where fitted);
- non destructive testing (NTD) of the separator (where fitted), as per AS/NZS 3788:2001; and
- an ultrasonic thickness testing program for fittings.

### **Workover Operations**

These guidelines are relevant to only those workover operations, which are performed during the life of the well to address such issues as cleaning the production casing, changing the depth of the production tubing, etc. The initial workover operations to prepare the well for production are not within the scope of the guidelines.

Although the frequency of the workover operations is very low, they are potentially hazardous and require close attention. For the purpose of the risk assessment one workover operation per year has been assumed.

Subsequent to the hydraulic fracturing operation (fracking), the production casing requires washing to the total depth of the casing to circulate frac sand/fill from the well. This post frac workover operation may be performed during the well life and is achieved by running small bore tubing from a workover rig into the production casing. A high-pressure pump is then used to pump fresh water down the tubing.

### **Wireline Operations**

During this operation measuring equipment is run into the well to record changes in technical parameters of the well with time.

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<sup>7</sup> The technical characteristics of the equipment are included under the heading "Equipment Specifications and Operating Conditions".

### Well Isolation

The wells are assumed to be isolated (shut-in) each year for 10 days, for example, during shut down of the treatment plant. The pressure in the well will rise to a maximum of 3790 kPa (early/intermediate stages of well operation) over a period of 24 hours and remains at that level until subsequent start up. For established wells (after about two years), the maximum pressure will typically be 1038 kPa, as shown in Table 3.

## Design Assumptions and Operational Safeguards

This section describes the design basis on which hazard identification and risk assessment have been carried out. It provides a brief overview, followed by a description of the general arrangement of equipment, telemetry, specification of key equipment, and design and operational safeguards.

### General

As noted in section 1.2, three representative well head configurations have been selected on the basis of information provided by Sydney Gas Ltd. These are:

1. **Manually Controlled Wells** – pumped or free flowing wells (with or without pump/separator), manual well controls and a flow meter and pressure indicator (local reading).
2. **Automatically Controlled Wells (With Separator/Optional Pump)** - pumped or free flowing wells, with separator (with or without pump), remote well monitoring and control and fire detection (fusible loop) with automatic well isolation.
3. **Automatically Controlled Wells (No Pump/Separator)** – free flowing wells, without separator, with remote well monitoring and control and fire detection (fusible loop) with automatic well isolation.

Table 3 shows the operating pressures of typical wells at various stages of their operating life.

**Table 3: Well Operating Pressures**

Well and Operating Stage	Absolute pressure (psi)	Absolute pressure (kPa)
Free flowing well, up to variable choke (early operation)	max 120 psi	830 kPa
Free flowing well, up to variable choke (after 6 months)	max 100 psi	690 kPa
Free flowing well, up to variable choke (established - typically after 2 years)	max 60 psi	414 kPa
Pumped well, up to variable choke	max 40 psi	275 kPa
Any well, from the variable choke (i.e. with the meter run and the gathering lines) <sup>8</sup>	max 72 psi	500 kPa
Shut-in well (start of operation)	max 550 psi	3790 kPa
Shut-in well (after 6 months)	max 250 psi	1730 kPa
Shut-in well (after two years)	max 150 psi	1038 kPa

For the purpose of the risk assessment, two stages of well life have been considered: **early/intermediate operation** (shut-in pressure up to 3790 kPa) and **established** (shut-in pressure of 1038 kPa or less).

<sup>8</sup> For older wells, once the pressure immediately before the variable choke falls below 500 kPa, the pressure after the variable choke will fall correspondingly.

For the purpose of applying land use controls, separation distances applying to the early/intermediate operation period should be applied until operating conditions reach those of an established well.

## Equipment Arrangement

### *Manually Controlled Well*

This is the base configuration, with manual operation and local instrumentation. The equipment layout is shown in Figure 1. The key components are:

- a well head collar, which connects the well casing and tubing to the aboveground piping and equipment;
- a pump (optional), which pumps water from the bottom of the well, thus allowing free gas flow, may be installed at the well head;
- a separator (optional) to separate the water from the gas. The separator is connected to a water tank. The process of dewatering depends upon the nature of the well. The separator is disconnected and removed after completion of the dewatering;
- a meter run (flow meter) to measure the gas volumetric rate produced by the well – manual reading; and
- a **manual shutdown valve** to isolate the well.

