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Report for **ARROW Energy Major Pipelines**

Initial Safety Management Study

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REV 0

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1. Summary

It is a requirement of AS 2885.1 to undertake an Initial Safety Management Study (Initial SMS) in the preliminary design phase for a high-pressure gas pipeline. The Initial SMS is conducted in order to determine high consequence events and their proposed controls, and to provide sufficient information to stakeholders in the process of regulatory approvals for the project.

The Initial SMS workshop for the Arrow Bowen Pipeline (ABP) was held on 25 and 26 August 2011 in the Arrow Energy offices in Brisbane. The workshop was attended by the pipeline proponents (Arrow Energy), a GIS operator (Arrow Energy) and pipeline engineers (GHD). The workshop attendance record is attached in Appendix C.

The study was based on the requirements of AS 2885.1 2007. The following parameters were considered for the study:

- Basic pipeline design parameters.
- Location Class assessments including definition of high consequence areas.
- Typical threats in typical locations.
- Location specific threats, particularly in high consequence areas.
- Radiation contours for 4.7 and 12.6 kW/m^2 in the event of full bore rupture.

The study started with a location analysis, based on pipeline route alignment established on the ABP GIS and various GIS data including aerial imagery and topographic maps of the area along the alignment.

The version of the pipeline route alignment/GIS data that was used for the Initial SMS is referred to as “Revision D”.

All KPs determined in the initial SMS workshop are correlated with the “Revision D” alignment, and are referred to as “AB” in the Arrow Energy approved designation.

The location analysis produced a list of features along the route with associated possible threats.

The threats were identified as location-specific, length-specific and overlay threats (which correspond to the whole pipeline route). Possible protective measures (both procedural and physical) and further actions were proposed which would need to be completed and finally determined in the further design and pipeline route adjustment.

The Location Class along the ABP has been designated as predominantly rural (R1).

Due to the presence of a school and kindergarten within the measurement length at AB 465, the location class is designated as T1 with a Secondary location class-Sensitive (S) at this location.

The requirements for T1, S and Industrial locations include compliance to ‘no rupture’ criteria, considering all identified credible threats, which means installation of no rupture/heavy wall pipe in these areas (refer to Appendix E). The requirements for Heavy Industrial include compliance to no rupture criteria where pipeline failure would create potential for consequence escalation. The SMS concluded that Heavy Industrial locations along the ABP were not of high consequence and as such did not warrant the ‘no rupture’ criteria.

The major general threats identified in the Initial SMS study include:

- Contour forming for agricultural land.
- Blade ploughing.
- Third party interference by excavation or construction activities.
- Failure of maintenance activities on gas and oil pipelines adjacent to the ABP.
- Mining land subsidence.
- Induced voltages from parallel overhead high-voltage power lines.

The actions resulting from the Initial SMS can be summarised as follows:

- Further investigation of land use in terms of proposed developments, power generating and industrial and mining facilities, in order to determine a potential impact on the pipeline, and assess the consequence of pipeline failure.
- Determine the areas subject to flooding and inundation through further studies and site surveys.
- Further investigate the impact that some overlay threats, in particular blade ploughing and land contouring, may have on the pipeline in order to determine the appropriate protection measures (primarily depth of cover).

The safety management study process will therefore be continued through further design and formalised within the detailed safety management study process.

The future detailed safety management study shall determine exact physical and procedural measures, assess whether these measures eliminate the threat, assign consequence and likelihood values to non-eliminated threats, determine the risk ranking and assign appropriate risk treatment actions.

2. Project Description

Arrow Energy (the Principal), is proposing to develop a pipeline network in central eastern Queensland (a copy of the route map is attached as Appendix A) that will deliver coal seam gas from its gas fields in the Bowen and Surat Basins to a proposed LNG facility to be located on Curtis Island near Gladstone.

The proposed network will be approximately 1,200 km long and will incorporate scraper stations and intermediate mainline valves.

A pipeline licence has been granted for the major part of the proposed pipeline from the Surat Basin to the facilities on Curtis Island.

No part of the proposed pipeline from the Bowen Basin has yet been assessed and this preliminary engineering is associated with the full extent of approximately 610 km of pipeline length.

The ABP system will consist of a DN800 (32”), Class 600 buried steel pipeline. For the purpose of the Initial SMS an operational case of a single pipeline, with full capacity/base load being supplied from Bowen, was considered.

This report also considers a possible future upgrade of the ABP to DN1050 (42”) pipe diameter and the pipeline design parameters are reflected in section 2.1.1 below.

However the Initial ABP SMS workshop was based on the current DN800 pipeline diameter.

A pipeline schematic drawing and the overall route map are attached in Appendix A.

2.1 Pipeline

The pipeline design parameters listed below are preliminary and are subject to change based on required gas quantities, design work in the future and outcomes from the further detailed safety management studies.

In particular:

- Potential further pipeline route optimisations and adjustments will be considered.
- The pipeline diameter has been nominated as DN800, based on different design flow cases.

For the purpose of the Initial SMS the option of DN800 pipe diameter with maximum allowable operating pressure (MAOP) of 10.2 MPa was used, as it presents a conservative case in terms of radiation contour and energy discharge rate in the event of pipeline rupture.

2.1.1 ABP Mainline

The ABP route runs from near Glenden north of Moranbah to a new Gathering Hub where the ABP intersects with the Arrow Surat Pipeline serving the Surat Basin. Preliminary pipeline design parameters used during the SMS were:

◗ Diameter	DN800
◗ Pressure Design Factor	0.8
◗ Pipe Grade	API 5L X70

Standard Wall Pipe Thickness R1/R2	10.7 mm (Notes **1**, **4**)
High Consequence Heavy Wall Pipe Thickness	12.5 mm (Notes **2**, **4, 7**)
Rail Crossing Heavy Wall Pipe Thickness	14.9 mm (Notes **3**, **4**)
Road crossing Heavy Wall Pipe Thickness	13.8 mm (Notes **3, 5**, **4**)
Pipeline Assemblies	12.8 mm (Notes **6, 7**)
Maximum Allowable Operating Pressure (MAOP)	10.2 MPa
Length	478 km approx.

Diameter	DN1050 (possible upgrade)
Pressure Design Factor	0.8
Pipe Grade	API 5L X70
Standard Wall Pipe Thickness R1/R2	14.0 mm (Notes **1**, **4**)
High Consequence Heavy Wall Pipe Thickness	14.5 mm (Notes **2**, **4, 7**)
Rail Crossing Heavy Wall Pipe Thickness	19.6 mm (Notes **3**, **4**)
Road crossing Heavy Wall Pipe Thickness	18.0 mm (Notes **3, 5**, **4**)
Pipeline Assemblies	16.8 mm (Notes **6, 7**)
Maximum Allowable Operating Pressure (MAOP)	10.2 MPa
Length	478 km approx.

For a complete list of assumptions used for the SMS and conclusion of preliminary calculations, refer to Appendix B.

Notes:

1. Based on pressure containment with Fd = 0.8. Occasional vehicle crossings and other criteria not considered.

2. Excludes design for S and T2 areas.

3. Depending on quantities required, consider rationalising the high consequence road crossing and rail crossing heavy wall materials.

4. Other wall thickness criteria, such as fatigue, not considered.

5. For designated, not occasional crossings.

6. Based on pressure containment with Fd = 0.67.

7. Depending on quantities required, consider rationalising the high consequence heavy wall and pipeline assemblies materials.

2.2 Pipeline Facilities and Stations

The pipeline facilities will comprise the following:

- Mid-point scraper station and main line valves (locations to be determined).
- Custody Transfer Metering Station at the connection to the Gas Gathering Hub.

3. Location Analysis

The location analysis is a structured assessment of the land through which a pipeline passes. The objective is to systematically identify land use and population density, providing important information on any activities that potentially pose a threat to pipeline integrity, and thus present a risk to the asset and/or the community. The location analysis determines the location class for this pipeline.

3.1 Measurement Length

AS 2885.1 requires a “measurement length” to be calculated. The land within a measurement length along the pipeline route is assessed for a particular location class.

The measurement length is the radius of the 4.7 kW/m^2 radiation contour for a full bore rupture, calculated in accordance with API RP 521. This radiation will cause injury after 30 seconds exposure.

The main determinant of radiation contour is pipeline pressure and pipeline diameter.

The radiation contour has been determined as listed in Table 1 below:

Table 1 Radiation Zones

Pipeline	Approximate Radiation Zone (m) for 4.7 kW/m^2
DN800 – 10.2 MPa (Main Line)	1,100
DN1050 – 10.2 MPa (possible upgrade)	1,250

The radiation contour zone of 1,100 m for DN800 and 1,250 m for DN1050 (possible upgrade) has been used for both the mainline and the lateral locations – for consistency. This is a conservative approach, as the laterals are likely to be of smaller diameter.

The gas composition used for the modelling was based on the coal seam methane gas composition provided for the initial SMS for the SGP.

3.2 Location Classes

Location classes as specified in AS 2885.1 Clause 4.3.4 and Clause 4.3.5 are defined below.

3.2.1 Primary Location Class

The pipeline route shall be classified into one of the Primary Location Classes R1, R2, T1 and T2 as defined below.

RURAL (R1): Land that is unused, undeveloped or is used for rural activities such as grazing, agriculture and horticulture. Rural applies where the population is distributed in isolated dwellings. Rural includes areas of land with public infrastructure serving the rural use; roads, railways, canals, utility easements.

RURAL RESIDENTIAL (R2): Land that is occupied by single residence blocks typically in the range 1 ha to 5 ha or is defined in a local land planning instrument as rural residential or its equivalent. Land used for other purposes but with similar population density shall be assigned Rural Residential location class.

Rural Residential includes areas of land with public infrastructure serving the Rural Residential use; roads, railways, canals, utility easements.

NOTE: In Rural Residential societal risk (the risk of multiple fatalities associated with a loss of containment) is not a dominant design consideration.

RESIDENTIAL (T1): Land that is developed for community living. Residential applies where multiple dwellings exist in proximity to each other and dwellings are served by common public utilities. Residential includes areas of land with public infrastructure serving the residential use; roads, railways, recreational areas, camping grounds/caravan parks, suburban parks, small strip shopping centres. Residential land use may include isolated higher density areas provided they are not more than 10% of the land use. Land used for other purposes but with similar population density shall be assigned Residential location class.

HIGH DENSITY (T2): Land that is developed for high density community use. High Density applies where multi storey development predominates or where large numbers of people congregate in the normal use of the area. High Density includes areas of public infrastructure serving the High Density Use; roads, railways, major sporting and cultural facilities and land use areas of major commercial developments; cities, town centres, shopping malls, hotels and motels.

NOTE: In Residential and High Density areas the societal risk associated with loss of containment is a dominant consideration.

In Rural and Rural Residential areas, consideration shall be given to whether a higher location class may be necessary at any location where a large number of people may be present for a limited period.

NOTE: Examples include roads subject to heavy traffic congestion and sports fields.

3.2.2 Secondary Location Class

Location classes S, CIC, I, HI and W are subclasses that may occur in any primary location class. The affected length is generally less than the length of the primary location class. Where the land use through which the pipeline route passes is identified as S, CIC, I, HI or W the requirements of the primary location class (R1, R2, T1, T2) shall be applied together with additional consideration and additional requirements established for the S, CIC, I or W location class, as follows:

SENSITIVE USE (S): The Sensitive Use location class identifies land where the consequences of a failure may be increased because it is developed for use by sectors of the community who may be unable to protect themselves from the consequences of a pipeline failure. Sensitive uses are defined in some jurisdictions, but include schools, hospitals, aged care facilities and prisons. Sensitive Use location class shall be assigned to any portion of pipeline where there is a sensitive development within a measurement length. It shall also include locations of high environmental sensitivity. The design requirements for high density shall apply.

NOTE: In Sensitive Use areas, the societal risk associated with loss of containment is a dominant consideration.

INDUSTRIAL (I): The Industrial location class identifies land that poses a different range of threats because it is developed for manufacturing, processing, maintenance, storage or similar activities or is defined in a local land planning instrument as intended for light or general industrial use. Industrial applies where development for factories, warehouses, retail sales of vehicles and plant predominates. Industrial includes areas of land with public infrastructure serving the industrial use. Industrial location class shall be assigned to any portion of pipeline where the immediately adjoining land use is industrial. The design requirements for residential shall apply.

NOTE: In Industrial use areas the dominant consideration may be the threats associated with the land use or the societal risk associated with the loss of containment.

HEAVY INDUSTRIAL (HI): Sites developed or zoned for use by heavy industry or for toxic industrial use locations shall be considered classified as Heavy Industrial. They shall be assessed individually to assess whether the industry or the surroundings include features that:

(i) Contain unusual threats to the pipeline, or

(ii) Contain features that may cause a pipeline failure to escalate either in terms of fire, or for the potential release of toxic or flammable materials into the environment.

Depending on the assessed severity the design, requirements of R2, T1 or T2 shall be applied.

NOTE: In Heavy Industrial use areas the dominant consideration may be the threats associated with the land use or a range of location specific risks associated with the loss of containment.

COMMON INFRASTRUCTURE CORRIDOR (CIC): Land defined as a Common Infrastructure Corridor (CIC), or which because of its function results in multiple (more than one) parallel infrastructure development within a common easement or reserve, or in easements which are in close proximity.

CIC classification includes pipelines within reserves or easements for roads, railways, powerlines, buried cables, or other pipelines.

NOTE: In CIC areas the dominant consideration may be the threats associated with the land use by other infrastructure operators or the higher consequences of loss of containment associated with increased transient population (e.g. roads) or other parallel infrastructure.

SUBMERGED (W): Land that is continuously or occasionally inundated with water to the extent that the inundation water, or activities associated with it, is considered a design condition affecting the design of the pipeline. Pipeline crossings of lakes, estuaries, harbours, marshes, flood plains and navigable waterways are always included. Pipeline crossings of non-navigable waterways, rivers, creeks, and streams, whether permanent or seasonal, are included where they meet the design criterion.

The Submerged class extends only to the estimated high water mark of the inundated area.

NOTE: The Submerged class refers only to onshore pipelines designed to this Part. Submarine or offshore pipelines are designed to AS 2885.4.

3.2.3 Required Protective Measures

The required protective measures for threats are dependent on location class, given in section 5.5.4 of AS 2885.1. This section is reproduced below.

5.5.4 Design for protection—General requirements

> *The pipeline design shall identify and document the external interference threats for which design for pipeline protection is required. Activities which could occur during the design life of the pipeline shall be considered.*
>
> *NOTE: For guidance on the definition of design cases for protection, see Appendix D of AS 2885.1 - 2007.*
>
> *External interference protection shall be achieved by selecting a combination of physical and procedural controls from the methods given in Table 5.5.4(A) and Table 5.5.4(B).*
>
> *The following shall apply:*
>
> *(a) A minimum of 1 physical control and 2 procedural controls shall be applied in R1 and R2 location classes.*
>
> *(b) A minimum of 2 physical control and 2 procedural controls shall be applied in T1 and T2 location classes.*
>
> *(c) For each control, all reasonably practicable methods shall be adopted.*
>
> *(d) Physical controls for protection against high powered boring equipment or cable installation rippers shall not be considered absolute.*
>
> *(e) In CIC location class, agreements to control the activities of each user shall be implemented with other users of the CIC wherever possible.*
>
> *The adoption of minimum requirements for pressure design wall thickness, depth of cover and marking shall not be assumed to constitute design for protection.*
>
> *The effectiveness of each external interference protection design shall be reviewed by a safety management study validation workshop.*

3.3 Location Analysis Results

In the course of Initial SMS, a Location Class has been assigned to the areas along the pipeline route. The indicative pipeline route map is shown in Appendix A.

The SMS Location and Threat Analysis Table, attached as Appendix D, comprises the initial location analysis for the ABP pipeline route, and identifies particular features along the route such as isolated houses, road crossings, industrial developments, sensitive use locations, etc.

Locations along the pipeline are further defined in the SMS Table as one of the following:

- **Point** – relates to the specific location on the pipeline, isolated school, road crossing or powerline crossing etc.
- **Length** – relates to an interval of the pipeline route, such as residential area, farming/agricultural land, pipeline running parallel to power lines, etc.
- **Overlay** – associated with the very long section of the pipeline or over the entire pipeline.

Location Class is normally assigned with lengths, or with a single feature which due to change of location class (and requirement to extend more conservative into less conservative location class) has been spread to the length.

The Location Class designation along the ABP route is summarised below.

3.3.1 R1

The majority of the ABP route is classified as R1 – Rural. This includes land used predominantly for grazing and to some extent for agricultural activities. At some sections of the route presence of isolated dwellings (typically 3-5 dwellings per kilometre of pipeline length) was determined. The presence of isolated dwellings does not alter the Location Class (refer Sec 3.2.1 for definition of R1), but has been considered in the route selection as much as practically possible.

3.3.2 R2

Two sections of pipeline have been identified as R2 Location Class.

The first section (AB 391 onwards) is due to rural residential development in the vicinity of the pipeline.

The second section refers to common corridors that intersect the AB pipeline. Potential threats to the pipeline associated with these corridor sections will be further investigated.

- SGIC at AB 418 to 469.5
- GSDA at AB 469.5 to 478
- Marlborough Nickel Corridor AB 329 to 407.9

3.3.3 Industrial and Heavy Industrial

Sections of the route near existing and future substations, active coal mines and from AB 391 generally to the end of the pipeline (through Gladstone industrial area) have been classified as R1-Industrial and Heavy Industrial as listed in the Table 2.

Table 2 Industrial and Heavy Industrial Location Class

Chainage (KP)	Location Class	Comment
AB 103, AB - 405	R1 - I	Future and existing substations
AB 391 onwards	R2 - I	Small Industry
AB 74 to 77	R1 – HI (not high consequence)	Active mine (coal)
AB 433 to 435	R1 – HI (not high consequence)	Adjacent active mine (salt)
AB 469.5 to 478	R2 – HI	Potential future use of GSDA

3.3.4 T1 – Sensitive Use

A section of the route at the township of Raglan (AB 446 to 469), with residential areas and a state primary school within measurement length of the pipeline (AB 465) is classified as T1-Sensitive Use.

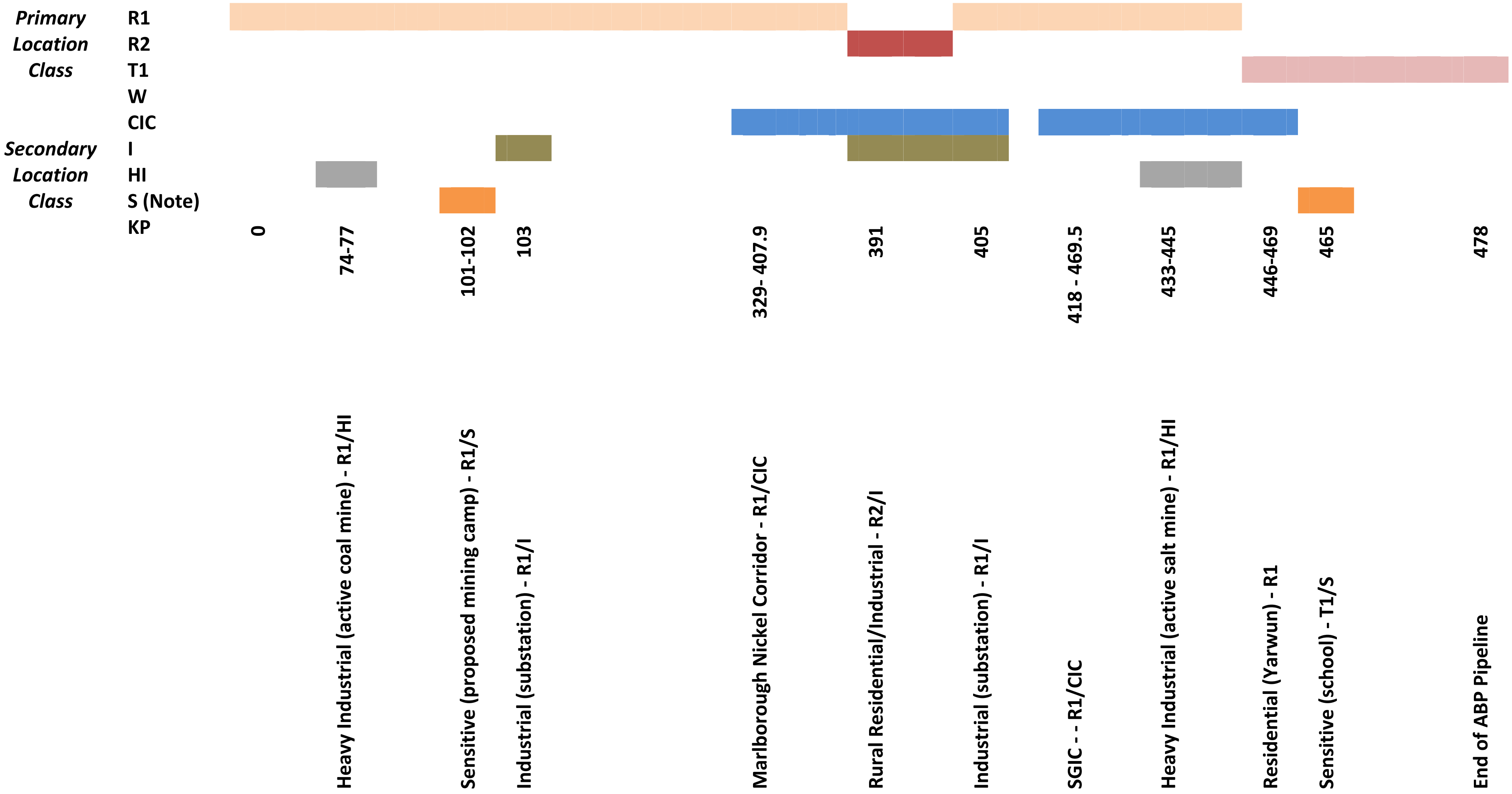
3.3.5 CIC - Common Infrastructure Corridor

The areas where the pipeline alignment is in parallel with the existing and future pipelines (designated government Stanwell Gladstone Infrastructure Corridor downstream of Gracemere have been designated as CIC Location Class as summarised in Table 3 below. These sections will be further investigated for declared CIC projects and considered in the Detailed Safety Management Study.

Table 3 CIC Location Class

Chainage (KP)	Location Class	Comment
AB – 418 to 469.5	CIC	SGIC
AB – 329 to 407.9	CIC	Marlborough Nickel Corridor

Figure 1 - Locations Classes - Visual Guide



Note: The ability to define S (and other location classes) at the ISMS stage depends on the available land use / GIS data collected by the Project.

4. Risk Identification

4.1 Penetration Resistance

Pipe wall thickness provides a resistance to penetration from an external interference threat. The level of pipeline protection by resistance to penetration depends on the pipe wall thickness, material strength and the physical parameters of the external interference threat.

Based on the input from the field it was determined that the maximum size of excavator that presents a realistic threat from excavation for non-pipeline projects or work under control of third parties is a 35 tonne excavator. The “non-pipeline projects or work under control of third parties” refers to excavation activities on the farms such as watering dam excavation, installation of drains or buried water PE lines, installation of other services by third parties, and similar. Refer to Section 5.3 for further details about possible use of other excavators or other external interference threats.

Penetration resistance calculations have been carried out to assess penetration resistance for the DN800 pipeline (current design case), and are provided in the attached wall thickness calculation report (Appendix E).

4.2 No Rupture

The measurement length defines an area around the pipeline that is to be assessed for consequences of loss of pipeline containment, whether from a “leak” or a “rupture”. The general land use, the presence of residential areas, sensitive locations (schools, day care centres, hospitals, prisons, aged care facilities and similar) are determined and the appropriate location class assigned.

The pipeline within a High Consequence Area (T1, T2, I and S location classes) must be designed for ‘no rupture’ so that a rupture is not a credible failure mode. ‘Rupture’ in this context refers to a full-diameter breach of the pipeline, or a ductile fracture, arrested within the initiating pipe that results in two open pipe ends releasing gas. ‘No rupture’ compliance as per AS 2885.1 requirements is achieved by either:

1. Applying extra heavy wall pipe, so that the hoop stress does not exceed 30% of SMYS, or;
2. Determining the hoop stress such that that the “critical defect length” is less than 150% of the largest equivalent defect length identified in that location.

It needs to be verified whether the 35 tonne excavator is the largest credible threat overall, specifically in the high consequence areas. This will be done in the process of further design and in the process of conducting the detailed safety management study.

4.3 Energy Discharge Rate

In addition to the no rupture requirements, AS 2885.1 sets maximum allowable energy discharge rates. These rates must not exceed 10 GJ/s in Residential (T1), and Industrial locations (I), or 1 GJ/s in High Density (T2) and Sensitive (S) Locations.

Energy discharge rates have been calculated and are listed in Table 4.

Table 4 Energy Discharge Rates

Energy Discharge (GJ/s)	DN 800 and DN 1050 Pipeline Case (10.2 MPa)
1	46 mm hole
10	144 mm hole

Refer to the attached wall thickness calculation report (Appendix E) for a complete summary of the resistance to penetration calculation.

