

**BROWSE BASIN GAS TECHNICAL REPORT
DEVELOPMENT OPTIONS STUDY**

**REPORT 1 of 3
LNG PLANT SITE SELECTION VALIDATION**

**Prepared for
THE NORTHERN DEVELOPMENT TASKFORCE**

May 2008

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INTRODUCTION

The Browse Basin, offshore of north-west Western Australia, holds substantial resources of natural gas. At the date of this report, there is no hydrocarbons production from the Basin and there are no hydrocarbons based projects that are either under construction or approved for construction. However, two of the Basin joint ventures, one operated by Woodside Energy Limited (Woodside), and the other by INPEX Browse Ltd (INPEX), are planning to use their known gas resources for “greenfields” land based Liquefied Natural Gas (LNG) projects¹ (**Figure 1**).

The two projects are based on total gas resources of approximately 27 Trillion cubic feet (Tcf). While some of these resources were discovered over thirty years ago, the basin is “gas prone” and has been relatively lightly explored. The level of exploration activity has increased in recent years and it is likely that other companies currently active in the area will eventually propose LNG projects using Browse Basin gas.

From a technical perspective, the “logical” sites for a land based LNG plant to receive, process and export Browse Basin gas are on the Northern and Southern Kimberley coast or on one of the islands off the coast (**Figure 2**). The North Kimberley area is totally undeveloped, has no infrastructure and is an eco-tourist destination. The South Kimberley has some development (Broome and Derby), has minimal infrastructure and has several tourist destinations (Broome and Cape Leveque).

At the time of this report, both the Woodside and INPEX operated Joint Ventures have conceptualised their respective projects on a “stand alone” basis and have evaluated potential LNG processing sites on the basis of the individual requirements of those projects. Woodside has prepared a shortlist of several potential sites and INPEX has chosen the Maret Islands as its preferred site. Forecast total LNG production from the two projects is in the order of 20 to 25 Mtpa.

The Kimberley Northern Development Taskforce (Taskforce) is an inter-departmental body formed by the Government of Western Australia. The Project Manager is Mr. Gary Simmons from DoIR. The taskforce has been engaged to set the framework by which the State will protect and manage the important heritage, environment and tourism values of the Kimberley area while facilitating structured industrial development. The West Kimberley Subdivision of the Taskforce was established to manage across-government planning processes and stakeholder consultation in regard to selection and development of a suitable location or locations for the processing of Browse Basin gas reserves.

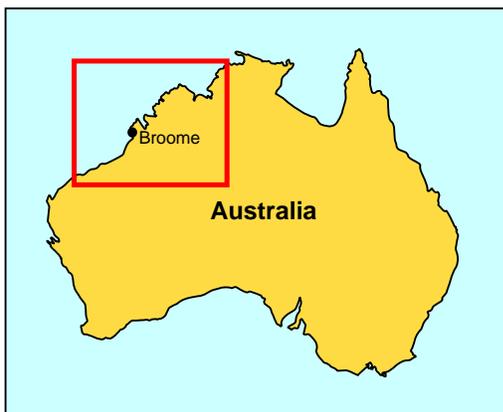
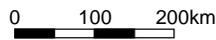
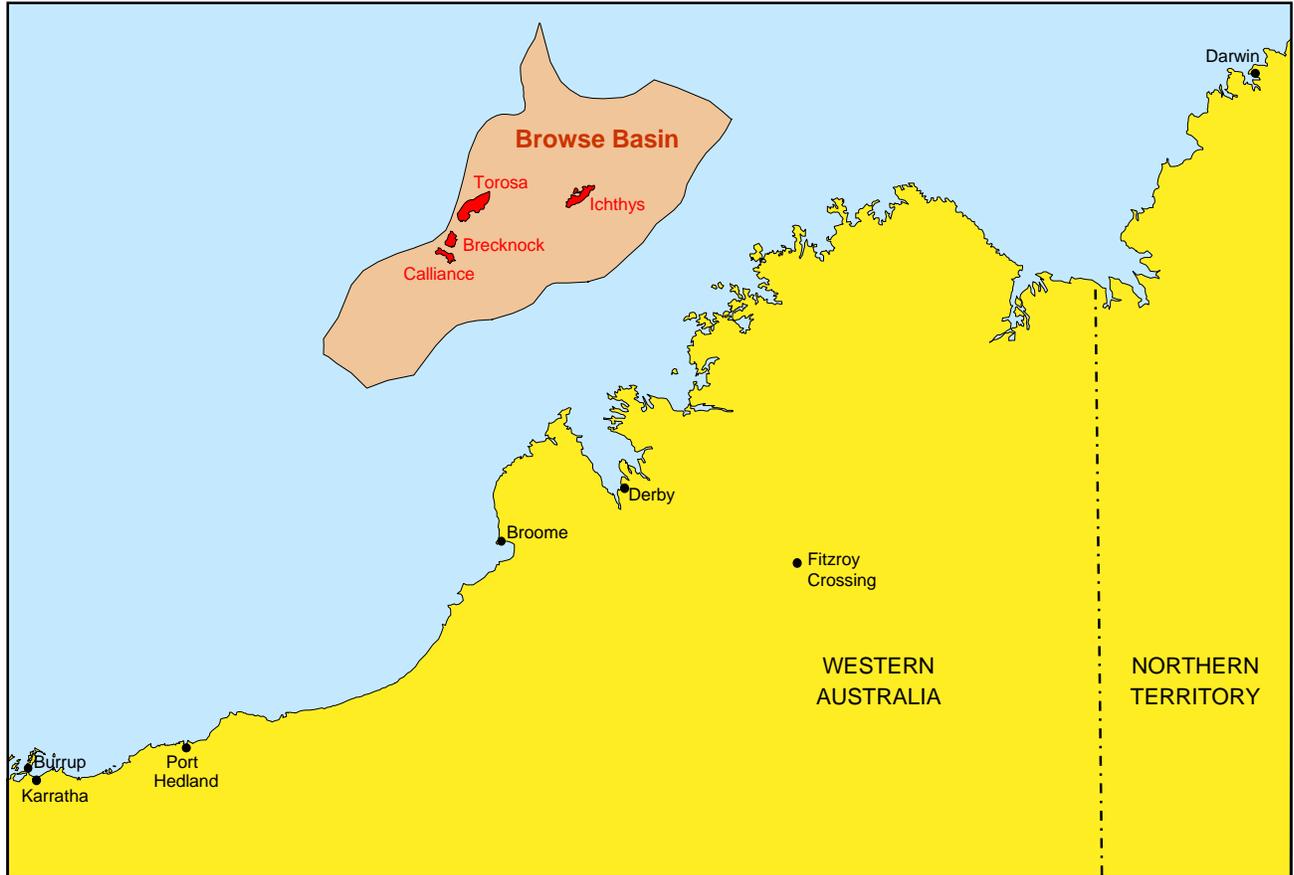
The Taskforce, through DoIR, has retained Gaffney, Cline & Associates (GCA) to provide independent advice on technical issues associated with the selection and development of onshore and offshore locations, for the processing of the Browse Basin gas. This advice is to be in the form of a report titled “Browse Basin Development Options Study” (The Study).

¹ During the course of the study Shell Development (Australia), (Shell) announced that it plans to develop the Prelude field, in the Browse Basin, using a floating LNG facility (FLNG) with no onshore processing facilities. The proposed development is described briefly in Section 2.4. Since it will not use an onshore processing hub it is not considered in the report

The objective of the Study is to review specific technical and economic issues surrounding the processing of existing and yet to be discovered resources at a common LNG plant location or hub. The study has been undertaken in three parts as follows:-

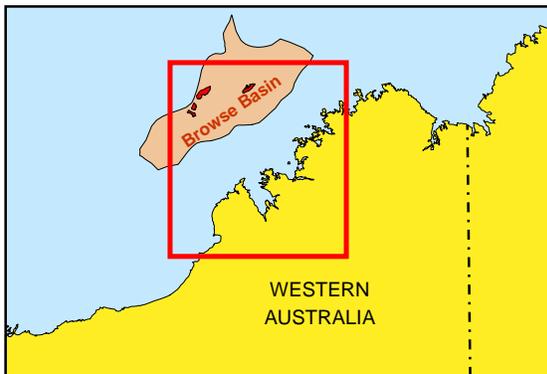
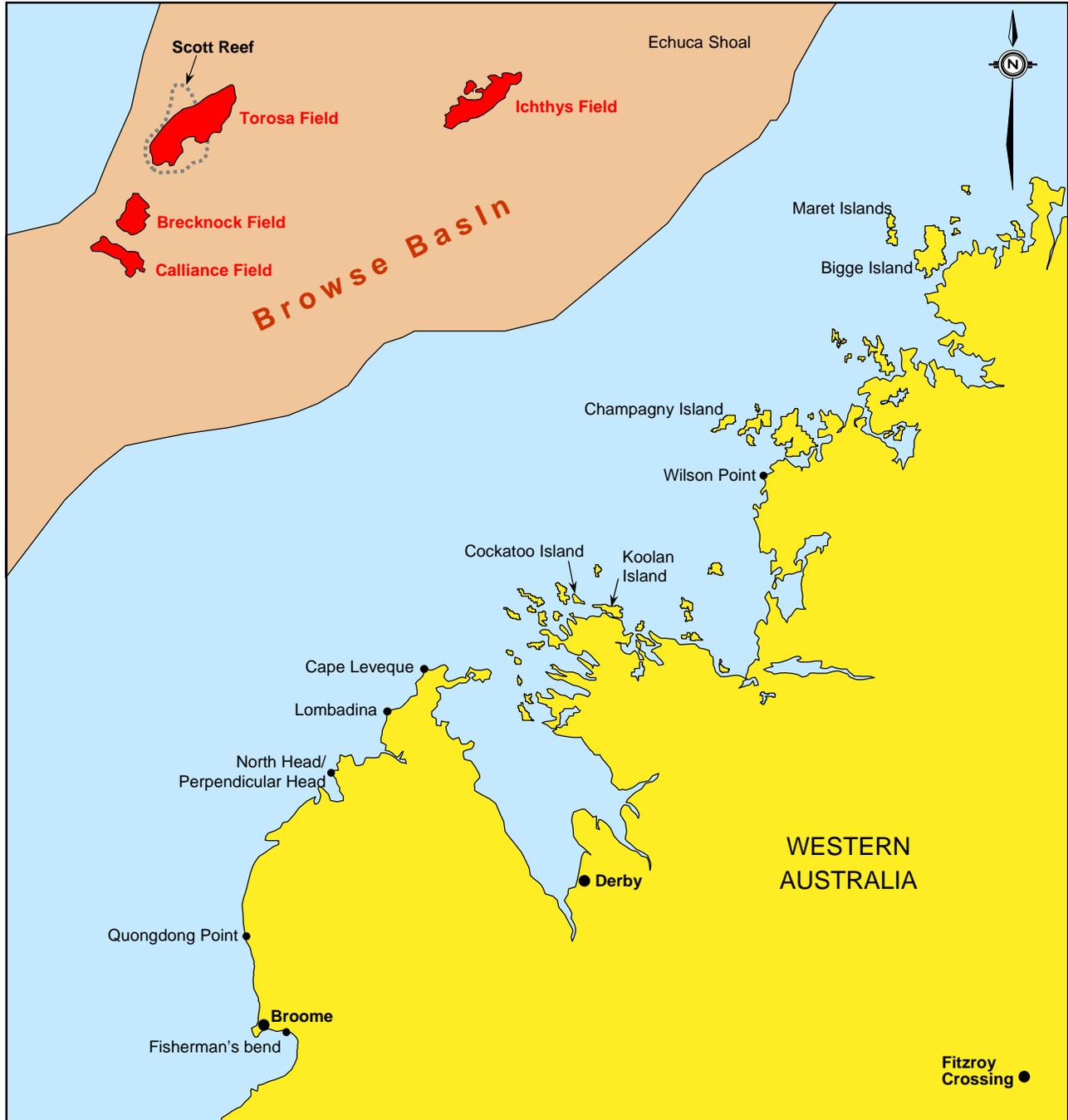
1. Review the existing site selection processes undertaken by Woodside and INPEX and provide commentary on the technical suitability of the sites considered to date in the context of a gas processing hub.
2. Consider and evaluate the key technical issues governing the offshore facilities required to develop Browse Basin Gas in the context of a gas processing hub.
3. Review the potential for an onshore infrastructure hub to support Browse Basin gas development and comment on the key technical, commercial and economic issues surrounding the co-location of the gas processing infrastructure at an onshore infrastructure hub.

