Gas Transmission Pipelines Augmentation Review Report

South Australian South East Region Gas Transmission Options Study

Department for Energy and Mining (SA)

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EXECUTIVE SUMMARY

The recent discovery of gas in Haselgrove – 3, the drilling of Haselgrove – 4, and planned exploration wells into the Dombey and the Nangwarry prospects has highlighted demand for expansion of existing gas transmission line infrastructure..

The SA Department for Energy and Mines, DEM, has engaged GPA Engineering to undertake an independent review of existing gas transmission assets in the region and develop options and preliminary capital cost estimates for the delivery of new gas production into the existing SEA Gas Pipeline.

This report summarises the findings of this investigation, providing preliminary budget capital cost estimates for an identified set of potential new gas production profiles.

The prospect of new gas discoveries in the south east of South Australia has required a review of the existing gas transmission infrastructure in the region and the ability for it to accommodate increased local gas production profiles ranging from an additional 10TJ per day to as much as 50 TJ per day.

Given success in the Dombey and the Nangwarry prospects, and further exploration, new gas flows are expected in the vicinity of the original Katnook Gas Plant located near Penola. This location provides a ready access to the South East Pipeline System (SEPS) currently owned and operated by Epic Energy to provide gas to local SE consumers, and also the 80MW Ladbroke Grove Power Station (LGPS) operated by Origin Energy.

The gas for these consumers is currently supplied from the SEA Gas owned and operated main transmission pipeline via the South East South Australia (SESA) pipeline owned and operated by APA Group. The SESA gas receipt point is located at Poolaijelo in Victoria and the SESA gas delivery point is located adjacent the Ladbroke Grove facility at Katnook.

Due to the LGPS being a peak demand power station, its intermittent operation results in a highly variable local load profile. The local demand fed from the existing SESA pipeline can vary from as low as 2TJ/d to 22TJ/d with a contracted MDQ totalling as much as 38TJ/d for a nominal SESA pipeline capacity of 40 TJ/d. As such, in order to guarantee a new gas producer access to local and remote gas markets, and to ensure that any new gas production is not subject to frequent curtailment, a cost effective option has been investigated making use of the existing gas transmission infrastructure. Specifically the use of the SESA pipeline as a bi-directional pipeline able to deliver gas either into the SEA Gas pipeline or source gas from that pipeline to meet local peak demand and /or local gas facility outages has been reviewed.

The Maximum Allowable Operating Pressure (MAOP) of the SEA Gas pipeline is 15.3 Megapascal at guage (MPag) whereas the MAOP of the SESA pipeline is only 10.2 MPag. This requires compression which is proposed to be installed at the Poolaijelo tie-in to ensure uninterrupted access to the SEA Gas pipeline for gas delivery.

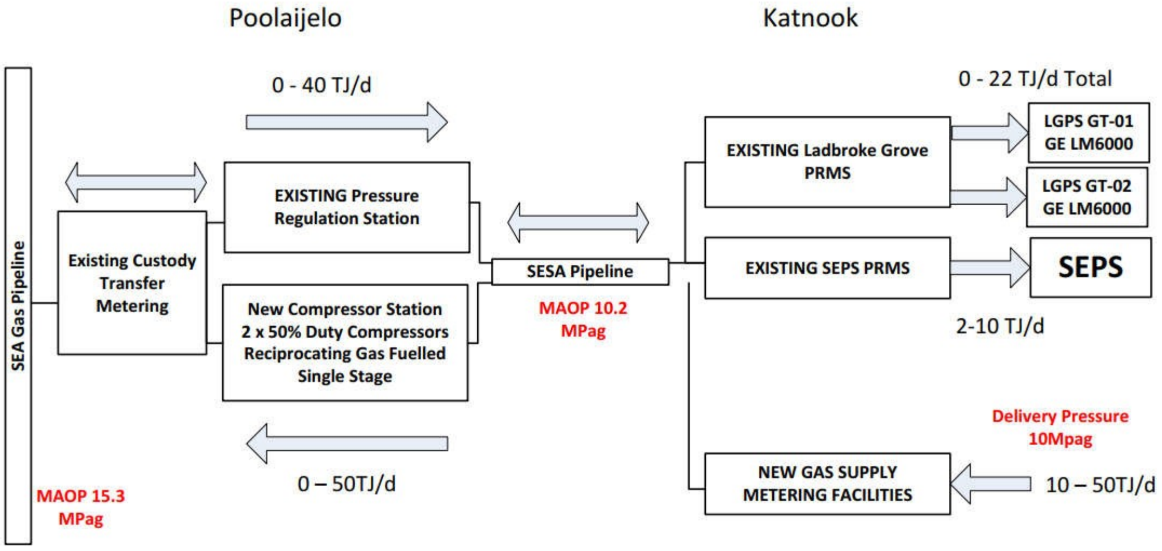
GPA has undertaken a preliminary review including cost estimates for the following prospective incremental production profiles:

- 10 TJ/d Low Production Demand Case
- 30TJ/d Medium Production Demand Case
- 50 TJ/d High Production Demand Case

Preliminary estimates indicate the costs of augmentation of the existing gas transmission infrastructure including a new compressor station at Poolaijelo for the above three production scenarios as follows including contingency sums and allowances for scope growth during project definition:

Production Profile	Total Installed Cost ($AUS 2019)
10 TJ/d Low Production Case	$ 30.6 M
30 TJ/d Medium Production Case	$ 45.4 M
50 TJ/d High Production Case	$ 71.9 M

The overall system block diagram is represented below:
Note PRMS is Pressure Reduction and Metering System.



The above concept diagram and costs are preliminary and can only be considered at best as having accuracy in the range of +/- 30%. In addition a number of alternative options and further investigations have been identified in the report that would be required prior to finalisation of any development strategy for the augmentation of the existing gas transmission infrastructure.

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1 INTRODUCTION

The recent discovery of gas in Haselgrove – 3, the drilling of Haselgrove – 4, and planned exploration wells into the Dombey and the Nangwarry prospects in the South East of Australia and proposed exploitation of these potential reserves has highlighted a requirement to review the existing gas transmission line infrastructure in the region and its capability and options for its utilisation in delivering additional gas production to the South Australian and Eastern Australian markets.

The SA Department for Energy and Mines, DEM, has engaged GPA Engineering to undertake an independent review of existing gas transmission assets in the region and develop options and preliminary capital cost estimates for the delivery of new gas production into the existing SEA Gas Pipeline.

This report summarises the findings of this investigation, providing preliminary budget capital cost estimates for an identified set of potential new gas production profiles.

1.1 SCOPE AND OBJECTIVE

The objective of this study is to provide DEM an independent assessment of feasible options and associated preliminary capital costs for delivering increased gas production in the South East region to new and existing markets utilising the existing gas transmission infrastructure.

This is required due to potential new gas discoveries and developments which are expected to deliver gas quantities in excess of the projected demands of the local SE market.

To encourage further exploration and development in the region cost effective gas delivery options are required to enable gas producers to economically export gas to the eastern Australian gas market whilst not compromising existing or opportunities for increased gas supply to local SA consumers.

GPA's scope is understood to be limited to:

- ➢ Evaluation of technical options for gas delivery into the SEA Gas pipeline and associated capital cost estimates

GPA's scope excludes:

- ➢ An evaluation of the commercial implications of options presented in terms of available uncommitted capacity in each pipeline or the ability or terms of any subsequent supply contract negotiations
- ➢ Validation of production profiles and/or potential new gas consumers and markets

The major deliverables for the study include:

- This formal report detailing all options considered, findings and recommendations
- High Level Budget capital cost estimates for recommended feasible options
- Potential development timelines for options

2 EXISTING GAS TRANSMISSION INFRASTRUCTURE

2.1 OVERVIEW OF EXISTING PIPELINES

The existing gas transmission infrastructure located in the south-east of South Australia includes the following major elements:

- The SEA Gas transmission pipeline system transporting natural gas from Port Campbell and Iona in Victoria to various offtakes and inter-connected pipeline systems in Victoria and South Australia.
- The South East Pipeline System (SEPS) is an 82km pipeline system that was built in 1991 to deliver gas from the Katnook processing plant near Penola in south eastern South Australia to Snuggery and Mount Gambier. Following a gradual decline in the availability of gas from Katnook, an APA-owned lateral, the South East South Australia (SESA) pipeline, was commissioned in 2005 to supply gas from the SEA Gas pipeline into the SEPS.
- The 45 kilometre SESA Pipeline is a transmission pipeline that supplies natural gas from the SEA Gas Pipeline at Poolaijelo to Epic Energy SA's SEPS at Katnook, near Penola and to the Australian Gas Networks' distribution network, at Ladbroke Grove.
- Ladbroke Grove PRMS, fed from the SESA pipeline providing pressure regulation, metering and filtration prior to delivery to the Ladbroke Grove Power Station (LGPS) consisting of 2, GT1 and GT2, open cycle gas turbines each capable of a nominal power output of 40MW.

This study assumes the discovery of new gas reserves in the Katnook / Hazelgrove area that will be required to tie into the above systems in the vicinity of the original Katnook gas plant, for delivery of gas to local regional and eastern seaboard consumers.

An overview of the major features of the pipelines in the south east appears below in Figure 2.1.

Design and operating parameters of the existing pipeline systems are further detailed in Sections 2.3, 2.4, 2.5 and 2.6 below.

2.2 OVERVIEW OF EXISTING CONSUMERS

The existing natural gas consumers in the region are supplied from gas sourced from the SEA Gas pipeline via the SESA pipeline delivering into the Ladbroke Grove PRMS and SEPS.

Consumers in the region are summarised as:

- The Origin Energy owned and operated Ladbroke Grove 80MW power station comprising 240MW GE LM6000 open cycle gas turbines operating as a "peak demand" power station.
- Consumers connected to the SEPS including the township of Mount Gambier and the major consumer, the Kimberley Clark Australia, KCA, paper mill located at Millicent/Tantanoola.
- A Penola lateral pipeline supplying the Midfields Group Meat Processing factory, (formerly the Safries / McCain's potato processing facility).
- A lateral from the SEPS to the Nangwarry Timber Mill has been mothballed at present.

The current typical consumption profiles for the above consumers are further discussed in Section 3 below.

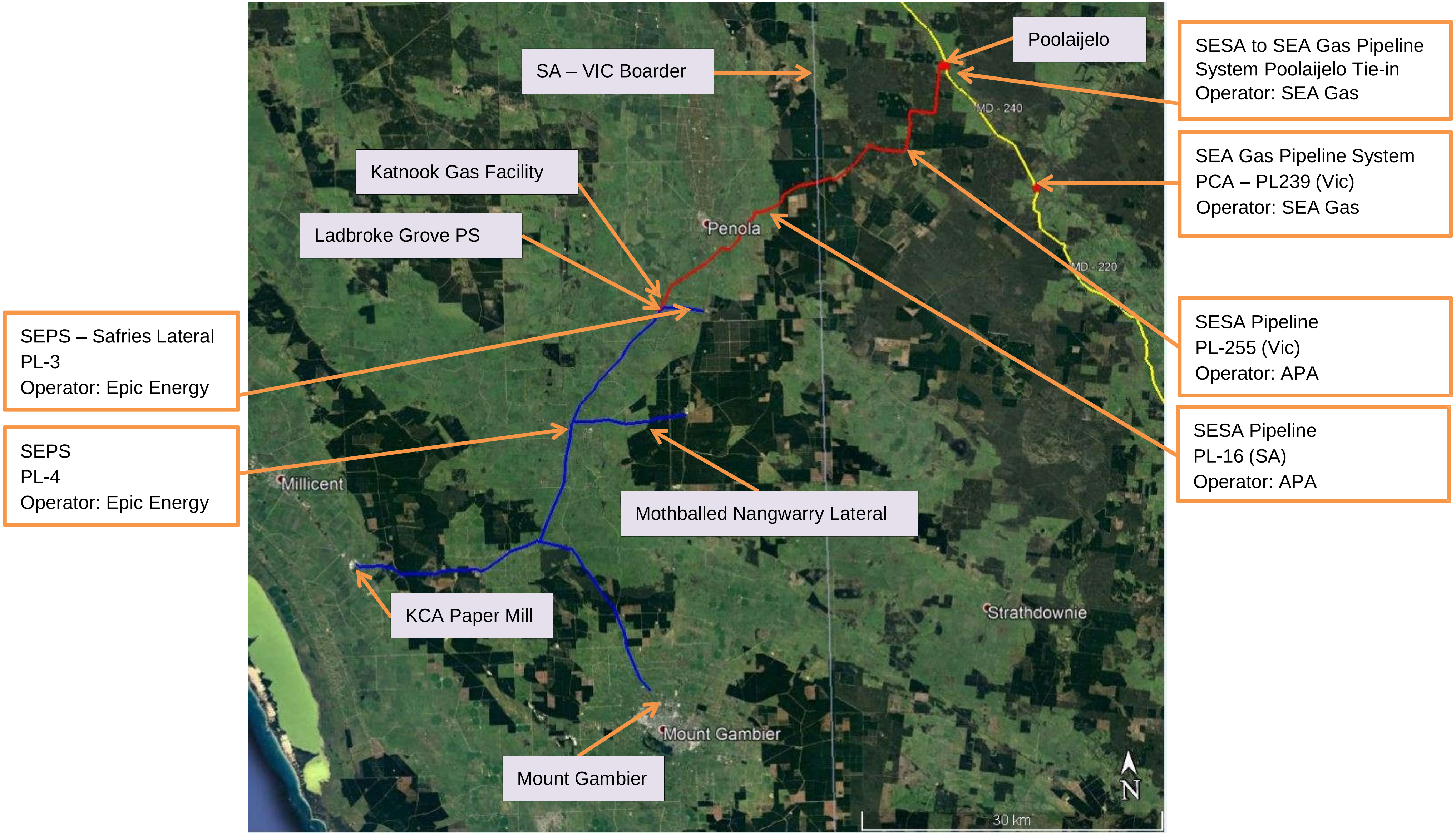


Figure 2.1 – South-east SA Gas Transmission Pipeline Infrastructure

2.3 SEA GAS PIPELINE SYSTEM DESIGN PARAMETERS

SEA Gas operates the transmission pipeline systems that transport natural gas from Port Campbell and Iona in Victoria to various offtakes and interconnected pipeline systems in South Australia and Victoria.

The primary function of a pipeline system is to provide safe, reliable transportation of high pressure gas.

Approximately 50% of Adelaide’s natural gas energy needs are delivered by SEA Gas.

The pipelines operated by SEA Gas include the:

- Port Campbell to Adelaide (PCA) pipeline ;
- Port Campbell to Iona (PCI) pipeline; and
- Mortlake pipeline.

The PCA is the main pipeline in the SEA Gas pipeline system. The length of the PCA is approximately 680km, traversing from Port Campbell in South West Victoria to Pelican Point in South Australia. For approximately half of this length the PCA consists of twin 14″ diameter pipes with the remainder being single 18″ diameter pipe. There are two compressor stations located on the PCA; one at Coomandook, in South Australia and the other at Miakite, in Victoria.

The SESA pipeline PCA tie-in is at Poolaijelo in Victoria.

The overall SEA Gas pipeline system appears below in Figure 2.2.

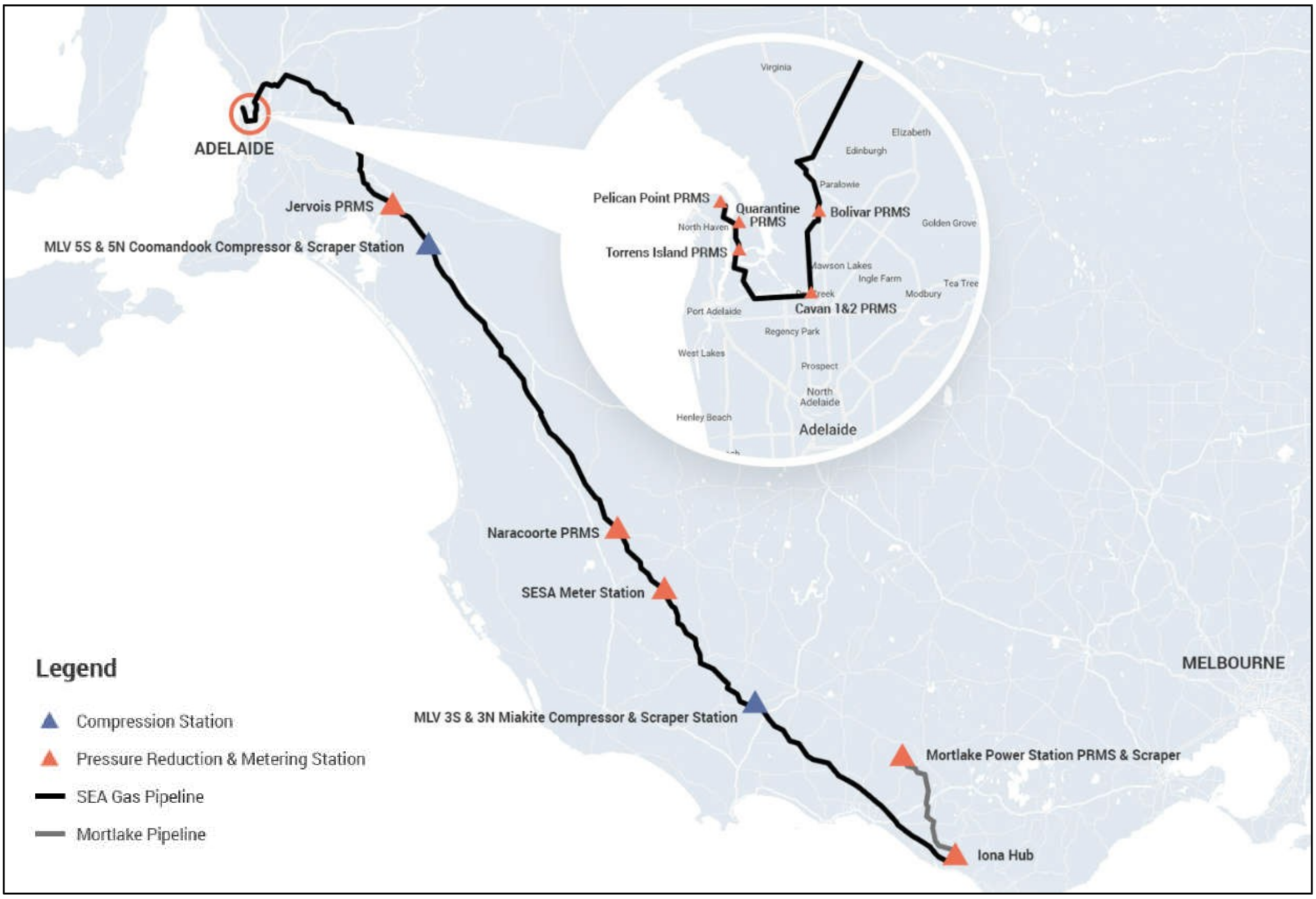


Figure 2.2 – SEA Gas Transmission Pipeline Infrastructure

The design and operating characteristics of the SEA Gas PCA pipeline which provides the interconnection point with the SE pipeline networks via the SESA pipeline appear summarised in Table 2.1 below.