In order to confirm whether the energy discharge criteria are met for the T1, I and S Location Class, the threats that could create a hole in the pipe bigger than specified in Table 4 needs to be further investigated and the resulting risks need to be thoroughly evaluated in a Detailed SMS.

4.4 High Consequence Areas

"High consequence" areas are locations where pipeline failure can be expected to result in multiple fatalities or major environmental damage. For ABP, all the areas designated as T1 (residential), I (industrial), and S (sensitive) are high consequence areas.

The route changes in the future are possible, and more detailed investigation during the design process will confirm the presence of features such as nursing homes, schools, day care centres and similar which may convert some areas into S location class.

The protection measures assigned to all high consequence areas are increased depth of cover (1,200 mm) and heavy wall pipe.

4.5 Environmental and Land Constraints

The areas of environmental and land constraint have been investigated and mapped within the GIS. No major environmental or land constraints have been determined during the Initial SMS, as apparently the areas of concern have been avoided by careful route planning.

5. Threat Analysis and Safety Management Study

A comprehensive list of threats has been produced through the Initial SMS taking into consideration previous experience and through the location analysis, using all available data and input from those who have been investigating the proposed pipeline route in the field.

These threats will ultimately be associated with each and every location, as determined in the location analysis. The Detailed SMS will then determine whether there are sufficient physical and procedural measures in place to eliminate the threat, depending on the location class.

The typical overlay and location-specific threats have been identified in the course of location analysis as shown in the SMS Location and Threat Analysis Table attached in Appendix D.

Overlay threats apply uniformly along the pipeline, whilst location specific threats are related to a point location or a section (“length”) of the pipeline.

The threats can be also distinguished as either “design” or “external interference” events. The term “design” should be interpreted very generally to mean all non-interference events (including operations). It should not apply only to those items related to the engineers’ design.

The external interference events present the greatest danger to the pipeline, as statistically most pipeline failures are as a direct result of external interference.

Furthermore, preliminary protection measures have been assigned in order to reduce all identified risks to an acceptable level. This is the first step in the formal SMS. In the course of detailed design, this process needs to be taken to the further level, which includes the detailed identification of threats, evaluation of consequence and likelihood of pipeline failure, and formal ranking of risk and effectiveness of proposed protection measures.

5.1 Overlay Threats

Listed below are some typical overlay or general threats from the complete listing:

- Corrosion - external and internal;
- Stress corrosion cracking;
- Inadequate or incomplete maintenance;
- Inadequate testing and inspection;
- Undetected damage to pipe, coating or equipment;
- Undetected critical weld defects;
- Excavation of an existing pipeline or other service for maintenance or installation;
- Terrorism, sabotage and vandalism; and
- Fencing.

5.2 Location Specific Threats

Listed below are some typical location specific threats, from the complete listing:

- Excessive external traffic loads;
- Construction of other pipelines in Stanwell Gladstone Infrastructure Corridor;
- Floods – erosion of cover;
- Floods – floatation;
- Pipeline scouring;
- Table drain and road grading, and road maintenance;
- Excavation of existing pipeline by third party;
- Induced voltages from parallel power lines;
- Quarry blasting;
- Mining land subsidence;
- Train derailment; and
- Earthquake.

5.3 External Interference

External interference represents the most serious threat to most pipelines. Examples of external interference threats include:

- Blade ploughing;
- Table drain and road grading, road maintenance;
- Excavation by third party for farming activities;
- Installation of third party services;
- Road construction; and
- Contour drain forming using bulldozers or graders.

6. Proposed Pipeline Risk Strategy

This section outlines the current risk mitigation strategies that are proposed for the threats that have been identified as a result of the Initial SMS. The measures indicated are proposed to reduce the risk of the listed threats occurring to an acceptable level.

For the purpose of this Initial SMS the threats and the proposed protection measures are previewed and summarised only in the following section.

6.1 Overlay Threats

6.1.1 Excavation of an Existing Pipeline by Third Party

Excavation around the pipeline by third party for non-pipeline projects, or work under control of third parties, refers to excavation activities on the farms such as watering dam excavation, excavation for new drains, existing drains maintenance, installation of buried water PE lines; or it refers to other third party work such as installation of other utility services by third parties, maintenance of existing utility services and similar.

Excavation presents a threat by puncturing the pipeline with an excavator bucket. The maximum credible size of the machinery used by a third party has been identified as a 35 tonne excavator fitted with penetration teeth. More destructive plant such as excavators greater than 55 tonnes (normally used in mines) is considered to be significantly rarer if not unlikely threats for these types of works.

The 35 tonne excavator fitted with penetration teeth would not penetrate either heavy or standard wall pipe.

The pipeline will be monitored for third party work occurring along the right of way on a regular basis. Pipeline marker signs will be installed at inter-visible intervals to indicate that there is a buried gas pipeline. The signs will also show the operator’s phone numbers so that contractors etc. can ring prior to commencing work or in case of an emergency. The stakeholders along the pipeline will be contacted regularly and will be supplied with maps to ensure that they have the necessary information at hand to identify the location of the pipeline.

Where the pipeline crosses third party services, the pipeline will generally pass under the other service, Marker tape and marker mesh will be installed across the pipeline to provide an indication for gas pipeline, and installation of concrete slab installed above the pipeline to provide a physical barrier will be considered.

6.1.2 Corrosion – Internal

The gas entering the pipeline will be dehydrated to the transmission gas specification requirements, which will ensure that free water will not enter the pipeline. The current gas composition has no components which could initiate internal corrosion without water.

6.1.3 Corrosion – External

The pipeline will be coated with a high integrity protective coating as its primary protection from external corrosion. This protective coating will be reinforced by a cathodic protection (CP) system, using an impressed current or sacrificial anode system. The CP system will be monitored as part of the pipeline management system to ensure that the correct negative potential is maintained along the pipeline. CP test points will be located at critical crossings, and at regular intervals to assist with monitoring performance.

6.1.4 Incorrect Construction, Testing and Inspection

The pipeline will be tested and constructed in accordance with AS 2885.1. The pipeline may be constructed in an alliance or similar contractual arrangement to ensure that a balance between cost and quality imperatives is maintained. The pipeline will be constructed from API 5L line pipe and therefore will undergo extensive non-destructive testing. The pipeline will be constructed in accordance with a total quality control plan including Non Destructive Testing (NDT), welding and holiday detection of the coating. After installation, the pipeline will be hydrostatically tested in accordance with AS 2885.5.

6.1.5 Inadequate or Incomplete Maintenance

The pipeline will be maintained in accordance with AS 2885.3. This involves using a pipeline integrity management plan and a Safety and Operating Plan. Pipeline operations will follow the requirements of these plans, including scheduled maintenance and pipeline integrity checks, such as coating surveys and intelligent pig runs. The pipeline and facilities will be operated by experienced and competent operators who are familiar with the operation and the maintenance of the equipment being used.

6.1.6 Terrorism

In the light of the current political climate globally and in Australia, the possibility of a terrorist act cannot be dismissed. A terrorist act on a pipeline may occur in a rural area if the objective is to interrupt supply, and to escape apprehension. It is presumably less likely that an attack would occur in a heavily populated area, since detection is more likely. Another factor is that it takes time to expose and damage a buried pipeline, and presumably terrorists would have little time (before detection) if working in a populated area.

Pipeline stations present a potential target as the high-pressure gas equipment is above-ground, albeit protected by a fenced compound. Again, it is considered more likely that such a site would be attacked when it is unattended. The mitigation measures will be the restriction of access to pipeline stations and facilities by security fencing and intruder alarms and by patrolling the pipeline.

6.1.7 Sabotage, Vandalism and Malicious Damage

As the pipeline is buried along its entire route and is fairly remote, the likelihood of potential deliberate sabotage is reduced. The main areas of higher risk are the pipeline stations. Compared with terrorism, vandalism is anticipated to have lesser consequences, although frequency would be higher. Locations chosen for the above ground facilities will consider visibility and access. The metering stations are likely to be fitted with intruder alarms to indicate unauthorised access.

6.1.8 Stress Corrosion Cracking (SCC)

SCC occurs generally downstream of compressor stations, where the pipeline is subjected to a high stress range and high temperature. The risk of SCC occurring on the pipeline will be comprehensively evaluated and specific measures may need to be implemented. These may include specific joint coatings, sections of heavy wall pipe, or a more extensive coating inspection and maintenance program.

6.1.9 Earthquake

Operating experience has shown that buried gas pipelines are particularly resistant to earthquake forces.

The route will be reviewed to determine areas of especially high acceleration coefficient, and intersection with faults (as per AS 1170). Where faults are encountered, correlation will be sought with recent seismic activity to determine whether the fault should be classified as active.

Where positively active faults are intersected, precautions such as heavy wall pipe or above-ground roller-supported pipe will be considered.

6.2 Location Specific Threats

6.2.1 Mining Land Subsidence

Areas subject to ground movement are primarily the areas in the mining leases, in particular where long wall mining and underground coal gasification (UCG) is anticipated. These areas have been avoided by pipeline route selection where it was feasible; however the pipeline traverses mining leases at some locations (AB 74 to 77, EL 3 to 6, DL 7.3 to 14.1, SL 3.1 to 6.7). The likely extent and magnitude of land subsidence needs to be established by liaising with the miner, in order to either avoid the land subsidence areas by further route adjustments or assess what design options could be implemented to accommodate for subsidence of certain magnitude.

6.2.2 Construction of Other Pipelines in Gladstone State Development Area

It is very likely that at least one other large diameter high pressure gas pipeline will have been installed in government Gladstone State Development Area (GSDA) near Gladstone, parallel to the ABP. Given the diameters of these pipelines, the size of the excavating machinery for maintenance of this type of works could well be in the order of 80 or 90 tonne. The data for this type of the machinery needs to be gathered and assessed for penetration resistance as they are not specified in AS 2885.1. However it has been assessed that in this case it can be relied to a significant extent on procedural methods, such as site supervision and work permit system, for the protection of the pipeline. This is because the construction of the other pipelines is anticipated to be happening in the time period before the ABP is installed, therefore there will be general awareness of both the ABP installation and of other projects (due to their size), and accurate GIS data on the ABP location will be available.

6.2.3 Blade Ploughing

The location analysis indicates that blade ploughing is likely to occur in multiple long sections of the pipeline route. Blade ploughing is a land clearing activity carried out periodically to control the regrowth of native vegetation, generally to a depth that does not exceed 300-400 mm. However, the blade plough can penetrate deeper at some locations because of uneven terrain, localised washouts, melon holes etc.

In areas that may be subject to blade ploughing, now or in the future, the pipeline is proposed to be buried with a cover of 1,200 mm. In order to confirm the realistic depth of cover that would provide adequate protection against blade ploughing, the threat of blade ploughing needs to be further investigated to more accurately determine what is the maximum depth that a blade plough could penetrate.

6.2.4 Contour Forming

Land contour forming for agricultural purposes has been identified in some areas. At quite a few locations along the route this threat is considered as co-existent with blade ploughing.

Contour forming is normally carried out by a bulldozer and grader, to a depth on occasions beyond 700 mm. The areas where contour forming is regarded as possible have been initially identified, and need to be further confirmed through site surveys, landowner liaison or other methods. The proposed protection measure is an increased depth of cover of 1,200 mm, to ensure that it is not affected by contour forming or maintenance. Further investigation of the contour forming threat is required in order to confirm the realistic depth of cover that would provide adequate protection.

6.2.5 Induced Voltages

The location analysis has identified several areas where the pipeline alignment is parallel with high voltage power lines for some distances, for example at AB 81 to 85.6, AB 462.9 to 464 and EL 47 to 48.5. Where this occurs, a study will be performed to calculate the effect of the induced voltage and the fault current on the pipeline during detailed design. Design measures will be implemented, as required, to ensure continued pipeline integrity and operator safety.

The pipeline has been located, as far as practicable, to avoid parallel railway lines, and therefore to avoid potentially serious induced voltages and fault currents. If proximity is unavoidable, suitable mitigation such as installation of monolithic insulation joints, and other measures will be employed to ensure the continued integrity of the pipeline and its cathodic protection system.

6.2.6 Failure of Control and Protective Equipment

The design intention is for pipeline and station pressure control systems to be high integrity, with full redundancy. The pipeline may be protected from high temperature by a shutdown system.

The design philosophy at the meter station will incorporate dual regulator runs to minimise the possibility of supply interruption from a single component failure.

6.2.7 Excessive External Traffic Loads

Several types of road crossing were identified in the location analysis. These are:

- Formed gravel,
- Unformed dirt,
- Bitumen,
- Paper roads (road casements without a gazetted road), and
- Landholders' access tracks.

These crossings will be designed with additional cover, heavy wall pipe and concrete slabs within table drains, as per the standard crossing design.

To ensure that the pipelines cannot be overloaded in these locations, the depth of cover will be checked as specified in AS 2885.1, i.e. in accordance with the requirements of API Recommended Practice 1102 "Steel Pipelines Crossings - Rail, Roads and Highways". The loads used in the calculations will be the maximum allowable axle loadings in accordance with the requirements of the Department of Main Roads.

6.2.8 Floods - Erosion of Cover

Erosion of cover is also possible at creek and river crossings, especially on the banks. For the majority of the creek and river crossings, increased depth of cover of 1,200 mm and 2,000 mm respectively will be used and protection measures installed on the banks as required by the crossing design.

6.2.9 Floods – Floatation

The low lying areas identified in the location analysis as prone to flooding may require buoyancy control measures. These measures would include extra depth (1,200 mm), concrete coating of the pipeline, set-on weights, or other buoyancy control measures to ensure that the pipe is negatively buoyant.

Flood areas will be determined in the further investigation and considered in the design.

6.2.10 Pipeline Scouring

The location analysis does not identify specific locations currently susceptible to scouring, however where these areas are identified during design and construction, trench breakers will be installed to prevent tunnelling of water and contour banks will be used to divert flows away from the pipeline onto undisturbed areas.

6.2.11 Train Derailments

Sections of the route where the pipeline runs parallel with or crosses, a rail line will be installed generally with additional depth of cover, using heavy wall pipe. Rail crossings will be carried out by thrust boring or horizontal directional drilling and will be at an increased depth of cover as specified in AS 2885.1 i.e. in accordance with the requirements of API Recommended Practice 1102 "Steel Pipelines Crossings – Rail, Roads and Highways". The proposed design is a minimum depth of cover of 2,000 mm under the table drain, which will prevent possible contact during a derailment.

6.2.12 Table-Drains, Road Grading, and Road Maintenance

As mentioned above, standard construction methods are to be used across roads. These standard construction details include concrete slabs under the table drains to prevent accidental over-excavation above the pipeline. The pipeline is also buried with additional cover, and pipeline marker tape is installed, across the road reserve.

6.2.13 Quarry Blasting

The pipeline passes close to some currently operating quarries. Blasting studies and calculations, for some recently completed pipelines, indicated that separations as small as 50 m between explosive charges up to 200 kg, and pipelines, are adequate to ensure that the pipeline is not damaged. It is therefore considered likely that the pipeline route will be able to be easily adjusted to bypass quarry areas and maintain the necessary separation. This will be reviewed during detailed design.

7. Actions

During the course of the Initial SMS, actions were identified to either confirm conditions along the route, investigate risk elimination by realignment of the route, confirm the presence of sensitive areas or nearby facilities, and further investigate the likely consequence of some external interference threats.

This will be done in preparation for the Detailed SMS, in order to confirm the designated Location Class, determine threats to a further level of certainty and detail, propose required protection and mitigate risks to the lowest practical level. The outstanding actions that need to be addressed are listed in Table 5 and Table 6.

Table 5 Actions from Workshop

Chainage (KP)	Threat Description	Action	Close Out
Powerline crossings AB 70.1, 76.9, 77.9, 81 to 85.6, 253.5, 303.8, 354.6, 462.9 to 464 EL 13, 47.7, 47.8 to 48.5	Fault to earth - electrocution	Check radius of effect of earth faults - does it affect the pipeline.	
Active mine (coal) AB 74 to 77, EL 3 to 6 SL 3.1 to 6.7 DL 7.3 to 14.1	Vibrations from blasting	Check with the coal mining companies with respect to potential blasting.	
SGIC at AB 418 to 469.5 GSDA at AB 469.5 to 478 Marlborough Nickel Corridor AB – 329 to 407.9		Check declared CIC projects with interests.	
Typical parallel water pipeline AB 90 to 93	Vehicle loads during maintenance activities	Make sure the fence is specified in the licence agreement.	
*Cleared areas - purpose unknown AB 0 to 478 (all), EL 37 to end of lateral	Blade ploughing	Review previous study by GHD on depth of blade ploughing to see whether 1,200 mm is enough.	
Possible cultivation AB 159 onwards, AB 172 to 174, AB 211 onwards, DL 0 onwards	Blade ploughing	Review previous study by GHD on depth of blade ploughing to see whether 1,200 mm is enough.	

Chainage (KP)	**Threat Description**	**Action**	**Close Out**
Centre pivot irrigation to grow vegetation AB 244 to 245	TBC	Determine method and depth of tillage for centre pivot irrigation.	
Contour banks (may be extended) AB 311, AB 318 to 319, AB 343 to 344, AB 358 to 359, AB 372 to 373	Damage to pipe	Determine the depth required for contour banks.	
Possible flood plains AB 320 onwards, AB 428 onwards, EL 29	Inundation with simultaneous liquefaction	Carry out appropriate geotech study.	
Entire length	Material Defects	Require contractor to demonstrate minimised and careful handling of coated pipe.	
Entire length	Hydrotesting issues and 0.8 design factor issues	Make sure pipe spec captures recent industry lessons learned on items such as stress-strain curves, coating process, strain ageing, yield ratio, field weldability (all tests done on coated pipe). Consider the initial additional impact of spiral welded pipe.	
Entire length	Coating damage in general	Ensure spec prescribes the use of brush type jeeper.	
Entire length	Undiagnosed welding defects due to poor NDT	Baseline calibration of AUT.	
Entire length	Cyclic fatigue of pipeline due to operation of upstream gathering system and downstream LNG plant	Confirm that cyclic operation does not give rise to fatigue design on the pipeline.	

**Note: Identified cleared areas with the ‘purpose unknown’ differ from identified areas where cultivated land was evident.*

Table 6 General Actions

Item #	Action	Assigned To
1	Railway depth of cover - measured from bottom of ballast?	GHD
2	Specify minor and major watercourse crossings in the pipeline walk through	GHD
3	Investigate possible third party CSG well at AB 89.	Arrow
4	Investigate land use in area at AB 95 to 97, AB 98 to 100, AB 107, AB 133 to 137, AB 244 to 245 and check whether cleared area will be expanded with land owner.	Arrow
5	Determine type of pipeline in easement at AB 96.8 approx.	Arrow
6	Investigate the type of mining and mining methods at AB 227 to 228.	Arrow
7	Investigate potential contour banks at AB 299 to 300, AB 319.	Arrow
8	Investigate possible easement at AB 303.5.	Arrow
9	Investigate cadastral portion at AB 364.	Arrow
10	Investigate nature of structure/dwelling at AB 371.5.	Arrow
11	Investigate nature of dwelling at SW of AB 373.	Arrow
12	Check with local council the zoning at AB 380 to ensure that density does not increase further.	Arrow
13	At AB 383 dwelling within 100 m of centreline, investigate moving the dwelling or the pipeline route.	Arrow
14	Investigate structure/ruin at AB 386.5	Arrow
15	Investigate at NE of AB 397 looped track, is this a commercial enterprise.	Arrow
16	Investigate AB 410.7 possible quarry. Is future quarry intended?	Arrow
17	At AB 433 determine possible future extensions to salt mining.	Arrow
18	At AB 446.3 waste transfer station needs to be relocated. Pipeline cannot be relocated due to SGIC.	Arrow
19	Check at AB 445.5 to 446.5 (the reserve) what land use approvals are required for this apparent break in the SGIC.	Arrow
20	Investigate at SW AB 446. Are these ponds/sewerage plants or what?	Arrow
21	Investigate at AB 454 - 455 the number of houses/occupants in this town/village.	Arrow
22	Calculate the overlap of measurement lengths in T1 and sensitive location class zones.	GHD

Item #	Action	Assigned To
23	Investigate the feasibility of medium/heavy vessel making it up major rivers far enough to damage pipeline.	Arrow
24	Investigate operating pressures for slurry pipelines to further consider threats posed to adjacent gas pipelines.	GHD
25	GHD to determine frequency of DCVG surveys for detecting latent defects from third party impact.	GHD
26	Determine the probability of blasting.	Arrow
27	Try to find photo of lightning strike - Brian Martin, EPRA papers.	GHD
28	Send sketch showing current MLV locations to GHD.	Arrow
29	Ground truth between EL 8-9.	Arrow
30	Confirm existence of well at EL 30 and evaluate if too close to the pipeline.	Arrow
31	At EL 46 realign pipeline slightly to avoid mining township (if required once measurement length of EL is confirmed).	Arrow
32	Check the proximity of wellheads at DL 3, 3.5, 6.7.	Arrow

8. Conclusions

The scope of the Initial SMS for ABP was as follows:

- Identification of basic pipeline design parameters.
- Location analysis, including definition of “high consequence” areas.
- Identification of typical overlay general threats.
- Identification of main location specific threats.
- Preliminary proposed risk strategy to reduce all identified risks to ALARP.

The scope has generally been fulfilled and the results of the Initial SMS workshop summarised in the SMS Location and Threat Analysis Table in Appendix D.

In the course of the Initial SMS, a significant number of issues were identified that require further investigation or action. These can be summarised as follows:

- Confirmation of conditions along the route;
- Investigation of extent of flooding areas;
- Confirmation of presence and extent of sensitive areas; and
- Further investigation of some major external interference threats in order to determine optimum protection measures.

These actions are noted in the SMS Location and Threat Analysis Table and the separate comprehensive list of actions has been presented for clarity in Section 7 of this Report.

The pipeline route that was assessed in the course of the Initial SMS is referred to as Revision D. The indicative map of the route is provided in Appendix A. Any changes in the route that may occur after the Initial SMS workshop will need to be evaluated. The SMS process will therefore be continued through further design and formalised by conducting a detailed SMS.

The detailed SMS shall determine the exact physical and procedural measures required to mitigate threats, assess whether these measures eliminate the threat, assign consequence and likelihood values to non-eliminated threats, determine the risk ranking and assign appropriate risk treatment actions.

9. Disclaimer

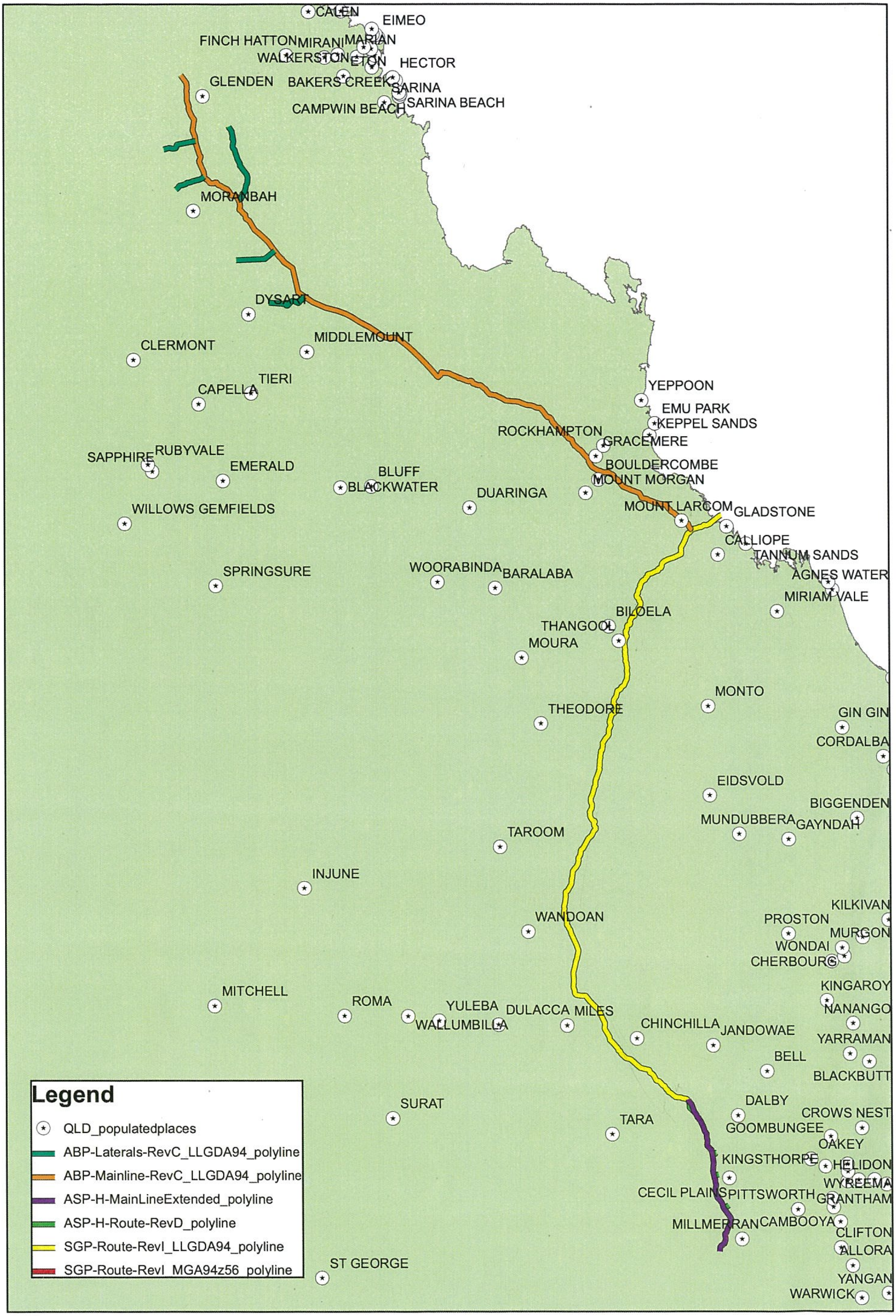
This Report: has been prepared by GHD for Arrow Energy Pty Ltd and may only be used and relied on by Arrow Energy Pty Ltd for the purpose agreed between GHD and Arrow Energy Pty Ltd as set out in Section 1 of this Report.