Separate reports will be prepared for each of the three areas of review outlined above. This, the first report, covers the site selection and suitability for an LNG hub, based on the information made available to GCA by DoIR, Woodside and INPEX. The full scope of work for this first report is shown in **Appendix I**.



**Browse Basin
Location Map**

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Potential Kimberley Sites for Browse Basin LNG Facilities

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CONCLUSIONS

The scope of work provided for this study by DoIR lists a number of very specific points to be addressed. This has been done in detail in the relevant sections in the body of the report. GCA's "high level" conclusions and recommendations are summarised as follows:-

1. The site selection technical factors suggested by the industry for screening LNG sites are considered appropriate and comprehensive. Seismicity is an additional factor that could be used to further discriminate between sites in the Southern Kimberley and sites in the seismically less active Northern Kimberley.
2. Woodside has adopted a qualitative approach to evaluate potential sites against technical and non technical criteria. While Woodside's technical analyses are valid, more quantitative analysis is required to rank the potential sites.
3. INPEX adopted a quantitative approach to evaluate eleven potential sites against a range of technical and non technical criteria. .
4. INPEX and Woodside have evaluated the potential sites for a "stand alone" LNG development, requiring a maximum of ~300 hectares of available area. Generally, they have expressed their preference for sites closest to their respective fields.
5. GCA's remit was to consider site selection in the context of an LNG Hub. To undertake this assessment GCA has considered three Hub concepts for evaluation:-
 - i. A **Single Operator LNG Hub** with up to 5 LNG trains that could be accommodated on a site of 360 hectares.
 - ii. A **Multi Operator LNG Hub** with up to 10 LNG trains that could be accommodated on a site of 660 hectares.
 - iii. A **Gas Processing Hub** which provides for a multi operator LNG Hub and several large scale Gas to Liquids (GTL) plants. This will require a minimum of 950 hectares.

The three concepts provide the basis for "bracketing" the site area and marine requirements to be considered for evaluating options for a hub to process Browse basin gas. GCA is not advocating any particular concept, and there are many other valid hub configurations that could fit within the site areas defined above.

6. Of the indicative list of sites considered, locations that could accommodate a Gas Processing Hub, with over 950 hectares of technically suitable land with a manageable marine environment, are:
 - i. **Northern Kimberley**:- Bigge Island, Wilson Point
 - ii. **Southern Kimberley**:- Cape Leveque, North Head / Perpendicular Head, Lombadina (Packer Island), Quondong point and Fisherman's Bend.

Of these sites, Wilson Point has the most favourable marine conditions.

7. While Scott Reef and Echuca Shoals are theoretically technically suitable for a Gas Processing Hub, there are too many technical "firsts" associated with their development to recommend either of them as the lynchpin for future production of the Browse Basin gas resources.

8. It is technically feasible to pipe Browse Basin gas to existing LNG Hubs at either Darwin or Burrup.
9. A firm and consistent vision of the hub does not yet exist amongst the stakeholders consulted by GCA. This needs to be addressed before the concept can be further progressed.
10. To progress technical analysis of site suitability for a hub development “pooling” of available information held by individual stakeholders supplemented by additional “on site” topographical, marine and geotechnical evaluation will be required.

It is noted that GCA’s scope of work covered only the technical aspects of the hub site selection. The conclusions above have not taken into account any of the socio-economic aspects of a hub selection including those arising from land ownership and environmental considerations.

1. SUMMARY

1.1 Study Methodology

Over the three weeks to 4th March, GCA project personnel met with representatives from the Northern Development Taskforce and representatives from the following companies:- Woodside Energy Limited, Shell Development Australia, INPEX, BHP Billiton Limited and Conoco-Phillips. GCA also met with the operator of the Cockatoo Island mine, Portman Iron Ore Ltd.

At the meetings, and subsequent to the meetings, Woodside and INPEX provided GCA with documentation pertinent to their stand alone projects. Use of the data by GCA was covered by normal industry confidentiality agreements.

Subsequent to these meetings the GCA study team convened in Singapore to analyse the data provided in the light of its own LNG experience and to prepare this report. Team members included personnel with extensive first hand experience at PT Arun, Ras Laffan, Sakhalin and Angola LNG. One of the team members also has an ongoing role in the planning of Angola's first LNG hub.

The evaluations conducted in this report are based on the expertise of the Team Members involved, leveraging public information and tools (including SRTM maps incorporated in the Google Earth® software), as well as the information provided by Browse basin tenement holders. Thompson Clarke Shipping (TCS) were retained by GCA to provide advice on the marine aspects of the study.

No site visits were undertaken and all estimation work has been done at a very high level, mostly by analogy.

1.2 Site Evaluation for Stand Alone LNG Projects

DoIR have requested the review of site selection processes used by Woodside and INPEX and to include the following aspects of site evaluation in this report:-

- Port suitability including metocean and offloading.
- Land Area requirements
- Site elevation and gradient
- Proximity to gas fields
- Distance to navigable waters
- Proximity of site to the coastline
- Pipeline approach
- Geotechnical conditions
- Proximity to existing infrastructure

GCA has reviewed all sites considered technically suitable by Woodside and INPEX against these criteria together with additional sites listed in the scope of work or subsequently requested for evaluation by DoIR (**Appendix I**).

GCA has not sought to identify and evaluate every site that shows promise of technical suitability as an LNG hub. The list of sites reviewed in this study should be considered as representative of potential Kimberley LNG hub sites.

While somewhat different approaches have been used by Woodside and INPEX (**Section 2.1**), their site evaluations have been conducted in a professional and logical manner, based on environmental, socio-economic and technical aspects. While there was considerable variation in the mix of qualitative and quantitative data available, it is considered that both operators incorporated the DoIR technical factors listed above into their evaluations. The variation in the outcomes of both evaluations appears to be due to the initial selection of sites, the significant influence of the distance to each operator's fields and different assessments of certain criteria, such as land area requirements and LNG carrier navigation.

However, GCA considers that the approach and criteria used by both Browse Basin operators for the technical evaluation of potential sites for stand alone LNG facilities are appropriate. GCA made an independent assessment for the different sites considered for two general technical factors: (1) port availability and navigability, which included water depth, current, wind speed, tides, wave height and general navigability, and (2) land availability and suitability which included topography, elevated areas, site gradient and soil or rock types.

The assessments made by Woodside and Inpex for these technical factors were then compared to those made by GCA. In most cases GCA agreed with one or both operators with no instances of GCA differing with both operators on any of the broad points of evaluation. There are however instances where GCA has differed from one operator. These are:-

- **Bigge Island:-** INPEX judged that the waters around the Island are not readily navigable by large vessels. However Woodside and GCA consider that, depending on the port location, a breakwater or dredging would allow access of LNG carriers.
- **Maret Islands:-** Woodside assessed the site as having insufficient land and unsuitable geotechnical characteristics. GCA and INPEX consider the land area adequate and have access to actual geotechnical data which confirms the site's suitability.
- **Koolan Island:-** Woodside consider the site to lie in water unsuitable for LNG carrier navigation owing to its proximity to King Sound. INPEX and GCA consider that Koolan Island has suitable marine conditions, with limited dredging and no breakwater required.
- **Cockatoo Island:-** Woodside consider the site to lie in water unsuitable for LNG carrier navigation owing to its proximity to King Sound. INPEX and GCA consider that Cockatoo Island has suitable marine conditions, with limited dredging and no breakwater required.
- **Cockatoo Island:-** INPEX considered that sufficient land was available should the area of the mine site be used in conjunction with a "Compact LNG" design, whereas Woodside and GCA estimate that the available area of approximately 250 hectares is insufficient to support a "stand alone" LNG facility.

1.3 LNG Hub Concepts

From GCA's meetings with stakeholders it was apparent that a common vision for the Browse LNG hub had not yet materialised. Although there are a number of alternatives that can be considered, for the purposes of this report, GCA has defined three concepts as the basis for arriving at the range of land and marine requirements that should reasonably be considered:-

- **Single Operator LNG Hub:-** A site operated by a single entity which has the capability to receive gas from a number of fields and operators. The hub processes gas to LNG, and stores and loads LNG on behalf of the field operators. An existing example of this concept is PT Arun in Indonesia. For this study a maximum of 5 LNG trains and support facilities requiring 360 hectares has been used as the basis for evaluation.
- **Multi Operator LNG Hub:-** A site that has common infrastructure, such as harbour, wharves, airstrip and camps which can be consolidated or shared, but where two or more operating entities independently receive and process gas to LNG and independently store and load LNG. An existing example could be the Burrup LNG developments, in which the NWSJV and Pluto will be operated independently. For this study, two independent operators with a maximum of 10 LNG trains and independent support facilities requiring 660 hectares have been used as the basis for evaluation.
- **Gas Processing Hub:-** A concept similar to the multi operator hub but which also provides for additional basic "value adding" processes such as Gas to Liquids (GTL), methanol or fertiliser production. An existing example is Ras Laffan with the caveat that petrochemicals production is not contemplated for the Browse Hub. For this study a total of a maximum of 10 LNG trains and a number of GTL based facilities have been used as the basis for evaluation. This concept requires 950 hectares or more.

The above concept has been used for the purpose of setting a basis for evaluating potential sites. The facilities ultimately located at such a site could differ markedly from those described.

No matter which of the above concepts is adopted, it has been assumed for the purposes of this study that the development of Brecknock, Calliance and Torosa gas condensate fields by the Woodside operated Browse Joint Venture; and the INPEX operated Ichthys gas condensate field, would be the "foundation" suppliers of gas to the Hub.

1.4 Site Evaluation For LNG And Gas Processing Hubs

A substantial amount of work has been undertaken by Woodside and INPEX to screen sites for their stand alone LNG projects. INPEX have performed preliminary geotechnical studies on their preferred Maret Islands site. Woodside have undertaken some geotechnical studies of the other sites they are considering. While both Woodside and INPEX are now actively considering hub concepts, they have not provided any data to GCA that evaluates sites for hub development. Evaluations of potential sites in the context of an LNG Hub, with higher land area requirements than for stand alone developments and consideration of the distances to all the potential upstream fields, will lead to different rankings and shortlisted sites.