Owner / Operator	SEA Gas
MAOP	15,306 kPag
Main PCA Twin Pipeline Diameter	350 mm (twin parallel pipeline in common trench at Poolaijelo)
Main PCA Twin Pipeline WT	7.84 mm / 9.8 mm
Poolaijelo Lateral Length – To SESA Connection	550 m
Poolaijelo Lateral Diameter	200 mm
Poolaijelo Lateral WT	6.7 mm
Design Operating Pressure Range	3100 kPag to 15000 kPag
Normal Operating Pressure	6894 kPag to 14000 kPag
Max PCA Design Throughput	314 TJ/d 2 Compressor Stations in Operation 242 TJ/d in Free Flow
Normal PCA Throughput	140 TJ/d in 2017
Design Temperature Max / Min	+55^{o}C / 0^{o}C (-10 0^{o}C permitted during pipeline re-pressurisation)
System Constraints (Noted)	Pipeline Gas Temperature limited to 45 degrees C max. No reverse flow path past Poolaijelo PRMS currently. Water content must be less than 75 mg/cubic meter.

Table 2.1 – SEA Gas Transmission Pipeline Design Characteristics and Operating Data

2.4 SESA PIPELINE DESIGN PARAMETERS

The 45km long, DN200 SESA pipeline supplies odorised natural gas from an off-take of the SEA Gas pipeline (near Poolaijelo in western Victoria) to the Ladbroke Grove Power Station (LGPS) in South Australia, and to industrial and domestic customers within the south east region of South Australia via Epic Energy's SEPS.

The pipeline has a maximum allowable operating pressure of 10,200kPag.

The SESA Pipeline is operated in compliance with the *Petroleum and Geothermal Energy Act 2000* (SA) and the Victorian *Pipelines Act 2005*. The pipeline falls under two separate pipeline licenses; the first 22km (in Victoria) is subject to PL 255 (Vic) originally issued on 1/3/05 and is a perpetual licence, the last 23km (in South Australia) is subject to PL 16 (SA) originally issued on 23/2/05 and due to expire on 22/2/26.

The natural gas supplying the SESA pipeline is currently sourced predominantly from offshore Victoria reserves and conforms to the AEMO Gas Quality Specifications and Australian Standard AS4564-2011. Gas entering the SEA Gas pipeline is monitored for quality using gas chromatography and water dew point analysis at the injection points which is the primary method of ensuring adequate gas quality for the SESA pipeline.

A process flow diagram, PFD, depicting the metering, pressure regulation and custody transfer points associated with the inlet and discharge of the SESA pipeline and proposed augmentation to cater for bi-directional flow appears in Appendix 2A.

The design and operating characteristics of the SESA pipeline appear summarised in Table 2.2 below.

Owner / Operator	APA Group
MAOP	10,200 kPag
Diameter / Length	DN200, 45 km (22 km in Vic, 23 km in SA)
WT	4.01 mm / 6.1 mm
Normal Operating Pressure	9,300 kPag to 8,900 kPag at the Poolaijelo PRMS
Max Design Throughput	40 TJ per day of clean, dry, odorised gas (from SEA Gas). (Max free-flow capacity of 70TJ/d subject to inlet conditions)
Normal Throughput	6 TJ/d to 22 TJ/d Dependent on operation of LGPS
Design Temperature Max / Min	+55^{o}C / -10^{o}C
System Constraints (Noted)	Discharge pressure to SEPS and inlet limited operationally to 6400 kPag at SEPS PRMS to limit liquid dropout at SEPS Delivery points. Maximum design Inlet pressure to Ladbroke Grove PRMS and SEPS PRMS Heater is 9300kPag to prevent low temperature shutdown. Maximum Inlet Temperature to Ladbroke Grove PRMS and SEPS PRMS downstream of heaters is 65 degree C.

Table 2.2 – SESA Transmission Pipeline Design Characteristics and Operating Data

The Ladbroke Grove Power Station PRMS forms part of the SESA pipeline end-of-line facilities. Design details of the PRMS appear below in Section 2.6

2.5 SEPS PIPELINE SYSTEM DESIGN PARAMETERS

The SEPS is an 82km pipeline system that was built in 1991 to deliver gas from the Katnook processing plant near Penola in south eastern South Australia to Snuggery and Mount Gambier. Following a gradual decline in the availability of gas from Katnook, an APA-owned lateral, the SESA pipeline, was commissioned in 2005 to supply gas from the SEA Gas pipeline into the SEPS.

The SEPS directly supplies gas to the KCA (Formerly Apcel) paper mill located at Tantanoola near Millicent via a 46.1km DN150 pipeline. A tee at Glencoe marks the start of an 18.9 km DN150 lateral pipeline feeding the township of Mount Gambier and surroundings. A further 11.5 km DN50 lateral supplied the Nangwarry paper mill which was decommissioned in 2010 but the lateral remains serviceable and available if required to supply new customers. The above lateral pipeline network falls under operating licence PL-4.

At the Katnook facility a DN50 lateral fed the former Safries factory located on the outskirts of Penola. The lateral and meter station were out of service until 1 January 2014 due to the closure of the Safries facility. In February 2017 the lateral was reinstated. The meter station was refurbished and reinstated and renamed the Penola Meter Station currently supplying gas to Midfield Group who acquired the Safries site from McCain's in 2017.

The overall SEPS configuration appears below in Figure 2.3.

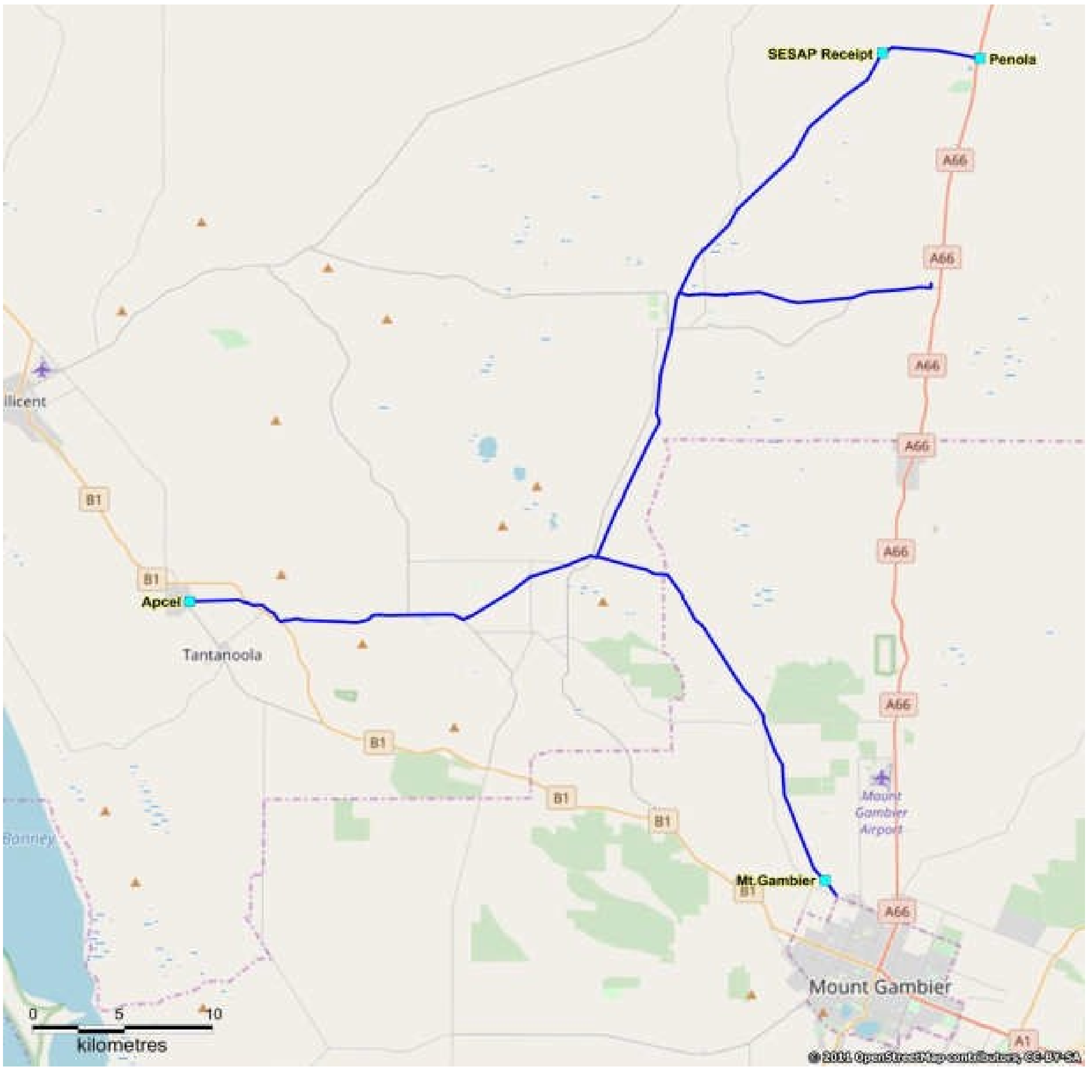


Figure 2.3 – SEPS Transmission Pipeline Infrastructure

The design and operating characteristics of the SEPS appears summarised in Table 2.3 below.

Owner / Operator	Epic Energy
MAOP	9850 kPag (Limited by Nangwarry Lateral) 10000 KPag (Main Laterals and Penola)
Diameter	DN150 (Apcel Lateral, Mt Gambier Lateral), DN50 (SAFRIES)
WT	4.20 mm (Apcel Lateral, Mt Gambier Lateral), 3.91 mm (SAFRIES)
Normal Operating Pressure	6000 kPag
Design Throughput	16 TJ/d / Normal clean, dry, odorised gas
Constrained Max Throughput	9.5 TJ/d Normal clean, dry, odorised gas
System constraints	Inlet Pressure limited to 6,400 kPag due to downstream low temperature liquid drop out issues.

Table 2.3 – SEPS Transmission Pipeline Design Characteristics and Operating Data

2.6 LADBROKE GROVE PRMS DESIGN PARAMETERS

The Ladbroke Grove Power Station, LGPS, is located 45 kilometres north of Mount Gambier and 9 kilometres south west of Penola in South Australia and is operated by Origin Energy. The LGPS consists of two, 37 MW open cycle gas turbine generators and has been in operation since February 2000. Prior to commissioning of the SESA Pipeline, the LGPS was supplied with gas from the adjacent Katnook and Ladbroke Grove gas fields.

Adjacent to the LGPS is Epic Energy's SEPS off-take station. Prior to commissioning of the SESA Pipeline, the SEPS was supplied from the adjacent Katnook gas fields. The decline of the Ladbroke Grove and Katnook gas fields necessitated a new gas source for both the power station and the retail market. Origin Energy Retail Limited identified that the nearby SEA Gas Pipeline represented the most viable alternative gas source. Origin Energy Retail Limited built the SESA pipeline to allow SEA Gas pipeline transported gas to be fed to LGPS and the SEPS.

A process flow diagram, PFD, depicting the metering, pressure regulation and custody transfer points associated with Ladbroke Grove Pressure Reduction and Metering System (PRMS) at the discharge of the SESA pipeline and proposed augmentation to cater for bi-directional flow appears in Appendix 2A.

The Ladbroke Grove PRMS design and operating characteristics are summarised in Table 2.4 below.

Owner / Operator	APA Group
MAOP	10200 kPag
Diameter	DN150
Normal Operating Inlet / Outlet Pressure	9300 kPag / 5000 kPag (SEPS) 9300 kPag / 4500 kPag (LGPS GT1 & GT2)
Max Throughput / Normal Throughput	Max 24 TJ/d two units / Normal 12 TJ/d for one unit clean, dry, odorised gas
System constraints	Inlet Pressure to PRMS limited to 9300 kPag to prevent low GT delivery temperature during winter. Heater has 10% over design. SEPS is operating under a pressure constraint by Epic Energy with the LG PRMS SEPS slam shut set to close at a maximum pressure of 6000 kPag.

Table 2.4 – Ladbroke Grove PRMS Design Characteristics and Operating Data

3 EXISTING GAS CONSUMPTION PROFILES

As described in Section 2.2, the consumer demand profile for the south east region is dominated by two major consumers:

- KCA Paper Mill
- Origin Energy LGPS comprising 2 GE LM6000 OCGTs.

The remaining consumers are classed as general local distribution or small industrial consisting of the Midfield Group processing facility at Penola and the township of Mount Gambier and surroundings.

The agreed Maximum Daily Quantities for each consumer is detailed below in Table 3.1.

Pipeline System	Consumer / Supplier	Type	MDQ
SESA	SEA Gas Pipeline	Receipt Point	40 TJ/d
SESA	Origin Ladbroke Grove Power Station	Delivery Point	22TJ/d (GT1 & GT2)
SESA	Epic Energy SEPS	Delivery Point	16TJ/d

Table 3.1 – SESA Agreed Maximum Daily Quantities

Although the above represent the MDQs for the south east natural gas systems, the dominance of the consumer profile of the LGPS introduces a high variability in actual daily consumption due to the power station being a "peak demand" power station.

Actual typical gas consumption profiles are represented in Figure 3.1 below.

Typical consumption data provide by DEM to GPA for a one month period between February and March 2019 represented in Figure 3.1 highlights the variability in gas demand and the distribution of gas usage amongst the major consumers detailed above.

Total gas demand local to the south-east region can vary between in excess of 20TJ/day when the KCA paper mill is on-line and there is a requirement to run both units within the LGPS down to approximately 6 TJ/day if the LGPS is not running.

Further should a KCA paper mill outage occur at a time where power demand does not justify the operation of the LGPS, total local gas demand may fall well below 5 TJ/d to approximately 2TJ/d which is the approximate gas demand from the Penola MS and the township of Mount Gambier.

Based on the current consumer demand profile, if a new gas producer was to enter the market at a level of production greater than approximately 5TJ/d, export of gas into the SEA Gas pipeline via reverse flow down the SESA pipeline would be required to ensure a consistent avenue to market for the gas.

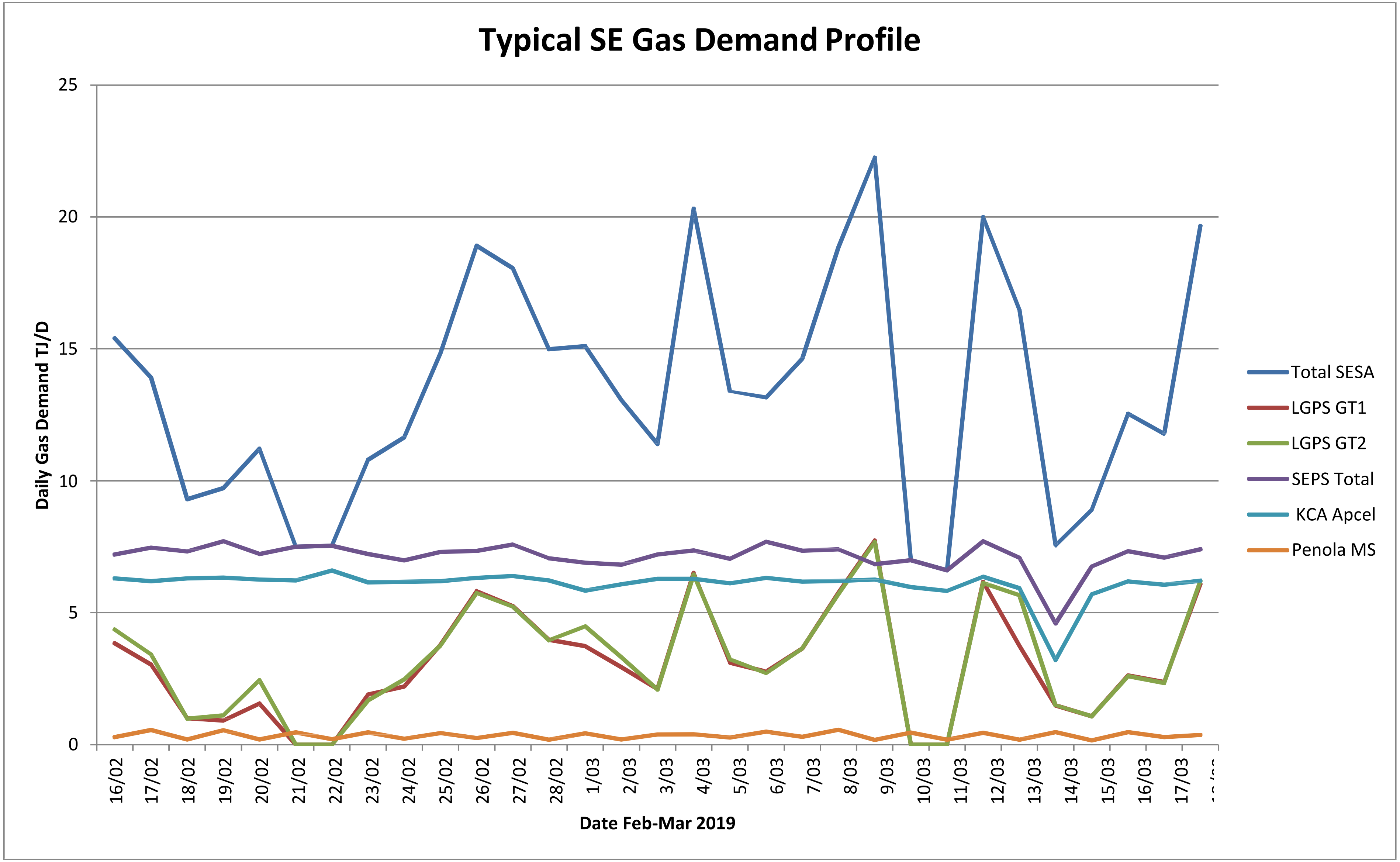


Figure 3.1 – South-east Gas Demand Typical Profile Feb-Mar 2019

4 FUTURE GAS PRODUCTION SCENARIOS

DEM have completed preliminary modelling of a number of potential production cases based on the prospective Haselgrove field located near the existing Katnook Gas processing facility.

The modelling has been based on historical data from commercial fields in the SA Otway Basin matched to production history from the former Katnook and Haselgrove producing reservoirs.

Standard decay profiles have been assumed to arrive at a number of prospective production profiles based on the estimated total size of the new gas reserves.

The modelling assumptions utilised by DEM to arrive at the production scenarios utilised in this report are summarised in Table 4.1 below.