GHD otherwise disclaims responsibility to any person other than Arrow Energy Pty Ltd *arising in connection with this Report. GHD also excludes implied warranties and conditions, to the extent legally permissible.*

The services undertaken by GHD in connection with preparing this Report were limited to those specifically detailed in the Report and are subject to the scope limitations set out in the Report.

Appendix A

ABP and ASP Pipelines Route Map (for Initial SMS – Alignment Rev D)


CALEN
EIMEO
FINCH HATTON
MIRANI
MARIAN
WALKERSTON
ETON
HECTOR
GLENDEN
BAKERS CREEK
SARINA
CAMPWIN BEACH
SARINA BEACH
MORANBAH
DYSART
MIDDLEMOUNT
CLERMONT
TIERI
CAPELLA
YEPPOON
EMU PARK
KEPPEL SANDS
ROCKHAMPTON
GRACEMERE
SAPPHIRE
RUBYVALE
EMERALD
BLUFF
BLACKWATER
BOULDERCOMBE
MOUNT MORGAN
DUARINGA
WILLOWS GEMFIELDS
MOUNT LARCOM
GLADSTONE
CALLIOPE
TANNUM SANDS
SPRINGSURE
WOORABINDA
BARALABA
AGNES WATER
MIRIAM VALE
BILOELA
THANGOOL
MOURA
MONTO
THEODORE
GIN GIN
CORDALBA
EIDSVOLD
BIGGENDEN
MUNDUBBERA
GAYNDAH
TAROOM
INJUNE
KILKIVAN
WANDOAN
PROSTON
MURGON
WONDAI
CHERBOURG
KINGAROY
MITCHELL
ROMA
YULEBA
DULACCA
MILES
NANANGO
WALLUMBILLA
CHINCHILLA
JANDOWAE
YARRAMAN
BELL
BLACKBUTT
DALBY
SURAT
CROWS NEST
TARA
GOOMBUNGEE
OAKEY
KINGSTHORPE
HELIDON
WYREEMA
CECIL PLAINS
PITTSWORTH
GRANTHAM
MILLMERRAN
CAMBOOYA
CLIFTON
ALLORA
ST GEORGE
YANGAN
WARWICK
Legend
QLD_populatedplaces
ABP-Laterals-RevC_LLGDA94_polyline
ABP-Mainline-RevC_LLGDA94_polyline
ASP-H-MainLineExtended_polyline
ASP-H-Route-RevD_polyline
SGP-Route-RevI_LLGDA94_polyline
SGP-Route-RevI_MGA94z56_polyline

Appendix B

Assumptions for SMS and Conclusion of Preliminary Calcs

ABP Pipeline
Assumptions for SMS and Conclusion of Preliminary Calcs

High level assumptions:

- Stations and facilities not considered.
- Construction not considered except for construction adjacent to operating pipeline.
- Assumed homestead within measurement lengths are not treated as sensitive
- Assumed all pipelines and laterals are piggable

		Comments
Pipeline Nominal Diameter	DN 800 (32 inch)	
Pipe Material	API 5L X70	
Pipeline Length	478 km approx.	
Pipeline Contents	CSM	
Rich Gas Composition (assumed)	Methane - 98.45%, Ethane (0.10%), Propane (0.10%), i-butane (0.10%), n-butane (0.10%), i-pentane (0.10%) , n-pentane (0.10%), Hexane (0.10%), Nitrogen (0.70%), Carbon Dioxide (0.15%)	As per SGP Design Basis
Primary Location Classes Along Route	R1	
Secondary Location Classes Along Route	TBD	
Design Factor	0.8 Pipeline 0.67 Facilities	
Corrosion Allowance	0 mm	
External Threats / Plant in the Region	Refer to SMS	
Is "NO RUPTURE" Design Required ?	Yes in high consequence areas	
Can rupture occur? If so, for what size plant?	No for up to 35T excavator, assuming heavy wall pipe used	
Permissible Energy Release Rates in Each Location Class	High Consequence - 10GJ	
Calculated Energy Release Rate	No Leak	
Measurement Length (4.7kW/m2) (injury in 30 secs exposure)	1100 m approx.	
Largest excavator size considered (design excavator)	35T	
Worst case tooth	Twin Tiger (one tooth)	
Are the Nominated Excavators Capable of Achieving "Leak"?	No - standard wall No - heavy wall	
Are there any "non-excavator" Threats/ Plant Capable of Achieving Rupture ?	Yes refer to SMS	

Preliminary Depth of Cover Selections

Area/ Feature	**DOC (minimum)**	
R1 and R2 Areas	750mm	
High Consequence Areas (exl. T2)	1200mm (TBD)	
W Areas	TBD	
Track - Open Cut	1200mm	
Road - Bored	Crossing Cover	1500mm
	Table Drain	1200mm
	Concrete Slabs in Drain	No
Road - Open Cut	Crossing Cover	1500mm
	Table Drain	1200mm
	Concrete Slabs in Drain	No
Highway Crossing	Crossing Cover	2000mm
	Table Drain	2000mm
	Concrete Slabs in Drain	No
Legal Planned Road Reserve/ Crossing	1200mm	
Water Course - Minor (<10m toe to toe)	Crossing Cover	1200mm

Water Course - Major	Crossing Cover	2000mm
Railway	Crossing Cover	2000mm
	Table Drain	2000mm
Foreign Utility	Normally cross below foreign utility, as opposed to above.	600mm
Foreign Utility - Above Ground	As per surrounding area	
HV Power Line Crossing	As per surrounding area	
Man Made Drain	1200mm	
Parallel to Road	Underneath Road	1500mm
	Beside	1200mm
HV Power Line Parallel	As per surrounding area	
Fibre Optic Parallel	As per surrounding area	
Flood Plains	TBD	

Preliminary Wall Thickness Selections

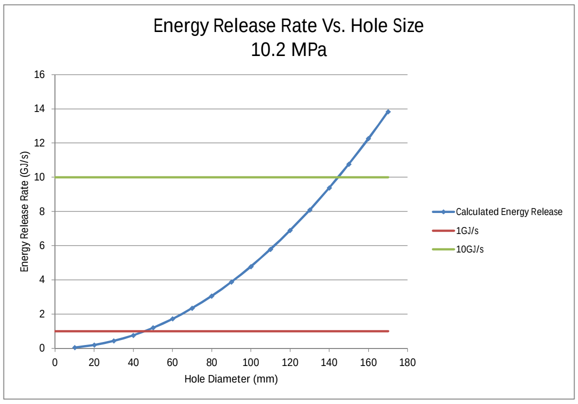
R1/R2 "Standard Wall (Note 1)	**High Consequence "Heavy Wall" (Note 2)**	**Road Crossing "Heavy Wall" (Note 5)**	**Rail Crossing "Heavy Wall" (Note 3)**	**Pipeline Assemblies (Note 6)**
10.7 mm	12.5 mm	13.8 mm	**14.9 mm**	**12.8 mm**

Combine? (Note 3)

Combine? (Note 3)

Notes
1. Based on pressure containment with Fd = 0.8 Occasional vehicle crossings and other criteria not considered.
2. Excludes design for S and T2 areas.
3. Depending on quantities required, consider rationalising the high consequence road crossing and rail crossing heavy wall materials.
4. Other wall thickness criteria, such as fatigue, have not been considered.
5. For designated, not occasional crossings.
6. Based on pressure containment with Fd = 0.67.

Hole size	Area	Energy release (GJ/s)
10	78.53981634	0.047894947
20	314.1592654	0.191579788
30	706.8583471	0.431054522
40	1256.637061	0.76631915
50	1963.495408	1.197373672
60	2827.433388	1.724218088
70	3848.451001	2.346852398
80	5026.548246	3.065276601
90	6361.725124	3.879490698
100	7853.981634	4.789494689
110	9503.317777	5.795288573
120	11309.73355	6.896872352
130	13273.22896	8.094246024
140	15393.804	9.38740959
150	17671.45868	10.77636305
160	20106.19298	12.2611064
170	22698.00692	13.84163965
180	25446.90049	15.51796279
190	28352.8737	17.29007583
200	31415.92654	19.15797876
210	34636.05901	21.12167158
220	38013.27111	23.18115429
230	41547.56284	25.3364269
240	45238.93421	27.58748941
250	49087.38521	29.93434181
260	53092.91585	32.3769841
0		1
170		1
0		10
170		10



Appendix C

Workshop Attendance Record

Attendance List
Arrow Energy
ABP Pipeline

Title: Pipeline Risk Assessment Review (SMS)

Date: Thursday 25th of August 2011

Venue: Brisbane

Name	Title	Organisation	Signature
Angelo Velardo	Pip. Engineer	ARROW	AV.
IAN GRUNNEL	ENG'G+EST, MAN.	ARROW	
RUBI TURNA	PIPELINE ENG.	GHD	
TONY MILLS.	CO-FACILITATOR	GHD.	Tony Mills.
STEPHEN CHAN	GIS SPECIALIST	ARROW	
JACK DOYLE	CO-FACILITATOR	GHD	
Xia Gang	VP_major pipeline.	Arrow	
IAIN BURGESS	PROJECT MANAGER.	ARROW	

Attendance List
Arrow Energy
ASP Pipeline

Title: Pipeline Risk Assessment Review (SMS)

Date: Friday 26th of August 2011

Venue: Brisbane

Name	Title	Organisation	Signature
RUBI TURNA	PIPELINE ENG.	GHD	
Jack Doyle	Co-facilitator	GHD	
Anthony (Tony) Mills	Co-facilitator	GHD.	Tony Mills.
Angelo Velarde	Pipe. Engineer	ARROW.	
IAN GUNNEL	ENG'G & EST. MANG	ARROW	
IAIN BURGESS	PROJ MANAGER	AMON	

Appendix D

SMS Location and Threat Analysis Table

SMS Location and Threat Analysis Table

Initial SMS Workshop Record

Project:	**AB Gas Pipeline to Rev D Alignment**
Date:	**Thursday/Friday August 25th/26th 2011**
Location:	**Arrow Energy Offices, Bne**
Facilitator:	**J Doyle**

Note that the workshop was conducted in accordance with the Pipeline Safety Management Process of AS 2885.1 to 2007, as illustrated in the flowchart in Figure 2.3.1 of AS 2885.1. When reviewing this workshop record it should be read in conjunction with the flowchart.

Severity

Dimensions	**Catastrophic**	**Major**	**Severe**	**Minor**	**Trivial**
People	Multiple fatalities, or	Several fatalities or major injuries, or	Hospital treatment, or	First Aid Treatment, or	"Minimal"
Supply	long supply interruption, or	restricted supply, or	Short interruption of prolonged restriction, or	Short supply restriction, or	No impact on supply
Environment	ecosystem changed or made unviable	longtoterm environ impacts, hard to rectify	Env Effects <1Ha and <2yr, easily rectified	Env impact <0.1Ha & few weeks	"Minimal"

Risk Ranking

	Catastrophic	**Major**	**Severe**	**Minor**	**Trivial**
Frequent	Extreme	Extreme	High	Intermediate	Low
Occasional	Extreme	High	Intermediate	Low	Low
Unlikely	High	High	Intermediate	Low	Negligible
Remote	High	Intermediate	Low	Negligible	Negligible
Hypothetical	Intermediate	Low	Negligible	Negligible	Negligible

Frequency

Once per year or more	**Frequent**
Several times in life of p/l	**Occasional**
Possible, but probably not in life of this p/l	**Unlikely**
Not anticipated for this p/l	**Remote**
Never occurred on similar p/l	**Hypothetical**

Pr= Procedural
Ph= Physical
R1and R2 require 1Ph + 2 Pr
T1 and T2 require 2 Ph + 2 Pr

Location Analysis					**Threat Analysis**	**Protection Analysis**			**Failure Analysis** (refer Fracture Control Plan and Environmental & Other Plans	**Risk Assessment** AS 4360 / 2885 App F				**Risk Treatment**	**ALARP Analysis** (if required)	**Actions**
No.	**Point/Length Location (Approx. KP)**	**Primary Location Class**	**Secondary Location Class (if applicable)**	**Predominant Land Use and Other Features**	**Credible Threats**	**Required Measures for External Interference Threats**	**Selected Protection Measures**	**Failure of Protective Measures Possible?**		**Comments / Actions from *Initial* SMS**	**Severity**	**Frequency**	**Risk Ranking**	**NEG: Review in Future LOW: Management Plan INTER: Retoevaluate or ALARP analysis HIGH Retoevaluate ASAP EXTREME: Retoevaluate**		
1. Location Specific Threats																
1.1	Typical Track Crossing AB 0 to 478 (All) All laterals	R1		Grazing	Vehicle Loads Road maintenance activities i.e. excavations and grading Vehicle collision/Bogged vehicles (any vehicles) Erosion at track edges	1Ph + 2 Pr	Depth of cover (Ph) Signage (Pr) Wall thickness (Ph) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr)	No Yes, for major rework No No								
1.2	Future Road crossings AB 0 to 478 (All) All laterals	R1			Vehicle Loads Road construction activities i.e. excavations and grading Vehicle collision (any vehicles) Bogged vehicles (any vehicles) Erosion at track edges	1Ph + 2 Pr	Depth of cover (Ph) Signage (Pr) Wall thickness (Ph) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr)	No Yes, for major rework No No No								
1.3	Typical Road Crossing AB 0 to 478 (All) All laterals	R1			Vehicle Loads Road maintenance activities i.e. excavations and grading Vehicle collision (any vehicles) Bogged vehicles (any vehicles) Erosion at track edges Road realignment Installation of large traffic signs/guard rails/light posts	1Ph + 2 Pr	Depth of cover (Ph) Signage (Pr) Wall thickness (Ph) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr)	No No No No No Yes Yes								
1.4	Typical Highway Crossing AB 95, 404.9, 416.4	R1			Vehicle Loads Road maintenance activities i.e. excavations and grading Vehicle collision (any vehicles) Bogged vehicles (any vehicles) Erosion at track edges Road realignment Installation of large traffic signs/guard rails/light posts		Depth of cover (Ph) Signage (Pr) Wall thickness (Ph) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr)	No No Yes, due to size and weight of vehicles No No Yes Yes								
1.5	Typical watercourse major crossings i.e. rivers AB 0 to 478 (All) All laterals	R1			Flotation Vessel (small)/anchor/tree impact Large objects during flood impacting the pipeline Erosion of cover		Depth of cover (Ph) Heavy wall (Ph) CWC (Ph)	No TBA Yes, large objects and in combination with erosion of cover Yes								
1.6	Typical watercourse minor crossings i.e. creeks, drains, streams AB 0 to 478 (All) All laterals	R1			Flotation Erosion of cover Large objects during flood impacting the pipeline		Depth of cover (Ph)	No Yes Yes, large objects and in combination with erosion of cover								

SMS Location and Threat Analysis Table

1.7	Typical Rail Crossing AB 90, 92.3, 101, 393, 416.5, 427.6, 471 EL 47	R1			Train Loads Train derailment to impact on pipeline Rail maintenance activities i.e. sleeper replacement, track relays Induced voltage from train line		Wall thickness (Ph) Depth of cover (Ph) Signage (Pr) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr) Correct pipeline earthing design (Ph)	No Yes No No								
1.8	Powerline crossings AB 70.1, 76.9, 77.9, 81 to 85.6, 253.5, 303.8, 354.6, 462.9 to 464 EL 13, 47.7, 47.8 to 48.5	R1		Power Lines In Proximity	Fault to earth to electrocution Fault to earth to coating damage Power pole installation		Lateral separation (Ph) Operation safety procedures i.e. earth mats (Pr) Signage (Pr) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	No Yes Yes		Check radius of effect of earth faults to does it affect the pipeline.						
1.9	Typical buried gas pipeline crossing AB 0 to 478	R1		Other Pipeline in Vicinity	Pipeline maintenance activities i.e. excavation Vehicle loads during maintenance activities Installation of other pipelines Catastrophic failure of third party pipeline due to CP conflict Catastrophic failure of third party pipeline due to any cause		Depth of cover / separation / concrete slabs (Ph) Signage (Pr) Marker Tape (Pr) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	Yes Yes Yes Yes Yes								
1.10	Typical buried water/slurry pipeline crossing AB 11.8 EL 46.9	R1		Other Pipeline in Vicinity	Pipeline maintenance activities i.e. excavation Vehicle loads during maintenance activities Water leak causing loss of cover		Depth of cover / separation / concrete slabs (Ph) Signage (Pr) Marker Tape (Pr) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	Yes Yes Yes								
1.11	Typical above ground water/slurry pipeline crossing AB 387.2	R1		Other Pipeline in Vicinity	Vehicle loads during maintenance activities Water leak causing some loss of cover		Signage (Pr) Marker Tape (Pr)	Yes Yes								
1.12	CSG infrastructure Arrow: wells, flow lines, dam construction AB 81.8, 89 EL 30.2 DL 2.2, 6	R1		Petroleum Lease	**Wells** (assumed Arrow wells): Drilling Vehicle loads/bogging **Flow lines** (assumed Arrow flow lines) Trenching Vehicle loads **Dam** (assumed Arrow Dam) Bulk excavation/scrapers/dozers Vehicle loads		Signage (Pr) Arrow inspector on site during activities (Pr) Accurate positioning of pipeline (Pr) Patrols (Pr)	Yes Yes Yes Yes Yes Yes								
1.13	CSG infrastructure third party: wells, flow lines, dam construction AB 81.8, 89 EL 30.2 DL 2.2, 6	R1		Petroleum Lease	**Wells** (third party) Drilling Vehicle loads/bogging **Flow lines** (third party) Trenching Vehicle loads **Dam** (third party) Bulk excavation/scrapers/dozers Vehicle loads		Signage (Pr) Arrow inspector on site during activities (Pr) Accurate positioning of pipeline (Pr) Patrols (Pr)	Yes Yes Yes Yes Yes Yes								
1.14	Active mine (coal) AB 74 to 77 EL 3 to 6 SL 3.1 to 6.7 DL 7.3 to 14.1	R1	Heavy Industrial (not high consequence (no coal stock piles and mine does not directly lay over pipeline))	Mining Lease	Possible open cut mining to physical impact of pipeline Possible underground mining to subsidence Vibrations from blasting Mine trucks traversing pipeline		Liaison between proponent companies and exclusion of mining around pipeline prevents work within the pipeline easement (Pr) Assumed that pipeline is not designed for any subsidence initially and capacity for subsidence ends up being calculated later	No Yes Yes No		Look for overlaps between underground mining and large water course crossings of pipelines.						
1.15	Adjacent active mine (salt) AB 433 to 435	R1	Heavy Industrial (not high consequence)	Mining Lease	Tracked vehicles adjacent to the pipeline or access track construction		Signage (Pr) Marker Tape (Pr) Patrols (Pr) Community liaison (Pr) Liaison between proponent companies and exclusion of mining around pipeline prevents work within the pipeline easement (Pr)	Yes								
1.16	CIC SGIC at AB 418 to 469.5 GSDA at AB 469.5 to 478 Marlborough Nickel Corridor AB 329 to 407.9	R2	CIC	Industrial	TBA					Check declared CIC projects with interests.						
1.17	Typical parallel gas pipeline AB 265 to 349 (AGL), AB 329.2 to 407.5 (Gladstone Nickel Project p/l), AB 408.7 to 411.1 (Gladstone to rocky p/l (AGL Jemena to tbc))	R1		Other Pipeline in Vicinity	Pipeline maintenance activities i.e. excavation Vehicle loads during maintenance activities Catastrophic failure of third party pipeline due to any cause		Arrow inspector on site during activities (Pr) Depth of cover / Concrete slabs (Ph) Signage (Pr) Marker Tape (Pr) Separation approx. 30m (Ph) Depth of cover / separation / concrete slabs (Ph) Third party liaison (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	No No No								
1.18	Typical parallel water pipeline AB 90 to 93	R1		Other Pipeline in Vicinity	Vehicle loads during maintenance activities Water leak causing loss of cover		Signage (Pr) Marker Tape (Pr) Separation (Ph) Proposed light duty fence between water and gas pipelines during construction (Pr) Third party liaison (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	Yes Yes		Make sure the fence is specified in the licence agreement.						

SMS Location and Threat Analysis Table

1.19	Parallel powerlines AB 81 to 85.6, 462.9 to 464 EL 47.8 to 48.5	R1		Power Lines In Proximity	Induced voltages from nearby power transmission lines Fault to earth to electrocution Fault to earth to coating damage Power pole installation		Correct earthing design (Ph) Lateral separation (Ph) Operation safety procedures i.e. earth mats (Pr) Signage (Pr) Arrow inspector on site during activities (Pr) Third party liaison (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	No No Yes Yes								
1.20	Future and existing substations AB 103, AB 405	R1	Industrial	Industrial	Blasting Bulk earth works Outlying earthing stakes Induced currents Fault to earth to electrocution Fault to earth to coating damage		Heavy wall (Ph) Depth of cover (Ph) Signage (Pr) Patrols (Pr) Marker tape (Pr) Third party liaison (Pr) Arrow inspector during site work (Pr) Dial before you dig (Pr) CP/earthing design (Ph) Accurate positioning of pipeline (Pr) Careful earthing design in the vicinity of the substation (Ph)	Yes Yes Yes No No No								
1.21	Proposed mining camp AB 101 to 102	R1	Sensitive	Mining Lease	No identified threat to the pipeline		Heavy wall (Ph) Depth of cover (Ph) Signage (Pr) Patrols (Pr) Marker tape (Pr) Third party liaison (Pr) Arrow inspector during site work (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	N/A								
1.22	Cleared areas to purpose unknown AB 0 to 478 km (all) EL 37 onwards	R1		Grazing	Blade ploughing Vehicle loads Rippers		Depth of cover 1200 mm (Ph) Signage (Pr) Patrols (Pr) Third party liaison (Pr) Arrow inspector during site work (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	No Yes No		Review previous study by GHD on depth of blade ploughing to see whether 1200 mm is enough.						
1.23	Possible cultivation AB 159 onwards, 172 to 174, 211 - onwards DL 0 onwards	R1		Cropping	Blade ploughing Vehicle loads Rippers		Depth of cover 1200 mm (TBC) (Ph) Signage (Pr) Patrols (Pr) Third party liaison (Pr) Arrow inspector during site work (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	No Yes No		Determine the depth of tillage.						
1.24	Centre pivot irrigation to grow vegetation AB 244 to 245	R1			TBC Underground water pipe installation		Depth of cover 1200 mm (TBC) (Ph) Signage (Pr) Patrols (Pr) Third party liaison (Pr) Arrow inspector during site work (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	No Yes		Determine method of tillage for centre pivot irrigation.						
1.25	Contour banking (may be extended) AB 311, 318 to 319, 343 to 344, 358 to 359, 372 to 373	R1		Cropping	TBC		Increase depth of cover (TBC) Signage (Pr) Patrols (Pr) Third party liaison (Pr) Arrow inspector during site work (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	No		Determine the height, and therefore depth of cover, required for contour banking.						
1.26	Possible flood plains AB 320 onwards AB 428 onwards EL 29	R1		None	Inundation with simultaneous liquefaction		Geotech study to define tenancy of flotation, with buoyancy control	No		Carry out appropriate geotech study.						
1.27	PASS (potential acid sulphates soil) AB 428 onwards	R1		None	Loss of FJC and corrosion to the pipeline		Study to confirm that PASS actually is ASS and then study to confirm that FJC will resist the acid	No								
1.28	Grazing AB 0 to 478 All Laterals	R1		Grazing	Installation of normal fence posts Installation of corner and strainer posts Stock damaging signs Dam construction		Signage (Pr) Patrols (Pr) Third party liaison (Pr)	No Yes Yes Yes								
1.29	Third party seismic surveys	R1		Grazing	Vibration from Seismic Surveys		Signage (Pr) Patrols (Pr) Third party liaison (Pr) Arrow inspector (Pr)	Yes								
1.30	Rural residential/possible industrial AB 391 onwards	R2	Industrial	Residential/Small Industry	Swimming pools and dam construction		Signage (Pr) Patrols (Pr) Third party liaison (Pr) Arrow inspector (Pr)	No								
1.30	Residential Yarwun AB 446 to 469	T1		Residential	Swimming pools and dam construction		Signage (Pr) Patrols (Pr) Third party liaison (Pr) Arrow inspector (Pr)	No								
1.31	Sensitive (school) AB 465	T1	Sensitive	Residential	No identified threat		Heavy wall (Ph) Depth of cover (Ph) Signage (Pr) Patrols (Pr) Marker tape (Pr) Third party liaison (Pr) Dial before you dig (Pr) Accurate positioning of pipeline (Pr)	N/A								
2. Design and Materials																
2.1	Entire Length				Design Errors		Design has been to approved standards and has been checked. Approvals matrix to AS 2885 Hydrotesting (partial measure) Experienced personnel (RPEQ) Second and third party verification of design. CNPC and Shell will also overview and audit design ISO 9001 accreditation	No								