DoIR has requested GCA to technically evaluate a number of potential hub sites against specific criteria listed in **Section 2.2**. This work is detailed in **Section 2.3** of the report and is summarised in **Table 1** below:-

TABLE 1

SUMMARY OF SITE SUITABILITY FOR LNG AND GAS PROCESSING HUB

	Port Availability and Navigation	Land Availability and Suitability		
		Single Op.	Multi Op.	Gas Proc.
North Kimberley				
Maret Islands	Y	Y	N	N
Bigge Island	Y	Y	Y	Y
Champagne Island East	Y	Y	N	N
Wilson Point	Y	Y	Y	Y
Koolan Island	Y	Y	N	N
Cockatoo Island	Y	N	N	N
South Kimberley				
Cape Leveque	Y	Y	Y	Y
Lombadina (Packer Island)	Y	Y	Y	Y
North/ Perpendicular Head	Y	Y	Y	Y
Quondong Point	Y	Y	Y	Y
Fisherman's Bend	Y	Y	Y	Y
Offshore Kimberley				
Scott Reef (1)	?	n.a.	n.a.	n.a.
Echuca Shoals (1)	?	n.a.	n.a.	n.a.
Existing LNG Site				
Burrup (NWS & Pluto)	Y	Y(2)	N	N

Notes:-

1. These sites are partially submerged and would be developed as "offshore" facilities.
2. There is insufficient land available in the Burrup area for a new Single Operator LNG Hub. GCA has assumed production would be integrated into existing gas processing hubs.

It is emphasised that the above sites have been evaluated on technical grounds only. Environmental, Land access and other community based issues have not been considered.

2. DISCUSSION

2.1 Woodside, INPEX, GCA Site Short Listing

2.1.1 Screening Criteria

The following considerations are based on GCA's review of the documentation made available by Woodside and INPEX. It is understood that both proponents have carried out significant analysis, which may not be reflected in the final documentation provided. GCA's comments with regards to the analysis done for site selection by both proponents are designed to highlight the different approaches adopted and provide the reader of this report with the background required to understand the different outcomes that have resulted from the analysis conducted by INPEX and Woodside.

It is important to note that the majority of the analysis conducted by INPEX and Woodside aims to identify the optimal location for a stand alone LNG facility, from the point of view of the development of each operator's Browse Basin fields. In particular, the relative locations of these fields will have a significant influence on each Operator's site preference. The outcomes of such analysis in the context of a Hub are therefore likely to be different.

Finally, one could consider that most sites are technically suitable for an LNG development. The ranking of these sites will be based on the relative costs associated to the preparation and operation of a given location. Indeed, for example, the additional costs linked incremental pipeline length could be compensated by the costs savings linked to reduced earth works required on a specific site, or similarly additional dredging might be mitigated by proximity to existing infrastructure for another site. Therefore, the final site selection will require the estimation of the major costs and the assessment of the impact of different sensitivities.

2.1.2 Woodside Site Selection

Woodside appears to have adopted a four-phase approach for site identification and assessment:

- i. Identification of areas of interest, mainly within 500 kilometres of the Woodside fields; however locations within 1,000 kilometres were also noted (Burrup and Darwin);
- ii. Desktop studies, literature reviews and meetings with key stakeholders to identify the potential issues with the sites identified;
- iii. Flyover and/or visits to the potential physical sites to verify desktop studies and collate additional data;
- iv. Assessment of each site against environmental, socio-economic, health, safety security and technical criteria to screen out unsuitable sites from further studies.

Woodside used the following technical criteria for the evaluation of potential onshore and island sites for stand alone LNG facilities:

- **Available Area:** sufficient available area for plant - 300 hectares for development preferred;

- **Site Elevation:** Land can be secured against flood and surge - site elevation at least 10 metres above Australian Height Datum (AHD) to avoid storm surge flooding;
- **Distance to Navigable Water:** Minimum dredging preferred with dredge spoil disposal options available. Minimum jetty lengths;
- **Maximum Slope:** no more than 5 degrees at plant location - minimise earth works disturbance and site preparation costs;
- **Proximity to Coastline:** cryogenic lines are a considerable expense. No more than 4 kilometres to loading facilities preferred;
- **Proximity to Fields:** offshore/onshore pipeline length as export pipelines are a major expense. Preference for having LNG plant as close as feasible to offshore field;
- **Geotechnical Conditions:** site soil type (need for piling) - prefer stable sands/rock to reduce piling requirements for LNG tanks and other equipment. Near shore ocean floor conditions for type of jetty piling;
- **Pipeline Location:** suitable beach and shore conditions for pipeline landing;
- **Carrier Navigation:** availability of sheltered water as docking facilities must be located within sheltered, navigable waters. Breakwater requirements should be minimised. Low ocean currents required for berthing and shipping ingress and exit. Wave heights and periods within acceptable range for berthing and port availability.

Woodside used the following technical criteria for the evaluation of potential offshore reef sites for stand alone LNG facilities:

- **Geotechnical Conditions:** suitable conditions for platform and/or GBS substructure installation;
- **Pipeline Location:** suitable shore crossing for main field pipeline to reef crossing;
- **Carrier Navigation:** availability of sheltered water as docking facilities must be located within sheltered, navigable waters. Breakwater requirements should be minimised. Low ocean currents (<2 knots) required for berthing and shipping ingress and exit;
- **Sheltered Water Location:** wave heights and periods within acceptable range for berthing and port availability;
- **Suitable Water Depth:** installation of Gravity Based Structures (GBS) substructures. Less than 20 metres water depth preferred for construction of GBS substructure;
- **Proximity to Fields:** minimising of main field pipeline lengths.

GCA considers these criteria are an acceptable basis for the technical evaluation of the potential sites for a stand alone development. While seismicity could have been included as an additional criteria, as a possible differentiator between the South Kimberley and the North Kimberley sites (**Appendix V**).

Other than “available area” all the criteria used by Woodside were valid for LNG Hub site selection. Land area requirements are addressed in detail in **Section 2.2.2**.

To allow further comparison of the relative merits of potential sites, detailed cost evaluation is required. In particular those costs linked to dredging, jetty length,

breakwater length and cut and fill will be required. These will have a significant impact on the final project costs (Capex & Opex) and timeline, which in turn could affect final site selection.

The outcome of this approach, based on the qualitative review of all the technical and non-technical criteria considered, has been the screening out of thirty five sites from the 41 identified initially. The remaining 6 sites were shortlisted by Woodside for further evaluation:

- Quondong Point
- James Price Point
- North Head
- Perpendicular Head
- Wilson Point
- Scott Reef (offshore)

These six sites meet appropriate technical criteria for a stand alone facility. GCA considers that a number of additional sites (see section 2.1.4) also meet the technical criteria.

2.1.3 INPEX Site Selection

INPEX appears to have adopted a six-phase approach for site identification and assessment:

- i. Identification of potential sites for onshore LNG facilities;
- ii. Initial screening of sites based on navigability, available area, minimal environmental disturbance and potential for community concern;
- iii. Quantitative ranking of each site based on publically available information, using criteria related to access, physical environment, development considerations, commercial and marketing issues, environmental sensitivity;
- iv. Flyover and/or visits to the potential physical sites to collate additional data;
- v. Revised quantitative ranking of each site based on the additional data collected and using the same criteria as previously.
- vi. Qualitative assessment of all initially identified sites, and ruling out of all technically unsuitable sites.

INPEX used a total of twelve technical criteria for ranking potential sites for stand alone LNG facilities. In addition to the technical criteria described below a number of non-technical features such as environmental impact, land tenure and cultural heritage were also considered. Desirable technical features were considered to be:

- **Road Access:** sites having easily upgradeable road access;
- **Sea Access:** sites with readily available sea access or gazetted as ports;
- **Air Access:** locations with existing airstrips capable of handling commercially chartered airplanes and helicopters;
- **Water Depth:** sites having sufficient water depth to meet the requirements of vessels for export of product;
- **Tides & currents:** Sites that afford some form of protection or have less tidal influence to minimise disruption to marine operations;

- **General Topography:** level sites with suitable geotechnical conditions for foundations;
- **Existing Infrastructure:** sites with existing infrastructure readily useable by the project;
- **Field Proximity:** proximity of site to Ichthys field or offshore facilities;
- **Technological Risk:** overall technical risk that may be site specific;
- **Hydrocarbon Storage:** sites with areas particularly suited for hydrocarbon storage;
- **Constructability:** locations presenting the opportunity to bring in large components or readily available fabrication work force;
- **Operability:** sites that can support a reasonable level of maintenance without significant logistical support.

GCA considers these criteria are an acceptable basis for the technical evaluation of the potential sites for a stand alone development. While seismicity could have been included as an additional criteria, as a possible differentiator between the South Kimberley and the North Kimberley sites (**Appendix V**).

GCA notes that INPEX has not highlighted a distinct criteria or explicit target for land area requirements. It appears nevertheless that land area has been considered in INPEX's study, and led to ruling out certain sites, such as Browse Island. INPEX has advised GCA that capacity expansion was not a corporate criteria at the commencement of the site assessment given the anticipated resistance to industrialisation in the Kimberley.

After the initial screening study, the top six sites were:

- Cockatoo Island
- Koolan Island
- Maret Islands
- Beagle Bay
- Cape Leveque
- Battery Point/Sampson Inlet

In addition to LNG facilities, INPEX has also assessed the potential suitability of the sites for other various downstream processes such as the manufacture of methanol, DME, ammonia/urea and GTL. Production of these alternative products was ultimately ruled out in favour of LNG.

A more detailed inspection and additional technical data for each of the sites led INPEX to rule out the following sites on technical grounds:

- Cockatoo Island
Previously unavailable geotechnical information regarding the foreshore and near harbour geology was accessed confirming that the site is geotechnically unsuitable for the type of development that would be required for a gas processing facility.
- Koolan Island
Mining activities on Koolan Island were resumed during the evaluation period, and as such, the site was no longer available.

- Beagle Bay
The requirement for considerable civil works to develop the site was reconfirmed during 2004. The anticipated impact associated with such extensive civil work on coastal mangrove communities in particular, was determined to be sufficient to substantiate its elimination.
- Battery Point/Sampson Inlet
The requirement for considerable civil works to develop the site was reconfirmed during 2004. The anticipated impact associated with such extensive civil work on coastal mangrove communities in particular, was determined to be sufficient to substantiate its elimination. It was also determined that Sampson Inlet was extensively used by the tourism and pearling industries

Based on both technical aspects, addressed in this study, and non technical aspects, not addressed in this study, INPEX identified Maret Islands as their preferred site for the installation of their LNG facilities. GCA understands that Cape Leveque was ruled out as a possible site, due to its distance from the Ichthys field and on non technical grounds. INPEX considered that the extra distance from the Ichthys field to Cape Leveque would require an offshore development with substantially more personnel offshore.