Parameter	Reference	Result
Mean commercial field size	The mean of the lognormal distribution of historic commercial fields in the SA Otway Basin, including 44 PJ Haselgrove Deep field (half 2C contingent resource).	~ 24 PJ (4 wells)
Haselgrove Deep field size	Adjusted according to Beach Energy booked contingent gas resource of 87 PJ	~ 24 PJ for Low Case (2 wells) ~ 49 PJ for Mid Case (4 wells) ~ 86 PJ for High Case (7 wells)
SA Otway well production decline curve	Matched to production history from the Katnook and Haselgrove gas fields in the onshore SA Otway Basin.	Initial rate = 6.34 TJ/day 'b' exponent = 0.01 (exponential decline) Decline rate = 3.2% per month
Haselgrove Deep well production decline curve	Assume decline curve as above with double initial production rate (qi). Based on Beach Energy flow rates from 10 day initial production test.	Initial rate = 12.68 TJ/day 'b' exponent = 0.01 (exponential decline) Decline rate = 3.2% per month
Timelines	Based on historic timelines for operations and a 20% success rate for exploration wells.	1 Jan 2020 - Haselgrove production begins (gas facility commissioned) After discovery, development wells sequentially drilled and connected in 90 days Exploration well discovers new field every 20 months (assuming 1 rig drills 3 exploration wells a year at 20% success rate)

Table 4.1 – DEM Production Modelling Assumptions

The preliminary modelling has resulted in three prospective production profiles being identified for consideration as depicted in Figures 4.1 to 4.3 below.

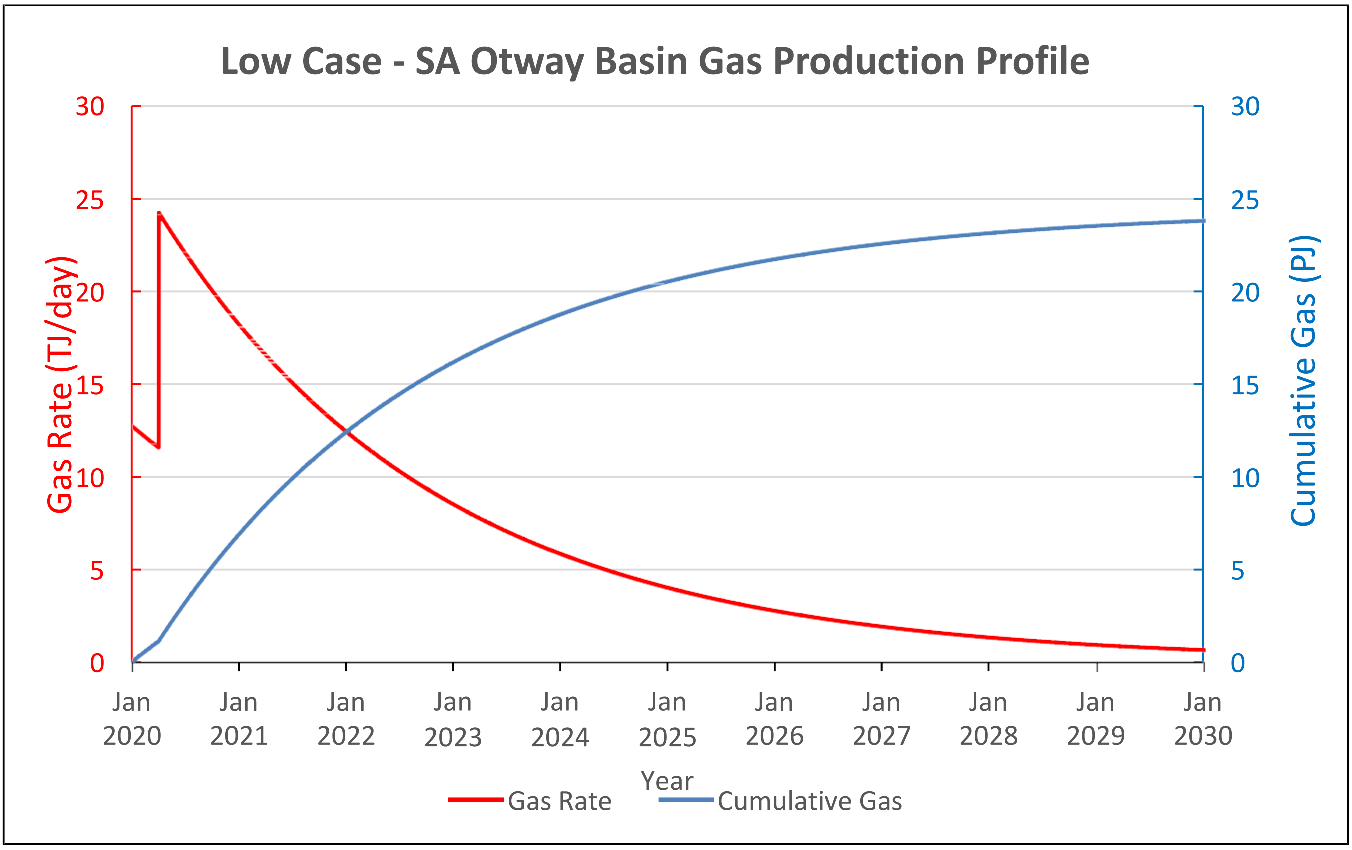


Figure 4.1 – Low Range Prospective Production Profile

The above "Low Range Scenario" is based on the following:

Low Case Scenario - 10 TJ/day gas processing facility

Haselgrove Deep gas field size = 24 PJ (average for SA Otway Basin).

No further discoveries are made.

If gas production is limited to a facility size, a reasonable plateau period would be 10 TJ/day from January 2020 for ~6 years followed by decline.

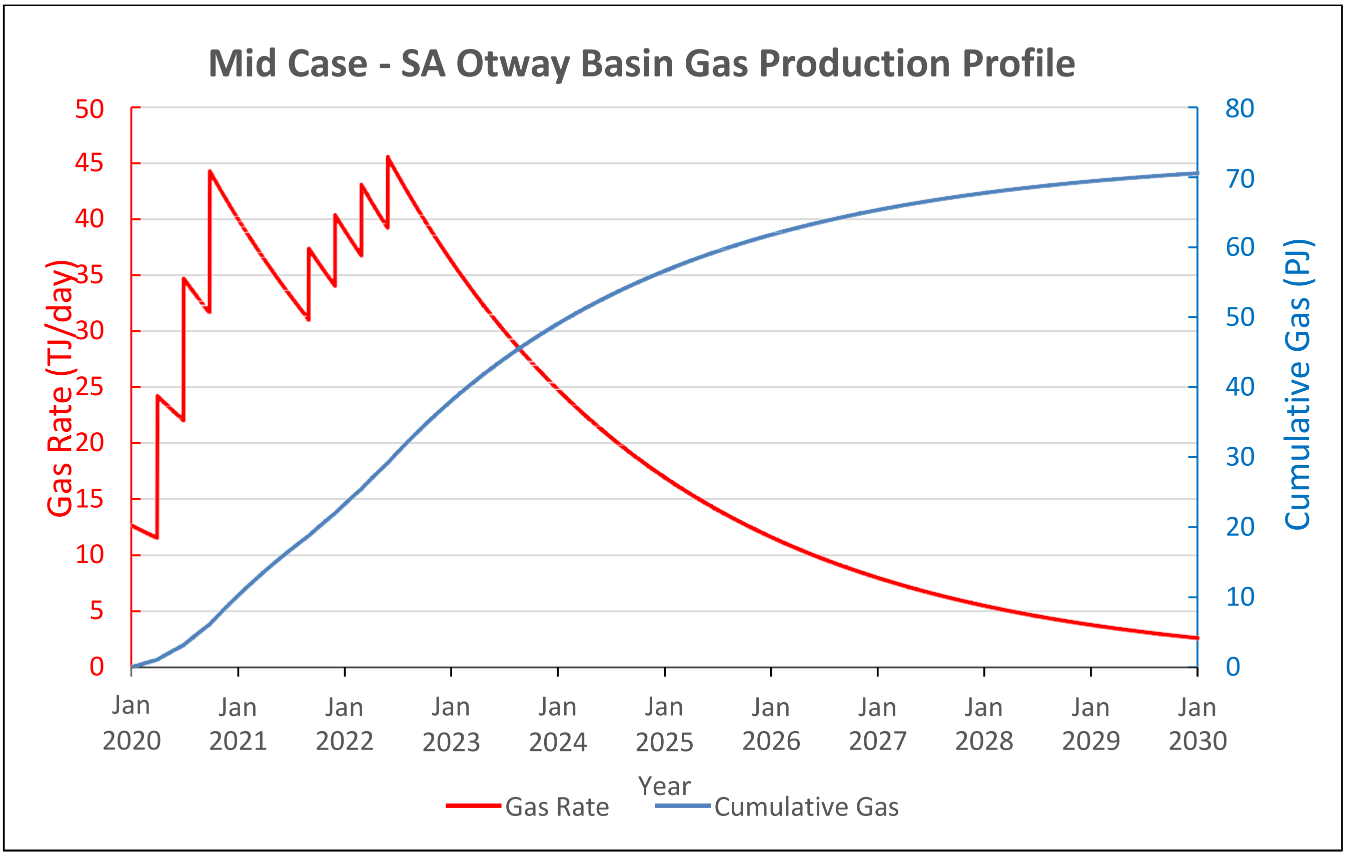


Figure 4.2 – Mid Range Prospective Production Profile

The above "Mid Range Scenario" is based on the following:

Mid Case Scenario - 30 TJ/day gas processing facility

Haselgrove Deep gas field size = 49 PJ (approximately half 2C booked contingent resource).

One further gas field discovery is made of 24 PJ (average for SA Otway Basin).

If gas production is limited to a facility size, a reasonable plateau period would be 30 TJ/day from June 2020 for ~6 years (after initial ramp up from January 2020) followed by decline.

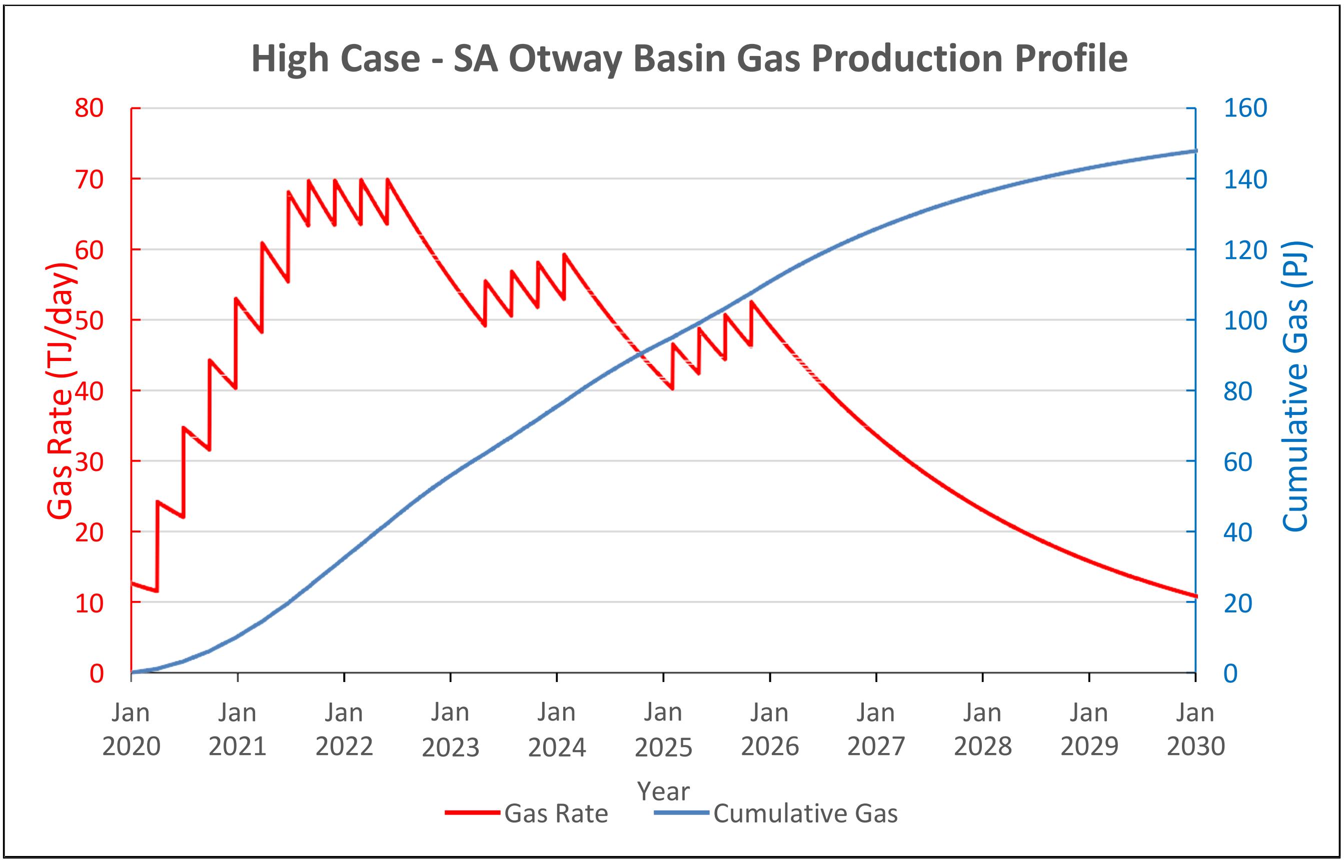


Figure 4.3 – High Range Prospective Production Profile

The above "High Range Scenario" is based on the following:

High Case Scenario - 50 TJ/day gas processing facility

Haselgrove Deep gas field size = 86 PJ (approximate 2C booked contingent resource).

Three further gas field discoveries are made of 24 PJ each (average for SA Otway Basin).

If gas production is limited to a facility size, a reasonable plateau period would be 50 TJ/day from January 2021 for ~7 years (after initial ramp up from January 2020) followed by decline.

Higher rates are possible if new gas field discoveries are more frequent and larger than average.

4.1 NEW TRANSMISSION CAPACITY REQUIREMENTS BASIS

Based on the DEM modelling presented above, for the purposes of this study three capacity options for determining future gas transmission requirements have been assessed.

With reference to the existing consumption profiles presented in Section 2.2, it is clear that the local demand via the LGPS and SEPS systems can vary greatly between 2 TJ/d and 22TJ/d.

Typically a consistent local demand may be considered to be approximately 6-7 TJ/d base load with an additional average demand of a further 10-12 TJ/d depending on the intermittent operation of the LGPS.

As such even for the Low Range Scenario of a 10 TJ/d production profile, export of gas via reverse flow through the SESA pipeline to the SEA Gas pipeline would be required if curtailment of new gas production is to be avoided.

For the purposes of this study only the SESA pipeline as a means of accessing other gas markets has been considered.

The viability of constructing additional laterals and connections has not been considered at this stage.

This study therefore specifically considers export of gas from Katnook through the existing SESA gas transmission infrastructure, to the existing Sea Gas pipeline at Poolaijelo for the following design cases:

- Low Production Case (0 -10TJ/d) Export via SESA with reverse flow still required from SESA to meet peak demands.
- Medium Production Case (10 - 30 TJ/d) Export via SESA with reverse flow still required from SESA during periods of local production facility outage.
- High Production Case (30 - 50 TJ/d) Export via SESA with reverse flow still required from SESA during periods of local production facility outage.

This will at minimum entail:

- Reverse flow through SESA to Poolaijelo
- A new Compressor at Poolaijelo to deliver gas to SEA Gas
- Reconfiguration of piping at Katnook/Ladbroke grove to receive new gas

NOTE: Free flow into SEA Gas pipeline may be possible when inlet pressures are low at the Poolaijelo tie in location. However, the frequency of this event is not well understood. Low availability market options may be further considered if the installation of compression is not economically justified.

5 SYSTEM PERFORMANCE REQUIREMENTS

In order to ensure that the full capacity of the SESA pipeline is able to be utilised, it is assumed that any new production will tie-in to the SESA pipeline upstream of the Ladbroke Grove PRMS as shown in the modified process flow sheet of Appendix 2A.

It is further assumed that it shall be a requirement that proponents wishing to deliver into the pipeline system must include suitable provisions in their facilities to enable delivery of gas to the new SESA Katnook receipt point at pressures up to the MAOP of the pipeline system which is stated as 10.2 MPag.

5.1 PIPELINE PRESSURE DROP MODELLING

Preliminary pressure drop calculations have been completed for the three reverse flow scenarios for the SESA pipeline with the results summarised in Table 5.1 below and detailed in the Basis of Design calculations appearing in Appendix 2B.

Scenario	Max Flow	Inlet Pressure at Katnook	Pressure at Poolaijelo	Pipeline Pressure Drop
Low Production Case	10 TJ/d	10.0 MPag	9.82 MPag	180 kPa
Medium Production Case	30 TJ/d	10.0 MPag	9.26 MPag	740 KPa
High Production Case	50 TJ/d	10.0 MPag	8.01 MPag	1990 KPa

Table 5.1 – SESA Pipeline Pressure Drops – 10 MPag Inlet Pressure

For comparative purposes the above cases were rerun assuming a delivery pressure at the receipt point at Katnook of 6MPag to provide a feel for pressure drops at lower inlet pressure with the results appearing in Table 5.2.

Scenario	Max Flow	Inlet Pressure at Katnook	Pressure at Poolaijelo	Pipeline Pressure Drop
Low Production Case	10 TJ/d	6.0 MPag	5.81 MPag	190 kPa
Medium Production Case	30 TJ/d	6.0 MPag	4.75 MPag	1250 KPa
High Production Case	50 TJ/d	6.0 MPag	<0 MPag	Excessive

Table 5.2 – SESA Pipeline Pressure Drops – 6 MPag Reduced Inlet Pressure

The above indicates that the High Flow Case is not able to be realistically supported at an inlet pressure as low as 6 MPag. It should be noted that GPA has not evaluated the impact of actually running at this lower pressure at the SESA inlet for the remaining 10 TJ/d and 30 TJ/d. A pressure at this low value would require further assessment of the capacities of existing pressure regulation and metering equipment forming part of the Ladbroke Grove PRMS and the ability to meet peak demands of the SEPS and LGPS consumers. In addition to achieve the required compression ratios at Poolaijelo, the compressor requirements would shift from single stage to multi-stage compressors which would impact the capital costs of these facilities significantly.

5.2 BASIS OF AUGMENTATION FACILITIES DESIGN ASSUMPTIONS

Based on the preliminary calculations detailed above, the following assumptions form the Basis of Design for the proposed augmentation facilities presented in this report including the compression facility at Poolaijelo.