Equipment common to the configurations include a **choke valve** and **non-return valve** to limit maximum flow from the well and prevent backflow, and a **gathering line**. A **pressure relief valve**, relieving to atmosphere, is installed at every well to protect the gathering line (and separator, if fitted) from over pressurisation.

The technical parameters of all equipment, used in the different operational scenarios, are included below under the heading “Equipment Specifications and Operating Conditions.”

### *Automatically Controlled Well (With Separator/Optional Pump)*

This is similar to the manually monitored configuration but with more sophisticated instrumentation and provision for remote isolation of the well. The equipment layout is shown in Figure 2. The key components are:

- separator, as per the previous case;
- pump, if necessary, as per the previous case;
- telemetry system for remote monitoring of the technical parameters (flow rate and pressure) and remote shutdown of the well; and
- automatic shutdown of the well. The system is triggered locally or remotely by abnormal well-head conditions (pressure or flow outside specified limits) or a detected emergency situation (fusible link).

### *Automatically Controlled Well (No Pump/Separator)*

This is similar to the previous configuration but there is neither a pump nor a separator. The equipment layout is shown in Figure 3.

## Telemetry System

The aim of the telemetry system is to acquire flow and pressure data from each well and transfer this information to a control room for analysis. This system can be utilised for remote monitoring and shutdown of wells and facilitates rapid response to a hazardous situation or event. The system provides for the following:

*Data transferred back to control centre:*

- flow rates;

- pressure; and
- high and low separator liquid levels.

*Automatic & Remote Controls:*

- high and low level switches in separator, if tripped, result in the automatic shutdown of the well and activate alarms at the control room; and
- remote closure of valves, to enable wells to be shutdown from the control room for reasons such as:
  - reduced gas demand;
  - well, gathering and plant operational reasons, i.e. hi/low pressure; and
  - environmental reasons, i.e. bush fires, flood etc.

### Equipment Specifications and Operating Conditions

Typical design and operating characteristics of key components of the gas well installation are described below.

1. The **well head** collar connects the well casing and tubing to the aboveground piping and equipment, which may include a separator, meter run, pumping unit and pressure and flow measuring and control instrumentation. It is designed to withstand at least twice the maximum shut-in pressure of the well. It typically has a pressure rating of 13800 kPag, which gives a considerable safety margin above the shut-in pressure of the well, as shown in Table 4.
2. **Separator:**

Design Pressure	850 kPag
Design Temperature	50° C
Diameter	400 mm

The separator operates in pressurised gas service and operates between 140 kPa and 500 kPa. The design pressure matches the pressure rating of the polyethylene gathering line. It is connected to a water tank, which is emptied as required.

3. The **meter run** consists of piping containing an orifice plate connected to a gas flow meter. Meter runs are constructed from Schedule 80 pipe.
4. The **pump** (optional) is used to pump water from the bottom of a well that is not free flowing (a pump is the exception rather than the rule). It is fitted with an automatic shutdown device to stop the pump running in the event of it becoming over-pressurised (“dead-headed”).
5. A **PSV** (Pressure Safety Valve) is installed on the separator (if a separator is part of the equipment) or otherwise directly on the pipeline. The design pressure of the separator is 850 kPag and the PSV is set to relieve at 500 kPag (or at the design pressure of the separator, whichever is the lower) to protect the piping downstream of the choke valve, including the gathering line. The vent line is vertical and at least 2 m above the top of the vessel (or enclosure if it is enclosed), or 3 m above ground level or any platform within the vicinity where someone can stand, whichever is the higher. There is no PSV upstream of the separator, as the well head and manifold equipment are pressure rated to withstand the maximum shut-in pressure of 3790 kPa.
6. The **choke valve** is a manually operated valve designed to limit the maximum flow from the well.
7. A **non-return valve** is installed at the end of the meter run to prevent backflow from the gathering line in the event of a major leak at the well installation.
8. **Operating pressures** are typically as shown in Table 3.