SMS Location and Threat Analysis Table

2.2	Entire Length				Material Defects		Materials have been selected to comply with design standards. NDT, ITPs, material certificates and hydrotests minimise the possibility of defects existing in the pipeline and facilities. Owners team QA inspections at start of steel making process and throughout the whole coating/delivery supply chain Retain expert advisers Real special precautions around handling of FBE (handling specification)	No, subject to acceptance and implementation of recommendations/actions		Require contractor to demonstrate minimised and careful handling of coated pipe.						
2.3	Entire Length				Hydrotesting issues and 0.8 design factor issues		The effect of coating process on the pipe Receiving metallurgical advice (as a result of the effect of FBE coating on the pipe)	No, subject to acceptance and implementation of recommendations/actions		Make sure pipe spec captures recent industry lessons learnt on items such as stresstostrain curves, coating process, strain aging, yield ratio, field weldability (all tests done on coated pipe). Consider the initial additional impact of spiral welded pipe.						
3. Latent Construction Defects																
3.1	Entire Length				Coating damage in general Coating damage after pipe lowering due to backfill		Appropriate specification Enforcement of specification on site and dedicated backfill inspector DCVG survey post burial and monitoring of the CP performance Proposing a DCVG regime (operations process)	No No		Ensure spec prescribes the use of brush type jeeper.						
3.2	Entire Length				Undiagnosed welding defects due to poor NDT		Appropriate spec Enforcement of spec Hydrotesting	No		Baseline calibration of AUT.						
3.3	Entire Length				Cyclic fatigue of pipeline due to operation of upstream gathering and downstream LNG plant		Liaison with upstream and downstream at the design basis stage Recording of number of pressure cycles (SCADA) Intelligent pigging	No		Confirm that cyclic operation does not give rise to fatigue design on the pipeline.						
4. Operation and Maintenance																
4.1	Entire Length				Pipeline Internal Corrosion		Non corrosive and dry gas Water sampling Regular pigging Occasional intelligent pigging Moisture analyser	No								
4.2	Entire Length				Pipeline External Corrosion		Cathodic protection DCVG surveys Protective coating Intelligent pigging Backfill specification and enforcement External coating spec and enforcement Proper discovery of ASS Field joint coating specs and enforcement	No								
4.3	Entire Length				Stress Corrosion Cracking / Environmental corrosion cracking		Assessed cyclic stresses High quality coating Intelligent pigging	No								
4.4	Entire Length				Fatigue Cracking		Assessed cyclic stresses Intelligent pigging	No								
4.5	Entire Length				Bacterial Corrosion		Control of gas quality	No								
4.7	Entire Length				Cathodic Protection Shielding		Quality coating	No								
4.8	Entire Length				Overpressure Control System Failure		Multi redundant pressure control system as per AS 2885	No								
4.9	Entire Length				Inadequate servicing of valves		Regular inspections to maintenance schedule Experienced personnel High quality valves	No								
4.10	Entire Length				Inadequate servicing or obscuring of signage.		Patrols.	No								
4.11	Entire Length				Inadequate servicing of CPUs.		Potential surveys CPU readings Maintenance schedule	No								
5. Operating Errors																
5.1	Entire Length				Lapsed or incorrect CP testing		Competent operators Available training Operating procedures Licensed operator Fail safe design	No								
5.2	Entire Length				Overheating of coating system		Spot dig ups on unpigged lines Routine audits of operating practices and SCADA history Competent operators Available training Operating procedures Licensed operator Fail safe design	Yes								
5.3	Entire Length				Incorrect as builts		QA procedures Audits Competent operators Available training Operating procedures Licensed operator Fail safe design	No								
5.4	Entire Length				Failure of third party liaison		QA procedures Audits Competent operators Available training Operating procedures Licensed operator	No								
5.5	Entire Length				Procedures which place too much onus operators having very high and very broad skill levels		Clear and unambiguous procedures and enforcement Review of operating procedures regularly	No								

SMS Location and Threat Analysis Table

6. Natural Events																
6.1	Entire Length				Bushfire		Depth of cover ROW patrols Appropriate facility design	No								
6.2	Entire Length				Lightning		Appropriate surge diversion Appropriate earthing	Yes								
6.3	Entire Length				Flooding		Refer to location specific	N/A								
6.4	Entire Length				Earthquake		Seismic study to determine active fault lines in the areas Special design at these locations	Yes								
6.5	Entire Length				Tsunami to refer to location specific		Depth of cover	No								
6.6	Entire Length				Soil to expansion/contraction		Highly adhesive factory and FJC	No								
6.7	Entire Length				Telluric effects		CP potential reads Appropriate CP design	No								
7. Security																
7.1	Entire Length				Incident due to sabotage, threat of sabotage or unauthorised operation.		ROW Patrols Fenced Facilities Buried	Yes								
7.2	Entire Length				Terrorism/Vandalism		ROW Patrols Fenced Facilities Buried	Yes								
8. Environment																
8.1	Entire Length				Ground water and soil contamination from fuel and other chemicals used on site e.g. lubricants		Low point drains Regular cleaning pigs (controls quantity) Spill response procedures Cleaning pig procedures Small quantities of contaminants used	No								

ALL CONTROLS FAILED AS PER SECTION 2.3.6 to defer to detailed SMS

Appendix E

Wall Thickness Calculation Report

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CALCULATION

ABP

Calculation for
Wall Thickness Requirement for Internal Pressure

41-24306

Revision

Rev No.	Calculation By:	Checked By:	Approved By:	Description:	Date:
A	E Bart	T Mills	T Mills	**Issued for Use For Preliminary SMS**	22-Aug-11
B	R Turna	P Nasehmanesh	P Nasehmanesh	**Issued for Use For Preliminary SMS**	29-Sep-11

Calculation Summary

This calculation determines the pipeline wall thickness for the ABP, taking into consideration internal pressure only.

1. Introduction

Arrow Energy (the Principal), is proposing to develop a pipeline network in central eastern Queensland that will deliver coal seam gas from its gas fields in the Bowen and Surat Basins to a proposed LNG facility to be located on Curtis Island near Gladstone. The proposed network will be approximately 1,200km long and will incorporate scraper stations and intermediate mainline valves.

A pipeline licence has been granted for the major part of the proposed pipeline from the Surat Basin, however an environment impact assessment of the initial 100km at the start of this pipeline, to the Kogan North Central Gas Processing Facility near Dalby in south-eastern Queensland, is required.

No part of the proposed pipeline from the Bowen Basin has yet been assessed and this preliminary engineering is associated with the full extent of approx. 610km of pipeline length, the subject of a separate report.

The ABP system will consist of a DN800 (32”), Class 600 buried steel pipeline.
This calculation also reflects a possible future upgrade of the ABP system to a DN1050 (42") pipe diameter.

This calculation only considers the internal pressure containment requirements. It is for preliminary design purposes only.

The design parameters are:
- DN800
- DN1050 (possible upgrade)
- API 5L X70
- MAOP/Design Pressure 10.2 MPa(g)
- Design Temperature: -10 to 60°C (assumed)

2. Design Basis and Scope

The basis for performing this calculation is in accordance with AS 2885.1-2007 Section 5.4.2, which requires numerous design, operation and constructability issues to investigated and (where applicable) wall thickness values to be calculated. The wall thickness shall be the greatest of the values calculated.

This calculation determines the pipeline wall thickness for the above mentioned project, taking into consideration internal pressure only.

The further requirements of AS2885.1 are covered in separate calculations.

3. Assumptions

3.1 Code Related Inputs

3.1.1 Specified Minimum Yield Strength

API Grade	SMYS (MPa)	UTS (MPa)
X 70	485	565(minimum)

3.1.2 Design Factor

The maximum allowable design factors are:

- 0.80 - general
- 0.67 - for pipeline assemblies and facilities

3.1.3 Gas Temperature

Where the pipeline design temperature is above 65°C the yield stress of the pipe steel shall be de-rated in line with AS2885.1 3.4.3 – Strength De-rating. The reduction in yield strength shall be 0.07%/°C by which the design temperature exceeds 23°C.

It is assumed that the maximum pipeline temperature is 60°C. Therefore strength de-rating is not required as per AS2885.1.

3.2 Design Basis Inputs

3.2.1 Additional Allowances

The gas flowing through the pipeline is assumed to be 'Sales Gas' quality. Consequently the gas is deemed to be 'Non-Corrosive'. Therefore, the pipeline will have a corrosion allowance of 0 mm.

3.2.2 Pressure Class & Pressure

The pipeline has a Design Pressure of 10.2 MPa.

4. Calculation Procedure

4.1 Internal Pressure

The pipeline wall thickness is calculated using the Barlow formula for internal pressure, using Equation 5.4.3 from AS 2885.1.

$$t_p = \frac{p_d \times D}{2 \times F_d \times \sigma_y}$$

P_d = Pressure (MAOP)
F_d = Design Factor
σ_y = Yield Strength
D = Outside Diameter
t_p = Wall Thickness

5. Calculation Results

5.1 Internal Pressure

The minimum wall thickness for internal pressure is tabled below both pipe diameters with the associated design factors.

	DN	DN (in)	OD (mm)	MAOP (MPa)	Grade	Design Factor	Minimum Wall Thickness (mm)
General	800	32	813	10.2	X 70	0.80	**10.69**
Pipeline Assemblies	800	32	813	10.2	X 70	0.67	**12.76**

	DN **upgrade**	**DN** (in)	**OD** (mm)	**MAOP** (MPa)	**Grade**	**Design Factor**	**Minimum Wall Thickness (mm)**
General	1050	42	1067	10.2	X 70	0.80	**14.03**
Pipeline Assemblies	1050	42	1067	10.2	X 70	0.67	**16.75**

6. Conclusion

Each location class requires the following minimum wall thickness to meet only the internal pressure design requirement. Results are rounded up to the nearest 0.1 mm.

- **All locations require a minimum wall thickness of 10.7 mm for DN800 or 14.1 mm for DN1050.**
- **Pipeline Assemblies and facilities require a minimum wall thickness of 12.8 mm for DN800 or 16.8 mm for DN1050.**

CALCULATION

ARROW ENERGY

Rail Crossing Calculation for ABP

41-24306

Revision

Rev No.	Calculation By:	Checked By:	Approved By:	Description:	Date:
A	E Bart	T Mills	T Mills	**Issued for Use for Preliminary SMS**	22-Aug-11
B	R Turna	P Nasehmanesh	P Nasehmanesh	**Issued for Use for Preliminary SMS**	29-Sep-11

Calculation Summary

This calculation determines the resistance to external loads for railway crossings along the proposed ABP pipeline route, in accordance with AS 2885.1 and API RP1102.

1. Introduction

Arrow Energy (the Principal), is proposing to develop a pipeline network in central eastern Queensland that will deliver coal seam gas from its gas fields in the Bowen and Surat Basins to a proposed LNG facility to be located on Curtis Island near Gladstone. The proposed network will be approximately 1,200km long and will incorporate scraper stations and intermediate mainline valves.

A pipeline licence has been granted for the major part of the proposed pipeline from the Surat Basin, however an environment impact assessment of the initial 100km at the start of this pipeline, to the Kogan North Central Gas Processing Facility near Dalby in south-eastern Queensland, is required.
No part of the proposed pipeline from the Bowen Basin has yet been assessed and this preliminary engineering is associated with the full extent of approx. 610km of pipeline length, the subject of a separate report.

The ABP system will consist of a DN800 (32”), Class 600 buried steel pipeline.
This calculation also reflects a possible future upgrade of the ABP system to a DN1050 (42") pipe diameter.

This calculation checks the resistance to external loads of DN800 pipe, at railway crossings on the ABP Pipeline route, in accordance with AS 2885.1 and API RP1102.

2. Input Data / Assumptions

2.1 Pipeline Parameters

Installed Temperature (Assumed)	21°C
Design Pressure	10.2 MPa
Max Operating Temperature	60°C
Min Operating Temperature	-10°C
Type / OD	813 mm
Type / OD (possible upgrade)	1067 mm
Pipe Grade / SMYS (MPa)	X70 / 485 MPa
Pipe Type (Seamless / ERW / SAW)	ERW
Design Factor	0.72

Steel Properties	
Young's Modulus (Es)	205,000,000 kPa
Coefficient of Thermal Exp. (α)	1.17E-05
Poisson's Ratio	0.30

2.2 Input Parameters

The soil type selected for the calculation was: Soft to medium clays and silts with low to medium plasticities; (loose sands and gravels). A soil density of 18.9 kN/m3 was chosen based on RP1102 recommendations. Refer to assumptions below.

Soil Type:	Soft to Medium clays and silts with low to Medium plasticities
Soil Density	18.9 kN/m³
Buried Depth to Top of Pipe	2000 mm
External Load - Pressure	96 kPa

The external load used for this calculation has been recommended by AS 2885, in the form of 356 kN or approximately 36 tonne per axle and a 20ft x 8 ft, 4 axle, wagon. 96 kPa = (4 * 356 kN / 20ft * 8 ft)

2.3 Assumptions

1 The 'Soft to medium clays and silts with low to medium plasticities; loose sands and gravels' soil type was assumed as recommended in Section 4.7.2.1 of RP1102. These parameters are generally conservative. Note that geotechnical data isn't available for the actual sites.

2 The pipe minimum and maximum operating temperatures as well as the installation temperature are assumed to be equivalent to the minimum and maximum gas temperatures as referenced in the SGP Basis of Design (08-GHD-3-02-0045). The calculations are very sensitive to temperature.

3. Calculation Results

The results are summarised below and detailed within Appendix A.

DN 800

Min. Wall Thickness (mm)	Cyclic Circumferential Stress (kPa)	Cyclic Longitudinal Stress (kPa)	Circumferential Stress (kPa)	Effective Stress (kPa)	Allowable Stress (kPa)
14.90	57,473	48,002	273,175	348,921	349,200

DN 1050 (possible upgrade)

Min. Wall Thickness (mm)	Cyclic Circumferential Stress (kPa)	Cyclic Longitudinal Stress (kPa)	Circumferential Stress (kPa)	Effective Stress (kPa)	Allowable Stress (kPa)
19.60	52,419	38,097	272,538	347,631	349,200

Effective stresses are within allowable limits
Girth weld stresses are within fatigue allowable limits
Longitudinal stresses are within fatigue allowable limits

4. Conclusion

The wall thickness at Railway crossings shall be a minimum of 14.9 mm for DN800 and 19.6 mm for DN1050.
The pipeline at the rail crossing is adequately designed to resist external loading as per API RP1102. Note that the API RP1102 calculation does not take any credit for added strength due to casings. This is because the space between the casing and pipeline is generally filled with a grout / cement, which can transmit loads from the casing to the pipeline. That is, API RP1102 requires that the pipeline on its own (without casing) be designed to withstand the loads experienced at a rail crossing.

Best practice installation techniques, in accordance with API RP1102, are recommended. API RP1102, Section 4.9 recommends the location of longitudinal welds at the 45, 135, 225 or 315 degree position with the crown at the zero position. Section 4.10 recommends locating girth welds at the crossing at a distance of at least 3m from the centreline of the tracks.

This calulation should be reviewed once the actual requirements of the rail authority are known.

5. References

API RP1102 - Steel Pipelines Crossing Railroads and Highways
AS 2885.1 - Pipelines - Gas and Liquid Petroleum Part 1: Design and Construction, Appendix V

Appendix 1 -
Railway Crossing Calculation
DN800

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Client: ARROW ENERGY
Project: ARROW ENERGY ABP PIPELINE
Calculation Title: Rail Crossing

APPENDIX 1

Job No: 41-24306

Pipeline Conditions		
Type / OD (mm)	DN800	813.0
Pipe Grade / SMYS (MPa)	X70	485
Wall Thickness (tw)	14.9	mm
Weld Type	Seamless and ERW	
Design Pressure (MAOP)	10.20	MPa
Buried Height	2000	mm
Design Factor	0.72	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

Steel Properties		
Young's Modulus (E_s)	2.1E+08	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.30	

Enter value between 1800 and 4300. If pipe depth > 4300, enter 4300 (conservative)

0.72 is used for crossing calc as per AS2885.1-2007 Section 5.7.3 c) (i)

Pipeline Options		
Trenched Construction?	Other	
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels	
Soil Unit Weight	18.9 kN/m^3	Recommended value from RP1102: 18.9
Single or Double Track Crossing?	Double	

Pipeline Results			
Cyclic Circumferential stress	S-Hr	57473	kPa
Cylic Long stress	S-Lr	48002	kPa
Circumferential stress	S-Hi	273175	kPa
Effective Stress	Seff (T2Min)	348921	kPa
	Seff (T2Max)	325811	kPa

	% of Allowable / Limit
Effective stresses are within allowable limits.	99.9
Girth weld stresses are within fatigue limits.	89
Longitudinal weld stresses are within fatigue limits.	37.89

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Client: ARROW ENERGY
Project: ARROW ENERGY ABP PIPELINE
Calculation Title: Rail Crossing
Job No: 41-24306

RP1102 Rail Crossing Calculation

Input Data	🟨
Input obtained from 1102 Figures/graphs	🟦

Input Data			
Design Pressure	MAOP	10.20	MPa
Pipe Material		X70	
Yield Strength	SMYS	485	MPa
Outside Diameter	D	813	mm
Wall thickness	tw	14.9	mm
Buried Height	H	2000	mm
DF - for allowable stress	DF	0.72	

RP1102 Calculated/Input Data		
	Other	Trenched Construction/Other ?
H/Bd	2.31	
tw/D	0.018	
Bd	864	D + 51mm if unknown, if trenched Bd = D
Bd/D	1.06	

RP 1102 Soil Data				
Soil Reaction Mod	E'	3.4	MPa	2
Soil Unit weight	y	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	

Earth Load				
Circ stiffness factor	K-he	3358		Obtained from figure 3
Earth Burial factor	Be	0.69	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	0.928		Obtained from figure 5
D	Be	**32864.7**	kPa	
Earth Excavation factor	Ee			
Live Load	w	**96.0**	kPa	96KPa as per Section 4.7.2.2.1
Impact Factor	Fi	1.711156667	DLA:	Default calculated based on Figure 7 for railways, else use DLA (refer App W of DR04561)

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

T Mills

1.45

Railroad Cyclic Stresses				
Stiffness factor	K-Hr	452.78		Obtained from figure 8
Geometry factor	G-Hr	0.632243047		Obtained from figure 9
Circ Double Track factor	N-Hr	1.222158874		Obtained from figure 10
Cyclic Circ stress	S-Hr	**57472.7**	kPa	
Long stiff factor	K-Lr	472.58829		Obtained from figure 11
Long Geo factor	G-Lr	0.550119738		Obtained from figure 12
Long Double Track factor	N-Lr	1.1239772		Obtained from figure 13
Cylic Long stress	S-Lr	**48001.9**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**273175.1678**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P\,(D - tw)}{2\,t_w}$$

Check for Allowable Stresses					
Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1	
Young's Modulus Steel	Es	2.1E+08	kPa	Obtained from Table A1	
Installation Temperature	T1	21.0	°C		
Max Operating Temperature	T2-max	60.0	°C		39.0
Min Operating Temperature	T2-min	-10.0	°C		-31.0
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT	
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT	
Poisson's ratio of steel	vs	0.3			
Possion's component		91,812.0	kPa	v(S-he + S-hi)	

Max Circumferential stress	S1	**363,512.5**	kPa
High Temp Max Longitudinal stress	S2 (T2max)	46,272.4	kPa
Low Temp Max Longitudinal stress	S2 (T2min)	214,167.4	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2Max)	**325,811.1**	kPa
	Seff (T2Min)	**348,920.8**	kPa

$$\boxed{S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}}$$

$$\boxed{S_2 = \Delta S_L - E_s \alpha_t (T_2 - T_1) + \nu_s (S_{He} + S_{Hi})}$$

$$\boxed{S_3 = -P}$$

$$\boxed{S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}}$$

Allowable Stress	Sa	349200	kPa	SMYS x DF

Effective stresses are within allowable limits.

Check for Fatigue				
Girth fatigue endurance limit	Sfg	485000	kPa	(Automatic Lookup) Obtained from Table 3
check for S-Lr < Sfg x DF	dSL	48002	kPa	

Girth weld stresses are within fatigue limits.

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hr < Sfl x DF		124106	kPa	Sfl x DF
Longitudinal Wel Stresses		47025.53885	kPa	

Longitudinal weld stresses are within fatigue limits.

Appendix 2 -
Railway Crossing Calculation
DN1050

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Client: ARROW ENERGY
Project: ABP
Calculation Title: Rail Crossing Calculation for ABP

APPENDIX 1

Job No: 41-24306

Pipeline Conditions		
Type / OD (mm)	DN1050	1067.0
Pipe Grade / SMYS (MPa)	X70	485
Wall Thickness (tw)	19.6	mm
Weld Type	Seamless and ERW	
Design Pressure (MAOP)	10.20	MPa
Buried Height	2000	mm
Design Factor	0.72	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

Enter value between 1800 and 4300. If pipe depth > 4300, enter 4300 (conservative)

0.72 is used for crossing calc as per AS2885.1-2007 Section 5.7.3 c) (i)

Steel Properties		
Young's Modulus (E_s)	2.1E+08	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.30	

Pipeline Options		
Trenched Construction?	Other	
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels	
Soil Unit Weight	18.9 kN/m^3	Recommended value from RP1102: 18.9
Single or Double Track Crossing?	Double	

Pipeline Results			
Cyclic Circumferential stress	S-Hr	52419	kPa
Cylic Long stress	S-Lr	38097	kPa
Circumferential stress	S-Hi	272538	kPa
Effective Stress	Seff (T2Min)	347631	kPa
	Seff (T2Max)	320599	kPa

	% of Allowable / Limit
Effective stresses are within allowable limits.	99.6
Girth weld stresses are within fatigue limits.	78
Longitudinal weld stresses are within fatigue limits.	33.13

RP1102 Rail Crossing Calculation

Input Data	🟨
Input obtained from 1102 Figures/graphs	🟦

Input Data

RP1102 Calculated/Input Data

Design Pressure	MAOP	10.20	MPa	Other		Trenched Construction/Other ?
Pipe Material		X70		H/Bd	1.79	
Yield Strength	SMYS	485	MPa	tw/D	0.018	
Outside Diameter	D	1067	mm	Bd	1118	D + 51mm if unknown, if trenched Bd = D
Wall thickness	tw	19.6	mm	Bd/D	1.05	
Buried Height	H	2000	mm			
DF - for allowable stress	DF	0.72				

RP 1102 Soil Data

Soil Reaction Mod	E'	3.4	MPa	2
Soil Unit weight	*y*	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	

Earth Load

Circ stiffness factor	K-he	3346		Obtained from figure 3	
Earth Burial factor	Be	0.54	Soil A	Obtained from figure 4	
Earth Excavation factor	Ee	0.911		Obtained from figure 5	
D	Be	**33398.3**	kPa		
Earth Excavation factor	Ee				
Live Load	w	**96.0**	kPa	96KPa as per Section 4.7.2.2.1	1.45
Impact Factor	Fi	1.711156667	DLA:		Default calculated based on Figure 7 for railways, else use DLA (refer App W of DR04561)

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Railroad Cyclic Stresses

Stiffness factor	K-Hr	452.47		Obtained from figure 8
Geometry factor	G-Hr	0.553161376		Obtained from figure 9
Circ Double Track factor	N-Hr	1.274939429		Obtained from figure 10
Cyclic Circ stress	S-Hr	**52419.2**	kPa	
Long stiff factor	K-Lr	472.22724		Obtained from figure 11
Long Geo factor	G-Lr	0.380625017		Obtained from figure 12
Long Double Track factor	N-Lr	1.290275333		Obtained from figure 13
Cylic Long stress	S-Lr	**38097.1**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**272537.7551**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P(D - tw)}{2t_w}$$

Check for Allowable Stresses

Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1	
Young's Modulus Steel	Es	2.1E+08	kPa	Obtained from Table A1	
Installation Temperature	T1	21.0	°C		
Max Operating Temperature	T2-max	60.0	°C		39.0
Min Operating Temperature	T2-min	-10.0	°C		-31.0

ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT

Poisson's ratio of steel	vs	0.3		
Possion's component		91,780.8	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**358,355.3**	kPa
High Temp Max Longitudinal stress	S2 (T2max)	36,336.4	kPa
Low Temp Max Longitudinal stress	S2 (T2min)	204,231.4	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2Max)	**320,599.4**	kPa
	Seff (T2Min)	**347,631.1**	kPa

$$\boxed{S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}}$$

$$\boxed{S_2 = \Delta S_L - E_s\alpha_t(T_2 - T_1) + \nu_s(S_{He} + S_{Hi})}$$

$$\boxed{S_3 = -P}$$

$$\boxed{S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}}$$

Allowable Stress	Sa	349200	kPa	SMYS x DF

Effective stresses are within allowable limits.