It has been assumed that:

1. Prospective Gas suppliers will provide gas at the SESA pipeline tie-in at Ladbroke Grove PRMS pig receiver.
2. Gas suppliers will guarantee “sales quality gas” at the tie-in at a pressure and temperature sufficient to enable gas to flow through the SESA line to the SEA Gas line without impact on existing system reliability. Nominally this has been assumed at 10,000 kPag and 20 degrees C for reverse flow to SEA Gas.
3. The gas will be clean, dry (75mg/cubic meter water), odorised gas from the supplier at the tie-in.
4. Where required, enhancements will be made to the existing system to enable gas to reverse flow in the SESA system at the quantities investigated.
5. The gas supplier will provide its own custody transfer gas metering facility at the SESA pipeline tie-in.
6. The maximum SEA Gas pipeline delivery pressure at Poolaijelo is assumed at 14 MPag.
7. There must be sufficient capacity turndown to meet low, medium and high flows.
8. The enhancements to the system meet APA, SEA Gas, Origin and Epic requirements.
9. Environmental and Safety obligations for the system are met.
10. Assumed ground temperature is 20 degree C (summer temperatures).
11. The Gas quality assumed for this study is SEA Gas Lean Gas to reflect lower High Heat Value (HHV) gas.
12. SESA pipeline roughness is assumed at 0.0005mm (600 Micron).
13. The maximum hourly reverse flow through the system required is 50TJ/d.
14. Compressor(s) to remain pressurised when stopped to minimise venting.

6 PROPOSED CONFIGURATION / EQUIPMENT SELECTION

The proposed configuration for assessment and costing as presented in this report consists of the following elements:

- Reconfiguration of piping at the inlet of the Ladbroke Grove PRMS to facilitate the tie-in of a new sales quality gas supply.
- Modifications to allow reverse flow through the SESA pipeline to Poolaijelo.
- Installation of pipework and valving to enable reverse flow past or through the existing Poolaijelo PRMS whilst retaining the capability to flow from the SEA Gas pipeline to Katnook if required to meet peak gas demands and/or to cater for situations in which the new local gas supply facilities are curtailed or not available.
- Utilisation of the Poolaijelo ultrasonic metering to measure both forward and reverse flow of gas with an allowance for some modification works included in the cost estimate.
- Utilisation of the existing Poolaijelo Gas Chromatograph to measure both forward and reverse flow gas quality
- Installation of a new Compressor station at Poolaijelo to deliver gas to SEA Gas at or above 14000 kPag.
- Allowance in the piping design to bypass compression and enable free flow in the reverse direction into the SEA Gas pipeline when SEA Gas pipeline pressure permit.

The schematic reflecting this augmentation arrangement is shown in Appendix 2A with a simplified diagrammatic representation appearing below in Figure 6.1.

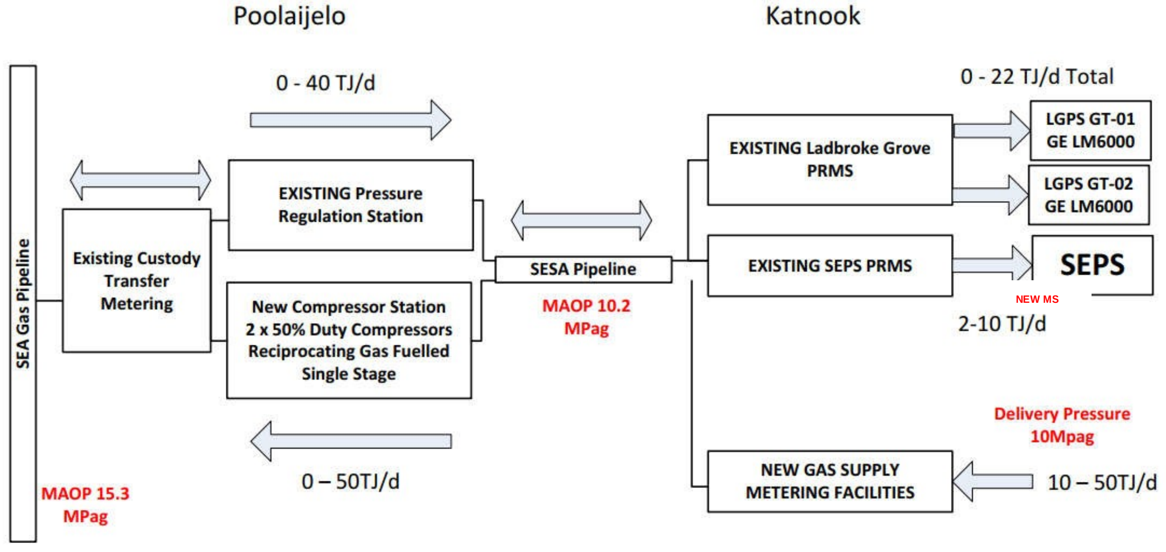


Figure 6.1 – Simplified Concept Diagram

Compression and facility options for each production scenario appear in the following sections.

6.1 COMPRESSION TECHNOLOGY SELECTION

The selection of the most suitable compression technology is based on the following characteristics:

- Throughput
- Gas Flow Turndown
- Maximum Capacity Requirements
- Variability of Gas Flow Requirements
- Sparing and Availability Constraints
- Delivery Requirements
- Cost

The two compressor styles considered appropriate for this service for each of the production profiles present are:

- Centrifugal gas turbine driven
- Reciprocating gas engine driven

Electric motor driven options may be considered as part of facility Front-End Engineering Design (FEED) scopes but this would involve detailed analysis of electricity availability in the Poolaijelo region and associated costs. This option has not been explored at this early concept stage.

With respect to centrifugal turbine driven versus reciprocation engine-driven compressors each have their advantages and disadvantages as outlined below.

Variable	Reciprocating	Centrifugal
Pressure ratio	From very low to very high	Similar range to reciprocating. but more limited at extremely high and low compression ratios
Discharge pressure	Up to 380 MPag	Up to 69 MPag
Maximum flow rate	5,000 Am^3/h	425,000 Am^3/h
Minimum flow rate	~1 Am^3/h	120 Am^3/h
Noise	Abatement required	Abatement required
Efficiency	Good (multi-stage) to Excellent (single stage)	Excellent
Typical driver	Gas-engine or electric motor	Turbines
Reliability	Good	Excellent
Flexibility[1]	Excellent	Fair
Opex	Good (multi-stage) to Excellent (single stage)	Excellent
TIC	Good to Excellent	Good

Table 6.1 Qualitative Comparison between Centrifugal and Reciprocating Compressors (Typical)

1. Flexibility refers to ability to adapt to changing feed conditions.

Based on consideration of the above factors, including the relatively low production rates and the early feasibility stage for these works this report provides approximate total installed cost (TIC) estimates for gas engine driven reciprocating compressor option only.

Other options should be further explored should the project proceed to detailed design as part of front end engineering prior to project sanction and final equipment selection.

6.2 LOW PRODUCTION CASE DESIGN BASIS

For the low production option or in cases where a proportion of gas produced may be allocated specifically to new or existing Southeast markets and the remainder is sent to SEA Gas Table 6.2 summarise the design basis sizing criteria for the proposed Poolaijelo compressor station.

Detailed calculations supporting the compressor power ratings stated appear in Appendix 2B.

	Low Flow Case
Flow rate	10 TJ/d
SESA Tie-in Delivery Pressure	10 MPag
Compressor Suction Pressure	9818 kPag
Single reciprocating Compressor	150 kW
Dual parallel Reciprocating Compressor	80 kW

Table 6.2 Low Production Case Compressor Duty

In the above case the 80kW option would most likely not be feasible and the actual final solution would most likely be a single 150kW reciprocating machine.

If availability was a concern a second standby compressor could be installed that would also provide some additional peak capability where additional flow to SEA Gas may be required on an infrequent basis when local SE demand rates are extremely low.

It is also clear that multiple units could be deployed to achieve the higher flow production cases listed below in N+1 configurations providing availability, turndown and the option for future expansion from the base case low flow scenario.

Similarly it should be noted that total duty can be met by one of the higher flow case compressors should investment for future production be deemed beneficial with required turndown able to be easily achieved via compressor speed control and recycle.

For the purposes of this study in each case 2 x 50% units have been assumed sized appropriately for the specific flow cases. Again the selection of compressor configuration would be the subject of FEED design activities should the project proceed.

Free flow into the SEA Gas pipeline is a valid option for the 10 TJ/d case depending on the operating pressure profile of the pipeline at Poolaijelo which could be further evaluated if compressor installation costs cannot be justified.

6.3 MEDIUM PRODUCTION CASE DESIGN BASIS

For the Medium production option Table 6.3 summarises the design basis sizing criteria for the proposed Poolaijelo compressor station.

Detailed calculations supporting the compressor power ratings stated appear in Appendix 2B.

	Medium Flow Case
Flow rate	30 TJ/d
SESA Tie-in Delivery Pressure	10 MPag
Compressor Suction Pressure	9262 kPag
Single Reciprocating Compressor	500 kW
Dual Parallel Reciprocating Compressor	250 kW

Table 6.3 Medium Production Case Compressor Duty

6.4 HIGH PRODUCTION CASE DESIGN BASIS

For the High production option Table 6.4 summarises the design basis sizing criteria for the proposed Poolaijelo compressor station.

Detailed calculations supporting the compressor power ratings stated appear in Appendix 2B.

	High Flow Case
Flow rate	50 TJ/d
SESA Tie-in Delivery Pressure	10 MPag
Compressor Suction Pressure	8006 kPag
Single reciprocating Compressor	1190 kW
Dual parallel Reciprocating Compressor	600 kW

Table 6.4 High Production Case Compressor Duty

A single 600kW compressor alone would provide in excess of approximately 30 TJ/d until the second compressor could be brought online.

As stated above, for the purposes of this study in each case 2 x 50% units have been assumed sized appropriately for the specific flow cases.

7 COST ESTIMATES

7.1 PURPOSE AND ACCURACY

Preliminary cost estimates are provided following for the Low, Medium and High Production flow cases representing gas flows through the SESA pipeline for an inlet pressure of 10 MPag at the Katnook delivery point.

The purpose of these estimates is to provide indicative TICs enabling further discussions with transmission pipeline operators as to the options available for fully utilising the existing pipeline infrastructure in the SE region.

The costs presented are preliminary in nature and have been derived by use of recent costings for other similar projects and the application of scaling and escalation factors to arrive at the TIC values stated.

Based on the data utilised the costs presented are thought to be in the range of +/- 30%, due to the application of contingent sums to cater for increases in the scope of works expected based on further detailed design activities.

7.2 METHODOLOGY AND REFERENCE DATA

GPA Engineering has been involved in numerous compression projects in recent years. Based on the preliminary nature of this feasibility study, GPA has utilised cost data from a number of previous projects involving similar equipment in the period from 2011 to 2017.

Escalation factors have been applied where pricing from previous projects has been utilised.

Escalated budget costs for major equipment have been applied to derive the main equipment package costs. These package costs include:

- Main Compressor Packages
- Compressor Gas After-coolers
- Control and Switchrooms
- Acoustic enclosures for compression equipment
- Large Bore Valves and speciality equipment and instrumentation

Installation costs have then been derived based on applying installation factors consistent with GPA's experience with similar projects as detailed below in Section 7.3.

Anticipated costs of compression have been separately itemised from general augmentation and end-of-line facilities costs.

7.3 ECONOMIC ASSUMPTIONS

The following escalation and installation factors have been applied in costing the options:

- Major Equipment installation Factor 2.5
- Second Unit installation Factor 2.0
- AUD to USD exchange rate April 2019 0.72
- CPI Escalation from 2011 13.01%
- AUD to USD exchange rate April 2011 0.74

7.4 FACILITY DESCRIPTION

Typically, the preliminary concept augmentation scope for the three cases includes the specification, procurement, installation and commissioning of the following key elements:

- Tie-in of New Gas Supplier Custody Transfer Metering Facilities to the SESA pipeline end of line facilities at the Ladbroke Grove PRMS.
- Tie-in of new compressor station to SESA pipeline end of line facilities adjacent to the existing Poolaijelo PRMS.
- The inclusion of 2 nominal 50% duty gas driven reciprocating compressors.
- Electric aftercoolers and sound proof compressor enclosures at the new Poolaijelo compression facility.
- A new compressor fuel gas system making use of SESA sales quality gas.
- Independent gas fuelled power supply/generation for operation of compressor site and electric drive of aftercoolers.
- A new Compressor Station Cold Vent.
- A new Compressor Station bypass line to enable bi-directional free-flow operating modes.
- Allowance for modification or qualification of existing SESA ultrasonic custody transfer metering for bi-directional flow.
- An allowance for land purchase for the compressor station at Poolaijelo.
- A small oily water system for dealing with compressor waste.
- Maintenance Shed
- Control room
- SCADA and controls systems
- EPCM
- Owners costs

7.5 COST ESTMATE EXCLUSIONS

There are additional costs outside the pipeline scope and are currently excluded from this estimate including:

- Any compression required for delivery of gas into the SESA system at 10 MPag to enable reverse flow.
- Gas processing equipment to meet the stringent dryness criteria of 75 mg/cubic meter to enable flow into the Class #900 SEA Gas pipeline system. Note that for the SESA and SEP Class #600 pipeline systems, only 112 mg/cubic meter is required by the gas supply specification.
- Odorising station at the Ladbroke Grove inlet to ensure gas to SEP and SEA Gas contains odorant at the correct concentration.
- Any financing or commercial costs not directly associated with the installed capital costs of the project.

7.6 HIGH PRODUCTION CASE TIC

For the 50 TJ/d High Production case the anticipated TIC is summarised below in Table 7.1.

Detailed cost estimating spreadsheets appear in Appendix 1.

GPA ENGINEERING				Document Title	Document Subtitle
				Total Installed Cost Estimate	Initial CAPEX Summary
Client Name	Department for Energy and Mines				Document No.
Client Project No.	N/A	GPA Project No.	19035		19035-EST-002 Rev A
Project Name	SESA Augmentation Study				

Option: **Option 50 TJ/d To SEA Gas**

Item	Description	Estimate		% of Total	Notes
1	**Owner's Costs**				
	Total Owner's Costs	$	4,279,926	6%	
2	**Installed Costs**				
2.2	Aftercoolers	$	1,345,960	2%	
2.9	Compressors	$	30,759,602	43%	
2.10	Sales Gas Meter Bidirectional	$	540,000	1%	
2.11	Tie-ins and bypass at Poolaijelo	$	2,916,065	4%	
2.12	Tie-in to Ladbroke Grove	$	1,458,033	2%	
2.16	Civils	$	241,638	0%	
2.17	Station Vent	$	180,000	0%	
2.18	Fuel Gas System	$	1,369,377	2%	
2.19	Power Generation	$	673,312	1%	
2.20	Major Valves, Instruments, Control Valves	$	4,120,103	6%	
2.22	Switchroom / Control Room / Workshop/Enclosures	$	1,358,305	2%	
2.23	Lighting, Earthing and Safety Equipment	$	348,772	0%	
	Total Installed Costs	$	45,311,166	63%	
	Base Estimate including Owner's Costs	**$**	**49,591,092**	**69%**	

Item	Description	Factor	Estimate		Notes
4	**Contingency**				
4.1	Risk and Contingency	30%	$	14,877,328	
4.2	Escalation	0%	$	-	
4.3	Design Growth	15%	$	7,438,664	
	Total Contingency	45%	**$**	**22,315,991**	
	Base Estimate plus Contingency	**$**			**71,907,083**

Item	Description	Factor	Estimate		Notes
3	**EPCM Cost (included in Total Installed Costs, item 2, above)**				
		15%	$	7,438,664	

Table 7.1 High Production Case TIC Summary

7.7 MEDIUM PRODUCTION CASE

For the 30 TJ/d Medium Production case the anticipated TIC is summarised below in Table 7.2.

Detailed cost estimating spreadsheets appear in Appendix 1.

GPA ENGINEERING		Document Title		Document Subtitle
		Total Installed Cost Estimate		Initial CAPEX Summary
Client Name	Department for Energy and Mines			Document No.
Client Project No.	N/A	GPA Project No.	16046	19035-EST-002 Rev A
Project Name	SESA Augmentation Study			

Option: **Option 30 TJ/d To Seagas**

Item	Description	Estimate	% of Total	Notes
1	**Owner's Costs**			
	Total Owner's Costs	$ 4,279,926	6%	
2	**Installed Costs**			
2.2	Aftercoolers	$ 1,191,480	3%	
2.9	Compressors	$ 13,017,182	29%	
2.10	Sales Gas Meter Bidirectional	$ 540,000	1%	
2.11	Tie-ins and bypass at Poolaijelo	$ 2,916,065	6%	
2.12	Tie-in to Ladbroke Grove	$ 1,458,033	3%	
2.16	Civils	$ 241,638	1%	
2.17	Station Vent	$ 180,000	0%	
2.18	Fuel Gas System	$ 1,369,377	3%	
2.19	Power Generation	$ 623,940	1%	
2.20	Major Valves, Instruments, Control Valves	$ 3,817,987	8%	
2.22	Switchroom / Control Room / Workshop/Enclosures	$ 1,358,305	3%	
2.23	Lighing, Earthing and Safety Equipment	$ 323,197	1%	
	Total Installed Costs	$ 27,037,204	60%	
	Base Estimate including Owner's Costs	**$ 31,317,130**	**69%**	

Item	Description	Factor	Estimate	Notes
4	**Contingency**			
4.1	Risk and Contingency	30%	$ 9,395,139	
4.2	Escalation	0%	$ -	
4.3	Design Growth	15%	$ 4,697,569	
	Total Contingency	45%	**$ 14,092,708**	
	Base Estimate plus Contingency	**$**	**45,409,838**	

Item	Description	Factor	Estimate	Notes
3	**EPCM Cost (included in Total Installed Costs, item 2, above)**			
		15%	$ 4,697,569	

Table 7.2 Medium Production Case TIC Summary

7.8 LOW PRODUCTION CASE

For the 10 TJ/d Low Production case the anticipated TIC is summarised below in Table 7.3.

Detailed cost estimating spreadsheets appear in Appendix 1.