2.1.4 GCA site screening

The sites listed below comprise the Study's scope of work. The sites have been selected by the Taskforce from those previously shortlisted by Industry:-

- Maret Islands
- Wilson Point
- Scott Reef
- North Head / Perpendicular Head
- Lombadina (Packer Island)
- Quondong Point
- Koolan / Cockatoo Islands
- Burrup – Tie in to existing NWS facilities / Pluto

In order to ensure the evaluation of a comprehensive set of potential sites, GCA has identified, through the review of analysis performed by Woodside and INPEX, additional sites that could be technically suitable for LNG developments. These sites have therefore been reviewed in further detail in this report, in addition to the ones identified in the Study's scope of work.

Certain sites have been ruled out for non technical reasons by Woodside and/or INPEX, even though they were likely to be technically suitable. The following additional sites have therefore been incorporated to the scope of this report:

- **South Kimberley**
 - Fisherman's Bend:

- Ruled out by Woodside because of socio-economic (interference with Pearl industry, heritage sites) and environmental (proximity to Broome) issues.
 - May be reconsidered as a potential site for the quality of its location (7 kilometres direct distance from Broome), its topography (fairly levelled elevation) and acceptable ocean conditions (protected deepwater, proximity to an established port).
- Cape Leveque:
 - Ruled out by Woodside because of societal and environmental issues.
 - May be reconsidered as a potential site for the quality of its location (road access and air strip), ocean conditions (deepwater less than 2 kilometres offshore and partially sheltered) and its acceptable topography.
- **North Kimberley**
 - Bigge Island (North and South sections)
 - Ruled out by Woodside because of socio-economic and environmental issues.
 - May be considered as a potential site for the quality of its topography (over 300 hectares available) and ocean conditions (deepwater close to coast).

Certain sites have been ruled out for technical reasons, but would require further analysis to confirm this evaluation. The following sites have therefore been incorporated to the scope of this report:

- **North Kimberley**
 - Champagny Island (East and West sections)
 - Ruled out by Woodside because of technical and socio-economic issues.
 - May be considered as a potential site for the quality of its topography (over 300 hectares available, requiring minimum earthworks) and ocean conditions (deepwater close to coast, requirement for a breakwater to be confirmed).
 - Echuca Shoals
 - Ruled out by INPEX because of technical and environmental issues.
 - May be considered as a potential site for its proximity to the Ichthys field, but feasibility and reliability of such offshore development to be further evaluated.

In addition, GCA has reviewed the potential of the sites within King Sound. These sites, which have been ruled out by Woodside and/or INPEX due to strong currents and tidal ranges impacting LNG carrier access, include:

- Deepwater Point (Woodside and INPEX)
- Swan Point (Woodside)
- Skeleton Point (Woodside)
- Cunningham Point (Woodside)

- One Arm Point (Woodside)
- Sunday Straight Island (Woodside)
- Point Tourment (Woodside)

GCA's assessment of the sites within King Sound from a marine standpoint, based on LNG carrier access, has confirmed their unsuitability for LNG developments (**Appendix II**). Therefore, these sites have not been shortlisted for a further evaluation according to the study criteria.

2.2 Technical Issues Governing Site Selection

2.2.1 Distance to Navigable Water and Port Suitability

Marine Facilities Availability

Potential availability of a suitable port for LNG and associated products is critical for any LNG development. As LNG production is completely integrated and individual product flows cannot be isolated from one another, the inability to off-take any product, once available storage has been exhausted, will cause the reduction or interruption of LNG production. For example, since condensate is produced concurrently with the flow of gas, any disruption to the shipping of condensate, if no additional condensate storage is available, will disrupt LNG production. The same problem exists in the case of LPG extraction and storage.

Variable or low availability of marine facilities at a selected site, for example due to weather conditions, could be mitigated by increasing storage capacity for LNG and associated products. The extra storage would then allow full production rates at the LNG plant for a longer period. Indeed, LNG operators try to run the plant at an even pace, as the plant is cryogenic and therefore LNG production swings could cause thermal shock and equipment damage.

To ensure sufficient marine availability of marine facilities at a given site, one must consider wind factors, surge factors, potential incidence and potential impact of cyclones.

Marine Facilities Concept

To ensure LNG off-take flexibility, the marine terminal should typically be able to accommodate at least three types of LNG tankers: Membrane, Q-Flex and Q-Max.

In addition, the marine facilities are likely to have to accommodate condensate tankers and LPG tankers. However, the requirement to accommodate LNG tankers will depend on the development concept selected by the Operator(s). Indeed, the condensate could also be loaded offshore, typically through an SPM.

TABLE 2
COMPARATIVE SHIP SPECIFICATIONS

Ship Size	Type	LOA m	Beam m	Draft m	DWT
125,000m ³	ALSOC Moss Rosenberg	272	47.3	11.4	66,800
145,000m ³	LNG membrane	283	43.4	11.35	79,084
216,000m ³	LNG Q Flex	315	50.0	12.0	106,900
266,000m ³	LNG Q Max	345	53.8	12.0	125,600
Aframax	Condensate Tanker	238	42.0	14.9	105,215
85,000m ³	LPG Tanker	230	36.6	11.62	54,500

A 15 meter draft berth box is recommended to accommodate the anticipated mix of vessels specified in **Table 2**. This would also apply to the channel, which will need to be a minimum of 300 meters wide, and to the 700 meters swing basin (twice the LOA of Q Max vessels).

If there is insufficient depth to bring LNG tankers close to the coast, it is likely that a longer LNG berth will be required and / or a channel will need to be dredged. Marine engineering will define the optimum combination of jetty length and dredging requirements, from an economic and technical perspective.

Typically, jetty length and dredging requirements will increase project Capex as the distance from the LNG plant to navigable waters increases. Dredging may also have a significant Opex impact, depending on the rate of deposition of silt on the sea bed. Indeed, the channel may need to be dredged on a regular basis, as would be the case close to a river mouth where the silt build up can be significant.

The berths should be in the form of a T Jetty, facing the prevailing wind (i.e. blowing the vessels onto the berth) and parallel to the prevailing current. The overall length should be about 800 metres, with LNG/LPG facilities at one end and condensate facilities at the other. An indicative berth concept plan is displayed in **Appendix IV**.

In addition to the LNG, LPG and condensate off-take facilities, a construction dock will probably be required during the initial plant construction phase. This will allow some of the construction materials, including some very large pieces of equipment specific to LNG facilities, to be shipped to the site.

Marine Facilities Traffic

On a yearly basis, offloading the anticipated production of a stand alone LNG development is expected to require up to 200 LNG ships (12 to 24 Mtpa LNG, depending on average ship capacity), 40 condensate ships (75 kbbl or 10,000 tonnes daily) and 20 LPG ships (70 kbbl or 5,800 tons daily).

Should the terminal serve as a hub, the LNG vessel and cargo traffic is assumed to double, whereas the condensate traffic is expected to increase by about 40% and the LPG traffic to remain constant.

Should the Operators elect to extract and load the condensate offshore, the condensate tanker traffic at the LNG Hub would be substantially reduced. If only residual amounts (<2%) of the produced condensate were recovered at the LNG Hub, trucking of condensate from the site may be an alternative to shipping.

These assumptions have been made for the purpose of estimating comparative ship and cargo exports, based on the stand alone development of Ichthys field and a hub development incorporating Woodside operated production.

TABLE 3
COMPARATIVE SHIP & CARGO EXPORTS

	LNG		Condensate		LPG	
	Ships (no)	Cargo (MM tons)	Ships (no)	Cargo (MM tons)	Ships (no)	Cargo (MM tons)
Browse						
Stand alone development	200	7.5	40	3.65	20	2.12
Hub development	400	15.0	55	5.02	20	2.12
Burrup						
Dampier comparison	209	12.5	49	3.3	29	1.5

Marine Facilities Sizing

The “In Port Time” for all types of LNG and LPG tankers is likely to be a total of 24 hours. The “In Port Time” for the Aframax tanker for condensate is likely to be ~30 hours, based on the current practice at Dampier.

In Dampier, there is typically one berthing window daily for LNG tankers (due to wind factors) while Aframax condensate tankers will only sail at high water on each tide owing to their greater draft. Such ship movement restrictions are critical as the terminal operation functions with a “tank tops” policy, i.e. using storage capacity to its maximum.

In the context of a stand alone development, a combined loading berth would not be suitable for the proposed marine facilities, as this would imply 280 days occupancy per annum (around 76% berth occupancy), which is typically considered unsustainable. In addition, membrane type LNG ships require immediacy of access during the cyclone season, which could be problematic since the condensate tankers are likely to be alongside the berth longer than LNG ships. The minimum marine facilities should therefore include one LNG/LPG berth with a loading station for each product and one multipurpose berth with one loading station for condensate and general supplies. This would be consistent with established practices at Dampier.

In the context of a hub development, with approximately 500 berth days per annum to satisfy the projected ship volume, the minimum requirement would be one dedicated LNG/LPG berth and one multipurpose berth for condensate and general services. However, this would imply 68% average berth occupancy which is generally considered difficult to sustain. One additional LNG/LPG berth would allow lower average berth occupancy.

An SPM facility could only handle the condensate tankers (~20% of the traffic in a stand alone terminal and ~10% in a hub terminal) and is not likely to obviate the need for a second berth on the jetty.

The marine facilities should also accommodate additional tugs to secure the tankers, with a minimum of 5 tugs (including one in reserve), and a minimum of 6 tugs should the facilities include an SPM.

Product Planning and Shipping

LNG companies typically review the complete shipping and LNG storage as one comprehensive activity. Computer models are used to review numbers of LNG tankers needed based on delivery distances, LNG storage, LNG production rates and LNG buyer off-take. Therefore, LNG storage capacity would reflect the turn around time for the LNG tankers, the prevailing weather conditions, the buyers' requirement for LNG and the LNG production rates would be set to match these other parameters.

LNG has been in the past, and to some extent will continue to be, sold on the basis of long term (25 years) sales purchase agreements. On an annual basis the buyers will negotiate with the LNG producers the type of LNG delivery schedule they would like. For the buyers, this is to a great extent based on the requirement of their customers who will receive the re-gasified LNG.

Although most LNG sales and purchase agreements specify that the buyer shall take the LNG on an even off-take basis, this may not consistently be done. The buyers typically prefer to reduce their gas deliveries in the summer months when their own customers require less gas due to the warmer temperatures. During this period of lower LNG demand, the LNG producers typically carry out necessary maintenance on the LNG production facilities. During the winter months, the LNG demand is greater and thus LNG storage and shipping require very close coordination.

Winds and Currents

The North coast of Australia and adjoining sea area are under the influence of the North West and South East monsoon, and of the tropical cyclones that affect the area especially during the summer and early autumn months.

The monsoonal winds drive the currents along the North West coast of Australia, which flow from the North or North East in the period September to February and with a weak counterflow from the South West from March to August. The time of the onset of the monsoon winds varies yearly. There is a low constancy of the predominant direction and the mean rate of the current in this season is less than 1 knot. Flows of 2 to 3 knots have been noted sometimes against the expected direction. During the North East flow, the currents reverse, as a counter current, in the region of the Eighty Mile Beach.

Beyond 60 miles from shore, the currents are East in winter and North West to North East in summer, with branches rotating clockwise sometimes from the North or North East with a current set East or sometimes South along the coast. The onshore component can be up to 2 knots but normally rates of ½ to 1 knot occur with a low constancy. During the month of February, the current is from an easterly direction with high constancy and rate of 1 knot. These change with the advent of autumn to a South West direction with a low constancy of about ½ knot. In winter months the currents are 1 knot in an easterly direction with a high constancy while in November, due to the transitional spring weather, the currents are negligible.