Table 4 shows the diameter and typical pressure rating of the well head and associated piping:

**Table 4: Piping Characteristics**

	<b>Materials of Construction</b>	<b>Diameter, ID [mm]</b>	<b>MAOP [kPa]</b>
Well Head Piping	Steel	125	13800
Top section of well casing	Steel	140	13800
Piping from the choke valve to the gathering line	Steel	50	850
Gathering line	Polyethylene	90-110	850

A typical high performance well will generate a gas flow of 500 m<sup>3</sup>/h. Flow meters are installed on each well head so that the flow rate of an individual well can be determined and used to select the most appropriate PSV.

The steel pressure piping upstream of the choke valve is designed to withstand 13800 kPa. The maximum actual pressure upstream of the variable choke is experienced when the well is shut-in. For an early operation well this is 3790 kPa but this progressively reduces to 1038 kPa, as shown in Table 3.

The polyethylene gathering line is designed for a maximum design pressure of 850 kPa (normal operation between 140 kPa and 500 kPa). It is tested prior to operation.

### Operational Safeguards

A number of operational and procedural safeguards need to be in place to ensure the ongoing integrity of the installation. The following safeguards have been taken into account in the risk assessment:

1. Against failure of the safety relief valve :
  - a. Once the system pressure has fallen below its set point, the PSV will reset after operation, thus continuing to protect the equipment and preventing a continuous gas release; and
  - b. the operating practices require retesting of each relief valve.
2. Against leak from the pressure piping and associated fittings:
  - a. three-weekly visual inspection;
  - b. 6-monthly soap leak testing; and
  - c. ultrasound thickness testing program for fittings, as determined by the safety management system (SMS).
3. Against leak from the separator - non-destructive testing (NDT).
4. Against confined space explosion:
  - a. in the separator (during start-up, shut-down and maintenance operations) due to the presence of oxygen:
    - i. prior to start-up the whole equipment is purged to eliminate the presence of O<sub>2</sub>.
  - b. in the water tank due to presence of methane (in case of a failure in the water dump valve):
    - i. the tank is vented to the atmosphere;
    - ii. it is located within the fenced off area of the pump well; and
    - iii. warning signage is displayed.
5. Against failure of the pump:
  - a. leak at pump seal or hole in the pump casing (due to corrosion or erosion) – included in the three-weekly visual inspection; and
  - b. overpressure (e.g. dead heading) – the well is fitted with automatic shut-off device which will stop the pump.
6. During workover operations:

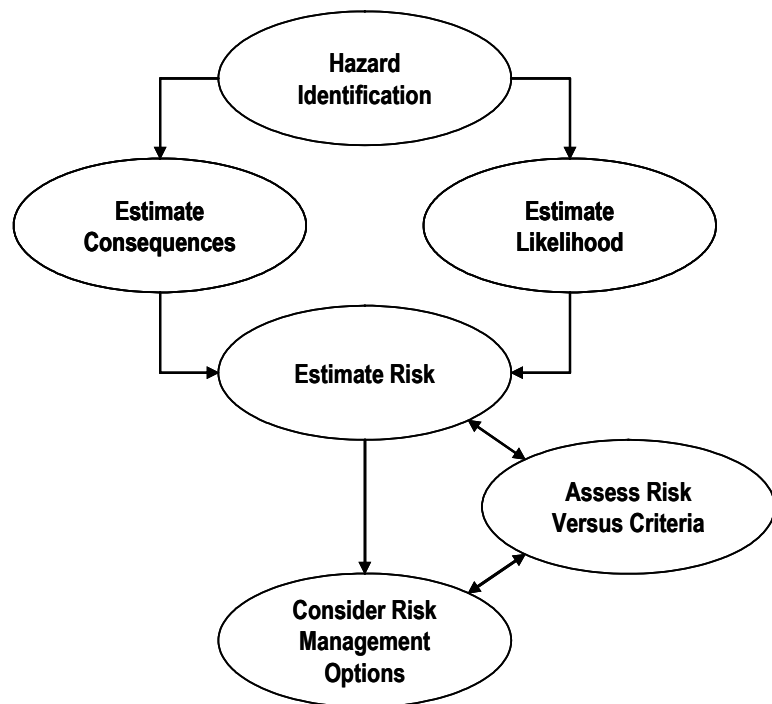
- a. against release of pressurised water and CSM during maintenance at pumping well – a blow-out preventer (BOP) is fitted to the well head; and
- b. a job safety analysis (JSA) is performed before carrying out each workover operation.