GPA ENGINEERING		Document Title		Document Subtitle
		Total Installed Cost Estimate		Initial CAPEX Summary
Client Name	Department for Energy and Mines			Document No.
Client Project No.	N/A	GPA Project No.	16046	19035-EST-002 Rev A
Project Name	SESA Augmentation Study			

Option: **Option 10 TJ/d To SEA Gas**

Item	Description	Estimate	% of Total	Notes
1	Owner's Costs			
	Total Owner's Costs	$ 4,279,926	6%	
2	Installed Costs			
2.2	Aftercoolers	$ 983,564	3%	
2.9	Compressors	$ 3,685,536	12%	
2.10	Sales Gas Meter Bidirectional	$ 540,000	2%	
2.11	Tie-ins and bypass at Poolaijelo	$ 2,916,065	10%	
2.12	Tie-in to Ladbroke Grove	$ 1,458,033	5%	
2.16	Civils	$ 241,638	1%	
2.17	Station Vent	$ 180,000	1%	
2.18	Fuel Gas System	$ 1,223,536	4%	
2.19	Power Generation	$ 557,489	2%	
2.20	Major Valves, Instruments, Control Valves	$ 3,411,366	11%	
2.22	Switchroom / Control Room / Workshop/Enclosures	$ 1,358,305	4%	
2.23	Lighing, Earthing and Safety Equipment	$ 288,776	1%	
	Total Installed Costs	$ 16,844,308	55%	
	Base Estimate including Owner's Costs	**$ 21,124,234**	**69%**	

Item	Description	Factor	Estimate	Notes
4	Contingency			
4.1	Risk and Contingency	30%	$ 6,337,270	
4.2	Escalation	0%	$ -	
4.3	Design Growth	15%	$ 3,168,635	
	Total Contingency	45%	**$ 9,505,905**	

Base Estimate plus Contingency $ 30,630,139

Item	Description	Factor	Estimate	Notes
3	EPCM Cost (included in Total Installed Costs, item 2, above)			
		15%	$ 3,168,635	

Table 7.3 Low Production Case TIC Summary

8 INDICATIVE PROJECT TIMING

Indicative project timing for this scope of works is 75 weeks which includes the following key milestones:

1. Feasibility Study
2. Environmental, Cultural Heritage, Council and Landowner Development Approvals
3. FEED
4. Final Investment Decision (FID)
5. Compressor and long deliverables procurement
6. Detailed Design
7. Fabrication
8. Major Package Deliveries
9. Site installation
10. Commissioning

It should be noted that conservative compressor delivery times may extend to 52 to 56 weeks depending on final selection.

9 PROJECT RISKS & POTENTIAL ISSUES

The following topics have been identified during this preliminary study as potential issues or risks to the presented costs, schedule or augmentation philosophy.

It is recommended that these be further discussed with the pipeline operators APA group and SEA Gas as part of any further negotiation and or exploration of gas transmission options for new gas discoveries in the SE of South Australia region.

The following topics and issues are tabled for further discussion:

- Developers gas quality in particular, HHV, density, total inerts, water and hydrocarbon dew point and suitability for SEPS, Ladbroke Grove Power Station, SESA and SEA Gas pipelines.
- Feasibility and acceptability of the tie-in locations to the main export pipeline by SEA Gas and the SESA pipeline by APA Group.
- Landowner willingness to sell or lease and suitability of the additional land required for a Compressor Station at Poolaijelo.
- Environmental requirements and identification of the nearest “sensitive receptor” that may result in significant noise constraints being applied.
- Venting has been allowed but flaring may be required for compressor station blowdown of odorised natural gas
- Capacity of the Ladbroke Grove PRMS heaters to prevent low temperature shutdown of the gas turbines at the 10,000 kPag receipt pressure.
- Ownership and operations responsibility for the new facilities.
- Further discussion with SEA Gas for possible alternate pipeline operation options to enable delivery of gas into their system as either free-flow or compressed gas based on opportunity constraints.
- Confirmation of expected design and build quality required by SEA Gas and/or APA Group for the compressor station and commercial issues in utilising the reverse capacity and use of any existing facilities.
- Availability of power and possible electric driver options to reduce noise and emissions.
- Possible availability of good condition used compression equipment suitable for the service which could dramatically reduce capital costs.
- Other impacts on stakeholders.
- Most suitable tie-in location based on the processing requirements of the prospective new gas suppliers.
- Clarification of Gas sampling requirements with SEA Gas at Poolaijelo given this has become a new receipt point for their pipeline.
- Identification of any contractual constraints on the use of spare capacities in existing pipeline systems.

10 SUMMARY AND CONCLUSIONS

The prospect of new gas discoveries in the south east of South Australia has required a review of the existing gas transmission infrastructure in the region and the ability for it to accommodate increased local gas production profiles ranging from an additional 10 TJ per day to as much as 50 TJ per day.

The new gas flows are expected to be from fields developed in the vicinity of the original Katnook Gas Plant located near Penola. This location provides a ready access to the South East Pipeline System, SEPS, currently owned and operated by Epic Energy to provide gas to local SE consumers, and also the 80MW Ladbroke Grove Power Station, LGPS, operated by Origin Energy.

The gas for these consumers is currently supplied from the SEA Gas owned and operated main transmission pipeline via the South East South Australia (SESA) pipeline owned and operated by APA Group. The SESA gas receipt point is located at Poolaijelo in Victoria and the SESA gas delivery point is located adjacent the Ladbroke Grove facility at Katnook.

Due to the LGPS being a peak demand power station, its intermittent operation results in a highly variable local load profile. The local demand fed from the existing SESA pipeline can vary from as low as 2 TJ/d to 22 TJ/d with a contracted MDQ totalling as much as 38 TJ/d for a nominal SESA pipeline capacity of 40 TJ/d. As such in order to guarantee a new gas producer access to local and remote gas markets, and to ensure that any new gas production is not subject to frequent curtailment, a cost effective option has been investigated making use of the existing gas transmission infrastructure. Specifically the use of the SESA pipeline as a bi-directional pipeline able to deliver gas either into the SEA Gas pipeline or source gas from that pipeline to meet local peak demand and /or local gas facility outages has been reviewed.

The MAOP of the SEA Gas pipeline is 15.3 MPag whereas the MAOP of the SESA pipeline is only 10.2 MPag. This requires compression which is proposed to be installed at the Poolaijelo tie-in to ensure uninterrupted access to the SEA Gas pipeline for gas delivery.

GPA has undertaken a preliminary review including cost estimates for the following prospective incremental production profiles:

- 10 TJ/d Low Production Demand Case
- 30TJ/d Medium Production Demand Case
- 50 TJ/d High Production Demand Case

Preliminary estimates indicate the costs of augmentation of the existing gas transmission infrastructure including a new compressor station at Poolaijelo for the above three production scenarios as follows:

Production Profile	Total Installed Cost ($AUS 2019)
10 TJ/d Low Production Case	$ 30.6 M
30 TJ/d Medium Production Case	$ 45.4 M
50 TJ/d High Production Case	$ 71.9 M

The above costs are preliminary and can only be considered at best having an accuracy in the range of +/- 30%. In addition a number of alternative options and further investigations have been identified in the report that would be required prior to finalisation of any development strategy for the augmentation of the existing gas transmission infrastructure.

11 REFERENCES

In order to compile this report the following references were utilised:

1. SESA Pipeline Fitness for Purpose Assessment June 2016, APA Group,
   Document: *320-RP-AM Version 1.0*

2. South East Pipeline Licence PL-3 & PL-4 Annual Report 2017, Epic Energy,
   Document: *S-31-107-AR-G-014 March 2018 Revision 0*

3. SESA Pipeline Licence 16 Annual Report 2017, APA group,
   Document: *2017 Annual Report September 2018 Version 1.1.1*

4. Prospective Gas Production Profiles 14 March 2019, DEM
   Document: *Email DEM to GPA Alexandra Wickham to Richard McDonough*

5. SA Pipelines Actual Flow Data 19 March 2019, DEM
   Document: *Email DEM to GPA Alexandra Wickham to Richard McDonough*
   Source: (AEMO) *https://www.aemo.com.au/Gas/Gas-Bulletin-Board*

6. SEA Gas 2018 Victorian Operational SMS, GPA Engineering,
   Document: *18288-REP-001 February 2019 Revision 0*

APPENDIX 1 COST ESTIMATES

Appendix 1A Compression Cost Estimate Calculations

The cost of compression included in the detailed cost estimates is based on utilisation of a cost per kW factor based on information solicited from compressor packager Enerflex in late 2011.

This factor was escalated for inflation to 2019 dollars and then compared with budget pricing obtained by GPA for similar compressor applications for other projects as late as 2017 and found to be relevant.

Compressor costs presented below are installed costs but exclude general Engineering, Procurement and Construction Management (EPCM) charges which have been separately itemised in the detailed cost estimates appearing in Appendix 1B.

HIGH PRODUCTION FLOW CASE

GPA ENGINEERING

GPA Engineering
L5/193 North Quay QLD 4000
T 07 3367 8900 | **M** 0418 817 387 | **F** 07 3367 0822

TYPICAL COMPRESSOR POWER CALCULATION

1					
2	Description				Calculate the Maximum power for a gas reciprocating compressor for the inlet to SEAGas at Poolaijello
3					Assume 100 kPa loss through the pipework and aftercooler
4					
5					
6	Suction pressure	P_1	8006	kPag	
7			8107	kPaa	
8			1176	PSIa	
9			1161	PSIg	
10	Discharge pressure	P_2	14000	kPag	
11			14101	kPaa	
12			2045	PSIa	
13			2031	PSIg	
14	Suction temperature	T_1	20	°C	
15			293.15	K	
16			68	°F	
17	Ratio of specific heats (Cp/Cv)	k	1.3	-	
18	Standard gas flowrate	Q	50	TJ/d	1 TJ/day — Otway Lean composition equals 1134 scmh
			1.3608	MMSCMD	
19			56,700	SCMH	
20			48,056,199	SCFD	
21			48	MMSCFD	
22	Overall efficiency	E	0.7	-	
23	Isentropic Efficiency	E_{isen}	0.7		
24	Standard pressure	P_S	101.3	kPa	
25	Standard temperature	T_S	15	°C	
26			288.15	K	
27	Inlet compressibility	Z_1	0.84	-	@8118kPag
28	Outlet Compressibility	Z_2	0.8956	-	@14000 kPag
29	Average Compressibility	Z_a	0.8678	-	$(Z_1 + Z_2) / 2$
30					
31	**Power for single stage**	P	**1,188**	**kW**	Equation 15.8, Campbells 1994, 7th Ed , vol 2, page 202
32			1.19	MW	
33					
34	**Discharge Temperature**	T_2	350.21	K	Equation 15.9, Campbells 1994, 7th Ed , vol 2, page 203
35			77.06	°C	
36					

Typical Overall Efficiency (E)

Centrifugal	0.65-0.75
High Speed Reciprocating	0.65-0.75
Low Speed Reciprocating	0.75-0.85

Campbells 1994, 7th Ed , vol 2, page 197

Typical Isentropic Efficiency (E_{isen})

Centrifugal	0.7-0.75
High Speed Reciprocating	0.7-0.75
Low Speed Reciprocating	0.83-0.90

Campbells 1994, 7th Ed , vol 2, page 203

37	**AGA8 Compressibility**	
38	Pressure [kPag]	8118
39	Temperature [deg C]	20
40	Rel density - SG	0.6371
41	N2 [% mol]	1.5
42	CO2 [% mol]	5.21
43		
44	Z Factor (AGA 8)	0.839887897
45		
46	**AGA8 Compressibility**	
47	Pressure [kPag]	14000
48	Temperature [deg C]	75
49	Rel density - SG	0.6371
50	N2 [% mol]	1.5
51	CO2 [% mol]	5.21
52		
53	Z Factor (AGA 8)	0.8956

Project #	**19035**
By	TW
Checked	BM
Date	16-Apr

Assumed $ per kW unit	$3,500	From Enerflex budget estimates provided on 19 August 2011
Cost per Unit	$4,156,703	
AUD adjust ment	$4,272,166.90	in Aug 2011 USD = 0.74 AUD
Installation cost first unit	$10,680,417	
Installed cost first Unit	$14,837,120	
Installation cost redundant unit	$8,313,405.86	
Installed cost redundant Unit	$12,470,109	
Total Cost main and standby	$27,307,229	
Total with CPI Escalation	**$30,859,899**	cumulative price change 13.01%

MEDIUM PRODUCTION FLOW CASE

GPA Engineering
L5/193 North Quay QLD 4000
T 07 3367 8900 | **M** 0418 817 387 | **F** 07 3367 0822

TYPICAL COMPRESSOR POWER CALCULATION

1					
2	Description		Calculate the Normal power for a gas reciprocating compressor for the inlet to SEAGas at Poolaijello		
3			Assume 100 kPa loss through the pipework and aftercooler		
4					
5					
6	Suction pressure	P_1	9262	kPag	
7			9363	kPaa	
8			1358	PSIa	
9			1343	PSIg	
10	Discharge pressure	P_2	14000	kPag	
11			14101	kPaa	
12			2045	PSIa	
13			2031	PSIg	
14	Suction temperature	T_1	20	°C	
15			293.15	K	
16			68	°F	
17	Ratio of specific heats (Cp/Cv)	k	1.3	-	
18	Standard gas flowrate	Q	30	TJ/d	1 TJ/day
			0.81648	MMSCMD	
19			34,020	SCMH	
20			28,833,719	SCFD	
21			29	MMSCFD	
22	Overall efficiency	E	0.7	-	
23	Isentropic Efficiency	E_{isen}	0.7		
24	Standard pressure	P_S	101.3	kPa	
25	Standard temperature	T_S	15	°C	
26			288.15	K	
27	Inlet compressibility	Z_1	0.8203	-	@9370kPag
28	Outlet Compressibility	Z_2	0.8627	-	@14000 kPag
29	Average Compressibility	Z_a	0.8415	-	$(Z_1 + Z_2) / 2$
30					
31	**Power for single stage**	P	**503**	**kW**	Equation 15.8, Campbells 1994, 7th Ed , vol 2, page 202
32			0.50	MW	
33					
34	**Discharge Temperature**	T_2	334.65	K	Equation 15.9, Campbells 1994, 7th Ed , vol 2, page 203
35			61.50	°C	
36					

Otway Lean composition equals 1134 scmh

Typical Overall Efficiency (E)

Centrifugal	0.65-0.75
High Speed Reciprocating	0.65-0.75
Low Speed Reciprocating	0.75-0.85

Campbells 1994, 7th Ed , vol 2, page 197

Typical Isentropic Efficiency (E_{isen})

Centrifugal	0.7-0.75
High Speed Reciprocating	0.7-0.75
Low Speed Reciprocating	0.83-0.90

Campbells 1994, 7th Ed , vol 2, page 203

37	**AGA8 Compressibility**	
38	Pressure [kPag]	9370
39	Temperature [deg C]	20
40	Rel density - SG	0.6371
41	N2 [% mol]	1.5
42	CO2 [% mol]	5.21
43		
44	Z Factor (AGA 8)	0.820342373
45		
46	**AGA8 Compressibility**	
47	Pressure [kPag]	14000
48	Temperature [deg C]	55
49	Rel density - SG	0.6371
50	N2 [% mol]	1.5
51	CO2 [% mol]	5.21
52		
53	Z Factor (AGA 8)	0.8627

Project #	**19035**
By	TW
Checked	BM
Date	16-Apr

Assumed $ per kW unit	$3,500	From Enerflex budget estimates provided on 19 August 2011
Cost per Unit	$1,759,079	
AUD adjust ment	$1,807,942.65	in Aug 2011 USD = 0.74 AUD
Installation cost first unit	$4,519,857	
Installed cost first Unit	$6,278,936	
Installation cost redundant unit	$3,518,158.67	
Installed cost redundant Unit	$5,277,238	
Total Cost main and standby	$11,556,174	
Total with CPI Escalation	**$13,059,632**	cumulative price change 13.01% since 2011

LOW PRODUCTION FLOW CASE

GPA Engineering
L5/193 North Quay QLD 4000
T 07 3367 8900 | **M** 0418 817 387

TYPICAL COMPRESSOR POWER CALCULATION

Description: Calculate the Minimum power for a gas reciprocating compressor for the inlet to SEAGas at Poolaijello
Assume 100 kPa loss through the pipework and aftercooler

Suction pressure	P_1	9818	kPag	
		9919	kPaa	
		1439	PSIa	
		1424	PSIg	
Discharge pressure	P_2	14000	kPag	
		14101	kPaa	
		2045	PSIa	
		2031	PSIg	
Suction temperature	T_1	20	°C	
		293.15	K	
		68	°F	
Ratio of specific heats (Cp/Cv)	k	1.3	-	
Standard gas flowrate	Q	10	TJ/d	1 TJ/day Otway Lean composition equals 1134 scmh
		0.27216	MMSCMD	
		11,340	SCMH	
		9,611,240	SCFD	
		10	MMSCFD	
Overall efficiency	E	0.7	-	
Isentropic Efficiency	E_{isen}	0.7		
Standard pressure	P_S	101.3	kPa	
Standard temperature	T_S	15	°C	
		288.15	K	
Inlet compressibility	Z_1	0.8125	-	@9926kPag
Outlet Compressibility	Z_2	0.8627	-	@14000 kPag
Average Compressibility	Z_a	0.8376	-	$(Z_1 + Z_2) / 2$
Power for single stage	P	**142**	**kW**	Equation 15.8, Campbells 1994, 7th Ed , vol 2, page 202
		0.14	MW	
Discharge Temperature	T_2	328.57	K	Equation 15.9, Campbells 1994, 7th Ed , vol 2, page 203
		55.42	°C	

Typical Overall Efficiency (E)

Centrifugal	0.65-0.75
High Speed Reciprocating	0.65-0.75
Low Speed Reciprocating	0.75-0.85

Campbells 1994, 7th Ed , vol 2, page 197

Typical Isentropic Efficiency (E_{isen})

Centrifugal	0.7-0.75
High Speed Reciprocating	0.7-0.75
Low Speed Reciprocating	0.83-0.90

Campbells 1994, 7th Ed , vol 2, page 203

AGA8 Compressibility

Pressure [kPag]	9926
Temperature [deg C]	20
Rel density - SG	0.6371
N2 [% mol]	1.5
CO2 [% mol]	5.21
Z Factor (AGA 8)	0.812462484

AGA8 Compressibility

Pressure [kPag]	14000
Temperature [deg C]	55
Rel density - SG	0.6371
N2 [% mol]	1.5
CO2 [% mol]	5.21
Z Factor (AGA 8)	0.8627

Project #	**19035**
By	TW
Checked	BM
Date	16-Apr

Assumed $ per kW unit	$3,500	From Enerflex budget estimates provided on 19 August 2011
Cost per Unit	$498,046	
AUD adjust ment	$511,880.56	in Aug 2011 USD = 0.74 AUD
Installation cost first unit	$1,279,701	
Installed cost first Unit	$1,777,747	
Installation cost redundant unit	$996,092	
Installed cost redundant Unit	$1,494,138	
Total Cost main and standby	$3,271,885	
Total with CPI Escalation	**$3,697,557**	cumulative price change 13.01%

Appendix 1B Total Installed Cost Detailed Estimates

ENGINEERING	Document Title	Document Subtitle
	Total Installed Cost Estimate	**Initial CAPEX Summary**

Client Name	**Department for Energy and Mines**			Document No.
Client Project No.	**N/A**	GPA Project No.	**19035**	**19035-EST-002 Rev A**
Project Name	**SESA Augmentation Study**			

Option: **Option 50 TJ/d To SEA Gas**

Item	Description	Estimate	% of Total	Notes
1	**Owner's Costs**			
	Total Owner's Costs	$ 4,279,926	6%	