Check for Fatigue

Girth fatigue endurance limit	Sfg	485000	kPa	(Automatic Lookup) Obtained from Table 3
check for S-Lr < Sfg x DF	dSL	38097	kPa	

Girth weld stresses are within fatigue limits.

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hr < Sfl x DF		124106	kPa	Sfl x DF
Longitudinal Wel Stresses		41115.05346	kPa	

Longitudinal weld stresses are within fatigue limits.

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CALCULATION

Arrow Energy

Preliminary Calculation for Resistance to Penetration and Measurement Length for ABP

41-24306

Revision

Rev No.	Calculation By:	Checked By:	Approved By:	Description:	Date:
A	**E Bart**	**T Mills**	**T Mills**	**Issued for Use for Preliminary SMS**	**25-Aug-11**
B	**R Turna**	**P Nasehmanesh**	**P Nasehmanesh**	**Issued for Use for Preliminary SMS**	**29-Sep-11**

Calculation Summary

This calculation determines the minimum pipeline wall thickness with respect to its ability to resist to penetration by an excavator, as required by AS 2885.1-2007, for the ABP

1. Introduction

Arrow Energy (the Principal), is proposing to develop a pipeline network in central eastern Queensland that will deliver coal seam gas from its gas fields in the Bowen and Surat Basins to a proposed LNG facility to be located on Curtis Island near Gladstone. The proposed network will be approximately 1,200km long and will incorporate scraper stations and intermediate mainline valves.

A pipeline licence has been granted for the major part of the proposed pipeline from the Surat Basin, however an environment impact assessment of the initial 100km at the start of this pipeline, to the Kogan North Central Gas Processing Facility near Dalby in south-eastern Queensland, is required.
No part of the proposed pipeline from the Bowen Basin has yet been assessed and this preliminary engineering is associated with the full extent of approx. 610km of pipeline length, the subject of a separate report.

The ABP system will consist of a DN800 (32"), Class 600 buried steel pipeline.
This calculation also reflects a possible future upgrade of the ABP system to a DN1050 (42") pipe diameter.

The aim of this calculation is to determine the minimum pipeline wall thickness with respect to penetration resistance by excavators.

The design parameters are:

- DN800
- DN1050 (possible upgrade)
- API 5L X70
- MAOP/Design Pressure 10.2 MPa
- Design Temperature: -10 to 60°C

2. Design Basis and Scope

The basis for performing this calculation is in accordance with AS 2885.1-2007 Section 5.4.2, which requires numerous design, operation and constructability issues to be investigated and (where applicable) wall thickness values to be calculated. The wall thickness shall be the greatest of the values calculated.

The methods and equations will be used as they appear in the standard when determining the required wall thickness for the design pressure of 10.2MPa(g). The wall thickness required to prevent full bore rupture and limit the release rate to 10GJ/s will be a factor in the selection of pipe for high consequence areas.

The further requirements of AS2885.1 are covered in separate calculations.

3. Assumptions

3.1 Code Related Inputs

3.1.1 Specified Minimum Yield Strength

API Grade	SMYS (MPa)	UTS (MPa)
X 70	485	570 (minimum)

(Source: API 5L, Table 6)

3.1.2 Pressure Class & Pressure

A Maximum Allowable Operating Pressure (MAOP) of 10.2 MPa(g) is assumed.

3.2 Design Basis Inputs

3.2.1 Additional Allowances

The gas flowing through the pipeline is assumed to be 'Sales Gas' quality. Consequently the gas is deemed to be 'Non-Corrosive'. Therefore, the pipeline will have a corrosion allowance of 0 mm.

3.2.2 Location Classes

It is expected that the route will consist of both rural and high consequence areas. The high consequence areas may have a variety of location classes however their requirements are common and they will therefore be grouped together. For this preliminary calculation Sensitive areas (s) and T2 areas, which have a limiting release rate of 1GJ/s, have not been designed for in this calculation.

3.3 Calculation Inputs

The following inputs have been used for the calculations.

Fracture Area	- 80 mm^2 at V-notch
Young's Modulus	- 205,000 MPa
Charpy Impact Energy	- 90J (assumed value)
B Factor	- 1.3 for High Consequence Areas. A value of 1.3 has been selected for conservatism over the equally credible value of 1.0

- Maximum discharge rate hole diameters (refer Appendix)
  - 10 GJ/s = 144 mm
- The expected gas composition used in this calculation was specified by Arrow Energy and is in the Design Basis (08-GHD-3-02-0045). To be conservative, the rich gas composition has been used.
- The largest credible excavator size is assumed to be 35 tonnes.

3.3.1 Charpy Impact Energy

The calculation determines wall thickness from an assumed Charpy value of 90J based on critical defect length. The wall thickness due to resistance to penetration has a low sensitivity to this value.

4. Calculation Procedure

The calculation process requires numerous iterative steps. This calculation does not provide evidence of the iterative steps undertaken to produce the finally selected pipe wall thickness, but does provide the working for the selected thickness

4.2 Resistance to Penetration

AS 2885.1 outlines the method to evaluate the pipe's ability to resist penetration for standard excavator sizes and bucket tooth types. The excavator sizes outlined in the standard are as follows: 5, 10, 15, 20, 25, 30, 35, 40 & 55 tonne machines. The documented bucket teeth types are 'general purpose', single and twin 'tiger teeth' and 'penetrating tooth'.

The pipe's resistance to penetration for excavator threats is calculated using Equation M3 (AS 2885.1).

The force exerted by a bucket (F_{BUCKET}) is calculated using Equation M4. The 'B' factor is applied to obtain the maximum force assuming the worst possible geometry (F_{MAX}), which varies between 0.75 and 1.3. Refer Equation M2.

The maximum force exerted on the pipe from a bucket and excavator combination can then be compared with the force required to penetrate the pipe, ultimately determining if the excavator's tooth can penetrate the pipe.

4.3 Critical Defect Length

The critical defect length (CDL) is the axial length of a defect that just exceeds the pipes ability to retain a flaw, such that the defect grows causing the pipe to rupture. The critical defect length is dependent on the pipeline parameters (diameter, grade, wall thickness) and the instantaneous operating pressure.

Calculating the critical defect length allows the type of failure mode to be determined by comparing the critical defect length with the maximum defect length an excavator can produce (L max). If the critical defect length is greater than the excavator defect length, then the defect will not grow and the failure mode is LEAK. In contrast, if the critical defect length is smaller than the excavators defect length, then the failure mode is RUPTURE. As per AS2885.1, the critical defect length must be at least 150% of the maximum defect length for the pipe to be considered No Rupture.

The method used to calculate the critical defect length for lower toughness steels is given in Section 4.8.5 – Critical Defect Length (AS 2885.1). This approach is an iterative process. A MS Excel spreadsheet was developed to solve the equations.

The following Equations from AS 2885.1-2007 have been utilised:

- Equation 4.8.5(2);
- Equation 4.8.5(4);
- Equation 4.8.5(5);
- Equation 4.8.5(3).

4.4 Special Provisions for High Consequence Areas

4.4.1 No Rupture

AS 2885.1 Clause 4.7.2 specifies that the pipeline shall be designed such that rupture is not a credible failure mode for the following location classes: T1, T2, I, S (and HI areas with the potential for an escalation in consequences). The Safety Management Study (risk assessment) will determine if the pipeline route passes through any of the aforementioned High Consequence Areas.

No Rupture is achieved by one of the following:

- The hoop stress shall not exceed 30% of SMYS or;
- The largest equivalent defect is determined for the location class, and the hoop stress at MAOP is selected such that the critical defect length is not less than 150% of the axial length of the largest equivalent defect. **This is conservatively applied to part-through wall defects, ie it assumes that non-leaking defects, of sufficient size, can still lead to rupture. This approach is appropoiate for the purposes of preliminary calculations.**

4.4.2 Maximum Discharge Rate

AS 2885.1 (Section 4.7.3) specifies that the maximum allowable discharge rate shall not exceed 10 GJ/s in Residential (T1), Industrial (I) and some heavy Industrial (HI) location classes.

Sensitive (S) locations shall be limited to 1 GJ/s, however these are not considered in this preliminary calculation.

5. Calculation Results

5.1 Resistance to Penetration

The results of the resistance to penetration calculation, summarised and tabled below, show that the High Consequence pipe cannot be penetrated by a 35T excavator irrespective of tooth type. The wall thickness for pipe in High Consequence areas was set by the CDL requirements listed in Section 5.2

DN800

General Purpose Tooth

				Excavator Weight								
Pipe Wall Thickness				5T	10T	15T	20T	25T	30T	35T	40T	55T
High Cons.	68.40%	12.5 mm	B = 1.3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Twin Tiger Tooth

				Excavator Weight								
Pipe Wall Thickness				5T	10T	15T	20T	25T	30T	35T	40T	55T
High Cons.	68.40%	12.5 mm	B = 1.3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Single Penetration Tooth

				Excavator Weight								
Pipe Wall Thickness				5T	10T	15T	20T	25T	30T	35T	40T	55T
High Cons.	68.40%	12.5 mm	B = 1.3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Leak	Leak

Single Tiger Tooth

				Excavator Weight								
	Pipe Wall Thickness			5T	10T	15T	20T	25T	30T	35T	40T	55T
High Cons.	68.40%	12.5 mm	B = 1.3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Leak	Leak

DN1050 (possible upgrade)

General Purpose Tooth

				Excavator Weight								
	Pipe Wall Thickness			5T	10T	15T	20T	25T	30T	35T	40T	55T
High Cons.	77.20%	14.53 mm	B = 1.3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Twin Tiger Tooth

				Excavator Weight								
	Pipe Wall Thickness			5T	10T	15T	20T	25T	30T	35T	40T	55T
High Cons.	77.20%	14.53 mm	B = 1.3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Single Penetration Tooth

				Excavator Weight								
	Pipe Wall Thickness			5T	10T	15T	20T	25T	30T	35T	40T	55T
High Cons.	77.20%	14.53 mm	B = 1.3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Leak

Single Tiger Tooth

				Excavator Weight								
	Pipe Wall Thickness			5T	10T	15T	20T	25T	30T	35T	40T	55T
High Cons.	77.20%	14.53 mm	B = 1.3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Leak

5.2 Special Provisions for High Consequence Areas

A 35 tonne excavator has been assumed to be the largest credible excavator size that could potentially impact the pipeline using any of the four tooth types.

5.2.1 Critical Defect Length

DN800

Critical Defect Lengths

	Wall Thickness (mm)	Design Factor (incidental)	Charpy Impact Energy	Critical Defect Length (mm)
High Cons.	12.50 mm	68.40%	90 J	**166.5 mm**

DN1050 (possible upgrade)

Critical Defect Lengths

	Wall Thickness (mm)	Design Factor (incidental)	Charpy Impact Energy	Critical Defect Length (mm)
High Cons.	14.53 mm	77.20%	90 J	**166.4 mm**

5.2.2 No Rupture

The No Rupture wall thickness for High Consequence pipe is tabulated below. Even though the pipeline cannot be penetrated by a 35 tonne excavator, the No Rupture requirements for 150% CDL have been applied. Consideration has not been given to Facilities and Road / Rail crossing pipe which can occur within a High Consequence Area, however it is envisaged that wall thicknesses and subsequently CDL would be larger.

High Consequence Pipe (12.5mm) DN800
35 Tonne Excavator

Tooth Type	Tooth Hole Diameter	Critical Defect	CDL% of Hole Size
General Purpose	110 mm	166.5 mm	151%
Twin Tiger	110 mm	166.5 mm	151%
Single Tiger	30 mm	166.5 mm	555%
Penetration	80 mm	166.5 mm	208%

High Consequence Pipe (14.53mm) DN1050
35 Tonne Excavator

Tooth Type	Tooth Hole Diameter	Critical Defect	CDL% of Hole Size
General Purpose	110 mm	166.4 mm	151%
Twin Tiger	110 mm	166.4 mm	151%
Single Tiger	30 mm	166.4 mm	555%
Penetration	80 mm	166.4 mm	208%

It can be seen that the worst case is for single point contact from a general purpose or tiger tooth bucket and it has been found that 12.5 mm thick pipe for the DN800 and 14.53 mm thick pipe for the DN1050 are required to (just) satisfy the 150% rule.

5.2.3 Maximum Discharge Rate

Calculations (shown in the appendix) to determine the energy discharge rate show that the hole size to produce an energy discharge rate of 10 GJ/s, is approximately 144 mm, which is larger than the maximum tooth diameter for a 35 tonne excavator. The equations and graphs used are valid for sales quality natural gas at typical ambient air temperatures, discharged through an orifice under choked flow conditions and have been taken from Appendix Y of AS2885.1. These equations are typically only used if the hole size is less than 25% of the pipeline diameter as they become increasing conservative with increasing percentage of hole size to diameter. As the results indicate that the hole size is less 25% of the pipeline diameter the equations are approximately valid.

The hole size required to produce an energy dischage rate of 1 GJ/s, has been calculated to be approximately 46 mm (shown in the appendix). The largest defect caused by a 35 tonne excavator (equipped with twin tiger teeth) is 110 mm (refer to Table M3, Appendix M of AS 2885.1 – 2007), which is clearly greater than the required hole size for limiting energy release rate of 46 mm in a T2 location class zone. However the results above show that the pipeline is not penetrated for an excavator size of up to 35 tonnes (the maximum credible threat) and as such the pipeline meets the requirements of limiting energy release rates in a T2 location class zone.

Please note this calculation is not dependent on pipe size and is applicable to both the DN800 and DN1050 pipe sizes.

5.3 Measurement Length

Measurement length is defined in AS2885.1 as the radius of the 4.7 kW/m2 radiation contour for a full bore rupture. It is calculated in accordance with Clause 4.10

The hand calculation appended uses the method of AS2885 Appendix Y to calculate a measurement length of 900m. To be conservative, a measurement length of 1100m for the DN800 will be used in the initial SMS workshop.

In addition, for a possible future upgrade of the ABP to DN1050 pipe size, the measurement length is approximated to be 1250m.

6. Conclusion

The wall thicknesses summarised below meet the resistance to penetration requirements. Note that there is some conservatism in this calculation.

DN800

Location	Minimum Wall Thickness	Comments
High Consequence	12.5 mm	- No penetration - No Rupture governs WT (for credible 35 tonne excavator) - Max discharge rates are acceptable

DN1050 (possible upgrade)

Location	Minimum Wall Thickness	Comments
High Consequence	14.5 mm	- No penetration - No Rupture governs WT (for credible 35 tonne excavator) - Max discharge rates are acceptable

Appendix
Supporting Calculations

CALCULATIONS

Client	Arrow Energy	Job no.	41-24306	Sheet	1 of 2
Project	ABP/AGP pipeline	Calcs by	EB	Date	23/8/11
Subject	Rupture Distance & Release Rate Calcs	Checked by		Date	30/8/11

Energy Release Rate for Maximum Credible Threat

From AS2885.1 Appendix Y3

Greatest threat hole size is 110mm Ø from 35 T excavator fitted with twin tiger teeth (if excavator was able to penetrate)

Y3 AS2885 $Q = \frac{m'}{\rho} \times GHV$

Pd = 10.2 MPa (g)
A = π x 55² = 9503 mm²
ρ = 0.701 kg/Sm³ (assumed)
GHV = 38.1 (SGP DB)

$m' = 1.1 \times 10^{-3} \times Pd \times A$

$Q = \frac{1.1 \times 10^{-3} \times 10.2 \times 9503}{0.701} \times 38.1$

$Q = 5.8 \, GJ/s$ //

Energy release rate if max credible thre could punctur 5.8GJ/s.

Exclusion Zone Full Bore Rupture (measurement length)

From AS 2885 Appendix Y2

Assume typical pipeline parameters.

For a pressure of 10.2 mpa(g) use Figure Y2.

Extrapolation was used for 4.7kN/m². line.

Y2 AS2885 DN800 line - Radiation Contour Radius = 900m

DN950 line - Radiation Contour Radius = 1100m

To be conservative radiation contours larger than these were used in the report.

Client Arrow Energy
Project ABP/AGP Pipeline
Subject Rupture Distance & Release Rate Calcs
Job no. 41-24306
Calcs by EB
Checked by T Mace
Sheet 2 of 2
Date 23/8/11
Date 30/8/11

Largest Allowable Holes Size for Release Rate ≤ 10GJ/s

AS2885.1 Appendix Y3

For a release rate of 10GJ/s

$$Q = \frac{m'}{\rho} \times GHV$$

$$m' = 1.1 \times 10^{-3} \times Pd \times A$$

$Pd = 10.2$ MPa (g)
$\rho = 0.701$ kg/sm^3 (assumed)
$GHV = 38.1$ mJ/sm^3 (SGP DB)
$Q = 10000$ mJ/s

$$Q = \frac{m'}{\rho} \times GHV$$

$$10\,000 = \frac{m'}{0.701} \times 38.1$$

$$m' = 184$$

$$\therefore 184 = 1.1 \times 10^{-3} \times 10.2 \times A$$

$$A = 16398 \text{ mm}^2$$

$$\therefore \phi = \sqrt{\frac{16398 \times 4}{\pi}}$$

$$\phi = 144 \text{mm}$$

∴ an excavator with tooth diameter of 144mm would have to puncture the pipeline to create energy release rate greater than allowable in high consequence (except T2, S) areas.

Client ARROW ENERGY
Job no. 41-24306
Sheet 3 of 3
Project ABP / ASP
Calcs by RT
Date 30/09/11
Subject RUPTURE DISTANCE & RELEASE RATE CALCS
Checked by P. Narehmann
Date 30/09/11

LARGEST ALLOWABLE HOLE SIZE FOR RELEASE RATE < 1GJ/S

AS 2885.1 APPENDIX Y3

for a release rate of 1 GJ/s

$$Q = \frac{m'}{\rho} \times GHV$$

$$m' = 1.1 \times 10^{-3} \times P_d \times A$$

$$Q = \frac{m'}{\rho} \times GHV$$

$$1000 = \frac{m'}{0.701} \times 38.1$$

$$m' = 18.4$$

$$\therefore 18.4 = 1.1 \times 10^{-3} \times 10.2 \times A$$

$$A = 1639.8 \text{ mm}^2$$

$$\phi = \sqrt{\frac{1639.8 \times 4}{\pi}}$$

$$\phi = 46 \text{ mm}$$

$P_d = 10.2$ MPa

$\rho = 0.701$ kg/sm³ (assumed)

$GHV = 38.1$ MJ/sm³ (SGP DB)

$Q = 1000$ MJ/s

$$A = \frac{\pi \phi^2}{4}$$

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CALCULATION

Arrow Energy

Calculation for ABP

Road Crossing Calculation

41-24306

Revision

Rev No.	Calculation By:	Checked By:	Approved By:	Description:	Date:
A	E Bart	A Mills	A Mills	Issued For Use in Preliminary SMS	22-Aug-11
B	R Turna	P Nasehmanesh	P Nasehmanesh	Issued For Use in Preliminary SMS	29-Sep-11

Calculation Summary

This calculation determines the minimum pipeline wall thickness for road crossings beneath open-cut paved highways and unpaved roads for the ABP in accordance with AS 2885.1, API RP1102 and "Guidelines for the Design of Buried Steel Pipe" by the American Lifeline Alliance.

1. Introduction

1.1 Background

Arrow Energy (the Principal), is proposing to develop a pipeline network in central eastern Queensland that will deliver coal seam gas from its gas fields in the Bowen and Surat Basins to a proposed LNG facility to be located on Curtis Island near Gladstone. The proposed network will be approximately 1,200km long and will incorporate scraper stations and intermediate mainline valves.

A pipeline licence has been granted for the major part of the proposed pipeline from the Surat Basin, however an environment impact assessment of the initial 100km at the start of this pipeline, to the Kogan North Central Gas Processing Facility near Dalby in south-eastern Queensland, is required.
No part of the proposed pipeline from the Bowen Basin has yet been assessed and this preliminary engineering is associated with the full extent of approx. 610km of pipeline length, the subject of a separate report.

The ABP system will consist of a DN800 (32”), Class 600 buried steel pipeline.
This calculation also reflects a possible future upgrade of the ABP system to a DN1050 (42") pipe diameter.

1.2 Objectives

This calculation is in response to Arrow’s request for GHD to determine the wall thickness required for the DN800 and DN1050 Pipeline. It specifically ascertains the minimum wall thickness for road crossings based on whether the pipeline can safely withstand the additional stresses induced by vehicles orthogonally traversing it. The worst case design scenarios will be examined for both occasional and designated crossings.

1.3 Methodology

The calculations performed will follow the method outlined in API RP1102 “Steel Pipelines Crossing Railroads and Highways” for burial depths of 900mm and greater. Burial depths of less than 900mm "Guidelines for the Design of Buried Steel Pipe" by the American Lifeline Alliance. AS2885.1 2007 will also be utilised.

The RP1102 calculation involves three main checks. The total effective stress experienced by the pipeline due to internal pressure, forces imparted by the overlying soil and forces imparted by vehicles is compared to the pipeline’s specified minimum yield strength. Checks are also performed to ensure that cyclic stresses experienced in the girth welds and longitudinal welds are below the stress limit for fatigue.

2. Input Data / Assumptions

2.1 Pipeline Parameters

Installed Temperature (Assumption 2)	21°C (assumed)
Design Pressure	10.2 MPa
Max Operating Temperature (Assumption 2)	60°C
Min Operating Temperature (Assumption 2)	-10°C
OD	813 mm
OD (possible upgrade)	1067 mm
Pipe Grade / SMYS	X70
Pipe Type	ERW (assumed)
RP1102 Design Factor	0.90 for occasional crossings 0.72 for designated crossings

2.2 Steel Parameters

Young's Modulus (Es)	205,000 MPa
Coefficient of Thermal Exp. (α)	1.17E-05
Poisson's Ratio	0.30

2.3 Soil Parameters

The soil type selected for the calculation was: Soft to medium clays and silts with low to medium plasticities; (loose sands and gravels). A soil density of 18.9 kN/m3 was chosen based on RP1102 recommendations. Refer to assumptions below.

Specific information regarding crossings has not yet been determined. Typical values for the pipelines burial depth at crossings has therefore been used.

Soil Type:	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels
Soil Density	18.9 kN/m3
Buried Depth to Top of Pipe	750mm, 900mm, 1200mm, 1500mm, 2000mm

2.4 Vehicle Parameters

Detailed information regarding specific axle loads that may cross the pipeline are yet to be determined however this calculation utilises the recommendations from AS2885.1, which equates to a load of approximately 16 tonnes per axle.

Description	**Wheel Load (kN)**	**Wheel Contact Area (m^2)**
W80 (single axle)	80	0.10
M1600 (tandem axle)	60	0.08

The M1600 tandem axle wheel load will always be the worse case when using API RP1102 and therefore calculations will be performed for only this wheel loading configuration for burial depths of 900mm and above. When using the "Guidelines for the Design of Buried Steel Pipe" the worse case is the single axle load and therefore calculations will be performed only for this wheel loading configuration for a burial depth of 750mm.

2.5 Assumptions

1 The 'Soft to medium clays and silts with low to medium plasticities; loose sands and gravels' soil type was assumed as recommended in Section 4.7.2.1 of RP1102. These parameters are generally conservative. Note that geotechnical data isn't available for the actual sites.

2 The pipe minimum and maximum operating temperatures as well as the installation temperature are assumed to be equivalent to the minimum and maximum gas temperatures as referenced in the SGP Basis of Design (08-GHD-3-02-0045). The calculations are very sensitive to temperature.

3 As an unsealed surface does not spread the load as well as a sealed surface it will be used as the design input for 'pavement type'. This will produce slightly conservative results for the major road crossings with engineered pavements.

3. Exclusions

This calculation report excludes special crossings.

4. Results Summary

DN800

Design Loads		MAOP (MPa(g))	Wheel Load (kN)	Depth of Coverage (mm)	Axle Type	Pavement	RP1102 Design Factor	Wall Thickness (mm)	Notes
	Occassional Crossing	10.2	60	900	Tandem	No Pavement	0.9	10.3	M1600 design load
		10.2	60	2000	Tandem	No Pavement	0.9	11.0	M1600 design load
	Designated Crossing	**10.2**	**60**	**1200**	**Tandem**	**No Pavement**	**0.72**	**13.6**	**M1600 design load**
		10.2	**60**	**1500**	**Tandem**	**No Pavement**	**0.72**	**13.8**	**M1600 design load**

DN1050 (possible upgrade)

Design Loads		MAOP (MPa(g))	Wheel Load (kN)	Depth of Coverage (mm)	Axle Type	Pavement	RP1102 Design Factor	Wall Thickness (mm)	Notes
	Occassional Crossing	10.2	60	900	Tandem	No Pavement	0.9	13.4	M1600 design load
		10.2	60	2000	Tandem	No Pavement	0.9	14.3	M1600 design load
	Designated Crossing	**10.2**	**60**	**1200**	**Tandem**	**No Pavement**	**0.72**	**17.8**	**M1600 design load**
		10.2	**60**	**1500**	**Tandem**	**No Pavement**	**0.72**	**18.0**	**M1600 design load**

As previously mentioned a separate method and guidelines were used for burial depths less than 900mm. According to this method, at a burial depth of 750mm, a wall thickness in excess of 11.0mm for DN800 and 13.0mm for DN1050 is needed to protect the integrity of the pipeline and procedural controls will be required to control the occurrence of the 80kN load at random "occasional" crossings along the route. No attempt will be made to increase the R1/R2 locations wall thickness in order to resist such loads.