## Hazard Identification and Risk Assessment Study

### Methodology

The Quantitative Risk Assessment procedure used for this study is described in *Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis*. The procedure is conceptually depicted in Figure 5.

**Figure 5: Risk Analysis Process**



For each activity, the possible initiation, development and consequences of incidents, as well as any mitigating factors, were systematically considered. Hazard identification techniques included drawing on past experience, reviews of previous studies and discussion with a CSM well operator and independent consultants.

Consequence calculations were carried out on each of the significant incidents considered during the hazard identification process. This involved estimating the effects of explosions and fires from CSM releases. Analysis of the results of these calculations provided a further refinement of the hazard identification process and assisted in directing detailed analysis towards those events with significant risk potential.

Frequency estimation involved consideration of historical accident and equipment failure rate data from various sources. Historical failure rate data were checked to ensure that their sources were consistent with the operations being studied.

Risk calculations were performed using a set of computer programs known as SAFETI. The programs were used to calculate the consequences of the identified failures and combine this information with the likelihood of each failure occurring to produce detailed estimates of the overall risk.

The results of the risk calculations were translated into the locational guidance information presented in this document. Evaluation of risk impacts was based on the criteria provided in *Hazardous Industry Planning Advisory Paper No. 4: Risk Criteria for Land Use Safety Planning*.

### **Identified Hazards**

As indicated in section 3, above, the types of incidents which are of concern for CSM installations are those involving fire or explosion. In order for these events to occur there are two requirements - loss of containment of CSM and ignition. Gas can be released due to equipment failure or maloperation.

Typical examples of initiating release scenarios are:

- leaks during routine operation from fixed piping, valves, pumps or the separator vessel due to equipment failure or mechanical damage; and
- leaks during maintenance or workover operations.

Depending on the circumstances of the release, the following credible outcomes could be expected:

- jet fires: these result from the ignition of a continuous release of CSM, producing a long stable, high temperature flame; and
- flash fires: these occur when a cloud of CSM vapour is ignited, resulting in a flame travelling through the cloud.

A review of on-line incident databases identified four examples of CSM well incidents since June 2000 involving gas release and a subsequent fire. All four incidents occurred in the United States. The injuries reported in these examples have been to personnel working at the well (e.g. when conducting start-up operations or well maintenance activities) rather than to any surrounding residents etc.

The various leak scenarios may be categorised according to their location, as discussed in the following paragraphs.

### ***Piping and Fittings***

Piping may be operated at pressures up to 3790 kPa (shut-in early operation well). Pressure piping and associated joints may fail as a result of erosion, corrosion, pressure surge or mechanical impact. Erosion and corrosion will typically cause small leaks but pressure surge and mechanical damage may lead to larger holes, through to complete line fracture. Releases from a pressure relief valve may be caused by failure of the valve itself or through the line pressure rising above the set pressure of the valve, for example through incorrect operation of the choke valve.

### ***Pump***

Gas well pumps may leak in three ways:

- The pump seal may fail;
- The pump casing may develop a hole due to corrosion or erosion; or
- The pump shaft may fail, resulting in a hole size equal to the shaft diameter.

However, gas leaks from pumped wells tend to be much smaller than for free-flowing wells, because of the significantly lower operating pressure (see Table 3).