Item	Description	Estimate	% of Total	Notes
2	**Installed Costs**			
2.2	Aftercoolers	$ 1,345,960	2%	
2.9	Compressors	$ 30,759,602	43%	
2.10	Sales Gas Meter Bidirectional	$ 540,000	1%	
2.11	Tie-ins and bypass at Poolaijelo	$ 2,916,065	4%	
2.12	Tie-in to Ladbroke Grove	$ 1,458,033	2%	
2.16	Civils	$ 241,638	0%	
2.17	Station Vent	$ 180,000	0%	
2.18	Fuel Gas System	$ 1,369,377	2%	
2.19	Power Generation	$ 673,312	1%	
2.20	Major Valves, Instruments, Control Valves	$ 4,120,103	6%	
2.22	Switchroom / Control Room / Workshop/Enclosures	$ 1,358,305	2%	
2.23	Lighting, Earthing and Safety Equipment	$ 348,772	0%	
	Total Installed Costs	$ 45,311,166	63%	
	Base Estimate including Owner's Costs	**$ 49,591,092**	**69%**	

Item	Description	Factor	Estimate	Notes
4	**Contingency**			
4.1	Risk and Contingency	30%	$ 14,877,328	
4.2	Escalation	0%	$ -	
4.3	Design Growth	15%	$ 7,438,664	
	Total Contingency	45%	**$ 22,315,991**	

Base Estimate plus Contingency **$ 71,907,083**

Item	Description	Factor	Estimate	Notes
3	**EPCM Cost (included in Total Installed Costs, item 2, above)**			
		15%	$ 7,438,664	

1	**Indirect Cost**				**$4,279,925.98**
1.1	***Owners Costs***				***$4,279,925.98***
1.1.1	*Other*				*$4,279,925.98*
1.1.1.1	Item	Other (Average)	0.11111111	Estimate	$4,279,925.98
2	**Direct Cost**				**$38,519,334.20**
2.2	***Aftercoolers***				***$1,345,960.00***
2.2.1	*Packaged Equipment*				*$585,200.00*
2.2.1.1	Item	No Factor	2	Budget Price	$585,200.00
2.2.2	*Package Installation Costs*				*$760,760.00*
2.2.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$280,896.00
2.2.2.2	Construction	Construction	1.4	Estimate	$819,280.00
2.2.2.3	Commissioning	Commissioning	0.12	Estimate	$70,224.00
2.2.2.4	EPCM	EPCM	0.6	Estimate	$351,120.00
2.9	***Compressors***				***$30,759,602.40***
2.9.1	*Packaged Equipment*				*$8,544,334.00*
2.9.1.1	Item	No Factor	2	Budget Price	$8,544,334.00
2.9.2	*Package Installation Costs*				*$22,215,268.40*
2.9.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$4,101,280.32
2.9.2.2	Construction	Construction	1.4	Estimate	$11,962,067.60
2.9.2.3	Commissioning	Commissioning	0.12	Estimate	$1,025,320.08
2.9.2.4	EPCM	EPCM	0.6	Estimate	$5,126,600.40
2.10	***Sales Gas Meter Bidirectional***				***$540,000.00***
2.10.1	*Packaged Equipment*				*$150,000.00*
2.10.1.1	Item	No Factor	1	Budget Price	$150,000.00
2.10.2	*Package Installation Costs*				*$390,000.00*
2.10.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$72,000.00
2.10.2.2	Construction	Construction	1.4	Estimate	$210,000.00
2.10.2.3	Commissioning	Commissioning	0.12	Estimate	$18,000.00
2.10.2.4	EPCM	EPCM	0.6	Estimate	$90,000.00
2.11	***Tie-ins and bypass at Poolaijelo***				***$2,916,065.00***
2.11.1	*Construction / Installation*				*$2,916,065.00*
2.11.1.1	Bulk Materials	No Factor	2	Estimate	$172,044.00
2.11.1.2	Construction	No Factor	2	Estimate	$2,160,808.00
2.11.1.3	Commissioning	No Factor	2	Estimate	$97,202.17
2.11.1.4	EPCM	No Factor	2	Estimate	$486,010.83
2.12	***Tie-in to Ladbroke Grove***				***$1,458,032.50***
2.12.1	*Construction / Installation*				*$1,458,032.50*
2.12.1.1	Bulk Materials	No Factor	1	Estimate	$86,022.00
2.12.1.2	Construction	No Factor	1	Estimate	$1,080,404.00
2.12.1.3	Commissioning	No Factor	1	Estimate	$48,601.08
2.12.1.4	EPCM	No Factor	1	Estimate	$243,005.42
2.16	***Civils***				***$241,638.00***
2.16.1	*Construction / Installation*				*$241,638.00*
2.16.1.1	Bulk Materials	No Factor	1	Estimate	$73,696.00
2.16.1.2	Construction	No Factor	1	Estimate	$126,984.00
2.16.1.3	Commissioning	No Factor	1	Estimate	$6,826.33
2.16.1.4	EPCM	No Factor	1	Estimate	$34,131.67
2.17	***Station Vent***				***$180,000.00***
2.17.1	*Packaged Equipment*				*$50,000.00*
2.17.1.1	Item	No Factor	0.5	Budget Price	$50,000.00
2.17.2	*Package Installation Costs*				*$130,000.00*
2.17.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$24,000.00
2.17.2.2	Construction	Construction	1.4	Estimate	$70,000.00
2.17.2.3	Commissioning	Commissioning	0.12	Estimate	$6,000.00
2.17.2.4	EPCM	EPCM	0.6	Estimate	$30,000.00
2.18	***Fuel Gas System***				***$1,369,376.95***
2.18.1	*Packaged Equipment*				*$302,123.75*
2.18.1.1	Item	No Factor	1	Budget Price	$302,123.75
2.18.2	*Package Installation Costs*				*$1,067,253.20*
2.18.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$145,019.40
2.18.2.2	Construction	Construction	1.4	Estimate	$422,973.25
2.18.2.3	Commissioning	Commissioning	0.12	Estimate	$36,254.85
2.18.2.4	EPCM	EPCM	0.6	Estimate	$181,274.25
2.19	***Power Generation***				***$673,311.60***
2.19.1	*Packaged Equipment*				*$187,031.00*
2.19.1.1	Item	No Factor	1	Budget Price	$187,031.00
2.19.2	*Package Installation Costs*				*$486,280.60*
2.19.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$89,774.88
2.19.2.2	Construction	Construction	1.4	Estimate	$261,843.40
2.19.2.3	Commissioning	Commissioning	0.12	Estimate	$22,443.72
2.19.2.4	EPCM	EPCM	0.6	Estimate	$112,218.60
2.20	***Major Valves, Instruments, Control Valves***				***$4,120,102.80***
2.20.1	*Packaged Equipment*				*$1,144,473.00*
2.20.1.1	Item	No Factor	1	Budget Price	$1,144,473.00
2.20.2	*Package Installation Costs*				*$2,975,629.80*
2.20.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$549,347.04
2.20.2.2	Construction	Construction	1.4	Estimate	$1,602,262.20
2.20.2.3	Commissioning	Commissioning	0.12	Estimate	$137,336.76
2.20.2.4	EPCM	EPCM	0.6	Estimate	$686,683.80
2.22	***Switchroom / Control Room / Workshop/Enclosures***				***$1,358,305.20***
2.22.1	*Packaged Equipment*				*$377,307.00*
2.22.1.1	Item	No Factor	1	Budget Price	$377,307.00
2.22.2	*Package Installation Costs*				*$980,998.20*
2.22.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$181,107.36
2.22.2.2	Construction	Construction	1.4	Estimate	$528,229.80

2.22.2.3	Commissioning	Commissioning	0.12	Estimate	$45,276.84
2.22.2.4	EPCM	EPCM	0.6	Estimate	$226,384.20
2.23	***Lighting, Earthing and Safety Equipment***				***$348,771.60***
2.23.1	*Packaged Equipment*				*$96,881.00*
2.23.1.1	Item	No Factor	1	Budget Price	$96,881.00
2.23.2	*Package Installation Costs*				*$251,890.60*
2.23.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$46,502.88
2.23.2.2	Construction	Construction	1.4	Estimate	$135,633.40
2.23.2.3	Commissioning	Commissioning	0.12	Estimate	$11,625.72
2.23.2.4	EPCM	EPCM	0.6	Estimate	$58,128.60

GPA ENGINEERING	Document Title	Document Subtitle
	Total Installed Cost Estimate	**Initial CAPEX Summary**

Client Name	Department for Energy and Mines			Document No.
Client Project No.	N/A	GPA Project No.	16046	**19035-EST-002 Rev A**
Project Name	SESA Augmentation Study			

Option: Option 30 TJ/d To Seagas

Item	Description	Estimate	% of Total	Notes
1	**Owner's Costs**			
	Total Owner's Costs	$ 4,279,926	6%	
2	**Installed Costs**			
2.2	Aftercoolers	$ 1,191,480	3%	
2.9	Compressors	$ 13,017,182	29%	
2.10	Sales Gas Meter Bidirectional	$ 540,000	1%	
2.11	Tie-ins and bypass at Poolaijelo	$ 2,916,065	6%	
2.12	Tie-in to Ladbroke Grove	$ 1,458,033	3%	
2.16	Civils	$ 241,638	1%	
2.17	Station Vent	$ 180,000	0%	
2.18	Fuel Gas System	$ 1,369,377	3%	
2.19	Power Generation	$ 623,940	1%	
2.20	Major Valves, Instruments, Control Valves	$ 3,817,987	8%	
2.22	Switchroom / Control Room / Workshop/Enclosures	$ 1,358,305	3%	
2.23	Lighing, Earthing and Safety Equipment	$ 323,197	1%	
	Total Installed Costs	$ 27,037,204	60%	
	Base Estimate including Owner's Costs	**$ 31,317,130**	**69%**	

Item	Description	Factor	Estimate	Notes
4	**Contingency**			
4.1	Risk and Contingency	30%	$ 9,395,139	
4.2	Escalation	0%	$ -	
4.3	Design Growth	15%	$ 4,697,569	
	Total Contingency	45%	**$ 14,092,708**	

Base Estimate plus Contingency **$ 45,409,838**

Item	Description	Factor	Estimate	Notes
3	**EPCM Cost (included in Total Installed Costs, item 2, above)**			
		15%	$ 4,697,569	

Item Number	Description	Factor Description	Factor	Value Basis	Mean Amount
1	**Indirect Cost**				**$4,279,925.98**
1.1	***Owners Costs***				***$4,279,925.98***
1.1.1	*Other*				*$4,279,925.98*
1.1.1.1	Item	Other (Average)	0.11111111	Estimate	$4,279,925.98
2	**Direct Cost**				**$38,519,334.20**
2.2	***Aftercoolers***				***$1,191,480.03***
2.2.1	*Packaged Equipment*				*$430,720.03*
2.2.1.1	Item	No Factor	2	Budget Price	$430,720.03
2.2.2	*Package Installation Costs*				*$760,760.00*
2.2.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$206,745.61
2.2.2.2	Construction	Construction	1.4	Estimate	$603,008.04
2.2.2.3	Commissioning	Commissioning	0.12	Estimate	$51,686.40
2.2.2.4	EPCM	EPCM	0.6	Estimate	$258,432.02
2.9	***Compressors***				***$13,017,182.40***
2.9.1	*Packaged Equipment*				*$3,615,884.00*
2.9.1.1	Item	No Factor	2	Budget Price	$3,615,884.00
2.9.2	*Package Installation Costs*				*$9,401,298.40*
2.9.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$1,735,624.32
2.9.2.2	Construction	Construction	1.4	Estimate	$5,062,237.60
2.9.2.3	Commissioning	Commissioning	0.12	Estimate	$433,906.08
2.9.2.4	EPCM	EPCM	0.6	Estimate	$2,169,530.40
2.10	***Sales Gas Meter Bidirectional***				***$540,000.00***
2.10.1	*Packaged Equipment*				*$150,000.00*
2.10.1.1	Item	No Factor	1	Budget Price	$150,000.00
2.10.2	*Package Installation Costs*				*$390,000.00*
2.10.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$72,000.00
2.10.2.2	Construction	Construction	1.4	Estimate	$210,000.00
2.10.2.3	Commissioning	Commissioning	0.12	Estimate	$18,000.00
2.10.2.4	EPCM	EPCM	0.6	Estimate	$90,000.00
2.11	***Tie-ins and bypass at Poolaijelo***				***$2,916,065.00***
2.11.1	*Construction / Installation*				*$2,916,065.00*
2.11.1.1	Bulk Materials	No Factor	2	Estimate	$172,044.00
2.11.1.2	Construction	No Factor	2	Estimate	$2,160,808.00
2.11.1.3	Commissioning	No Factor	2	Estimate	$97,202.17
2.11.1.4	EPCM	No Factor	2	Estimate	$486,010.83
2.12	***Tie-in to Ladbroke Grove***				***$1,458,032.50***
2.12.1	*Construction / Installation*				*$1,458,032.50*
2.12.1.1	Bulk Materials	No Factor	1	Estimate	$86,022.00
2.12.1.2	Construction	No Factor	1	Estimate	$1,080,404.00
2.12.1.3	Commissioning	No Factor	1	Estimate	$48,601.08
2.12.1.4	EPCM	No Factor	1	Estimate	$243,005.42
2.16	***Civils***				***$241,638.00***
2.16.1	*Construction / Installation*				*$241,638.00*
2.16.1.1	Bulk Materials	No Factor	1	Estimate	$73,696.00
2.16.1.2	Construction	No Factor	1	Estimate	$126,984.00
2.16.1.3	Commissioning	No Factor	1	Estimate	$6,826.33
2.16.1.4	EPCM	No Factor	1	Estimate	$34,131.67
2.17	***Station Vent***				***$180,000.00***
2.17.1	*Packaged Equipment*				*$50,000.00*
2.17.1.1	Item	No Factor	0.5	Budget Price	$50,000.00
2.17.2	*Package Installation Costs*				*$130,000.00*
2.17.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$24,000.00
2.17.2.2	Construction	Construction	1.4	Estimate	$70,000.00
2.17.2.3	Commissioning	Commissioning	0.12	Estimate	$6,000.00
2.17.2.4	EPCM	EPCM	0.6	Estimate	$30,000.00
2.18	***Fuel Gas System***				***$1,369,376.95***
2.18.1	*Packaged Equipment*				*$302,123.75*
2.18.1.1	Item	No Factor	1	Budget Price	$302,123.75
2.18.2	*Package Installation Costs*				*$1,067,253.20*
2.18.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$145,019.40
2.18.2.2	Construction	Construction	1.4	Estimate	$422,973.25
2.18.2.3	Commissioning	Commissioning	0.12	Estimate	$36,254.85
2.18.2.4	EPCM	EPCM	0.6	Estimate	$181,274.25
2.19	***Power Generation***				***$623,939.52***
2.19.1	*Packaged Equipment*				*$137,658.92*
2.19.1.1	Item	No Factor	1	Budget Price	$137,658.92
2.19.2	*Package Installation Costs*				*$486,280.60*
2.19.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$89,774.88
2.19.2.2	Construction	Construction	1.4	Estimate	$261,843.40
2.19.2.3	Commissioning	Commissioning	0.12	Estimate	$22,443.72
2.19.2.4	EPCM	EPCM	0.6	Estimate	$112,218.60
2.20	***Major Valves, Instruments, Control Valves***				***$3,817,987.02***
2.20.1	*Packaged Equipment*				*$842,357.22*
2.20.1.1	Item	No Factor	1	Budget Price	$842,357.22
2.20.2	*Package Installation Costs*				*$2,975,629.80*
2.20.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$549,347.04
2.20.2.2	Construction	Construction	1.4	Estimate	$1,602,262.20
2.20.2.3	Commissioning	Commissioning	0.12	Estimate	$137,336.76
2.20.2.4	EPCM	EPCM	0.6	Estimate	$686,683.80
2.22	***Switchroom / Control Room / Workshop/Enclosures***				***$1,358,305.20***
2.22.1	*Packaged Equipment*				*$377,307.00*
2.22.1.1	Item	No Factor	1	Budget Price	$377,307.00
2.22.2	*Package Installation Costs*				*$980,998.20*
2.22.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$181,107.36

2.22.2.2	Construction	Construction	1.4	Estimate	$528,229.80
2.22.2.3	Commissioning	Commissioning	0.12	Estimate	$45,276.84
2.22.2.4	EPCM	EPCM	0.6	Estimate	$226,384.20
2.23	***Lighing, Earthing and Safety Equipment***				***$323,197.14***
2.23.1	*Packaged Equipment*				*$71,306.54*
2.23.1.1	Item	No Factor	1	Budget Price	$71,306.54
2.23.2	*Package Installation Costs*				*$251,890.60*
2.23.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$46,502.88
2.23.2.2	Construction	Construction	1.4	Estimate	$135,633.40
2.23.2.3	Commissioning	Commissioning	0.12	Estimate	$11,625.72
2.23.2.4	EPCM	EPCM	0.6	Estimate	$58,128.60

GPA ENGINEERING	Document Title	Document Subtitle
	Total Installed Cost Estimate	**Initial CAPEX Summary**

Client Name	Department for Energy and Mines			Document No.
Client Project No.	N/A	GPA Project No.	16046	**19035-EST-002 Rev A**
Project Name	SESA Augmentation Study			

Option: **Option 10 TJ/d To SEA Gas**

Item	Description	Estimate	% of Total	Notes
1	**Owner's Costs**			
	Total Owner's Costs	$ 4,279,926	6%	
2	**Installed Costs**			
2.2	Aftercoolers	$ 983,564	3%	
2.9	Compressors	$ 3,685,536	12%	
2.10	Sales Gas Meter Bidirectional	$ 540,000	2%	
2.11	Tie-ins and bypass at Poolaijelo	$ 2,916,065	10%	
2.12	Tie-in to Ladbroke Grove	$ 1,458,033	5%	
2.16	Civils	$ 241,638	1%	
2.17	Station Vent	$ 180,000	1%	
2.18	Fuel Gas System	$ 1,223,536	4%	
2.19	Power Generation	$ 557,489	2%	
2.20	Major Valves, Instruments, Control Valves	$ 3,411,366	11%	
2.22	Switchroom / Control Room / Workshop/Enclosures	$ 1,358,305	4%	
2.23	Lighing, Earthing and Safety Equipment	$ 288,776	1%	
	Total Installed Costs	$ 16,844,308	55%	
	Base Estimate including Owner's Costs	**$ 21,124,234**	**69%**	

Item	Description	Factor	Estimate	Notes
4	**Contingency**			
4.1	Risk and Contingency	30%	$ 6,337,270	
4.2	Escalation	0%	$ -	
4.3	Design Growth	15%	$ 3,168,635	
	Total Contingency	45%	**$ 9,505,905**	

Base Estimate plus Contingency $ 30,630,139

Item	Description	Factor	Estimate	Notes
3	**EPCM Cost (included in Total Installed Costs, item 2, above)**			
		15%	$ 3,168,635	