Numerous tidal streams exist in the area as a result of the neap and spring tides experienced in the approaches to the large bays and inlets. Winds in the area are generally smooth or slight except for the seasonal monsoon winds. The lighter North West monsoon produces mainly slight seas, but the tropical cyclones are capable of producing very rough conditions in a short period of time. South East Trade winds also known as the South East Monsoon blow from East and South on the North flank of the high pressure systems (anticyclones) from May to October and are at Beaufort force 4 to 5 wind speed.

The North West or West monsoon prevails in the area between December to February with January and February being the strongest months. It also gives rise to land and sea breezes, the former being a lighter offshore wind that forms around midnight and dies down after sunrise and the latter setting onshore during summer, increasing in the late afternoon to Force 4 and dying down soon after dusk.

Squalls are a common feature of the North West Australian waters and coastal areas during the hot and transition months. The hot season of the North West monsoon is preceded by sharp, short lived squalls of increasing frequency and intensity with gale force winds and thunderstorms.

Overall, the metocean conditions described above are not expected to be unsuitable for the LNG trade in the North and South Kimberley.

However, the coast between Hidden Island and Cape Leveque incorporates the entrance to King Sound, where numerous shoals, reefs & islands extend up to 50 miles offshore, with currents and tidal streams running between 6 and 10 knots with violent tide rips and eddies. The area is presently unsurveyed in many parts and is currently not safe for entry by large deep draught vessels such as Q Flex and Q Max LNG tankers. There is a large variation in the strong spring tides which can have a range between high and low water of up to 11m. Such conditions render navigation dangerous for the LNG trade.

Tropical Cyclones and Storm Surge

Violent tropical cyclone winds form over the North West Australia in the Timor and Arafura Seas mainly during November to April, with most frequent occurrence between January and March. North West Australia experiences on average about four to five tropical cyclones a year. They generate substantial currents that significantly alter the normal pattern. Fetch area, speed of advance and wind strength effect changes to currents. The choppiest weather off North West Australia is associated with the fresh and gusty South East Trade winds and very rough and mountainous seas heralding the advent of a tropical cyclone.

Tropical cyclones form as minor clockwise circulations in low latitudes in the vicinity of the Inter Tropical Convergence Zone (ITCZ) in the area between 10° – 20° south of the equator. They usually move in a West South West direction, and where conditions are favorable the cyclone will deepen and develop. Cyclones generate strong winds from 34 to 64 knots beyond which they are categorised as severe. Winds in excess of 125 knots have been recorded. Hurricane strength is reached by 30% of Australian tropical cyclones and is accompanied by strong winds, torrential rain and mountainous seas which may cause abnormal water levels and storm surge waves. They tend to travel West or South West off the North and North West coasts of Australia at speeds of about 5 to 10 knots and often re-curve towards the South East or South to cross the coast of North West Australia between Onslow and Broome.

However, the paths of cyclones are often erratic which make it hard to forecast exactly when and where a cyclone will cross the coast. This makes it difficult to predict how high the astronomical tide will be when the storm surge strikes since the difference between high and low water is only a few hours. Every cyclone that affects the coast produces a storm surge. This surge is the difference between the actual observed sea level and the predicted sea level. However, not all storm surges rise to dangerous levels. The height of the surge depends on:

- The intensity of the cyclone - as the winds increase, the sea water is piled higher and the waves on top of the surge are taller.
- The forward speed of the cyclone - the faster the cyclone crosses the coast, the more quickly the surge builds up and the more powerfully it strikes.
- The angle at which the cyclone crosses the coast - in general, the more head on the angle, the higher the surge. However, other angles can lead to local zones of enhanced surge in areas such as narrow inlets and bays.
- The shape of the sea floor - the surge builds up more strongly if the slope of the sea bed at the coast is shallow. If the sea bed slopes steeply, or if fringing reefs are present, then the surge will be less.
- Local topography - bays, headlands and offshore islands can funnel and amplify the storm surge.

Many parts of the Australian coastline are vulnerable to storm surge and hence this data is monitored at several locations around the coast by the Australian National Tidal Centre. The combination of storm surge and normal (astronomical) tide is known as a storm tide. The worst impacts occur when the storm surge arrives on top of a high tide. When this occurs, the storm tide can reach areas that might otherwise have been safe. This also causes pounding waves generated by the strong hurricane force winds. The area of sea water flooding may extend along the coast for over 100 kilometres with water pushing several kilometres inland if the local lay of land is low. The combined effects of the storm tide and waves can knock down buildings, wash away roads and run ships aground. This has impacts on recommended LNG site elevation, as detailed in **Section 2.2.3**.

It should be noted that typically Dampier suffers from 3 cyclones per annum in the period November to April. Normally vessels will vacate the port as soon as it is thought such conditions are likely to close the port. Typically, port operations will be adversely effected for up to 3 days when this happens. Prompt departure from the berth is not a problem for Moss Rosenberg LNG, condensate and LPG tankers but can be for membrane LNG tankers, which must complete loading before vacating the berth once

they are more than 10% loaded – this can normally be achieved in no more than 24 hours.

2.2.2 Land Area Requirements

Development Concepts

GCA has defined three main alternatives in the context of the land area required for an LNG Development:

- **Single Operator LNG Hub:-** A site operated by a single entity which has the capability to receive gas from a number of fields and operators. The hub processes gas to LNG, and stores and loads LNG on behalf of the field operators. For this study a maximum of 5 LNG trains and support facilities, within a single LNG plant, requiring 360 hectares has been used as the basis for evaluation.
- **Multi Operator LNG Hub:-** A site that has common infrastructure but where two or more operating entities independently receive and process gas to LNG and independently store and load LNG. For this study two independent operators with a maximum of 10 LNG trains and independent support facilities (except items such as airstrips for example, which would typically be shared), within two LNG plants, requiring 660 hectares has been used as the basis for evaluation.
- **Gas Processing Hub:-** A concept similar to the multi operator hub but which also provides for additional basic “value adding” processes such as Gas to Liquids (GTL), methanol or fertilizer production. For this study a total of a maximum of 10 LNG trains and a number of GTL based facilities (in this example, two GTL plants, one ammonia plant and one methanol plant) have been used as the basis for evaluation. This concept requires at least 950 hectares. More available space could allow for additional independent operators or GTL based facilities.

General Area Requirements

In the context of a Single Operator LNG Hub, GCA recommends to allocate a minimum area of 300 hectares for typical core facilities, such as LNG liquefaction plant, gas treatment facilities, storage tanks, lay down areas, power plant, utilities, onshore pipeline, marine centre and perimeter fence. In addition, an area needs to be allocated for support facilities, such as airstrip, construction camp, staff accommodation, medical facilities and central fire fighting station. This area would typically represent an additional 60 hectares. Therefore, the total area required for a Single Operator LNG Hub would be ~360 hectares.

In the context of a Multi Operator LNG Hub with two or more operators, the size of the core facilities would typically increase by 300 hectares for each additional operator. In the case of two operators, used as a basis for this Study, the size of the core facilities would double, reaching 600 hectares. Indeed, LNG operators, and LNG clients in particular in Asia, put a strong emphasis on the reliability of supply, which favours the concept that each LNG operator should be able to function independently. Each LNG operator would therefore prefer to control its storage, power, utilities, marine centre etc. On the other hand, many of the support facilities could be commonly used, in particular the airstrip, which represents a large part of the support area requirements, as well as medical facilities and central fire fighting station. For the purpose of this study, the area

required for support facilities for two operators is estimated to be 60 hectares, as in the case of a Single Operator LNG Hub. Therefore, the total area required for a Multi Operator LNG Hub would be ~660 hectares.

In the context of a Gas Processing Hub with two or more operators, the size of the core facilities would remain the same as in the case of a Multi Operator LNG Hub. In addition, 150 hectares will be required for two GTL plants (75 hectares per plant), 35 hectares for an ammonia plant and 60 hectares for a methanol plant. The area required for support facilities will also increase, in particular due to the requirement for additional power generation and accommodation for the operation of the gas based industries on site. This would typically represent 100 hectares, therefore, the total area required for a Gas Processing Hub would be a minimum of 950 hectares.

These area requirements have been used for screening purposes when examining possible gas processing hub locations.

TABLE 4

GCA RECOMMENDED LAND AREA REQUIREMENTS (HECTARES)

	Single Operator LNG Hub	Multi Operator LNG Hub	Gas Processing Hub
Core facilities (1)	300	600	>600
GTL plant	0	0	150
Ammonia plant	0	0	35
Methanol plant	0	0	60
Support facilities (2) (3)	60	60	100
TOTAL	~360	~660	>950

Notes:**(1)** Inclusive of:

- LNG liquefaction plant
- Gas treatment facilities
- Storage tanks
- Lay down areas
- Power plant
- Utilities
- Onshore pipeline
- Marine centre
- Perimeter fence

(2) Inclusive of:

- Construction camps
- Central fire station and workshops
- Accommodation for staff
- Hospital
- Airstrip for moving people and smaller equipment

(3) Inclusive of:

- Power generation for gas based industries

LNG Plant Construction

Typical grassroots LNG plants take approximately 40 months to construct and require substantial manpower. The usual critical path is the construction of the concrete LNG storage tanks.

For example, it is not uncommon for grass roots plants in the Middle East to have 6,000 to 8,000 workers on site during the peak construction period. This peak would correspond to a point approximately 3 years into the construction period.

In Australia, with the use of modular construction, this manpower could be reduced to approximately 2,000 to 3,000 workers, but with a substantial increase in the construction labour required at South East Asian module fabrication sites. However, the manpower requirements will depend on the contracting strategy selected by the LNG Company.

Construction Area Requirements

The area requirement for construction activities is a function of the type of contracting strategy employed. For example, if a significant proportion of construction activities take place on site, the construction area requirements could be as high as 20% of the overall area. Large pipe fabrication requirements or pre casting of concrete would require large areas.

However, it is often more cost efficient to have parts of the plant constructed remotely and then have these modules shipped to the site. This represents considerably less assembly work and construction manpower than what would have been required with on site construction. This modular concept, where pipe fabrication is taking place offsite for example, also reduces the amount of area allocated to construction activities.

Therefore, construction area requirements will typically represent 20%, or less, of the total area allocated for the facilities.

Construction Camps

Under a typical Engineer Procure and Construct (EPC) contract used in the construction of LNG plants, it would be the responsibility of the contractor to provide the accommodation and recreational facilities required for his work force. It is also normally required for the EPC contractor to remove these facilities when the plant construction is complete. It is not unusual for the LNG plant operating company to reserve the right to purchase the camp at the end of construction. These facilities can be put to other uses such as training facilities or accommodation for large work groups during major LNG plant maintenance, when up to 200 additional workers could be required.

In the case of a common LNG hub it would be appropriate to retain the first construction camp for further use by other contractors to prevent camp re-construction and removal on a frequent basis. This should be a decision made early in the planning for a common LNG hub.

2.2.3 Site Elevation and Gradient

Site Elevation

Site elevation can be a critical factor in the selection of a suitable site on which to construct an LNG plant.