### ***Separator***

The separator (design pressure 850 kPag) operates at pressures up to 500 kPag. Leaks may arise from the separator for the same reasons as described for piping. Additionally, if the separator pressure is allowed to rise above its design pressure, the pressure relief valve will operate to protect the separator and the polyethylene gathering line.

### Representative Failure Cases

For the purpose of carrying out the risk assessment, the possible modes of failure can be grouped by representative hole sizes and pressures. Two cases have been considered for each well configuration, corresponding to a early/intermediate operation free-flowing well with a shut-in pressure of 3790 kPa and an established well (typically after two years) with a shut-in pressure of 1038 kPa.

Although similar representative failure cases have been considered for each well configuration, the CSM release rates vary because of the different shut-in and operational pressures. For the selected representative failure cases, the initial CSM release rates range from 0.02 to 73 kg/s for early/intermediate operation free-flowing wells and 0.01 to 19 kg/s for established wells.

### Consequences and Impacts

A CSM release may give rise to a jet fire or to a flash fire. The consequences to people who may be exposed depend on the duration of exposure and their distance from the fire. Flash fires, by their nature are of short duration. For jet fires, where heat flux levels are greater than those which would be expected to cause injury ( $4.7 \text{ kW/m}^2$ ), it is assumed that people are present throughout the duration of the release.

The conventions used in calculating the consequences and impacts of jet or flash fires are shown in Table 5. They are consistent with the guidance in *Hazardous Industry Planning Advisory Paper (HIPAP) No 4: Risk Criteria for Land Use Safety Planning*.

**Table 5: Consequences and Impacts of Flash and Jet Fires**

Event and Impact	Criterion
Jet Fire – Fatality	The modelling on which these guidelines are based uses heat flux as the criterion with a flux of $12.5 \text{ kW/m}^2$ corresponding to a probability of fatality of 0.7.
Flash Fire - Fatality	100% of people within a gas cloud of concentration greater than 0.5 times the Lower Flammable Limit (LFL).

In estimating the size of flammable gas clouds, typical calculation end points are LFL or 0.5 times the LFL. For this analysis 0.5 times the LFL has been used. This conservative value allows for the effects of imperfect mixing, which may give local concentrations higher than those predicted by dispersion monitoring.

Some events may have consequence distances that extend beyond the well-head area. However, after frequency of occurrence, directional effects and ignition probability have been taken into account, they may not contribute significantly to the cumulative individual risk of fatality at that location.

A representative range of meteorological conditions was used in the modelling.

### Likelihood of Hazardous Events

In calculating the likelihood of the consequences arising out of the representative failure cases, three factors need to be considered:

- the basic failure rate of each type of failure (eg the likelihood of a particular hole size per metre of piping);
- the overall failure rate applicable to the case, taking into account piping lengths and equipment configuration; and
- the probability that a gas release will lead to a jet fire or flash fire.

The failure rate data used in the analysis was checked by DIPNR against a number of sources to ensure its validity. Particular care was taken to ensure that the data used are appropriate to apply to CSM well facilities.

### Overall Risk Results

Individual risk is a measure of the likelihood of a given outcome at a particular location (in this case the death of any person who may be at that location). The risk results were compared with the relevant risk criteria from HIPAP No 4, as summarised below in Table 6.

**Table 6: Selected Individual Fatality Risk Criteria**

Land Use	Suggested Criteria (risk per million per year)
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open space	10

Separation distances for various types of land use have been derived by setting the separation distance equal to the radius of the relevant fatality risk contour, taking into account sensitivity issues, as shown in Table 7.

**Table 7: Separation Distances**

Well Configuration	Separation Distance (m)	
	Residential Use	Sensitive Use
<b>Early/Intermediate Operation Wells (Typically up to 2 years)</b>		
Manual	10	20
Automatically Controlled (With Separator/Optional Pump)	10	20
Automatically Controlled (No Pump/Separator)	5	10
<b>Established Wells (Typically after 2 years)</b>		
Manual	10	15
Automatically Controlled (With Separator/Optional Pump)	10	15
Automatically Controlled (No Pump/Separator)	5	8