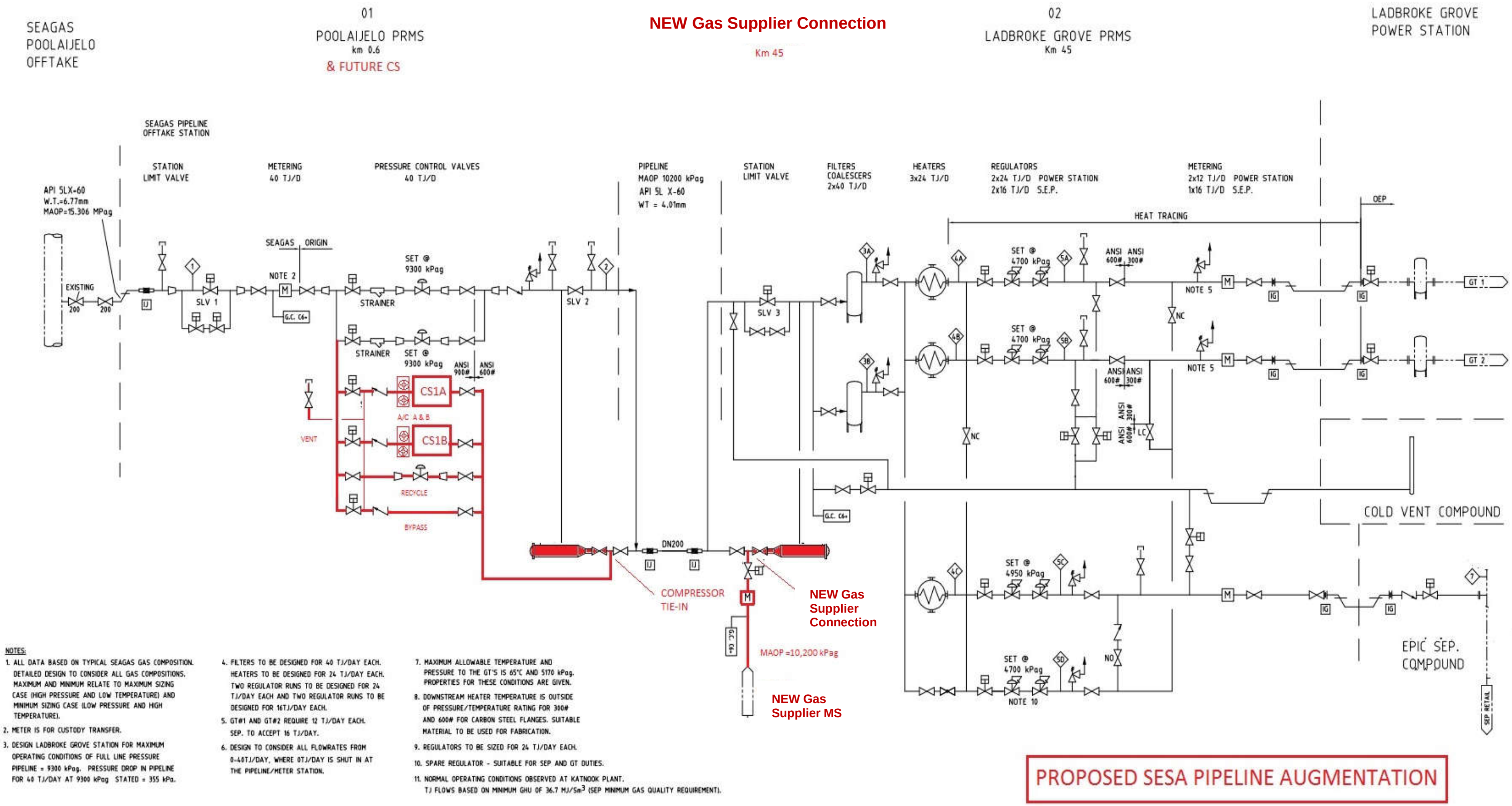
Item Number	Description	Factor Description	Factor	Value Basis	Mean Amount
1	**Indirect Cost**				**$4,279,925.98**
1.1	***Owners Costs***				***$4,279,925.98***
1.1.1	*Other*				*$4,279,925.98*
1.1.1.1	Item	Other (Average)	0.11111111	Estimate	$4,279,925.98
2	**Direct Cost**				**$38,519,334.20**
2.2	***Aftercoolers***				***$983,563.66***
2.2.1	*Packaged Equipment*				*$222,803.66*
2.2.1.1	Item	No Factor	2	Budget Price	$222,803.66
2.2.2	*Package Installation Costs*				*$760,760.00*
2.2.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$106,945.76
2.2.2.2	Construction	Construction	1.4	Estimate	$311,925.12
2.2.2.3	Commissioning	Commissioning	0.12	Estimate	$26,736.44
2.2.2.4	EPCM	EPCM	0.6	Estimate	$133,682.19
2.9	***Compressors***				***$3,685,536.00***
2.9.1	*Packaged Equipment*				*$1,023,760.00*
2.9.1.1	Item	No Factor	2	Budget Price	$1,023,760.00
2.9.2	*Package Installation Costs*				*$2,661,776.00*
2.9.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$491,404.80
2.9.2.2	Construction	Construction	1.4	Estimate	$1,433,264.00
2.9.2.3	Commissioning	Commissioning	0.12	Estimate	$122,851.20
2.9.2.4	EPCM	EPCM	0.6	Estimate	$614,256.00
2.10	***Sales Gas Meter Bidirectional***				***$540,000.00***
2.10.1	*Packaged Equipment*				*$150,000.00*
2.10.1.1	Item	No Factor	1	Budget Price	$150,000.00
2.10.2	*Package Installation Costs*				*$390,000.00*
2.10.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$72,000.00
2.10.2.2	Construction	Construction	1.4	Estimate	$210,000.00
2.10.2.3	Commissioning	Commissioning	0.12	Estimate	$18,000.00
2.10.2.4	EPCM	EPCM	0.6	Estimate	$90,000.00
2.11	***Tie-ins and bypass at Poolaijelo***				***$2,916,065.00***
2.11.1	*Construction / Installation*				*$2,916,065.00*
2.11.1.1	Bulk Materials	No Factor	2	Estimate	$172,044.00
2.11.1.2	Construction	No Factor	2	Estimate	$2,160,808.00
2.11.1.3	Commissioning	No Factor	2	Estimate	$97,202.17
2.11.1.4	EPCM	No Factor	2	Estimate	$486,010.83
2.12	***Tie-in to Ladbroke Grove***				***$1,458,032.50***
2.12.1	*Construction / Installation*				*$1,458,032.50*
2.12.1.1	Bulk Materials	No Factor	1	Estimate	$86,022.00
2.12.1.2	Construction	No Factor	1	Estimate	$1,080,404.00
2.12.1.3	Commissioning	No Factor	1	Estimate	$48,601.08
2.12.1.4	EPCM	No Factor	1	Estimate	$243,005.42
2.16	***Civils***				***$241,638.00***
2.16.1	*Construction / Installation*				*$241,638.00*
2.16.1.1	Bulk Materials	No Factor	1	Estimate	$73,696.00
2.16.1.2	Construction	No Factor	1	Estimate	$126,984.00
2.16.1.3	Commissioning	No Factor	1	Estimate	$6,826.33
2.16.1.4	EPCM	No Factor	1	Estimate	$34,131.67
2.17	***Station Vent***				***$180,000.00***
2.17.1	*Packaged Equipment*				*$50,000.00*
2.17.1.1	Item	No Factor	0.5	Budget Price	$50,000.00
2.17.2	*Package Installation Costs*				*$130,000.00*
2.17.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$24,000.00
2.17.2.2	Construction	Construction	1.4	Estimate	$70,000.00
2.17.2.3	Commissioning	Commissioning	0.12	Estimate	$6,000.00
2.17.2.4	EPCM	EPCM	0.6	Estimate	$30,000.00
2.18	***Fuel Gas System***				***$1,223,536.34***
2.18.1	*Packaged Equipment*				*$156,283.14*
2.18.1.1	Item	No Factor	1	Budget Price	$156,283.14
2.18.2	*Package Installation Costs*				*$1,067,253.20*
2.18.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$75,015.90
2.18.2.2	Construction	Construction	1.4	Estimate	$218,796.39
2.18.2.3	Commissioning	Commissioning	0.12	Estimate	$18,753.98
2.18.2.4	EPCM	EPCM	0.6	Estimate	$93,769.88
2.19	***Power Generation***				***$557,489.06***
2.19.1	*Packaged Equipment*				*$71,208.46*
2.19.1.1	Item	No Factor	1	Budget Price	$71,208.46
2.19.2	*Package Installation Costs*				*$486,280.60*
2.19.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$89,774.88
2.19.2.2	Construction	Construction	1.4	Estimate	$261,843.40
2.19.2.3	Commissioning	Commissioning	0.12	Estimate	$22,443.72
2.19.2.4	EPCM	EPCM	0.6	Estimate	$112,218.60
2.20	***Major Valves, Instruments, Control Valves***				***$3,411,365.91***
2.20.1	*Packaged Equipment*				*$435,736.11*
2.20.1.1	Item	No Factor	1	Budget Price	$435,736.11
2.20.2	*Package Installation Costs*				*$2,975,629.80*
2.20.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$549,347.04
2.20.2.2	Construction	Construction	1.4	Estimate	$1,602,262.20
2.20.2.3	Commissioning	Commissioning	0.12	Estimate	$137,336.76
2.20.2.4	EPCM	EPCM	0.6	Estimate	$686,683.80
2.22	***Switchroom / Control Room / Workshop/Enclosures***				***$1,358,305.20***
2.22.1	*Packaged Equipment*				*$377,307.00*
2.22.1.1	Item	No Factor	1	Budget Price	$377,307.00
2.22.2	*Package Installation Costs*				*$980,998.20*
2.22.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$181,107.36

2.22.2.2	Construction	Construction	1.4	Estimate	$528,229.80
2.22.2.3	Commissioning	Commissioning	0.12	Estimate	$45,276.84
2.22.2.4	EPCM	EPCM	0.6	Estimate	$226,384.20
2.23	***Lighing, Earthing and Safety Equipment***				***$288,776.18***
2.23.1	*Packaged Equipment*				*$36,885.58*
2.23.1.1	Item	No Factor	1	Budget Price	$36,885.58
2.23.2	*Package Installation Costs*				*$251,890.60*
2.23.2.1	Bulk Materials	Bulk Materials	0.48	Estimate	$46,502.88
2.23.2.2	Construction	Construction	1.4	Estimate	$135,633.40
2.23.2.3	Commissioning	Commissioning	0.12	Estimate	$11,625.72
2.23.2.4	EPCM	EPCM	0.6	Estimate	$58,128.60

APPENDIX 2 BASIS OF MODELLING

The following section contains details of the proposed additional facility augmentation works at both Katnook and Poolaijelo sites and preliminary process calculations supporting anticipated SESA pipeline pressure drops and compressor sizing for the 3 production scenarios.

Appendix 2A SESA SYSTEM PROPOSED AUGMENTATION

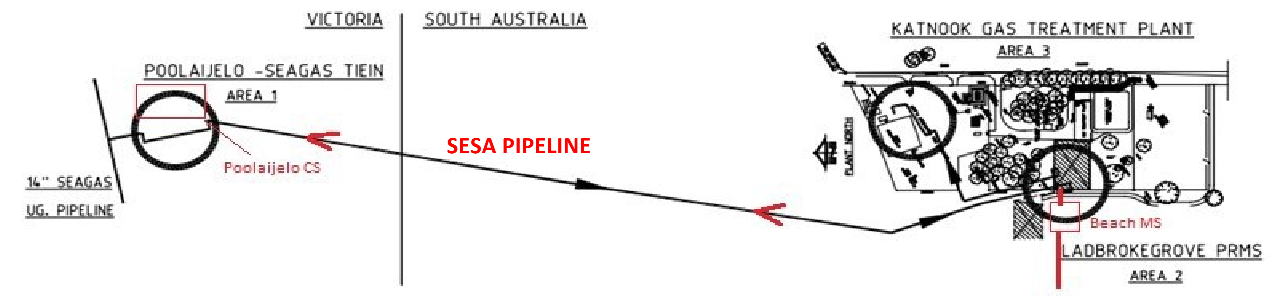


Appendix 2B SESA SYSTEM PROPOSED AUGMENTATION – Modelling Calculations Summary

GPA ENGINEERING	Document Title			Document No.		
	Basis of Modelling			19035-BOM-001		
Client Name	Dept of Energy and Mining SA			Date	16/4/19	By	APW
Client Project No.	NA	GPA Project No.	17734	Rev	A	Chkd	BM
Project Name	SESA Augmentation Study					QA	AS

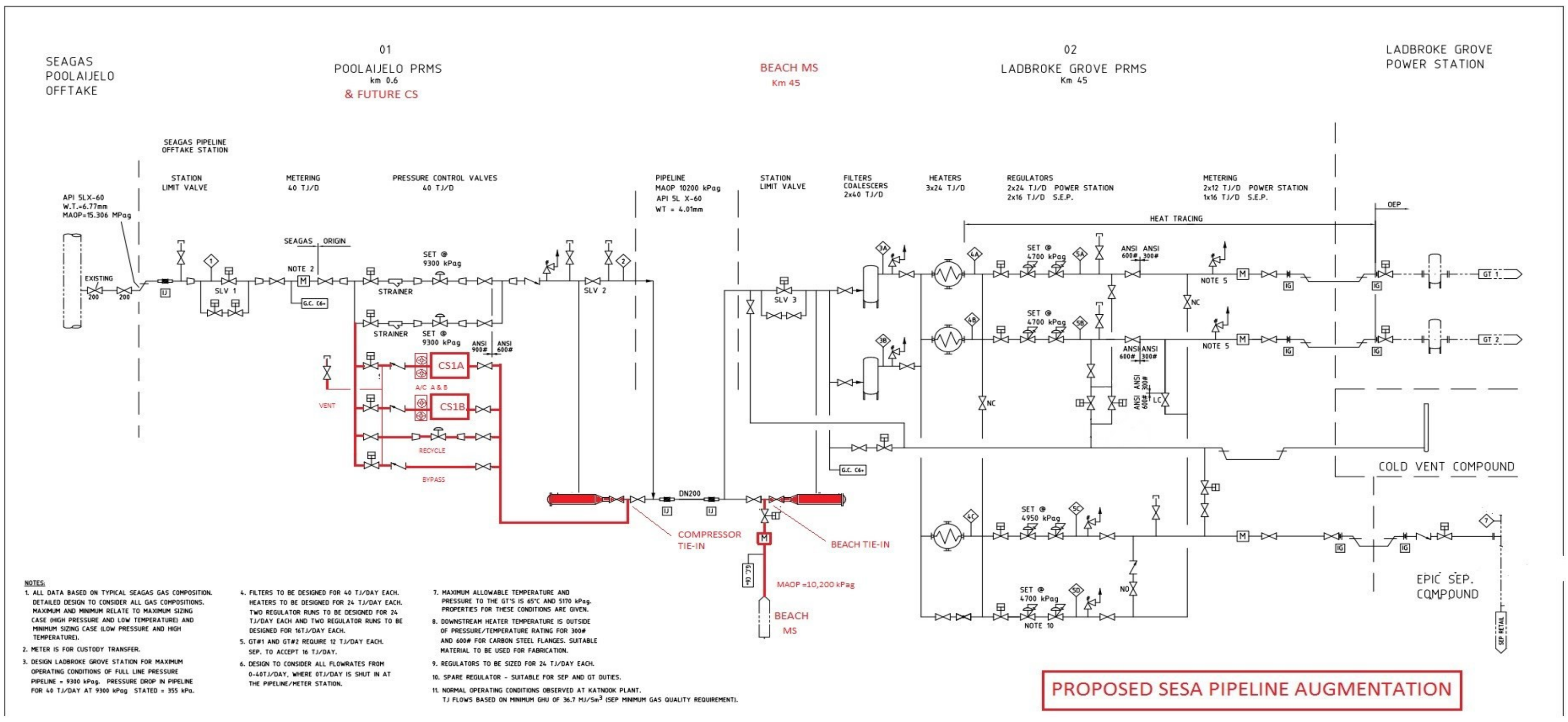
AIM

The aim of this modelling is to determine the limitations and augmentation of the SESA pipeline required to enable reverse flow back from Ladroke grove into the SeaGas line at various flows. The flows selected for modelling are 10, 30 and 50 TJ/d



PIPELINE DETAILS

The Augmented SESA system is described in the diagram below.



SESA Pipeline	Length (m)	Inner Diameter (mm)	Rough (micron)	elevation (m)
Sea Gas to Poolaijelo	550	205.5	600	125
Poolaijelo to Ladbroke Grove	44500	211.1	600	63

STATION DETAILS

Meter Station pressure and flow limits were based on the design criteria represented on the PFD . Flow Deliveries used were:

		Min Inlet (kPag)	Max Inlet (kPag)	DESIGN MAOP (kPag)
SEA Gas to Poolaijello	40 TJ/d	6894	14000	15306
SESA Pipeline	40 TJ/d	6711	10000	10200
SEPS - Current	10 TJ/d	5000	6400	9946
SEPS - Maximum	16 TJ/d	5000	6400	9946
Ladbroke Grove - one unit	12 TJ/d	4945	9300	10200
Ladbroke Grove - two units	24 TJ/d	4945	9300	10200
Beach Flow - low	10 TJ/d	10000	10000	10200
Beach Flow - medium	30 TJ/d	10000	10000	10200
Beach Flow - high	50 TJ/d	10000	10000	10200

System temperature limits were based on the design criteria represented on the PFD .