An LNG plant located at an elevation equal to the sea level would be exposed to potential flood damage in the event of storm surge. LNG plant equipment would be severely damaged by the ingress of water. It is also important to note that LNG buyers consider an LNG operator's ability to supply LNG on a reliable basis a critical factor in selecting that supplier. Installing an LNG plant at sea level where water damage due to storms or floods could occur would be seen as a significant risk by potential LNG buyers.

For example, an LNG storage tank in Hong Kong is being constructed at an elevation of 20 meters above sea level due to the concern over potential flooding during typhoons. This emphasizes the need for adequate elevation to minimize the risks of water damage and disruption of LNG production.

In the Kimberley area of Western Australia, an elevation of at least 10 to 15 meters above sea level would typically be considered acceptable.

Site Gradient

Site gradient is an equally essential criteria. Indeed, a significant elevation change resulting in steep slope would pose problems for plant construction and operation.

Modular construction would involve loads of up to 10,000 tons, whereas the heaviest load non modular construction would be approximately 1,000 tons. Self Propelled Modular Transporters, typically used to transport such equipment arriving by land or by sea, can typically operate with 10% gradients, but for large modules over 500 tonnes, this limit would be reduced to a maximum of 5% because of traction, Centre of Gravity (CoG) shift, ground surface issues etc.

From an operational point of view, having the plant at an elevation greater than the loading berths, which must be at sea level, would not be an issue. Typically, drainage of rain water on an elevated site would be effective, which is an asset in considering site selection.

Therefore a maximum site gradient of ~5% should be considered in site selection, mainly because of construction constraints. However, earth works can to some extent reduce the slope in the areas where heavy materials will be hauled, but at a significant cost especially if the site is rocky and requires a large amount of blasting.

2.2.4 Proximity to Gas Fields

The main impact of the distance between the plant site and the offshore gas fields is related to pipeline length.

Pipeline Construction and Installation

Pipelines from the offshore fields to the LNG facilities are a major expense and pipe procurement can lead to significant project delays. There are also some technical limitations to the maximum length of pipeline possible before booster compression is required. Technically, the current frontier for pipeline length is:

- Snøhvit – Raw Gas / multiphase pipeline – 143 kilometres
- Nam Con Son – Dehydrated Gas / two phase pipeline – 400 kilometres
- Langeled – Processed Gas / single phase pipeline – 1,200 kilometres

The distance from the gas fields to the LNG plant is mostly an economic and schedule issue. The longer the pipeline length the greater the cost and longer the procurement timeline will be. In addition, greater pipeline lengths also require additional compression. Indeed, pressure drop losses in the pipeline will increase with length and will necessitate additional compression to ensure the gas arrives at the required LNG Plant inlet pressure of approx 1,000psi (70bar). Additional compression platforms may be required

for pipeline lengths over ~500 kilometres, with an expected three compression platforms required for a distance of ~1,000 kilometres. These represent significant additional investments. The typical cost of a compression platform is in the range of US\$200MM to US\$400MM.

Pipeline Operation

In addition to the cost of original installation, longer pipeline length will also lead to increased annual maintenance and inspection costs. All subsea pipelines require annual inspection for both the external condition and the internal condition.

The internal pipeline condition is normally determined by the use of “intelligent pigs”. These are devices which travel through the pipe and are able to determine the internal condition of the pipeline. The normal areas of concern within a pipeline would be internal corrosion or possibly internal cracks on the steel surface due to either fatigue or from stresses induced by long unsupported pipeline spans.

External pipeline inspection is normally conducted to check for damage to the pipelines due for instance to ship anchors or fishing trawl boards. If pipelines have been trenched, external inspection would also reveal if the pipeline is actually in the trench or not. It is often difficult to lay pipelines directly in the trench that has been cut for installation, and essential to know to what extent the pipeline is not completely in the trench.

With multiphase pipelines, where gas is the major component, there will be liquid drop out as the pressure declines and the longer the pipeline the more this is likely to generate technical issues. Significant changes in sea floor elevations can also hold up liquids, resulting in liquid slugs, which operationally can be difficult to handle. These would typically also have an impact on the LNG related facilities, increasing the required size of the onshore “slug catcher”. Substantial flow assurance analysis by the operator is required.

The operation and maintenance of multiple compression stations offshore, which may be required depending on pipeline length, can have significant impacts on operating costs mainly due to the logistics of moving and accommodating personnel and personnel to the offshore locations.

Distance to Gas Fields

The length of the required pipeline will result in significant capital and operating costs for the upstream portion of the LNG project and have an impact on overall project economics. Such impact is not only the result of higher capital cost but also a significant increase in fuel consumption of the intermediate compression platforms, where needed, with accompanying increase in carbon footprint. Therefore, shorter pipelines would typically be preferred by LNG developers, with pipelines in the range of 400 to 500 kilometres typically being considered a maximum.

TABLE 5

DISTANCE FROM GAS FIELDS TO SHORTLISTED SITES
(In a straight line, approximation in kilometres)

	INPEX Ichthys	Woodside Browse (Scott Reef)
North Kimberley		
Maret Islands	200	340
Biggie Island	215	360
Champagny Island East	190	290
Wilson Point	220	320
Koolan / Cockatoo Islands	~250	~300
South Kimberley		
Cape Leveque	280	290
Lombadina (Packer Island)	300	300
North Head / Perpendicular Head	~330	~300
Quondong Point	425	390
Fisherman's Bend	460	440
Offshore Kimberley		
Scott Reef	150	0
Echuca Shoals	75	200
Existing developments		
Burrup (NWS & Pluto)	1,020	910
Darwin (Darwin LNG)	830	980

2.2.5 Proximity of Plant Site to Coastline

The proximity of the LNG plant to the coast is important as it impacts LNG rundown lines and construction access.

LNG Rundown Lines

Typically there are two types of rundown lines:

- from the LNG production facilities to the LNG storage tanks,
- from the storage tanks to the LNG loading berth.

These lines are transporting LNG at cryogenic temperatures (approximately minus 165 degrees Celsius) and as such require special steel and also significant insulation in order to maintain the cold temperature.

LNG rundown lines typically cost in the range of US\$25-30MM per kilometre. In addition to the significant costs, there are also technical issues if the lines are too long, which can cause gas to escape from the liquid LNG. Should this happen in the LNG rundown lines from the LNG production facilities to the LNG storage tanks, these would then contain excessive gas. The gas is however captured in the tank gas recovery system and is typically returned to the plant fuel gas system. Should this happen in the loading lines which transport the LNG from the storage tanks to the LNG tankers in the harbor, the excess gas would then typically be vented when loading. In some plants this gas is now captured and returned to the fuel gas system.

In considering sites for LNG facilities, a maximum distance of 5 kilometres from the LNG plant to the LNG storage tanks and another 5 kilometres from the LNG storage tanks to the loading berth are recommended. To minimize costs, it would be optimum to have the distance from the LNG plant to the tanks and from the LNG tanks to the LNG loading berth to be 1 kilometre each.

Construction Access

The proximity of the plant to the coastline will also impact the construction of the plant. In most cases, the plant construction will require the importation, by sea or road, of the construction materials and equipment. If importation is done by sea, then road transportation will be necessary from the construction dock to the LNG plant site. Construction materials can be considered in two distinct categories: major equipment (turbines, heat exchangers, vessels etc), and bulk materials (piping, fittings and other smaller equipment).

Bulk materials, for example pipes and fittings, are normally shipped in containers by container ship from overseas. Normally container ships will only call at specific ports designated as "ports of call" by their company and as a result the containers would need to be offloaded and then transported to the LNG site by barge or road.

In the case of major equipment or bulk materials transported by sea, the longer the distance from the plant to coastline, the more costly this ground transportation will be.



LNG flow to tanker overview
(Qatargas sample)

Proj. K1177 May08 Checked: *mdf* Fig. 3

LNG Tanks

The distance to the coastline will also have an impact on the location of the LNG storage tanks. Indeed, for safety reasons the LNG storage tanks are located at a minimum distance from the LNG plant. It is also customary to consider grouping all the necessary product tanks in one location. Depending on the adopted development concept, the incoming gas may contain condensate which must be separated, stabilized (excess gas removed) and stored at the LNG plant site. This could also be done directly offshore, before piping the gas, in some cases.

LPG's are also removed from the gas as part of the LNG production process. LNG is normally sold on the basis of the heating value of the gas. This can vary from country to country; however 1050 Btu's/ standard cubic foot is the value often used as a standard. To achieve this heating value requires the removal of LPG's. These LPG's are typically used as components of the refrigerant used to liquefy the gas and excess LPG can be extracted and sold separately.

A typical storage tank area in an LNG plant would include LNG, LPG and condensate storage tanks. Normally all these tanks would be grouped together at a specific distance from the LNG production facilities.

The tank area would also have containment walls as a separation from other products and to hold any spillage from the tanks in the event of catastrophic tank failure. Most LNG tanks are "full containment" which means that if the internal metal tank fails the LNG liquid would be contained by the outer concrete shell and no spillage to the atmosphere would occur.

LNG Loading

Some LNG vaporizes during normal LNG loading. The amount of gas liberated during loading is a function of the temperature of the ship's LNG tanks. Normally, LNG tankers will carry an LNG "heel" in the tanks. After LNG discharge at the receiving terminal, a small amount of LNG will be left in each LNG compartment in the ship. This heel of LNG serves two purposes, it allows gas to boil off from the liquid LNG which can be used as fuel for the LNG tanker boilers and it will be used to cool down the LNG tanks prior to arrival at the LNG loading port.

The temperature of the LNG tanks will directly affect the LNG loading rate. The LNG compartments in the LNG tanker can only be cooled down at a specific rate since the steel in the tanks cannot tolerate a fast temperature reduction. Faster than normal cooling down of the steel in the tanks could cause possible tank failure, resulting in LNG spillage. The LNG tanker can cool down the storage compartments by spraying LNG on the walls of the tanks and therefore making them ready for LNG loading.

If the tanks have not been reduced to an acceptable loading temperature by the tanker, then the only way to cool them down is to load LNG into the vessel and let it flash off in the tanks to reduce temperature. The gas would then be flared or recycled into the LNG plant system. It then takes much longer to load the LNG tanker. Normal LNG tanker loading can be achieved in ~12 hours (based on a tanker of 140,000 cubic meters) whereas the same tanker could take up to 24 hours to load if the tanker comes into port "hot" (minimum tank cool down by the tanker).

2.2.6 Pipeline Approach

The arrival of the offshore gas pipeline to the onshore LNG plant can encounter a range of technical challenges.

Should the selected site be surrounded by cliffs, and not have beaches, the pipeline approach may require significant earth works. This would be necessary to ensure an acceptable pipeline slope, failing which operational difficulties may arise, particularly if the arriving pipeline carries multiphase flows.

Should the selected site have suitable beaches, the pipeline would have to make a beach crossing. However, this can cause long term damage to the beach, disrupt the natural surroundings and the animal population if not handled properly.

Typical approaches would include burying the pipelines or elevating them over the beach and supporting them by an above ground structure. The latter would be highly visible and may not be acceptable from an aesthetic point of view. Cutting the beach and burying the pipeline would be the normal shore approach design; however care in design is needed to ensure that the tides do not uncover the pipelines, requiring future remedial action.