Detailed Results are shown in the Appendix

It is noted that the RP1102 calculation calls for higher wall thickness at deeper covers for any given wheel load. This counter-intuitive result has been encountered before and is a function of the way in which the method penalises increasing soil weight at a faster rate than it credits decreasing wheel load intensity as depth increases.

5. Conclusion

The primary objective of this report was to determine the minimum wall thickness required for Arrow's DN800 and DN1050 pipeline to safely withstand the stress induced by design vehicles orthogonally traversing it. Calculations were performed in line with API RP1102, AS 2885.1-2007 and Guidelines for the Design of Buried Steel Pipe. The calculation determined that the minimum allowable wall thickness for occasional crossings is 11.0mm for DN800 and 14.3mm for DN1050 at depths of 900mm and greater. It is recommended that this combination of 11.0mm/14.3mm and 900mm be used globally in an effort to provide resistance to vehicular loads. If the pipe were to be buried at a depth smaller than 900mm, additional procedural controls will be required.

This calculation determined that the minimum wall thickness for designated road crossings is 13.8mm for DN800 and 18.0mm for DN1050. In the event that specific road crossings and loads are identified at a later stage, additional protection measures such as concrete slabs should be considered.

6. References

API RP1102 - Steel Pipelines Crossing Railroads and Highways
AS 2885.1 - Pipelines - Gas and Liquid Petroleum Part 1: Design and Construction, Appendix V
Guidelines for the Design of Buried Steel Pipe - American Lifeline Alliance.

Appendix 1 - Calculation Summary
DN800

RP 1102, Pipeline Road Crossing Calculation

DN800 - Occasional Crossing - 900mm Burial Depth - No Pavement, tandem Axle

	Pipeline Conditions		
	Type / OD (mm)	DN800	813.0
	Pipe Grade / SMYS (MPa)	X70	485.0
	Wall Thickness (tw)	10.3	mm
	Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
	Design Pressure (MAOP)	10.20	MPa
##	Buried Height	900	mm
	Design Factor	0.9	
	Installation Temperature	21	°C
	Max Operating Temperature	60	°C
	Min Operating Temperature	-10	°C

0.72 for designated crossing or 0.90 for elsewhere as per AS2885.1-2007 Section 5.7.3 c)

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Trenched Construction?	Trenched		
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Pavement & Axle Type	No Pavement, tandem Axle		
Wheel Pressue	750	kPa	

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Cyclic Circular stress	S-Hh	25,902	kPa
Cylic Long stress	S-Lh	16,958	kPa
Circular stress	S-Hi	397,453	kPa
Effective Stress	Seff (T2max)	433,032	kPa
	Seff (T2min)	398,583	kPa
ALLOWABLE STRESS		436,500	kPa

	% of Allowable / Limit	
Effective stresses are within allowable limits.	99.2	ok
Girth weld stresses are within fatigue limits.	22.8	ok
Longitudinal weld stresses are within fatigue limits.	16.7	ok

RP1102 Road Crossing Calculation DN800 - Occasional Crossing - 900mm Burial Depth - No Pavement, tandem Axle

Input Data				**RP1102 Calculated/Input Data**			
Design Pressure	MAOP	10.20	MPa		Trenched		Trenched Construction/Other ?
Pipe Material		X70		H/Bd	1.11		
Yield Strength	SMYS	485	MPa	tw/D	0.013		
Outside Diameter	D	813	mm	Bd	813	mm	D + 51mm if unknown, if trenched Bd = D
Wall thickness	tw	10.3	mm	Bd/D	1.00		
Pipe Type		SMLS / ERW					
Buried Height	H	900	mm	No Pavement, tandem Axle	Tandem		Select pavement type and hence axle configuration from Table 1
DF - for allowable stress	DF	0.9	%	R	1.1		Select from Table 2
				L	1		Select from Table 2

RP 1102 Soil Data				
Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Reaction Mod	E'	3.4	MPa	2
Soil Unit weight	y	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	Assumption based upon soil type

Earth Load				
Circ stiffness factor	K-he	5267.92		Obtained from figure 3
Earth Burial factor	Be	0.3297	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	1.0000		Obtained from figure 5
Earth Load	S-he	**26686.6**	kPa	

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Live Load					
Axle Load	Pa	0	tonnes/axle	Value used to determine design wheel load. If chosen value results in design wheel load < 80kN, 80kN is used in accordance with recommendation in AS2885.1 V4	
Tandem axle wheel load	Pt	0	tonnes	insert value if known	
Single axle wheel load	Ps	0	tonnes	insert value if known	
Design wheel load	P		kN	Based on selection of tandem or single per above	
Wheel contact area	Ap	0	m2	Default figure is from RP1102 (0.093m2), user can select otherwise	
Live Load	w	**750.0**	kPa		
Impact Factor	Fi	1.5	DLA:	Default calculated based on Figure 7 for highways, else use DLA (refer App W of DR04561)	1.5

Highway Cyclic Stresses				
Circ Highway stiff factor	K-Hh	20.63		Obtained from figure 14
Circ Highway Geo factor	G-Hh	1.01		Obtained from figure 15
Cyclic Circ stress	S-Hh	**25901.8**	kPa	
Long Highway stiff factor	K-Lh	14.8699		Obtained from figure 16
Long Highway Geo factor	G-Lh	0.9216		Obtained from figure 17
Cylic Long stress	S-Lh	**16958.3**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**397453.3981**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P(D - t_w)}{2t_w}$$

Check for Allowable Stresses				
Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1
Young's Modulus Steel	Es	2.05E+08	kPa	Obtained from Table A1
Installation Temperature	T1	21.0	°C	
Max Operating Temperature	T2-max	60.0	°C	
Min Operating Temperature	T2-min	-10.0	°C	
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT
Poisson's ratio of steel	vs	0.3		
Possion's component		127,242.0	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**450,041.8**	kPa
Max Longitudinal stress	S2 (T2max)	**50,658.8**	kPa
	S2 (T2min)	**218,553.8**	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2max)	**433,031.8**	kPa
	Seff (T2min)	**398,583.4**	kPa

$$S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}$$

$$S_2 = \Delta S_L - E_s \alpha_t (T_2 - T_1) + v_s (S_{He} + S_{Hi})$$

$$S_3 = -P$$

$$S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}$$

Allowable Stress	Sa	436500	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Check for Fatigue				
Girth fatigue endurance limit	Sfg	82737	kPa	Obtained from Table 3
check for S-Lh < Sfg x DF		74463.4	kPa	Sfg x DF

Girth weld stresses are within fatigue limits. ok

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hh < Sfl x DF		155132	kPa	

Longitudinal weld stresses are within fatigue limits. ok

RP 1102, Pipeline Road Crossing Calculation

DN800 - Occasional Crossing - 2000mm Burial Depth - No Pavement, tandem Axle

Pipeline Conditions		
Type / OD (mm)	DN800	813.0
Pipe Grade / SMYS (MPa)	X70	485.0
Wall Thickness (tw)	11	mm
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
Design Pressure (MAOP)	10.20	MPa
## Buried Height	2000	mm
Design Factor	0.9	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

0.72 for designated crossing or 0.90 for elsewhere as per AS2885.1-2007 Section 5.7.3 c)

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Trenched Construction?	Trenched		
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Pavement & Axle Type	No Pavement, tandem Axle		
Wheel Pressue	750	kPa	

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Cyclic Circular stress	S-Hh	17,841	kPa
Cylic Long stress	S-Lh	13,393	kPa
Circular stress	S-Hi	371,836	kPa
Effective Stress	Seff (T2max)	428,737	kPa
	Seff (T2min)	393,886	kPa
ALLOWABLE STRESS		436,500	kPa

	% of Allowable / Limit	
Effective stresses are within allowable limits.	98.2	ok
Girth weld stresses are within fatigue limits.	18.0	ok
Longitudinal weld stresses are within fatigue limits.	11.5	ok

<u>*RP1102 Road Crossing Calculation*</u> **DN800 - Occasional Crossing - 2000mm Burial Depth - No Pavement, tandem Axle**

Input Data

Design Pressure	MAOP	10.20	MPa
Pipe Material		X70	
Yield Strength	SMYS	485	MPa
Outside Diameter	D	813	mm
Wall thickness	tw	11	mm
Pipe Type		SMLS / ERW	
Buried Height	H	2000	mm
DF - for allowable stress	DF	0.9	%

RP1102 Calculated/Input Data

	Trenched		Trenched Construction/Other ?
H/Bd	2.46		
tw/D	0.014		
Bd	813	mm	D + 51mm if unknown, if trenched Bd = D
Bd/D	1.00		
No Pavement, tandem Axle	Tandem		Select pavement type and hence axle configuration from Table 1
R	1.1		Select from Table 2
L	1		Select from Table 2

RP 1102 Soil Data

Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Reaction Mod	E'	3.4	MPa	2
Soil Unit weight	*y*	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	Assumption based upon soil type

Earth Load

Circ stiffness factor	K-he	4891.04		Obtained from figure 3
Earth Burial factor	Be	0.7310	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	1.0000		Obtained from figure 5
Earth Load	S-he	**54940.4**	kPa	

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Live Load

Axle Load	Pa	0	tonnes/axle	Value used to determine design wheel load. If chosen value results in design wheel load < 80kN, 80kN is used in accordance with recommendation in AS2885.1 V4
Tandem axle wheel load	Pt	0	tonnes	insert value if known
Single axle wheel load	Ps	0	tonnes	insert value if known
Design wheel load	P		kN	Based on selection of tandem or single per above
Wheel contact area	Ap	0	m2	Default figure is from RP1102 (0.093m2), user can select otherwise
Live Load	w	**750.0**	kPa	
Impact Factor	Fi	1.45	DLA:	Default calculated based on Figure 7 for highways, else use DLA (refer App W of DR04561) 1.45

Highway Cyclic Stresses

Circ Highway stiff factor	K-Hh	20.68		Obtained from figure 14
Circ Highway Geo factor	G-Hh	0.72		Obtained from figure 15
Cyclic Circ stress	S-Hh	**17841.1**	kPa	
Long Highway stiff factor	K-Lh	14.9413		Obtained from figure 16
Long Highway Geo factor	G-Lh	0.7493		Obtained from figure 17
Cylic Long stress	S-Lh	**13393.0**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

Internal Pressure Stress

Circ stress	S-Hi	**371836.3636**	kPa

$$S_{Hi} = \frac{P(D - t_w)}{2t_w}$$

Check for Allowable Stresses

Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1
Young's Modulus Steel	Es	2.05E+08	kPa	Obtained from Table A1
Installation Temperature	T1	21.0	°C	
Max Operating Temperature	T2-max	60.0	°C	
Min Operating Temperature	T2-min	-10.0	°C	
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT
Poisson's ratio of steel	vs	0.3		
Possion's component		128,033.0	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**444,617.8**	kPa
Max Longitudinal stress	S2 (T2max)	**47,884.5**	kPa
	S2 (T2min)	**215,779.5**	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2max)	**428,736.7**	kPa
	Seff (T2min)	**393,886.4**	kPa

$$\boxed{S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}}$$

$$\boxed{S_2 = \Delta S_L - E_s \alpha_t (T_2 - T_1) + v_s (S_{He} + S_{Hi})}$$

$$\boxed{S_3 = -P}$$

$$\boxed{S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}}$$

Allowable Stress	Sa	436500	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Check for Fatigue

Girth fatigue endurance limit	Sfg	82737	kPa	Obtained from Table 3
check for S-Lh < Sfg x DF		74463.4	kPa	Sfg x DF

Girth weld stresses are within fatigue limits. ok

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hh < Sfl x DF		155132	kPa	

Longitudinal weld stresses are within fatigue limits. ok

RP 1102, Pipeline Road Crossing Calculation

DN800 - Designated Crossing - 1200mm Burial Depth - No Pavement, tandem Axle

Pipeline Conditions		
Type / OD (mm)	DN800	813.0
Pipe Grade / SMYS (MPa)	X70	485.0
Wall Thickness (tw)	13.6	mm
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
Design Pressure (MAOP)	10.20	MPa
## Buried Height	1200	mm
Design Factor	0.72	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

0.72 for designated crossing or 0.90 for elsewhere as per AS2885.1-2007 Section 5.7.3 c)

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Trenched Construction?	Trenched		
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Pavement & Axle Type	No Pavement, tandem Axle		
Wheel Pressue	750	kPa	

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Cyclic Circular stress	S-Hh	25,682	kPa
Cylic Long stress	S-Lh	16,852	kPa
Circular stress	S-Hi	299,775	kPa
Effective Stress	Seff (T2max)	347,839	kPa
	Seff (T2min)	314,474	kPa
ALLOWABLE STRESS		349,200	kPa

	% of Allowable / Limit	
Effective stresses are within allowable limits.	99.6	ok
Girth weld stresses are within fatigue limits.	28.3	ok
Longitudinal weld stresses are within fatigue limits.	20.7	ok

RP1102 Road Crossing Calculation **DN800 - Designated Crossing - 1200mm Burial Depth - No Pavement, tandem Axle**

Input Data				
Design Pressure	MAOP	10.20	MPa	
Pipe Material		X70		
Yield Strength	SMYS	485	MPa	
Outside Diameter	D	813	mm	
Wall thickness	tw	13.6	mm	
Pipe Type		SMLS / ERW		
Buried Height	H	1200	mm	
DF - for allowable stress	DF	0.72	%	

RP1102 Calculated/Input Data			
	Trenched		Trenched Construction/Other ?
H/Bd	1.48		
tw/D	0.017		
Bd	813	mm	D + 51mm if unknown, if trenched Bd = D
Bd/D	1.00		
No Pavement, tandem Axle	Tandem		Select pavement type and hence axle configuration from Table 1
R	1.1		Select from Table 2
L	1		Select from Table 2

RP 1102 Soil Data				
Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Reaction Mod	E'	3.4	MPa	2
Soil Unit weight	*y*	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	Assumption based upon soil type
Earth Load				
Circ stiffness factor	K-he	3819.49		Obtained from figure 3
Earth Burial factor	Be	0.4577	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	1.0000		Obtained from figure 5
Earth Load	S-he	**26861.9**	kPa	

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Live Load				
Axle Load	Pa	0	tonnes/axle	Value used to determine design wheel load. If chosen value results in design wheel load < 80kN, 80kN is used in accordance with recommendation in AS2885.1 V4
Tandem axle wheel load	Pt	0	tonnes	insert value if known
Single axle wheel load	Ps	0	tonnes	insert value if known
Design wheel load	P		kN	Based on selection of tandem or single per above
Wheel contact area	Ap	0	m2	Default figure is from RP1102 (0.093m2), user can select otherwise
Live Load	w	**750.0**	kPa	
Impact Factor	Fi	1.5	DLA:	Default calculated based on Figure 7 for highways, else use DLA (refer App W of DR04561) 1.5
Highway Cyclic Stresses				
Circ Highway stiff factor	K-Hh	20.46		Obtained from figure 14
Circ Highway Geo factor	G-Hh	1.01		Obtained from figure 15
Cyclic Circ stress	S-Hh	**25681.9**	kPa	
Long Highway stiff factor	K-Lh	14.7770		Obtained from figure 16
Long Highway Geo factor	G-Lh	0.9216		Obtained from figure 17
Cylic Long stress	S-Lh	**16852.3**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**299775**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P(D - t_w)}{2t_w}$$

Check for Allowable Stresses				
Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1
Young's Modulus Steel	Es	2.05E+08	kPa	Obtained from Table A1
Installation Temperature	T1	21.0	°C	
Max Operating Temperature	T2-max	60.0	°C	
Min Operating Temperature	T2-min	-10.0	°C	
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT
Poisson's ratio of steel	vs	0.3		
Possion's component		97,991.1	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**352,318.8**	kPa
Max Longitudinal stress	S2 (T2max)	**21,301.9**	kPa
	S2 (T2min)	**189,196.9**	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2max)	**347,839.4**	kPa
	Seff (T2min)	**314,474.0**	kPa

$$\boxed{S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}}$$

$$\boxed{S_2 = \Delta S_L - E_s\alpha_t(T_2 - T_1) + v_s(S_{He} + S_{Hi})}$$

$$\boxed{S_3 = -P}$$

$$\boxed{S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}}$$

Allowable Stress	Sa	349200	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Check for Fatigue				
Girth fatigue endurance limit	Sfg	82737	kPa	Obtained from Table 3
check for S-Lh < Sfg x DF		59570.7	kPa	Sfg x DF

Girth weld stresses are within fatigue limits. ok

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hh < Sfl x DF		124105.6	kPa	

Longitudinal weld stresses are within fatigue limits. ok

RP 1102, Pipeline Road Crossing Calculation

DN800 - Designated Crossing - 1500mm Burial Depth - No Pavement, tandem Axle

Pipeline Conditions		
Type / OD (mm)	DN800	813.0
Pipe Grade / SMYS (MPa)	X70	485.0
Wall Thickness (tw)	13.8	mm
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
Design Pressure (MAOP)	10.20	MPa
## Buried Height	1500	mm
Design Factor	0.72	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

0.72 for designated crossing or 0.90 for elsewhere as per AS2885.1-2007 Section 5.7.3 c)

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Trenched Construction?	Trenched		
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Pavement & Axle Type	No Pavement, tandem Axle		
Wheel Pressue	750	kPa	

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Cyclic Circular stress	S-Hh	22,513	kPa
Cylic Long stress	S-Lh	15,610	kPa
Circular stress	S-Hi	295,357	kPa
Effective Stress	Seff (T2max)	346,286	kPa
	Seff (T2min)	312,806	kPa
ALLOWABLE STRESS		349,200	kPa

	% of Allowable / Limit	
Effective stresses are within allowable limits.	99.2	ok
Girth weld stresses are within fatigue limits.	26.2	ok
Longitudinal weld stresses are within fatigue limits.	18.1	ok

RP1102 Road Crossing Calculation DN800 - Designated Crossing - 1500mm Burial Depth - No Pavement, tandem Axle

Input Data

Design Pressure	MAOP	10.20	MPa
Pipe Material		X70	
Yield Strength	SMYS	485	MPa
Outside Diameter	D	813	mm
Wall thickness	tw	13.8	mm
Pipe Type		SMLS / ERW	
Buried Height	H	1500	mm
DF - for allowable stress	DF	0.72	%

RP1102 Calculated/Input Data

	Trenched		Trenched Construction/Other ?
H/Bd	1.85		
tw/D	0.017		
Bd	813	mm	D + 51mm if unknown, if trenched Bd = D
Bd/D	1.00		
No Pavement, tandem Axle	Tandem		Select pavement type and hence axle configuration from Table 1
R	1.1		Select from Table 2
L	1		Select from Table 2

RP 1102 Soil Data

Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Reaction Mod	E'	3.4	MPa	2
Soil Unit weight	*y*	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	Assumption based upon soil type

Earth Load

Circ stiffness factor	K-he	3819.49		Obtained from figure 3
Earth Burial factor	Be	0.5540	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	1.0000		Obtained from figure 5
Earth Load	S-he	**32514.0**	kPa	

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Live Load

Axle Load	Pa	0	tonnes/axle	Value used to determine design wheel load. If chosen value results in design wheel load < 80kN, 80kN is used in accordance with recommendation in AS2885.1 V4
Tandem axle wheel load	Pt	0	tonnes	insert value if known
Single axle wheel load	Ps	0	tonnes	insert value if known
Design wheel load	P		kN	Based on selection of tandem or single per above
Wheel contact area	Ap	0	m2	Default figure is from RP1102 (0.093m2), user can select otherwise
Live Load	w	**750.0**	kPa	
Impact Factor	Fi	1.5	DLA:	Default calculated based on Figure 7 for highways, else use DLA (refer App W of DR04561) 1.5

Highway Cyclic Stresses

Circ Highway stiff factor	K-Hh	20.46		Obtained from figure 14
Circ Highway Geo factor	G-Hh	0.89		Obtained from figure 15
Cyclic Circ stress	S-Hh	**22513.0**	kPa	
Long Highway stiff factor	K-Lh	14.7770		Obtained from figure 16
Long Highway Geo factor	G-Lh	0.8537		Obtained from figure 17
Cylic Long stress	S-Lh	**15610.4**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**295356.5217**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P(D - t_w)}{2t_w}$$

Check for Allowable Stresses

Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1
Young's Modulus Steel	Es	2.05E+08	kPa	Obtained from Table A1
Installation Temperature	T1	21.0	°C	
Max Operating Temperature	T2-max	60.0	°C	
Min Operating Temperature	T2-min	-10.0	°C	
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT
Poisson's ratio of steel	vs	0.3		
Possion's component		98,361.2	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**350,383.6**	kPa
Max Longitudinal stress	S2 (T2max)	**20,430.1**	kPa
	S2 (T2min)	**188,325.1**	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2max)	**346,286.0**	kPa
	Seff (T2min)	**312,806.4**	kPa

$$\boxed{S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}}$$

$$\boxed{S_2 = \Delta S_L - E_s \alpha_t (T_2 - T_1) + \nu_s (S_{He} + S_{Hi})}$$

$$\boxed{S_3 = -P}$$

$$\boxed{S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}}$$

Allowable Stress	Sa	349200	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Check for Fatigue

Girth fatigue endurance limit	Sfg	82737	kPa	Obtained from Table 3
check for S-Lh < Sfg x DF		59570.7	kPa	Sfg x DF

Girth weld stresses are within fatigue limits. ok

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hh < Sfl x DF		124105.6	kPa	

Longitudinal weld stresses are within fatigue limits. ok

Guidlines for the Design of Buried Steel Pipe, Pipeline Road Crossing Calculation

DN800 - Occasional Crossing - 750mm Burial Depth - No Pavement, single axle

Pipeline Conditions		
Type / OD (mm)	DN800	813.0
Pipe Grade / SMYS (MPa)	X70	485.0
Wall Thickness (tw)	12.8	mm
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
Design Pressure (MAOP)	10.20	MPa
Buried Height	750	mm
Design Factor	0.9	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Axle Type	Single		
Axle Spacing	0	mm	
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Design wheel load (Ps)	80	kN	Recommended value from AS2885: 80
Height of water table above pipe (hw)	0	m	0<=hw<=depth of cover

The spacing between axles in the axle set for tandem and triple axles.

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Circumferential stress	S-c	241,209	kPa
Longitudinal stress	S-l (T2 max)	-3,637	kPa
Longitudinal stress	S-l (T2 min)	-171,532	kPa
Radial stress	S-r	-10,200	kPa
Effective Stress	Seff (T2max)	248,193	kPa
	Seff (T2min)	360,271	kPa
ALLOWABLE STRESS		436,500	kPa

	% of Allowable / Limit	
Effective pipe stress is within the allowable pipe stress	82.5	ok
Ring Buckling Stress Check	99.5	

Guidelines for the Design of Buried Steel Pipe Calculation

Input Data

Design Pressure	MAOP	10200.00	kPa
Pipe Material		X70	
Yield Strength	SMYS	485	MPa
Outside Diameter	D	0.813	m
Outside Radius	R	0.4065	
Wall thickness	tw	12.8	mm
Pipe Type		SMLS / ERW	
Buried Height	C	0.750	m
DF - for allowable stress	DF	0.9	
Design wheel load	Ps	80	kN
Deflection lag factor	Dl	1.5	-
Bedding constant	K	0.1	-
Coeff thermal expansion	alpha	1.2E-05	per °C
Young's Modulus Steel	Es	2.05E+08	kPa
Installation Temperature	T1	21.0	°C
Max Operating Temperature	T2-max	60.0	°C
Min Operating Temperature	T2-min	-10.0	°C
Poisson's ratio of steel	v	0.3	-

80kN is used in accordance with recommendation in AS2885.1 V4

Calculated/Input Data

tw/D	0.016	
D/C	1.084	
C/D	0.9225092	
I	1.748E-07	m^3
(EI)eq	35.83	kN.m
Rw	1	-

$$I = \frac{t^3}{12}$$

$$(EI)_{eq} = EI + E_L I_L + E_C I_C$$

Assume (EI)eq = EI as this is more conservative and the coating and lining stiffenesses are assumed to be small compared to the pipe

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RP 1102 Soil Data

Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Reaction Mod	E'	3400	kPa	2
Soil Unit weight	*y*	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	Assumption based upon soil type

Earth Load

Earth Load	Pv	**14.18**	kPa

$$P_v = \gamma C$$

Applied Surface Load

Impact Factor	F'	1.15	
Offset Tandem surface load	Po2	**0**	
Offset Triple surface load	Po3	**0**	
Total surface Load	Pp	**78.09202541**	kPa

$$P_P = \frac{3P_S}{2\pi C^2\left[1+\left(\frac{d}{C}\right)^2\right]^{2.5}}$$

Impact Factor obtained from Appendix B3

NOTE: Variable d in the applied surface load equation is assumed to be 0 for a single axle as this gives a more conservative calculation.