	Min Temp(C)	Max Temp(C)	Comments
SEA Gas	0	45	Maximum based on coating limitations
Poolaijelo	-10	60	Maximum based on touch potentials
SESA Pipeline	0	45	Maximum based on coating limitations
SEPS	3	25	Maximum Downstream of heater
Ladbroke Grove - two units	28	65	Maximum Downstream of heaters
Beach Flow	20	20	Assumed

MODEL DETAILS

Equation of State	AGA8		
Pressure drop correlation	AGA IGT10 Using GPA's Pipedesign Program for Steady state gas flow		
Ground temperature	Summer	20°C	
Pipe wall heat transfer coefficient	If Required	10 W/m.K	
Gas temperatures:	Pipeline gas temperature	20°C	
Pipeline roughness	Assumed	0.0005mm	(600 micron)

GAS COMPOSITIONS

Component	Otway Gas Lean	
Methane	87.78	mol%
Ethane	5.500	mol%
Carbon Dioxide	5.210	mol%
Nitrogen	1.500	mol%
Propane	0.010	mol%
i-Butane	0.000	mol%
n-Butane	0.000	mol%
i-Pentane	0.000	mol%
n-Pentane	0.000	mol%
Hexane	0.000	mol%
Heptane	0.000	mol%
Octane	0.000	mol%
Nonane	0.000	mol%
Total	100.00	mol%

PROPERTIES

SG	0.6371
Density (kg/m3)	0.7848
HHV (MJ/m3)	36.729
Wobbe Index	46.015
1TJ = scmh	1134
Mwt	18.454
IsentrCoeff	1.3

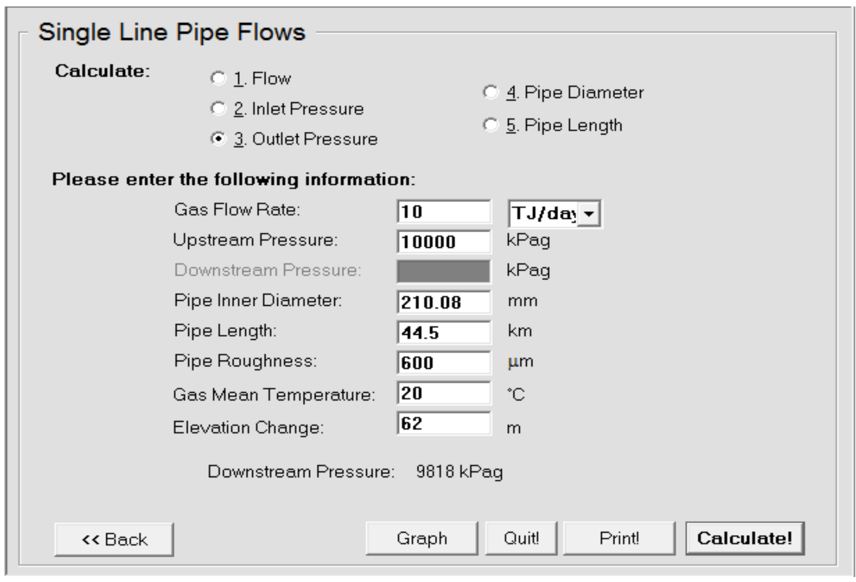
ASSUMPTIONS / CLARIFICATIONS

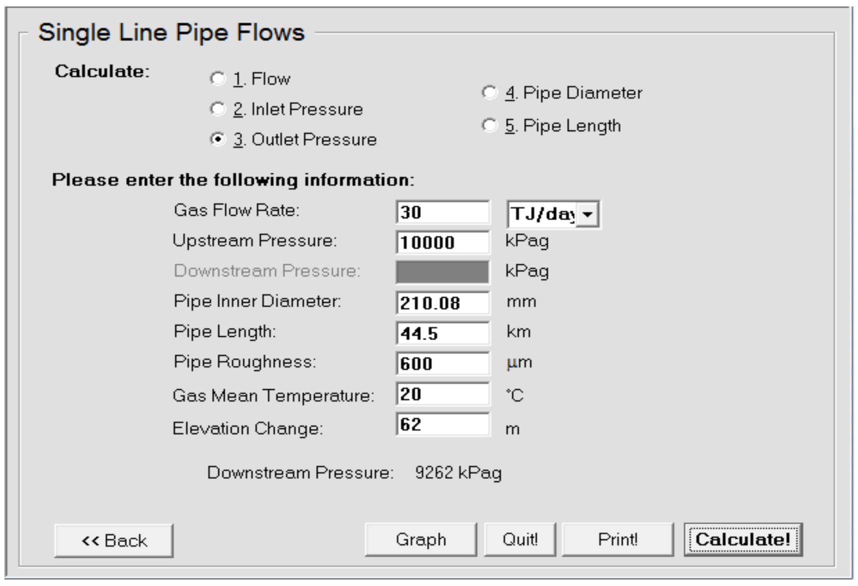
1	Gas temperatures:	Ex Beach Pipeline	20°C	
2	Steady State pipeline gas temperatures		20°C	
3	Pipeline roughness	Assumed	0.0005mm	600micron
4	Recip compression tie-in	at Poolaijelo pig trap		
5	Beach Tie-in	Ladbroke Grove pigtrap		

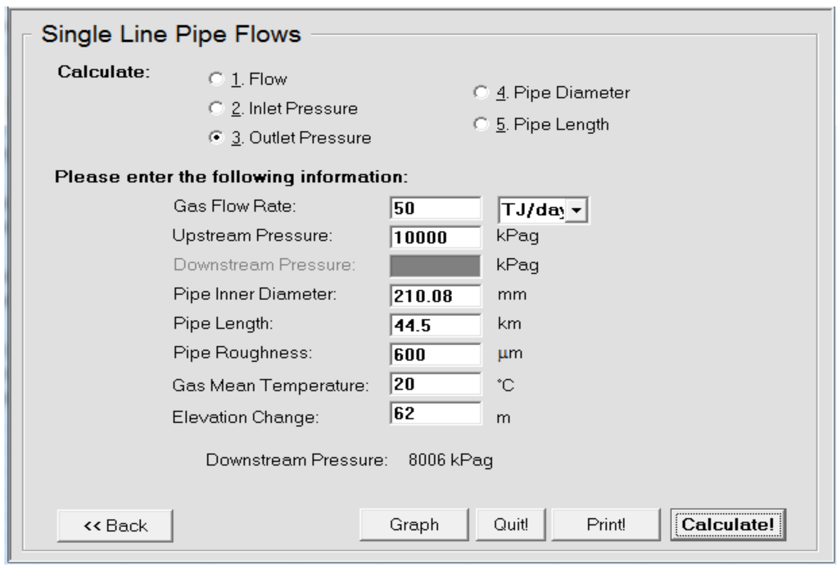
6 Beach will BOO compression to reach 10000 kPag at the Ladbroke GroveTie-in
7 Beach will BOO their own custody transfer metering
8 Beach Gas Quality same as Lean SEAGas quality
9 Existing Ultrasonic meter is used for custoday transfer to SEAGas at Poolaijelo
10 Note the 14000 kPag SEAgas inlet pressure is a maximum operational pressure at that Poolaijelo
11 It is assume the heaters at Ladbroke Grove can accommodate the minor additional JT cooiling when moving to 10000KPag from 9300 kPag
12 Lean Otway gas is assumed for the Beach Gas supply

RESULTS

Pressure Calculations at Various Reverse flows







Compressibility Calculation

Pressure [kPag]	**9818**	Pressure [kPag]	**9262**	Pressure [kPag]	**8006**
Temperature [deg C]	20	Temperature [deg C]	20	Temperature [deg C]	20
Rel density - SG	0.6371	Rel density - SG	0.6371	Rel density - SG	0.6371
N2 [% mol]	1.5	N2 [% mol]	1.5	N2 [% mol]	1.5
CO2 [% mol]	5.21	CO2 [% mol]	5.21	CO2 [% mol]	5.21
Z Factor (AGA 8)	**0.81246248**	Z Factor (AGA 8)	**0.82034237**	Z Factor (AGA 8)	**0.839887897**
Pressure [kPag]	14000	Pressure [kPag]	14000	Pressure [kPag]	14000
Temperature [deg C]	55	Temperature [deg C]	55	Temperature [deg C]	75
Rel density - SG	0.6371	Rel density - SG	0.6371	Rel density - SG	0.6371
N2 [% mol]	1.5	N2 [% mol]	1.5	N2 [% mol]	1.5
CO2 [% mol]	5.21	CO2 [% mol]	5.21	CO2 [% mol]	5.21
Z Factor (AGA 8)	**0.86272011**	Z Factor (AGA 8)	**0.86272011**	Z Factor (AGA 8)	**0.862720116**

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1					
2	Description				Calculate the Maximum power for a gas reciprocating compressor for the inlet to SEAGas at Poolaijello
3					Assume 100 kPa loss through the pipework and aftercooler
4					
5					
6	Suction pressure	P_1	8006	kPag	
7			8107	kPaa	
8			1176	PSIa	
9			1161	PSIg	
10	Discharge pressure	P_2	14000	kPag	
11			14101	kPaa	
12			2045	PSIa	
13			2031	PSIg	
14	Suction temperature	T_1	20	°C	
15			293.15	K	
16			68	°F	
17	Ratio of specific heats (Cp/Cv)	k	1.3	-	
18	Standard gas flowrate	Q	50	TJ/d	1 TJ/day Otway Lean composition equals 1134 scmh
			1.3608	MMSCMD	
19			56,700	SCMH	
20			48,056,199	SCFD	
21			48	MMSCFD	
22	Overall efficiency	E	0.7	-	
23	Isentropic Efficiency	E_{isen}	0.7		
24	Standard pressure	P_S	101.3	kPa	
25	Standard temperature	T_S	15	°C	
26			288.15	K	
27	Inlet compressibility	Z_1	0.84	-	@8118kPag
28	Outlet Compressibility	Z_2	0.8956	-	@14000 kPag
29	Average Compressibility	Z_a	0.8678	-	$(Z_1 + Z_2) / 2$
30					
31	**Power for single stage**	P	**1,188**	**kW**	Equation 15.8, Campbells 1994, 7th Ed , vol 2, page 202
32			1.19	MW	
33					
34	**Discharge Temperature**	T_2	350.21	K	Equation 15.9, Campbells 1994, 7th Ed , vol 2, page 203
35			77.06	°C	
36					
37	**AGA8 Compressibility**				
38	Pressure [kPag]		8118		
39	Temperature [deg C]		20		
40	Rel density - SG		0.6371		
41	N2 [% mol]		1.5		
42	CO2 [% mol]		5.21		
43					
44	Z Factor (AGA 8)		0.839887897		
45					
46	**AGA8 Compressibility**				
47	Pressure [kPag]		14000		
48	Temperature [deg C]		75		
49	Rel density - SG		0.6371		
50	N2 [% mol]		1.5		
51	CO2 [% mol]		5.21		
52					
53	Z Factor (AGA 8)		0.8956		

Typical Overall Efficiency (E)

Centrifugal	0.65-0.75
High Speed Reciprocating	0.65-0.75
Low Speed Reciprocating	0.75-0.85

Campbells 1994, 7th Ed , vol 2, page 197

Typical Isentropic Efficiency (E_{isen})

Centrifugal	0.7-0.75
High Speed Reciprocating	0.7-0.75
Low Speed Reciprocating	0.83-0.90

Campbells 1994, 7th Ed , vol 2, page 203

Project #	**19035**
By	TW
Checked	BM
Date	16-Apr

Assumed $ per kW unit	$3,500	From Enerflex budget estimates provided on 19 August 2011
Cost per Unit	$4,156,703	
AUD adjust ment	$4,272,166.90	in Aug 2011 USD = 0.74 AUD
Installation cost first unit	$10,680,417	
Installed cost first Unit	$14,837,120	
Installation cost redundant unit	$8,313,405.86	
Installed cost redundant Unit	$12,470,109	
Total Cost main and standby	$27,307,229	
Total with CPI Escalation	**$30,859,899**	cumulative price change 13.01%

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TYPICAL COMPRESSOR POWER CALCULATION

1					
2	Description		Calculate the Normal power for a gas reciprocating compressor for the inlet to SEAGas at Poolaijello		
3			Assume 100 kPa loss through the pipework and aftercooler		
4					
5					
6	Suction pressure	P_1	9262	kPag	
7			9363	kPaa	
8			1358	PSIa	
9			1343	PSIg	
10	Discharge pressure	P_2	14000	kPag	
11			14101	kPaa	
12			2045	PSIa	
13			2031	PSIg	
14	Suction temperature	T_1	20	°C	
15			293.15	K	
16			68	°F	
17	Ratio of specific heats (Cp/Cv)	k	1.3	-	
18	Standard gas flowrate	Q	30	TJ/d	1 TJ/day Otway Lean composition equals 1134 scmh
			0.81648	MMSCMD	
19			34,020	SCMH	
20			28,833,719	SCFD	
21			29	MMSCFD	
22	Overall efficiency	E	0.7	-	
23	Isentropic Efficiency	E_{isen}	0.7		
24	Standard pressure	P_S	101.3	kPa	
25	Standard temperature	T_S	15	°C	
26			288.15	K	
27	Inlet compressibility	Z_1	0.8203	-	@9370kPag
28	Outlet Compressibility	Z_2	0.8627	-	@14000 kPag
29	Average Compressibility	Z_a	0.8415	-	$(Z_1 + Z_2) / 2$
30					
31	**Power for single stage**	P	**503**	**kW**	Equation 15.8, Campbells 1994, 7th Ed , vol 2, page 202
32			0.50	MW	
33					
34	**Discharge Temperature**	T_2	334.65	K	Equation 15.9, Campbells 1994, 7th Ed , vol 2, page 203
35			61.50	°C	
36					
37	**AGA8 Compressibility**				
38	Pressure [kPag]		9370		
39	Temperature [deg C]		20		
40	Rel density - SG		0.6371		
41	N2 [% mol]		1.5		
42	CO2 [% mol]		5.21		
43					
44	Z Factor (AGA 8)		0.820342373		
45					
46	**AGA8 Compressibility**				
47	Pressure [kPag]		14000		
48	Temperature [deg C]		55		
49	Rel density - SG		0.6371		
50	N2 [% mol]		1.5		
51	CO2 [% mol]		5.21		
52					
53	Z Factor (AGA 8)		0.8627		

Typical Overall Efficiency (E)

Centrifugal	0.65-0.75
High Speed Reciprocating	0.65-0.75
Low Speed Reciprocating	0.75-0.85

Campbells 1994, 7th Ed , vol 2, page 197

Typical Isentropic Efficiency (E_{isen})

Centrifugal	0.7-0.75
High Speed Reciprocating	0.7-0.75
Low Speed Reciprocating	0.83-0.90

Campbells 1994, 7th Ed , vol 2, page 203

Project #	**19035**
By	TW
Checked	BM
Date	16-Apr

Assumed $ per kW unit	$3,500	From Enerflex budget estimates provided on 19 August 2011
Cost per Unit	$1,759,079	
AUD adjust ment	$1,807,942.65	in Aug 2011 USD = 0.74 AUD
Installation cost first unit	$4,519,857	
Installed cost first Unit	$6,278,936	
Installation cost redundant unit	$3,518,158.67	
Installed cost redundant Unit	$5,277,238	
Total Cost main and standby	$11,556,174	
Total with CPI Escalation	**$13,059,632**	cumulative price change 13.01% since 2011

GPA Engineering
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Description		Calculate the Minimum power for a gas reciprocating compressor for the inlet to SEAGas at Poolaijello		
		Assume 100 kPa loss through the pipework and aftercooler		
Suction pressure	P_1	9818	kPag	
		9919	kPaa	
		1439	PSIa	
		1424	PSIg	
Discharge pressure	P_2	14000	kPag	
		14101	kPaa	
		2045	PSIa	
		2031	PSIg	
Suction temperature	T_1	20	°C	
		293.15	K	
		68	°F	
Ratio of specific heats (Cp/Cv)	k	1.3	-	
Standard gas flowrate	Q	10	TJ/d	1 TJ/day Otway Lean composition equals 1134 scmh
		0.27216	MMSCMD	
		11,340	SCMH	
		9,611,240	SCFD	
		10	MMSCFD	
Overall efficiency	E	0.7	-	
Isentropic Efficiency	E_{isen}	0.7		
Standard pressure	P_S	101.3	kPa	
Standard temperature	T_S	15	°C	
		288.15	K	
Inlet compressibility	Z_1	0.8125	-	@9926kPag
Outlet Compressibility	Z_2	0.8627	-	@14000 kPag
Average Compressibility	Z_a	0.8376	-	$(Z_1 + Z_2) / 2$
Power for single stage	P	**142**	**kW**	Equation 15.8, Campbells 1994, 7th Ed , vol 2, page 202
		0.14	MW	
Discharge Temperature	T_2	328.57	K	Equation 15.9, Campbells 1994, 7th Ed , vol 2, page 203
		55.42	°C	

Typical Overall Efficiency (E)

Centrifugal	0.65-0.75
High Speed Reciprocating	0.65-0.75
Low Speed Reciprocating	0.75-0.85

Campbells 1994, 7th Ed , vol 2, page 197

Typical Isentropic Efficiency (E_{isen})

Centrifugal	0.7-0.75
High Speed Reciprocating	0.7-0.75
Low Speed Reciprocating	0.83-0.90

Campbells 1994, 7th Ed , vol 2, page 203

AGA8 Compressibility

Pressure [kPag]	9926
Temperature [deg C]	20
Rel density - SG	0.6371
N2 [% mol]	1.5
CO2 [% mol]	5.21
Z Factor (AGA 8)	0.812462484

AGA8 Compressibility

Pressure [kPag]	14000
Temperature [deg C]	55
Rel density - SG	0.6371
N2 [% mol]	1.5
CO2 [% mol]	5.21
Z Factor (AGA 8)	0.8627

Project #	**19035**
By	TW
Checked	BM
Date	16-Apr

Assumed $ per kW unit	$3,500	From Enerflex budget estimates provided on 19 August 2011
Cost per Unit	$498,046	
AUD adjust ment	$511,880.56	in Aug 2011 USD = 0.74 AUD
Installation cost first unit	$1,279,701	
Installed cost first Unit	$1,777,747	
Installation cost redundant unit	$996,092	
Installed cost redundant Unit	$1,494,138	
Total Cost main and standby	$3,271,885	
Total with CPI Escalation	**$3,697,557**	cumulative price change 13.01%

SUMMARY AND CONCLUSION

For a SEA Gas inlet pressure of 14000 kPag themaximum Compression ratio of 1.75 is withiin the bounds of a normal single stage compressor.
The variable flow may require a single or dual reciprocating compressor with min speed control and recycle. Aftercooling will be required

	Low flow	Medium Flow	High Flow
Flow rate	10 TJ/d	30 TJ/d	50 TJ/d
Min'm SEAgas inlet Pressure - no comp	9818 kPag	9262 kPag	8006 kPag
Single reciprocating Compressor	0.15MW	0.5MW	1.19 MW
Dual Reciprocating Compressor	0.08 MW	0.25MW	0.6 MW

It should be noted that the Sea Gas inlet pressure can be as low as 6894 kPag at the Poolaijelo takeoff.
At low Seagas inlet pressures it is feasible to delivery 50TJ/d without compression assuming their inlet pressure is less that 8006 kPag.
Seagas would need to advise the frequency of these occurrences.

The proposed conservative scope of augmentaion for cost estimation would be:

1. Tie - in of Beach MS to pig receiver at Ladbroke Grove MS
2. Tie-in of new xcompressor station to Pig Launcher at adjacent to Poolaijelo MS
3. 2 x 600 kW gas fueled Reciprocating compressors with aftercoolers and sound proof enclosures at Poolaijelo MS
4. Compressor Recycle Line
5. Compressor Fuel gas system
6. Compressor Station Vent
7. Compressor Station bypass line
8. Qualification of Ultrasonic metering for bi directional flow
9. land purchase
10. Footings and slabs
11. Oily water system
12. Maintenance Shed
13. Control room
14. SCADA amd controls systems
15. EPCM
16. Owners costs