To remove this risk, constructing a culvert or subterranean tunnel through which to pass the incoming pipelines could be considered. This type of approach would also be very useful when considering future pipeline expansions for increasing LNG capacity of the existing plant, or bringing in new gas discoveries to the LNG plant for processing, as would likely be the case for an LNG hub.

An initial underground installation, with spare capacity for future lines, would eliminate the need for multiple beach disruptions and minimize the risks of the pipelines being unearthed and damaged.

2.2.7 Geotechnical conditions

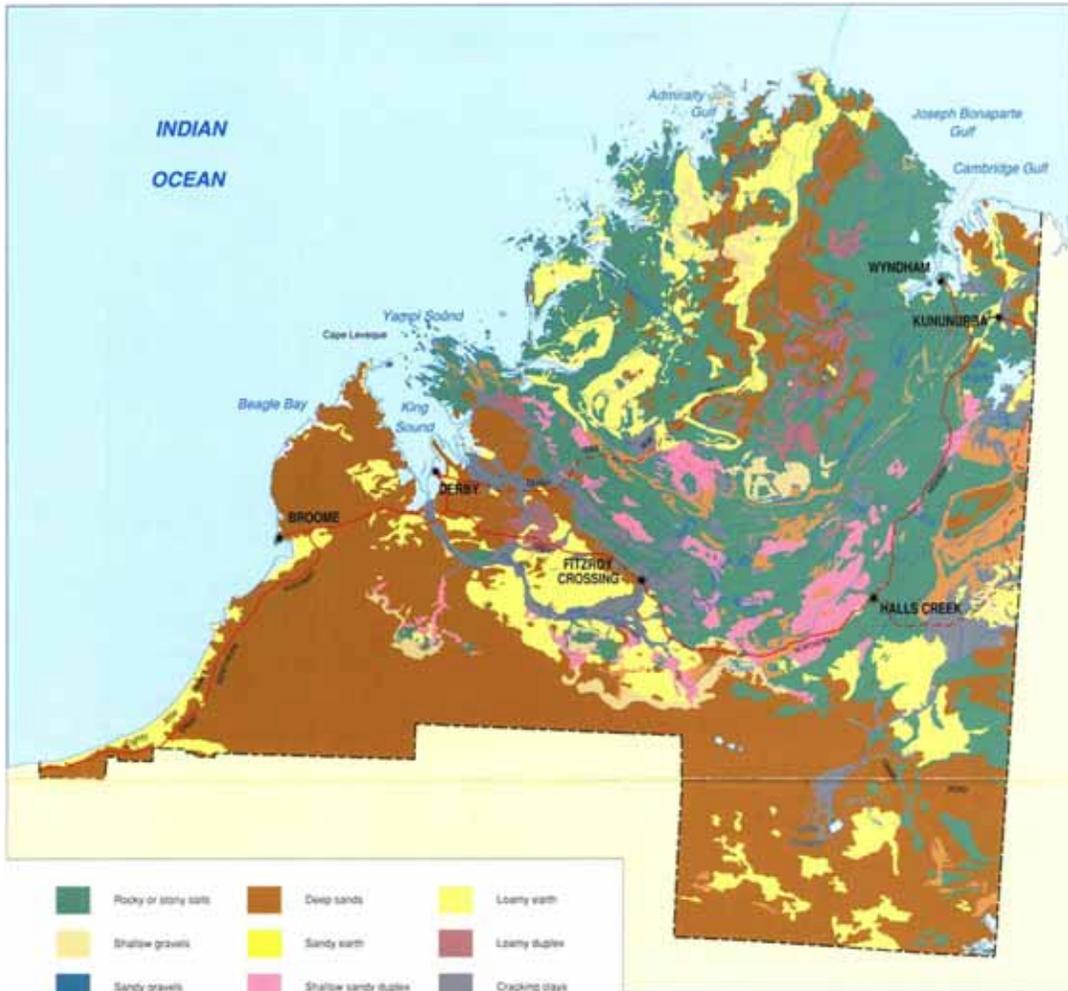
Geotechnical conditions can influence the choice of the LNG plant site and have significant impact on the subsequent costs. LNG facilities require substantial foundations that are able to withstand earthquake, cyclones etc. At the same time, earth works to get a level site are easier if the soil is relatively soft and does not require blasting.

If the site is particularly rocky, preparing the site would involve considerable blasting of the rock followed by reduction of the rock to a manageable size for use as fill. The positive aspect of a rocky site is that equipment foundations will be solid and require limited or no piling.

As a comparison, a site with a soft type of soil would require piling for most of the major equipment. It is possible to install LNG plant equipment on reclaimed land. In Qatar the LNG tanks for the RasGas project were installed on reclaimed land, which required 400 piles under each 130,000 cubic meter tank. This type of piling would increase the anticipated tank cost by approximately 10%. The LNG plant site in the Angolan LNG project, at the mouth of the river Congo, will be partially installed on reclaimed land. While this type of installation will increase the costs, it is technically feasible.

In economic terms, there will be an offset between the costs of rock removal versus another site where piling may be necessary prior to equipment installation. The type of terrain and the amount of cut and fill would need to be precisely assessed to evaluate the costs involved in preparing the site.

Most of the potential LNG sites considered in the Kimberley area have either deep sandy soils (pindan soil in the South Kimberley) or rocky / stony soils (in the North Kimberley) (**Figure 4**). The impacts of these would need to be considered in the estimation of the geotechnical works required to ensure suitability for LNG facilities.



- | | | | | | |
|--|----------------------|--|----------------------|--|--------------------|
| | Rocky or stony soils | | Deep sands | | Loamy earth |
| | Shallow gravels | | Sandy earth | | Loamy duplex |
| | Sandy gravels | | Shallow sandy duplex | | Cracking clays |
| | Loamy gravels | | Deep sandy duplex | | Non-cracking clays |
| | Shallow sands | | Shallow loams | | Wet soils |

KIMBERLEY REGION DOMINANT SOILS

- Major Roads sealed / unsealed
- Secondary Roads sealed / unsealed
- Minor Roads
- Region Boundary
- Rivers
- Lakes
- Major Towns (population > 5000)
- Urban Centres (population > 500)



THEME	SOURCE	DATE
Culture	DLA	1987
Transport	DLA	1987
Hydrography	DLA	1987
Name	DLA	June 1988
Soils	Atlas of Australian Soils	1988
REVISED		November 1998

DATA SOURCE SCALES VARY GREATLY.
MAP PRODUCT IS TO BE USED FOR BROAD BASED PLANNING ONLY.

**Kimberley Region
Dominant Soils**

Proj. K1177 May08 Checked: *mof* Fig. 4

2.2.8 Proximity to existing infrastructure

Existing infrastructure to assess would include: road access, port facilities, materials offloading facilities and laydown, construction camp, operations accommodation, airstrip, warehousing, supply base, marine offloading facility, access to quarry / construction materials, regional hospital facilities.

Consideration should also be given to services such as communications, utilities, law enforcement / security, customs and emergency response services.

Roads

The existence of infrastructure in the general area of a potential LNG plant site will have a significant impact on the selection of that particular site. For example the existence of heavy haul roads in the area would allow heavy modules to be delivered to the site with minimal expense, whereas other sites with no infrastructure would require the building and maintaining of roads at considerable cost and potential environmental impact. Existing roads would also allow the easy movement of personnel for both the construction phase and the operational phase of the project. The typical cost of an unsealed road is in the range of USD100 thousand per kilometre.

The onshore sites located in the South Kimberley will typically have some road access, which could require upgrading to become suitable to the transportation of heavy loads in all seasons. The onshore sites located in the North Kimberley will have very limited existing road access. These would require either the creation of new roads or the decision to transport all the material by sea, as would be the case for an offshore site.

Airport

Staffing an LNG plant in a remote location requires the operating company to make the decision whether to have their employees live close to the plant site accompanied by their families or to have the employees work on a rotational basis (fly in / fly out).

If the rotational basis is selected, at least 400 employees will be required to fill 200 positions at the plant (these numbers are for illustrative purposes only), due to the rotation and the requirement for additional personnel to cover vacation periods and sickness. The costs implied with this option could on the other hand offset the need to build a community to house the workers and their families. Building such a community will be a capital cost of the project, whereas the extra cost associated with having the workers on rotation will be an operating cost.

In either case, an existing airport close to the LNG plant site would be a substantial asset for the site selection, since the cost of constructing and operating an airport would not be required in the overall project costs. The typical cost of an airfield with appropriate capabilities and facilities is in the range of USD50 million.

Several airfields are in operation in the South Kimberley, close to the potential sites. Airfields also exist on the Koolan and Cockatoo islands in the North Kimberley, but would have to be built for the project in most other cases.

Harbour

Suitable facilities for export of products are one of the critical requirements for an LNG project. In the event that marine conditions prevent simple jetty structures for LNG and LPG loading, and in order to facilitate other activities such as tugs, pilot vessels and emergency response equipment, a conventional harbour may be required. The existence of a suitable harbour close to the potential LNG plant site would have a significant impact on the final selection of the LNG site.

During the construction phase of an LNG project, the existence of a harbour would also make the landing of construction materials easier and much less costly than having to construct a construction berth. In summary the existence of a harbour close to a potential LNG plant site could influence the selection of that site.

Electric Power

Electrical power is a key utility in the successful operation of an LNG plant. In remote locations, LNG plant operators would typically construct their own electrical power generation facilities. The power requirements of an LNG plant are dependent on the compressor drive philosophy adopted by the operator, with large gas turbine drives now being favoured to reduce costs. Direct power generation would also be reduced in these circumstances.

Capital expenditure on power generation could be removed from the owner's costs if there is existing electrical power available from a local power plant. From an operational point of view, an LNG plant operator might be reluctant to become reliant on an external supply of electrical power since the LNG reliability would then be tied to the reliability of the power generating company and would be a significant factor that could not be controlled by the LNG Company. The use of electrical power from a utility company could be a win-win for local industry and the LNG company who will be able to reduce the capital cost of the project by eliminating the power generation facility.

Local Towns

The existence of local towns close to a potential LNG plant site would have a positive impact on the site selection due to the availability of services, the possibility to house the permanent labour force for the LNG plant and potentially add to the community by moving employee's families.

There would also be some infrastructure surrounding the local town that would benefit the potential LNG project. During construction, there will be a large need for services for the very large construction work force, which could reach 3,000 employees. Rather than import all the necessary services, some could be provided by the local community. This would also allow the local community to develop some business opportunities for their own benefit.

The existence of a town close to a potential LNG plant site could be considered an asset for this location.

Available Local Labour Pool

One of the challenges in developing an LNG project and an LNG operating company is the sourcing of adequate labour to operate and maintain the plant. Locally available labour force would benefit the LNG plant operator.

In the context of the Kimberley, it is anticipated that the local labour pool would not be sufficient to meet all the LNG plant needs.