Ovality

Combined pressure on pipe	Pc	92.27	kPa
Ovality	dy/D	**0.018683573**	-

$$\frac{\Delta y}{D} = \frac{D_l K P}{\left(\frac{(EI)_{eq}}{R^3} + 0.061E'\right)}$$

Through-Wall Bending Stress

Circumferential Stress	S-c	**241209**	kPa

$$\sigma_{bw} = 4E\left(\frac{\Delta y}{D}\right)\left(\frac{t}{D}\right)$$

Ring Buckling Check

Factor of safety	FS	3	-
Empirical coefficient of elastic support	B'	0.21	-
Buckling vertical pressure load limit		**411.18**	kPa

$$B' = \frac{1}{1+4e^{(-0.065\frac{C}{D})}}$$

The vertical pressure load is below the buckling limit

$$\frac{1}{FS}\sqrt{32 R_W B' E' \frac{(EI)_{eq}}{D^3}}$$

Longitudinal Stress

Hoop Stress	S-h	323929.6875	kPa
Longitudinal Stress (T2 max)	S-l (T2max)	**-3637.4**	kPa
Longitudinal Stress (T2 min)	S-l (T2min)	**-171532.4**	kPa

$$S_H = PD / (2t)$$

$$\sigma_c = E\alpha(T_2 - T_1) - \nu\sigma_h$$

Radial Stress

Circ stress	S-r	**-10200.00**	kPa

$$\boxed{S_3 = -P}$$

Check for Allowable Stresses

Max Circumferential stress	S-c	**241,208.8**	kPa	S1
Max Longitudinal stress	S-l (T2max)	**-3,637.4**	kPa	S2 (T2 max)
	S-l (T2min)	**-171,532.4**	kPa	S2 (T2 min)
Max Radial stress	S-r	**-10,200.0**	kPa	S3
Effective Stress	Seff (T2max)	**248,192.6**	kPa	
	Seff (T2min)	**360,270.7**	kPa	

$$S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}$$

Allowable Stress	Sa	436500	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Appendix 2 - Calculation Summary
DN1050

RP 1102, Pipeline Road Crossing Calculation

DN1050 - Occasional crossing - 900mm Burial Depth - No Pavement, tandem axle

Pipeline Conditions			
Type / OD (mm)	DN1050	1067.0	
Pipe Grade / SMYS (MPa)	X70	485.0	
Wall Thickness (tw)	13.4	mm	
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW		
Design Pressure (MAOP)	10.20	MPa	
Buried Height	900	mm	
Design Factor	0.9		0.72 for designated crossing or 0.90 for elsewhere as per AS2885.1-2007 Section 5.7.3 c)
Installation Temperature	21	°C	
Max Operating Temperature	60	°C	
Min Operating Temperature	-10	°C	

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options				
Trenched Construction?	Trenched			
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels			For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9	
Pavement & Axle Type	No Pavement, Tandem Axle			
Wheel Pressue	750	kPa		

Pipeline Results					
Cyclic Circular stress	S-Hh	23,844	kPa		
Cylic Long stress	S-Lh	14,613	kPa		
Circular stress	S-Hi	400,997	kPa		
Effective Stress	Seff (T2max)	433,396	kPa		
	Seff (T2min)	398,282	kPa		
ALLOWABLE STRESS		436,500	kPa		
				% of Allowable / Limit	
Effective stresses are within allowable limits.				99.3	ok
Girth weld stresses are within fatigue limits.				19.6	ok
Longitudinal weld stresses are within fatigue limits.				15.4	ok

RP1102 Road Crossing Calculation **DN1050 - Occasional crossing - 900mm Burial Depth - No Pavement, tandem axle**

Input Data				**RP1102 Calculated/Input Data**			
Design Pressure	MAOP	10.20	MPa		Trenched		Trenched Construction/Other ?
Pipe Material		X70		H/Bd	0.84		
Yield Strength	SMYS	485	MPa	tw/D	0.013		
Outside Diameter	D	1067	mm	Bd	1067	mm	D + 51mm if unknown, if trenched Bd = D
Wall thickness	tw	13.4	mm	Bd/D	1.00		
Pipe Type		SMLS / ERW					
Buried Height	H	900	mm	No Pavement, Tandem Axle	Tandem		Select pavement type and hence axle configuration from Table 1
DF - for allowable stress	DF	0.9	%	R	1.1		Select from Table 2
				L	1		Select from Table 2

RP 1102 Soil Data				
Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Reaction Mod	E'	3.4	MPa	2
Soil Unit weight	*y*	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	Assumption based upon soil type

Earth Load				
Circ stiffness factor	K-he	5267.92		Obtained from figure 3
Earth Burial factor	Be	0.2338	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	1.0000		Obtained from figure 5
Earth Load	S-he	**24841.6**	kPa	

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Live Load					
Axle Load	Pa	0	tonnes/axle	Value used to determine design wheel load. If chosen value results in design wheel load < 80kN, 80kN is used in accordance with recommendation in AS2885.1 V4	
Tandem axle wheel load	Pt	0	tonnes	insert value if known	
Single axle wheel load	Ps	0	tonnes	insert value if known	
Design wheel load	P	750	kN	Based on selection of tandem or single per above	
Wheel contact area	Ap	0	m2	Default figure is from RP1102 (0.093m2), user can select otherwise	
Live Load	w	**750.0**	kPa		
Impact Factor	Fi	1.5	DLA:	Default calculated based on Figure 7 for highways, else use DLA (refer App W of DR04561)	1.5

Highway Cyclic Stresses				
Circ Highway stiff factor	K-Hh	20.63		Obtained from figure 14
Circ Highway Geo factor	G-Hh	0.93		Obtained from figure 15
Cyclic Circ stress	S-Hh	**23844.5**	kPa	
Long Highway stiff factor	K-Lh	14.8699		Obtained from figure 16
Long Highway Geo factor	G-Lh	0.7941		Obtained from figure 17
Cylic Long stress	S-Lh	**14613.0**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**400997.0149**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P(D - t_w)}{2t_w}$$

Check for Allowable Stresses				
Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1
Young's Modulus Steel	Es	2.05E+08	kPa	Obtained from Table A1
Installation Temperature	T1	21.0	°C	
Max Operating Temperature	T2-max	60.0	°C	
Min Operating Temperature	T2-min	-10.0	°C	
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT
Poisson's ratio of steel	vs	0.3		
Possion's component		127,751.6	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**449,683.1**	kPa
Max Longitudinal stress	S2 (T2max)	**48,823.1**	kPa
	S2 (T2min)	**216,718.1**	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2max)	**433,396.4**	kPa
	Seff (T2min)	**398,281.9**	kPa

$$\boxed{S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}}$$

$$\boxed{S_2 = \Delta S_L - E_s \alpha_t (T_2 - T_1) + v_s (S_{He} + S_{Hi})}$$

$$\boxed{S_3 = -P}$$

$$\boxed{S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}}$$

Allowable Stress	Sa	436500	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Check for Fatigue				
Girth fatigue endurance limit	Sfg	82737	kPa	Obtained from Table 3
check for S-Lh < Sfg x DF		74463.4	kPa	Sfg x DF

Girth weld stresses are within fatigue limits. ok

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hh < Sfl x DF		155132	kPa	

Longitudinal weld stresses are within fatigue limits. ok

RP 1102, Pipeline Road Crossing Calculation

DN1050 - Occasional crossing - 2000mm Burial Depth - No Pavement, tandem axle

Pipeline Conditions		
Type / OD (mm)	DN1050	1067.0
Pipe Grade / SMYS (MPa)	X70	485.0
Wall Thickness (tw)	14.3	mm
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
Design Pressure (MAOP)	10.20	MPa
Buried Height	2000	mm
Design Factor	0.9	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

0.72 for designated crossing or 0.90 for elsewhere as per AS2885.1-2007 Section 5.7.3 c)

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Trenched Construction?	Trenched		
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Pavement & Axle Type	No Pavement, Tandem Axle		
Wheel Pressue	750	kPa	

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Cyclic Circular stress	S-Hh	16,121	kPa
Cylic Long stress	S-Lh	10,949	kPa
Circular stress	S-Hi	375,438	kPa
Effective Stress	Seff (T2max)	435,805	kPa
	Seff (T2min)	400,157	kPa
ALLOWABLE STRESS		436,500	kPa

	% of Allowable / Limit	
Effective stresses are within allowable limits.	99.8	ok
Girth weld stresses are within fatigue limits.	14.7	ok
Longitudinal weld stresses are within fatigue limits.	10.4	ok

RP1102 Road Crossing Calculation **DN1050 - Occasional crossing - 2000mm Burial Depth - No Pavement, tandem axle**

Input Data

Design Pressure	MAOP	10.20	MPa
Pipe Material		X70	
Yield Strength	SMYS	485	MPa
Outside Diameter	D	1067	mm
Wall thickness	tw	14.3	mm
Pipe Type		SMLS / ERW	
Buried Height	H	2000	mm
DF - for allowable stress	DF	0.9	%

RP1102 Calculated/Input Data

	Trenched		Trenched Construction/Other ?
H/Bd	1.87		
tw/D	0.013		
Bd	1067	mm	D + 51mm if unknown, if trenched Bd = D
Bd/D	1.00		
No Pavement, Tandem Axle		Tandem	Select pavement type and hence axle configuration from Table 1
R	1.1		Select from Table 2
L	1		Select from Table 2

RP 1102 Soil Data

Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Reaction Mod	E'	3.4	MPa	2
Soil Unit weight	*y*	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	Assumption based upon soil type

Earth Load

Circ stiffness factor	K-he	5267.92		Obtained from figure 3
Earth Burial factor	Be	0.5673	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	1.0000		Obtained from figure 5
Earth Load	S-he	**60268.5**	kPa	

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Live Load

Axle Load	Pa	0	tonnes/axle	Value used to determine design wheel load. If chosen value results in design wheel load < 80kN, 80kN is used in accordance with recommendation in AS2885.1 V4
Tandem axle wheel load	Pt	0	tonnes	insert value if known
Single axle wheel load	Ps	0	tonnes	insert value if known
Design wheel load	P	750	kN	Based on selection of tandem or single per above
Wheel contact area	Ap	0	m2	Default figure is from RP1102 (0.093m2), user can select otherwise
Live Load	w	**750.0**	kPa	
Impact Factor	Fi	1.45	DLA:	Default calculated based on Figure 7 for highways, else use DLA (refer App W of DR04561) 1.45

Highway Cyclic Stresses

Circ Highway stiff factor	K-Hh	20.63		Obtained from figure 14
Circ Highway Geo factor	G-Hh	0.65		Obtained from figure 15
Cyclic Circ stress	S-Hh	**16121.0**	kPa	
Long Highway stiff factor	K-Lh	14.8699		Obtained from figure 16
Long Highway Geo factor	G-Lh	0.6155		Obtained from figure 17
Cylic Long stress	S-Lh	**10948.5**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**375438.4615**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P(D - t_w)}{2t_w}$$

Check for Allowable Stresses

Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1
Young's Modulus Steel	Es	2.05E+08	kPa	Obtained from Table A1
Installation Temperature	T1	21.0	°C	
Max Operating Temperature	T2-max	60.0	°C	
Min Operating Temperature	T2-min	-10.0	°C	
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT
Poisson's ratio of steel	vs	0.3		
Possion's component		130,712.1	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**451,828.0**	kPa
Max Longitudinal stress	S2 (T2max)	**48,119.1**	kPa
	S2 (T2min)	**216,014.1**	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2max)	**435,804.9**	kPa
	Seff (T2min)	**400,156.8**	kPa

$$\boxed{S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}}$$

$$\boxed{S_2 = \Delta S_L - E_s\alpha_t(T_2 - T_1) + v_s(S_{He} + S_{Hi})}$$

$$\boxed{S_3 = -P}$$

$$\boxed{S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}}$$

Allowable Stress	Sa	436500	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Check for Fatigue

Girth fatigue endurance limit	Sfg	82737	kPa	Obtained from Table 3
check for S-Lh < Sfg x DF		74463.4	kPa	Sfg x DF
Girth weld stresses are within fatigue limits.				ok
Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hh < Sfl x DF		155132	kPa	
Longitudinal weld stresses are within fatigue limits.				ok

RP 1102, Pipeline Road Crossing Calculation

DN1050 - Designated crossing - 1200mm Burial Depth - No Pavement, tandem axle

Pipeline Conditions		
Type / OD (mm)	DN1050	1067.0
Pipe Grade / SMYS (MPa)	X70	485.0
Wall Thickness (tw)	17.8	mm
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
Design Pressure (MAOP)	10.20	MPa
Buried Height	1200	mm
Design Factor	0.72	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

0.72 for designated crossing or 0.90 for elsewhere as per AS2885.1-2007 Section 5.7.3 c)

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Trenched Construction?	Trenched		
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Pavement & Axle Type	No Pavement, Tandem Axle		
Wheel Pressue	750	kPa	

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Cyclic Circular stress	S-Hh	23,642	kPa
Cylic Long stress	S-Lh	14,522	kPa
Circular stress	S-Hi	300,613	kPa
Effective Stress	Seff (T2max)	346,493	kPa
	Seff (T2min)	312,320	kPa
ALLOWABLE STRESS		349,200	kPa

	% of Allowable / Limit	
Effective stresses are within allowable limits.	99.2	ok
Girth weld stresses are within fatigue limits.	24.4	ok
Longitudinal weld stresses are within fatigue limits.	19.0	ok

RP1102 Road Crossing Calculation DN1050 - Designated crossing - 1200mm Burial Depth - No Pavement, tandem axle

Input Data				**RP1102 Calculated/Input Data**			
Design Pressure	MAOP	10.20	MPa		Trenched		Trenched Construction/Other ?
Pipe Material		X70		H/Bd	1.12		
Yield Strength	SMYS	485	MPa	tw/D	0.017		
Outside Diameter	D	1067	mm	Bd	1067	mm	D + 51mm if unknown, if trenched Bd = D
Wall thickness	tw	17.8	mm	Bd/D	1.00		
Pipe Type		SMLS / ERW					
Buried Height	H	1200	mm	No Pavement, Tandem Axle	Tandem		Select pavement type and hence axle configuration from Table 1
DF - for allowable stress	DF	0.72	%	R	1.1		Select from Table 2
				L	1		Select from Table 2

RP 1102 Soil Data					
Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels			
Soil Reaction Mod	E'	3.4	MPa	2	
Soil Unit weight	y	18.9	kN/m3		Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa		Assumption based upon soil type

Earth Load				
Circ stiffness factor	K-he	3819.49		Obtained from figure 3
Earth Burial factor	Be	0.3330	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	1.0000		Obtained from figure 5
Earth Load	S-he	**25652.6**	kPa	

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Live Load					
Axle Load	Pa	0	tonnes/axle	Value used to determine design wheel load. If chosen value results in design wheel load < 80kN, 80kN is used in accordance with recommendation in AS2885.1 V4	
Tandem axle wheel load	Pt	0	tonnes	insert value if known	
Single axle wheel load	Ps	0	tonnes	insert value if known	
Design wheel load	P	750	kN	Based on selection of tandem or single per above	
Wheel contact area	Ap	0	m2	Default figure is from RP1102 (0.093m2), user can select otherwise	
Live Load	w	**750.0**	kPa		
Impact Factor	Fi	1.5	DLA:	Default calculated based on Figure 7 for highways, else use DLA (refer App W of DR04561)	1.5

Highway Cyclic Stresses				
Circ Highway stiff factor	K-Hh	20.46		Obtained from figure 14
Circ Highway Geo factor	G-Hh	0.93		Obtained from figure 15
Cyclic Circ stress	S-Hh	**23642.1**	kPa	
Long Highway stiff factor	K-Lh	14.7770		Obtained from figure 16
Long Highway Geo factor	G-Lh	0.7941		Obtained from figure 17
Cylic Long stress	S-Lh	**14521.7**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**300613.4831**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P(D - t_w)}{2t_w}$$

Check for Allowable Stresses				
Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1
Young's Modulus Steel	Es	2.05E+08	kPa	Obtained from Table A1
Installation Temperature	T1	21.0	°C	
Max Operating Temperature	T2-max	60.0	°C	
Min Operating Temperature	T2-min	-10.0	°C	
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT
Poisson's ratio of steel	vs	0.3		
Possion's component		97,879.8	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**349,908.1**	kPa
Max Longitudinal stress	S2 (T2max)	**18,860.0**	kPa
	S2 (T2min)	**186,755.0**	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2max)	**346,493.3**	kPa
	Seff (T2min)	**312,320.4**	kPa

$$S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}$$

$$S_2 = \Delta S_L - E_s\alpha_t(T_2 - T_1) + v_s(S_{He} + S_{Hi})$$

$$S_3 = -P$$

$$S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}$$

Allowable Stress	Sa	349200	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Check for Fatigue				
Girth fatigue endurance limit	Sfg	82737	kPa	Obtained from Table 3
check for S-Lh < Sfg x DF		59570.7	kPa	Sfg x DF

Girth weld stresses are within fatigue limits. ok

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hh < Sfl x DF		124105.6	kPa	

Longitudinal weld stresses are within fatigue limits. ok

RP 1102, Pipeline Road Crossing Calculation

DN1050 - Designated crossing - 1500mm Burial Depth - No Pavement, tandem axle

Pipeline Conditions		
Type / OD (mm)	DN1050	1067.0
Pipe Grade / SMYS (MPa)	X70	485.0
Wall Thickness (tw)	18	mm
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
Design Pressure (MAOP)	10.20	MPa
Buried Height	1500	mm
Design Factor	0.72	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

0.72 for designated crossing or 0.90 for elsewhere as per AS2885.1-2007 Section 5.7.3 c)

Steel Properties		
Young's Modulus (E_s)	205,000,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Trenched Construction?	Trenched		
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Pavement & Axle Type	No Pavement, Tandem Axle		
Wheel Pressue	750	kPa	

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Cyclic Circular stress	S-Hh	20,644	kPa
Cylic Long stress	S-Lh	13,158	kPa
Circular stress	S-Hi	297,217	kPa
Effective Stress	Seff (T2max)	347,217	kPa
	Seff (T2min)	312,810	kPa
ALLOWABLE STRESS		349,200	kPa

	% of Allowable / Limit	
Effective stresses are within allowable limits.	99.4	ok
Girth weld stresses are within fatigue limits.	22.1	ok
Longitudinal weld stresses are within fatigue limits.	16.6	ok

RP1102 Road Crossing Calculation — DN1050 - Designated crossing - 1500mm Burial Depth - No Pavement, tandem axle

Input Data				**RP1102 Calculated/Input Data**		
Design Pressure	MAOP	10.20	MPa		Trenched	Trenched Construction/Other ?
Pipe Material		X70		H/Bd	1.41	
Yield Strength	SMYS	485	MPa	tw/D	0.017	
Outside Diameter	D	1067	mm	Bd	1067 mm	D + 51mm if unknown, if trenched Bd = D
Wall thickness	tw	18	mm	Bd/D	1.00	
Pipe Type		SMLS / ERW				
Buried Height	H	1500	mm	No Pavement, Tandem Axle	Tandem	Select pavement type and hence axle configuration from Table 1
DF - for allowable stress	DF	0.72	%	R	1.1	Select from Table 2
				L	1	Select from Table 2

RP 1102 Soil Data					
Soil Type		Soft to medium clays and silts with low to medium plasticities; loose sands and gravels			
Soil Reaction Mod	E'	3.4	MPa	2	
Soil Unit weight	*y*	18.9	kN/m3		Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa		Assumption based upon soil type

Earth Load				
Circ stiffness factor	K-he	3819.49		Obtained from figure 3
Earth Burial factor	Be	0.4239	Soil A	Obtained from figure 4
Earth Excavation factor	Ee	1.0000		Obtained from figure 5
Earth Load	S-he	**32649.1**	kPa	

$$K_{He} = f\left\{\frac{t_w}{D}, E'\right\}$$

$$B_e = f\left\{\frac{H}{B_d}\right\}$$

$$E_e = f\left\{\frac{B_d}{D}\right\}$$

Live Load				
Axle Load	Pa	0	tonnes/axle	Value used to determine design wheel load. If chosen value results in design wheel load < 80kN, 80kN is used in accordance with recommendation in AS2885.1 V4
Tandem axle wheel load	Pt	0	tonnes	insert value if known
Single axle wheel load	Ps	0	tonnes	insert value if known
Design wheel load	P	750	kN	Based on selection of tandem or single per above
Wheel contact area	Ap	0	m2	Default figure is from RP1102 (0.093m2), user can select otherwise
Live Load	w	**750.0**	kPa	
Impact Factor	Fi	1.5	DLA:	Default calculated based on Figure 7 for highways, else use DLA (refer App W of DR04561) 1.5

Highway Cyclic Stresses				
Circ Highway stiff factor	K-Hh	20.46		Obtained from figure 14
Circ Highway Geo factor	G-Hh	0.82		Obtained from figure 15
Cyclic Circ stress	S-Hh	**20643.9**	kPa	
Long Highway stiff factor	K-Lh	14.7770		Obtained from figure 16
Long Highway Geo factor	G-Lh	0.7195		Obtained from figure 17
Cylic Long stress	S-Lh	**13157.6**	kPa	
Internal Pressure Stress				
Circ stress	S-Hi	**297216.6667**	kPa	

$$K_{Hh} = f\left\{\frac{t_w}{D}, E_r\right\}$$

$$S_{Hi} = \frac{P(D - t_w)}{2t_w}$$

Check for Allowable Stresses				
Coeff thermal expansion	alpha	1.2E-05	per °C	Obtained from Table A1
Young's Modulus Steel	Es	2.05E+08	kPa	Obtained from Table A1
Installation Temperature	T1	21.0	°C	
Max Operating Temperature	T2-max	60.0	°C	
Min Operating Temperature	T2-min	-10.0	°C	
ΔT component at max T2		93,541.5	kPa	E*alpha*ΔT
ΔT component at min T2		-74,353.5	kPa	E*alpha*ΔT
Poisson's ratio of steel	vs	0.3		
Possion's component		98,959.7	kPa	v(S-he + S-hi)

Max Circumferential stress	S1	**350,509.7**	kPa
Max Longitudinal stress	S2 (T2max)	**18,575.8**	kPa
	S2 (T2min)	**186,470.8**	kPa
Max Radial stress	S3	**-10,200.0**	kPa
Effective Stress	Seff (T2max)	**347,217.3**	kPa
	Seff (T2min)	**312,809.6**	kPa

$$\boxed{S_1 = S_{He} + \Delta S_{Hh} + S_{Hi}}$$

$$\boxed{S_2 = \Delta S_L - E_s \alpha_t (T_2 - T_1) + v_s (S_{He} + S_{Hi})}$$

$$\boxed{S_3 = -P}$$

$$\boxed{S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}}$$

Allowable Stress	Sa	349200	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Check for Fatigue				
Girth fatigue endurance limit	Sfg	82737	kPa	Obtained from Table 3
check for S-Lh < Sfg x DF		59570.7	kPa	Sfg x DF

Girth weld stresses are within fatigue limits. ok

Long fatigue endurance limit	Sfl	172369	kPa	Obtained from Table 3
check for S-Hh < Sfl x DF		124105.6	kPa	

Longitudinal weld stresses are within fatigue limits. ok

Guidlines for the Design of Buried Steel Pipe, Pipeline Road Crossing Calculation

DN1050 - Occasional Crossing - 750mm Burial Depth - No Pavement, single axle

Pipeline Conditions		
Type / OD (mm)	DN1050	1067.0
Pipe Grade / SMYS (MPa)	X70	485.0
Wall Thickness (tw)	16.8	mm
Pipe Type (Seamless / ERW / SAW)	SMLS / ERW	
Design Pressure (MAOP)	10.20	MPa
Buried Height	750	mm
Design Factor	0.9	
Installation Temperature	21	°C
Max Operating Temperature	60	°C
Min Operating Temperature	-10	°C

Steel Properties		
Young's Modulus (E_s)	205,500,000	kPa
Coefficient of Thermal Exp. (α)	1.17E-05	per °C
Poisson's Ratio (v_s)	0.3	

Pipeline Options			
Axle Type	Single		
Axle Spacing	0	mm	
Soil Type / Description	Soft to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Unit weight	18.9	kN/m^3	Recommended value from RP1102: 18.9
Design wheel load (Ps)	80	kN	Recommended value from AS2885: 80
Height of water table above pipe (hw)	0	m	0<=hw<=depth of cover

The spacing between axles in the axle set for tandem and triple axles.

For soil types Soft to medium clays and silts with high plasticities & Soft to medium clays and silts with low to medium plasticities; loose sands and gravels the resilient modulus, Er, is assumed to be 34 MPa

Pipeline Results			
Circumferential stress	S-c	241,192	kPa
Longitudinal stress	S-l (T2 max)	-3,632	kPa
Longitudinal stress	S-l (T2 min)	-171,527	kPa
Radial stress	S-r	-10,200	kPa
Effective Stress	Seff (T2max)	248,174	kPa
	Seff (T2min)	360,251	kPa
ALLOWABLE STRESS		436,500	kPa

	% of Allowable / Limit	
Effective pipe stress is within the allowable pipe stress	82.5	ok
Ring Buckling Stress Check	99.5	

Guidelines for the Design of Buried Steel Pipe Calculation

DN1050 - Occasional Crossing - 750mm Burial Depth - No Pavement, single axle

Input Data

Design Pressure	MAOP	10200.00	kPa
Pipe Material		X70	
Yield Strength	SMYS	485	MPa
Outside Diameter	D	1.067	m
Outside Radius	R	0.5335	
Wall thickness	tw	16.8	mm
Pipe Type		SMLS / ERW	
Buried Height	C	0.750	m
DF - for allowable stress	DF	0.9	
Design wheel load	Ps	80	kN
Deflection lag factor	Dl	1.5	-
Bedding constant	K	0.1	-
Coeff thermal expansion	alpha	1.2E-05	per °C
Young's Modulus Steel	Es	2.05E+08	kPa
Installation Temperature	T1	21.0	°C
Max Operating Temperature	T2-max	60.0	°C
Min Operating Temperature	T2-min	-10.0	°C
Poisson's ratio of steel	v	0.3	-

Calculated/Input Data

tw/D	0.016	
D/C	1.423	
C/D	0.7029053	
I	3.951E-07	m^3
(EI)eq	81.00	kN.m
Rw	1	-

$$I = \frac{t^3}{12}$$

$$(EI)_{eq} = EI + E_L I_L + E_C I_C$$

Assume (EI)eq = EI as this is more conservative and the coating and lining stiffenesses are assumed to be small compared to the pipe

80kN is used in accordance with recommendation in AS2885.1 V4

RP 1102 Soil Data

Soil Type		Soil to medium clays and silts with low to medium plasticities; loose sands and gravels		
Soil Reaction Mod	E'	3400	kPa	2
Soil Unit weight	*y*	18.9	kN/m3	Recommended value from RP1102
Soil Resilient Mod	Er	34	MPa	Assumption based upon soil type

Earth Load

Earth Load	Pv	**14.18**	kPa

$$P_v = \gamma C$$

Applied Surface Load

Impact Factor	F'	1.15	
Offset Tandem surface load	Po2	**0**	
Offset Triple surface load	Po3	**0**	
Total surface Load	Pp	**78.09202541**	kPa

$$P_P = \frac{3P_S}{2\pi C^2\left[1+\left(\frac{d}{C}\right)^2\right]^{2.5}}$$

Impact Factor obtained from Appendix B3

NOTE: Variable d in the applied surface load equation is assumed to be 0 for a single axle as this gives a more conservative calculation.

Ovality

Combined pressure on pipe	Pc	92.27	kPa
Ovality	dy/D	**0.01868121**	-

$$\frac{\Delta y}{D} = \frac{D_l K P}{\left(\frac{(EI)_{eq}}{R^3} + 0.061E'\right)}$$

Through-Wall Bending Stress

Circumferential Stress	S-c	**241192**	kPa

$$\sigma_{bw} = 4E\left(\frac{\Delta y}{D}\right)\left(\frac{t}{D}\right)$$

Ring Buckling Check

Factor of safety	FS	3	-
Empirical coefficient of elastic support	B'	0.21	-
Buckling vertical pressure load limit		**408.90**	kPa

$$B' = \frac{1}{1+4e^{(-0.065\frac{C}{D})}}$$

The vertical pressure load is below the buckling limit

$$\frac{1}{FS}\sqrt{32 R_W B' E' \frac{(EI)_{eq}}{D^3}}$$

Longitudinal Stress

Hoop Stress	S-h	323910.7143	kPa
Longitudinal Stress (T2 max)	S-l (T2max)	**-3631.7**	kPa
Longitudinal Stress (T2 min)	S-l (T2min)	**-171526.7**	kPa

$$S_H = PD / (2t)$$

$$\sigma_c = E\alpha(T_2 - T_1) - \nu\sigma_h$$

Radial Stress

Circ stress	S-r	**-10200.00**	kPa

$$\boxed{S_3 = -P}$$

Check for Allowable Stresses

Max Circumferential stress	S-c	**241,192.5**	kPa	S1
Max Longitudinal stress	S-l (T2max)	**-3,631.7**	kPa	S2 (T2 max)
	S-l (T2min)	**-171,526.7**	kPa	S2 (T2 min)
Max Radial stress	S-r	**-10,200.0**	kPa	S3
Effective Stress	Seff (T2max)	**248,173.5**	kPa	
	Seff (T2min)	**360,251.0**	kPa	

$$S_{eff} = \sqrt{\frac{1}{2}\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}$$

Allowable Stress	Sa	436500	kPa	SMYS x DF

Effective stresses are within allowable limits. ok

Appendix F

Pipeline Preliminary Walk Through

Point/Length Location (Approx KP)	Primary Location Class	Secondary Location Class (if applicable)	Predomінant Land Use and Other Features	Feature
ABP Pipeline				
AB - 0.8	R1		Grazing	Track crossing
AB - 4.5	R1		Grazing	Minor Watercourse - Cerito Creek
AB - 11.8	R1		Grazing	U/G water line
AB - 12.2	R1		Grazing	Minor Watercourse - Sutter Creek
AB - 20.0	R1		Grazing	Track crossing
AB - 22.0	R1		Grazing	Track crossing
AB - 26.8	R1		Grazing	Track crossing
AB - 27.2	R1		Grazing	Minor Watercourse p/l crossing
AB - 34.8	R1		Grazing	Sutter Development Rd crossing
AB - 35.5	R1		Grazing	Lenton Downs Rd crossing
AB - 36.8	R1		Grazing	Lenton Downs Rd crossing
AB - 46.7	R1		Grazing	Rd crossing
AB - 50.2	R1		Grazing	Major Watercourse - Isaac River crossing
AB - 50.5	R1		Grazing	Major Watercourse crossing
AB - 52.7	R1		Grazing	Track crossing
AB - 58.3	R1		Grazing	Track crossing
AB - 59.2	R1		Grazing	Track crossing
AB - 68.2	R1		Grazing	Track crossing
AB - 70.1	R1		Power Lines In Proximity	Powerlines crossing
AB - 73.5	R1		Mine Road	Burton Coal easement/rd
AB - 76 - 77	R1	HI	Mining Lease	Ellensfield Mining Lease, Vale Petroleum Lease - active
AB - 76.9	R1		Power Lines In Proximity	Powerline crossing
AB - 77.9	R1		Power Lines In Proximity	Powerline re-crossing
AB - 81 - 85.6	R1		Power Lines In Proximity	Powerline runs parallel
AB - 81.8	R1		Petroleum Lease	Adjacent csg well
AB - 89	R1		Petroleum Lease	Adjacent csg well
AB - 90	R1		Grazing	Railway & water p/line crossing
AB - 90 - 93	R1		Grazing	Parallel water p/line
AB - 92.3	R1		Grazing	Goonyella branch rail line & water p/line crossing
AB - 95	R1		Grazing	Peak Downs Highway crossing
AB - 95	R1		Grazing	Homestead ~ 2km west
Elphinstone Lateral KP's from North End				
EL - 0	R1		Agricultural	Start of Elphinstone lateral, Lake Elphinstone ~ 2km west
EL - 2.8	R1		Agricultural	??Water pond ??adjacent
EL - 3 - 6 ??	R1		Mining Lease	Mitsubishi Coal // & 2km east

Track/lane crossing	🟨
Watercourse/creek crossing	🟦
Road crossing	🟧
Powerline Crossing	🟪
Pipeline crossing	🟫
CSG well	🟥
Homestead	🟥

EL - 13	R1		Power Lines In Proximity	Powerline Crossing
EL - 14.9	R1		Agricultural	unnamed road reserve crossing
EL - 19.9	R1		Agricultural	Carborough Range - unnamed road reserve
EL - 25.2	R1		Agricultural	Track crossing
EL - 25.7	R1		Agricultural	Track crossing
EL - 28.1	R1		Agricultural	Track crossing
EL - 28.3	R1		Agricultural	Track end?
EL - 30.2	R1		Agricultural	adjacent SW7 csg wellsite (<100m)
EL - 35.2	R1		Agricultural	Track crossing
EL - 35.8	R1		Agricultural	Track crossing
EL - 45 - 46	R1		Mining Lease	parellel to Coppabella m/lease (~1km east)
EL - 46.7	R1		Agricultural	Track crossing
EL - 46.9	R1		Other Pipeline in Vicinity	U/G Water line
EL - 47	R1		Industrial	Railway - Goonyella branch
EL - 47.7	R1		Power Lines In Proximity	Powerline crossing
EL - 47.8 - 48.5	R1		Power Lines In Proximity	Parallel Powerlines < 100m
EL - 48.5 - 52	R1		Grazing	Petroleum lease to end of lateral
EL - 52	R1		Grazing	Joins ABP mainline
AB - 95-97				Possible cultivation over the pipeline
AB - 95.9	R1		Grazing	Elphinstone Lateral
AB - 99.3	R1		Grazing	Easement crossing
AB - 100 - 101	R1		Other Pipeline in Vicinity	Coppabella p/line. P/line crosses road easement twice
AB - 101	R1		Mining Lease	Norwich Park branch rail line
AB - 101.9	R1		Mining Lease	Rd crossing
AB - 103 - 105	R1		Grazing	Large road easement runs parallel
AB - 107	R1		Grazing	Road reserve crossing
AB - 105.1	R1		Grazing	Minor Watercourse - North Creek crossing
AB - 106.8 - 107	R1		Grazing	Rd reserve crossing
AB - 109.3	R1		Grazing	Annandale rd crossing
AB - 111.5	R1		Grazing	Olive Downs B Haul road crossing?
AB - 111.8	R1		Grazing	Track crossing
AB - 112	R1		Grazing	Annandale rd crossing
AB - 119	R1		Grazing	Annandale rd crossing
AB - 122.3	R1		Grazing	Track crossing
AB - 125.3	R1		Grazing	Track crossing
AB - 126	R1		Grazing	Track crossing

AB - 127	R1		Grazing	Track crossing
AB - 129.1	R1		Grazing	Track crossing
AB - 129.8	R1		Grazing	Track crossing
AB - 132	R1		Grazing	??east 400m??
AB - 132.5	R1		Grazing	Track crossing
AB - 133	R1		Grazing	??east???
AB - 137	R1		Grazing	??east???
AB - 137	R1		Grazing	Annandale rd crossing
Saraji Lateral KP's from West End				
SL - 0	R1		Agricultural	Start of Dysaht lateral
SL - 0.5	R1		Other Pipeline in Vicinity	CQP p/l crossing
SL - 3.1 - 6.7	R1		Mining Lease	Mining Development Licence
SL - 7.5	R1		Agricultural	Track crossing
SL - 13 - 14	R1		Grazing	lateral runs along track
SL - 16	R1		Grazing	Track crossing
SL - 18.8	R1		Grazing	Major Watercourse - Isaac River crossing
SL - 19.7	R1		Grazing	Track crossing
SL - 25.8	R1		Grazing	joins ABP main line
AB - 137.2	R1		Grazing	Saraji Lateral
AB - 142 - 152	R1		Grazing	Fitzroy Development Rd runs parallel
AB - 145.2	R1		Grazing	Track crossing
AB - 151.6	R1		Grazing	Track crossing
AB - 151 - 152	R1		Grazing	?? What't this??
AB - 157	R1		Grazing	Track crossing
AB - 159.2	R1		Grazing	Track crossing
AB - 161.2	R1		Grazing	Track crossing
AB - 164.6	R1		Grazing	Major Watercourse - Isaac River
AB - 165	R1		Grazing	Homestead ~2km west
AB - 165.5	R1		Grazing	Carfax rd crossing
AB - 170.2	R1		Grazing	Track crossing
AB - 170.3	R1		Grazing	Minor Watercourse - Stephens Creek crossing
Dysaht Lateral KP's from West End				
DL - 0	R1		Agricultural	Start of Dysaht lateral
DL - 0 - 15	R1		Agricultural	On Golden Mile Road alignment
DL - 0	R1		Other Pipeline in Vicinity	CQP 1km south west of Dysaht lateral start
DL - 0.3	R1		Agricultural	Track start

DL - 2.2	R1		Grazing	Bowen Norwich Park CSG p/lease - start
DL - 3.7	R1		Grazing	Track start
DL - 6	R1		Grazing	CSG wellhead - on alignment
DL - 7.3 - 14.1	R1		Mining Lease	Mining Development Licence
DL - 10.6	R1		Mining Lease	??? > 300m s/west???
DL - 12	R1		Mining Lease	Track crossing
DL - 15.3	R1		Grazing	Track crossing
DL - 16.5	R1		Grazing	Track crossing
DL - 17.1	R1		Grazing	Minor Watercourse - Stephens Creek crossing
DL - 20.2	R1		Grazing	Track crossing
DL - 20.2 - 25.7	R1		Grazing	lateral runs along Fitroy Development Road
DL - 25.7	R1		Grazing	end of Dysaht Lateral
AB - 172.7	R1		Grazing	Dysaht Lateral
AB - 173	R1		Grazing	Fitzroy Development Road crossing
AB - 180.5	R1		Grazing	Track crossing
AB - 189.5	R1		Grazing	Track crossing
AB - 193.3	R1		Grazing	Track crossing
AB - 194.8	R1		Grazing	Track crossing
AB - 195.5	R1		Grazing	May Downs Carfax road
AB - 196	R1		Grazing	Track crossing
AB - 201.5	R1		Grazing	Track crossing
AB - 205.2	R1		Grazing	Track crossing
AB - 205.7	R1		Grazing	Track crossing
AB - 206	R2		Grazing	Langley Homestead ~ 2km south west
AB - 210.9	R1		Grazing	Track crossing
AB - 211.9	R1		Grazing	Track crossing
AB - 212.9	R1		Grazing	Major Watercourse - Rolf Ck (Isaac River) crossing
AB - 228.1	R1		Grazing	May Downs road crossing
AB - 234	R1		Grazing	Track crossing
AB - 234.7	R1		Grazing	Major Watercourse - Isaac River crossing
AB - 238.5	R1		Grazing	(caused a 90deg kink - non-perren??) watercourse
AB -239.7	R1		Grazing	??Similar?? Watercourse
AB - 245	R2		Grazing	Clive Homestead ~ 2km north east
AB - 245.9	R1		Grazing	Track crossing
AB - 253.5	R1		Power Lines In Proximity	Powerline crossing
AB - 254.7	R1		Petroleum Lease	Manly Access Road crossing

AB - 262.2	R1		Grazing	Track crossing
AB - 263.7	R1		Grazing	Tartrus Road crossing
AB - 265 - 271	R1		Other Pipeline in Vicinity	AGL p/line < 1km away running parallel
AB - 276 - 277	R1		Grazing	Track parallel / crossing
AB - 271 - 278	R1		Other Pipeline in Vicinity	AGL p/line 200-300m away, running parallel
AB - 278 - 349	R1		Other Pipeline in Vicinity	AGL p/line < 1km away, running parallel
AB - 279	R1		Grazing	Track crossing
AB - 280	R1		Grazing	unnamed rd reserve crossing
AB - 281.5	R1		Grazing	Track crossing
AB - 282.2	R1		Grazing	unnamed rd reserve crossing
AB - 284.7	R1		Grazing	Duaringa Apis Ck rd crossing
AB - 289.7 - 291.8	R1		Grazing	Apis Ck Stud Holding rd runs parallel
AB - 293	R1		Grazing	Track starts
AB - 293 - 299	R1		Grazing	Track runs parallel
AB - 300.2	R1		Grazing	Track crossing
AB - 301.8	R1		Grazing	Track crossing
AB - 302.3	R1		Grazing	Track crossing
AB - 303.3	R1		Grazing	Track crossing
AB - 303.8	R1		Power Lines In Proximity	Powerline crossing
AB - 304.1	R1		Other Pipeline in Vicinity	AGL P/line crossing
AB - 306.5	R1		Grazing	Track crossing
AB - 308.1	R1		Grazing	Track crossing
AB - 310.1	R1		Other Pipeline in Vicinity	AGL P/line crossing
AB - 310.1	R1		Grazing	Morbank Rd crossing
AB - 311.3	R1		Grazing	Morbank Rd runs parallel
AB - 316.7	R1		Grazing	Genroy Marlborough Rd crossing
AB - 316.5	R1		Other Pipeline in Vicinity	AGL P/line crossing
AB - 319.5	R1		Grazing	Major Watercourse - Fitzroy River crossing
AB - 322.2	R1		Grazing	Unnamed rd reserve crossing
AB - 324	R1		Grazing	Redbank Homestead 500m NE
AB - 324.4	R1		Grazing	Unnamed road reserve crossign
AB - 327.8	R1		Grazing	Track starts
AB - 328.3	R1		Grazing	Rd reserve crossing
AB - 329.2	R1		Other Pipeline in Vicinity	Marlborough Nickel's Gladstone Nickel Project p/line crossing
AB - 329.2 - 407.5	R1		Other Pipeline in Vicinity	Gladstone Nickel Project p/line runs approx parallel
AB - 338	R1		Grazing	Fairview Rd crossing

AB - 341	R1		Grazing	Rd reserve crossing
AB - 313.1 - 313.3	R1		Grazing	unnamed rd reserve crossing
AB - 344.1	R1		Grazing	Marble Ridges rd crossing
AB - 349.2	R1		Grazing	unnamed rd reserve crossing
AB - 351.1	R1		Grazing	Glenroy Rd crossing
AB - 354.6	R1		Power Lines In Proximity	Powerline easement crossing
AB - 355.9	R1		Grazing	Craignought Rd crossing
AB - 356.1	R1		Grazing	unnamed rd crossing
AB - 357.6	R1		Grazing	unnamed rd crossing
AB - 357.9	R1		Grazing	Morinish Rd crossing
AB - 360.2	R1		Grazing	unnamed rd crossing
AB -365.4	R1		Grazing	Dahua Ridgelands Rd crossing
AB - 368.3	R1		Grazing	(temp closed) rd crossing
AB - 370.1	R1		Grazing	unnamed rd crossing
AB - 370.3	R1		Grazing	unnamed rd crossing
AB - 371.1	R1		Grazing	unnamed rd crossing
AB - 373	R1		Grazing	unnamed rd crossing
AB - 375.2	R1		Grazing	Harding Road crossing
AB - 379.9	R1		Grazing	Tucker Road + unnamed rd crossing
AB - 380	R1		Grazing	track crossing
AB - 382.5	R1		Grazing	Cunningham Road & track crossing
AB - 384	R1		Grazing	unnamed rd crossing
AB - 385	R1		Grazing	unnamed rd crossing
AB - 387.2	R1		Grazing	Above ground water p/line crossing
AB - 390.7	R1		Grazing	Hopper Rd crossing
AB - 391.3	R1		Grazing	Minor Watercourse - Scrubby Ck & Neercol Ck crossing
AB - 391.8	R1		Grazing	Kabra Scrubby Ck Rd crossing
AB - 392.2	R1		Grazing	Freehold Land ???
AB - 392.8	R1		Grazing	Capricorn H/way crossing
AB - 393	R1		Grazing	Railway Crossing
AB - 393.1	R1		Grazing	Somerset Rd crossing
AB - 395	R1		Grazing	Boongarry Rd crossing
AB - 395.1	R1		Other Pipeline in Vicinity	Stanwell Gas P/line crossing
AB - 395.3	R1		Grazing	unnamed rd reserve crossing
AB - 398.3	R1		Grazing	unnamed rd reserve crossing
AB - 400.1	R1		Grazing	unnamed rd reserve crossing

AB - 402.1	R1		Other Pipeline in Vicinity	P/line crossing
AB - 402.5	R1		Other Pipeline in Vicinity	P/line crossing
AB - 402.8	R1		Grazing	Minor Watercourse - 4 Mile Ck & unnamed road crossing
AB - 402.9	R1		Grazing	Track crossing
AB - 404	R1		Grazing	unnamed rd crossing
AB - 404.9	R1		Grazing	Burnett Highway crossing
AB - 407.2	R1		Grazing	unnamed rd reserve crossing
AB - 407.5	R1		Other Pipeline in Vicinity	Gladstone Nickel Project P/line end
vKP 408.7	R1		Other Pipeline in Vicinity	AGL Jemena Gladstone - Rockhampton P/line crossing
AB - 408.7 - 411.1	R1		Other Pipeline in Vicinity	AGL Jemena Gladstone - Rockhampton P/line runs parallel
AB - 409	R1		Grazing	unnamed rd crossing
AB - 410.8	R1		Grazing	Mogilno Rd crossing
AB - 412.5	R1		Grazing	McLean Rd crossing
AB - 414	R1		Grazing	Bob's Creek Rd crossing
AB - 416.4	R1		Grazing	Bruce Highway crossing
AB - 416.5	R1		Grazing	North Coast Railway Line crossing
AB - 418	R1		Grazing	Archer - 1km West
AB - 421.4	R1		Grazing	unnamed rd / small w/course crossing
AB - 427.6	R1		Grazing	C Q Salt Railway Siding crossing
AB - 430	R1		Grazing	Minor Watercourse - Inkerman Creek crossing
AB - 431.4	R1		Grazing	Bajool - Pt Alma Rd crossing
AB - 433	R1		Grazing	Toonda - Pt Alma Rd crossing
AB - 436.7	R1		Grazing	unnamed rd crossing
AB - 438.2	R1		Grazing	unnamed rd crossing
AB - 438.8	R1		Grazing	Twelve Mile Road crossing
AB - 442.2	R1		Grazing	Twelve Mile Road crossing
AB - 445	R2		Grazing	Raglan area
AB - 446.7 - 446.8	R2		Grazing	Minor watercourse - Raglan Ck crossing
AB - 450	R1		Grazing	unnamed road crossing
AB - 452.2	R1		Grazing	unnamed road crossing
AB - 455	R2		Grazing	Reedy Creek Road crossing
AB - 455 to 460.3	R2		Grazing	runs parallel to Raglan Station Road
AB - 461 - 463	R2		Grazing	North of Ambrose
AB - 462	R1		Grazing	Darts Creek Road crossing
AB - 462.5	R1		Other Pipeline in Vicinity	CQP p/line crossing
AB - 462.9 - 464	R1		Power Lines In Proximity	Powerline crossing & running parallel

AB - 465.5	R1		Grazing	Popenia Road crossing
AB - 467	R2		Grazing	start of Mt Larcom area
AB - 467.5	R2		Grazing	Gostevsky Road crossing
AB - 469.7	R2		Grazing	Narrows Road crossing
AB - 469.9	R2	Industrial	Other Pipeline in Vicinity	CQP p/line crossing
AB - 470.3	R2	Industrial	Other Pipeline in Vicinity	Santos GLNG P/line crossing
AB - 470.4	R2	Industrial	Other Pipeline in Vicinity	QCLNG P/line crossing
AB - 470.4	R2	Industrial	Other Pipeline in Vicinity	APacLNG P/line crossing
AB - 471 - 476	R2	Industrial	Other Pipeline in Vicinity	
AB - 471	R2	Industrial	Other Pipeline in Vicinity	Railway crossing
AB - 476.1	R2	Industrial	Other Pipeline in Vicinity	CQP P/line crossing
AB - 478	R2	Industrial	Other Pipeline in Vicinity	end of p/line
AB - 418 - end	R2	Industrial	Petroleum Lease	SGIC Corridor
AB - 469.5 - end	R2	Industrial	Petroleum Lease	GSDA Corridor
AB - 329- 407.9	R2	Industrial	Petroleum Lease	Marlborough Nickel Corridor

Appendix G

General Action Items Closed Out

Memorandum

04 October 2011

To	Ian Grimmer		
Copy to	Iain Burgess		
From	Rubi Turna	Tel	(07) 3316 3271
Subject	ABP Initial SMS General Actions Closed Out	Job no.	41/24306

As per Table 6 in Section 7 of the ABP Initial SMS Report (08-ABP-02-0006 Rev C), the following general actions assigned to GHD have been closed out.

Item #	General Action	Comment	Status
1	Railway depth of cover - measured from bottom of ballast?	Railway depth of cover is measured from bottom of rail not ballast as per API 1102.	Completed
2	Specify minor and major watercourse crossings in the pipeline walk through.	Refer to Appendix F of ABP Initial SMS Report (08-ABP-02-0006 Rev C).	Completed
22	Calculate the overlap of measurement lengths in T1 and Sensitive location class zones.	T1 location class runs from AB 446 – 469 km. The S location class is located at AB 465. For a DN 800 pipe size the measurement length is 1.1 km which gives an overlap distance of 463.9 to 466.1 km. For a DN 1050 pipe size the measurement length is 1.25 km which gives an overlap distance of 463.75 to 466.25 km.	Completed
24	Investigate operating pressures for slurry pipelines to further consider threats posed to adjacent gas pipelines.	The Marlborough Nickel slurry pipeline is classified as high pressure however unable to ascertain exact pressure.	Unable to ascertain

25	GHD to determine frequency of DCVG surveys for detecting latent defects from third party impact.	Frequency of DCVG surveys are based on the result of CPU test readings and at the discretion of the operator. In some cases, DCVG surveys on similar size pipelines have been conducted on a yearly basis.	Completed
27	Try to find photo of lightning strike.	Occurred on the Amadeus Basin Pipeline.	Unable to locate

Regards

Rubi Turna
Pipeline Engineer

GHD 2011

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