KIMBERLEY REGION KEY FEATURES



Produced by the Geological Survey of Western Australia.
Map product is to be used for broad based planning only.
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September 2008

THEME	SOURCE	DATE
Cultural	DLGWA	1998
Transport	DLG	1998
Hydrography	DLG	1998
Towns	DLGWA	Nov 2005
Local Government	DLG	2004
Aboriginal Communities	Department of Indigenous Affairs	2004
Important Resource Projects	DLG - modified from MINEREX and RIRMG databases	Nov 2004

Kimberley Region Key Features

Proj. K1177 May08	Checked: <i>[Signature]</i>	Fig. 5
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2.3 Sites Evaluation and Likely Technical Issues for an LNG Hub

2.3.1 North Kimberley: Maret Islands

TABLE 6

MARET ISLANDS LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	Y	Y	N
Multi Operator LNG Hub			N						
Gas Processing Hub			N						

Navigable Water for LNG Carriers & Port Suitability

The Maret Islands have suitable marine conditions to support LNG operations. Breakwater, capital and maintenance dredging are probably unnecessary. Variability of depth contours around the island is to be noted, with deep water close inshore on North West and South West extremities of the Islands. These will probably affect berth and plant location.

For the purposes of this study, GCA estimates this site would require a ~500 meter jetty.

Land Area Requirements

The Maret Islands appear to have an area of ~360 hectares of usable land, which would be sufficient for a Single Operator LNG Hub, but would be unsuitable for a Multi Operator LNG Hub or a Gas Processing Hub. Precise surveying would be required to confirm the exact area of usable land.

In addition, the airstrip and accommodation would need to be at a safe distance from the processing facilities, which further constrains the development options on Maret Islands. To achieve this purpose, INPEX has proposed to place all process facilities on the South Island and all other facilities on the North Island.

Site Elevation and Gradient

The Maret Islands are relatively flat, with elevation ranging from sea level to ~35 meters, which would be acceptable for construction of facilities:

- North Island: ~150ha, with a peak elevation of ~35 meters
- South Island: ~210ha, with a peak elevation of ~25 meters

Proximity to Gas Fields

The Maret Islands are located ~200 kilometres from the INPEX operated Ichthys field and ~340 kilometres from the Woodside operated Browse (Scott Reef) fields. This distance does not present any specific issues in terms of pipeline construction.

For the purposes of this study, GCA estimates the pipeline length as the straight line distance from the fields to the site.

Proximity of Plant Site to Coastline

The plant site could be within one kilometre from the coastline, which is technically suitable.

Pipeline Approach

The capacity and size of the gas pipelines from the individual fields dictates that they would be run separately from each field with a separate landfall on the island. The normal construction technique for shore approaches appear to be viable at this location, although alternatives (such as underground culvert) could be considered to reduce disruption of the beach.

Geotechnical Conditions

The Maret Islands do not show any signs of erosion, flooding or weather impact. Geotechnical studies have been completed at the site, which have concluded that the geotechnical conditions on Maret Island are suitable for an LNG facility.

Proximity to Existing Infrastructure

The Maret Islands are relatively isolated with essentially no infrastructure in the vicinity. The closest significant harbour is Derby, ~420 kilometres from Maret Islands. The port of Broome is ~530 kilometres from Maret Islands. The closest airstrip for passenger transportation is located on Cockatoo Island which is 235 kilometres distant.

Summary Evaluation

The Maret Islands can accommodate a Single Operator LNG Hub, but could not accommodate a Multi Operator LNG Hub or a Gas Processing Hub due to the constraint of land area.

The Maret Islands would be technically suitable from a marine standpoint.

INPEX have suggested a development on Maret Islands that could ultimately produce up to 31.8 Mtpa of LNG from a Single operator LNG facility. This facility would have an initial LNG production of 8.4mtpa and could be expanded to the maximum capacity by adding trains. GCA concurs with this assessment.

2.3.2 North Kimberley: Bigge Island

TABLE 7

BIGGE ISLAND LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	Y	Y	N
Multi Operator LNG Hub			Y						
Gas Processing Hub			Y						

Navigable Water for LNG Carriers & Port Suitability

Bigge Island (North) has deep water at the Western edge of the island, but is exposed to the weather. This may require breakwater protection. Elsewhere shallow water exists that may require dredging and / or long jetties.

For the purposes of this study, GCA estimates this site would require a ~500 meter jetty.

Land Area Requirements

Bigge Island has over 950 hectares of available land. This is sufficient area for the development of a Gas Processing Hub.

Site Elevation and Gradient

Bigge Island appears to be terraced with elevations ranging from 15 to 45 meters on the North West coast of the island where the possible site has been identified. From available data, it appears that adequate land with acceptable gradient exists for the development of a Gas Processing Hub.

Proximity to Gas Fields

The Bigge Island potential LNG hub site is located 215 kilometres from the INPEX operated Ichthys field and 360 kilometres from the Woodside operated Browse fields. No insurmountable technical problems are anticipated in installing pipelines from these fields to the Bigge Island site.

For the purposes of this study, GCA estimates the pipeline length as the straight line distance from the fields to the site.

Proximity of Plant Site to Coastline

There are no apparent technical issues regarding the possible distance of the plant site from the coast, since at this location a distance of approximately one kilometre would be anticipated.

Pipeline Approach

The coast of Bigge Island has a few small sandy beaches which could serve as a landfall location for the incoming gas supply pipeline for a single LNG plant. It is not anticipated that installing the two lines necessary for a two plant LNG hub would be problematic. Multiple facilities that could be present in a major gas processing hub may be developed on a staggered basis and may source gas from different fields. In considering a master plan for the development of a gas processing hub it could be appropriate to consider an under ground culvert that would pass under the beach with all incoming lines then passed through the culvert or tunnel with minimum disruption to the beach.

Geotechnical Conditions

Bigge Island terrain is weathered, with a rugged and rocky surface. Detailed survey work would be required to estimate the earth works involved in site preparation. Earth works required are assessed as substantial at this stage.

Proximity to Existing Infrastructure

Bigge Island (North and South) is uninhabited and a stopping point for cruise and charter boats. The Island is located ~410 kilometres from Derby which has port facilities and the closest airstrip is located at Cockatoo Island which is ~230 kilometres from Bigge Island. There is no existing infrastructure on the island or the surrounding area that would assist an LNG development.

Summary Evaluation

Bigge Island has adequate area to cover any of the possible development options. The land has some undulations and rocky surface which is expected to require substantial work for site preparation. There is no existing infrastructure on Bigge Island; this would have to be installed as an integral part of the project. Multiple pipeline beach crossings for a potential gas processing hub may require further study to develop a suitable technique which minimises or eliminates any damage to the beach. Bigge Island would be technically marginal from a marine standpoint.

2.3.3 North Kimberley: Champagny Islands

TABLE 8

CHAMPAGNY ISLAND LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	N	Y	N
Multi Operator LNG Hub			N						
Gas Processing Hub			N						

Navigable Water for LNG Carriers & Port Suitability

Champagny Island has deep water close to the coast but is exposed to strong currents, swells and seas and may therefore require a breakwater. Detailed marine surveying would be required to confirm LNG carrier access.

For the purposes of this study, GCA estimates this site would require a ~500 meter jetty.

Land Area Requirements

Champagny Island has a total usable area of approximately 360 hectares, due to the irregular shape of the land and the jagged coastline. This would be suitable for a Single Operator LNG Hub, and there would be options for limited expansion. However, the construction of a Multi Operator LNG Hub or a Gas Processing Hub would not be feasible.

Site Elevation and Gradient

The potential site for the installation of facilities has elevations ranging from 10 to 40 meters. The rest of the island has low elevations, which would not be suitable for the safe operation of an LNG plant. The island appears to be rocky with little or no sandy beaches. Site gradient would be acceptable for the movement of heavy construction equipment.

Proximity to Gas Fields

Champagny Island is located 190 kilometres from the INPEX operated Ichthys field and 290 kilometres from the Woodside operated Browse fields. There are no insurmountable pipeline issues surrounding gas lines from the offshore fields.

For the purposes of this study, GCA estimates the pipeline length as the straight line distance from the fields to the site.

Proximity of Plant Site to Coastline

The topography of the island is such that there will be no technical problems with the distance of the LNG plant from the shore, which is likely to be less than one kilometre.

Pipeline Approach

It appears that the coastline of the island is rugged with essentially no beaches which would make the landing of the pipeline onshore potentially technically challenging. In this type of terrain it may be necessary to carry out some blasting to allow an appropriate landfall for the incoming gas pipeline. Close study of this would be needed before making a decision to utilise the Champagny Islands as a possible LNG plant location.

Geotechnical Conditions

Minimum earthworks are anticipated on this site, as the island is relatively flat.

Proximity to Existing Infrastructure

There is no existing infrastructure on Champagny Island. Access would be by air and sea. An airstrip would have to be constructed. All construction equipment would have to be transported to the island by sea. The construction of a suitable offloading facility would also be required.

Summary Evaluation

Although the total surface of the Champagny Islands would almost meet the overall requirement for a Multi Operator LNG Hub, due to the geometry of the island it would not be possible to install two separate LNG plants.

It should also be noted that a considerable section of the area, which has not been selected for the LNG site, has an elevation insufficient for the safe operation of such an infrastructure.

The land fall for the incoming gas line would also be technically challenging.

2.3.4 North Kimberley: Wilson Point

TABLE 9

WILSON POINT LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	N	Y	Y	Y	N	N
Multi Operator LNG Hub			Y						
Gas Processing Hub			Y						

Navigable Water for LNG Carriers & Port Suitability

Wilson Point would be a technically suitable site from a marine standpoint. Neither capital nor maintenance dredging would be required; the jetty length is likely to be small. A breakwater would probably not be required.

For the purposes of this study, GCA estimates this site would require a ~500 meter jetty.

Land Area Requirements

Wilson Point is a coastal location, where available land is constrained by the steep slope of the terrain. There is sufficient land available to construct any of the types of hubs considered.

Site Elevation and Gradient

Wilson Point is an elevated site with cliffs on the shore line. The potential site elevation increases to 50 meters within 500 metres from the coast and significant elevation range (from 15 meters to over 110 meters within a 950 hectares site). The gradient for heavy construction equipment would be challenging as would be the overall construction effort. Considerable earth works would be required which would result in significant costs.

Proximity to Gas Fields

Wilson Point is located 220 kilometres from the INPEX operated Ichthys field and 320 kilometres from the Woodside operated Browse fields. No technical issues are apparent with the pipelines required from these fields to the potential LNG plant site.

For the purposes of this study, GCA estimates the pipeline length to this site to be ~220 kilometres from the INPEX operated Ichthys field and ~320 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

The plant site is situated relatively close to the coast and no technical issues are envisioned in this context. The distance from the plant site to the coastline is likely to be less than one kilometre.

Pipeline Approach

Several sandy coves exist which would allow the offshore pipeline to be landed in a beach environment. The cutting of the beach could be achieved with the necessary remedial work to restore the beach to its original state.

Geotechnical Conditions

Significant earthworks are anticipated at Wilson Point, in part due to the cliffs and relief along the shoreline. These earthworks may be complicated by hard rocks in the area and possible fault lines.

Proximity to Existing Infrastructure

Wilson Point is in a relatively remote area. The closest port would be Derby which is located ~270 kilometres from Wilson Point by sea. There are airports at Derby and Fitzroy Crossing which is ~330 kilometres by land from Wilson Point.

Summary Evaluation

Wilson Point could be developed as a Gas Processing Hub; however site preparation would be difficult and would result in significant costs. Landfall of the offshore pipeline presents some issues however these can be overcome. The plant can be laid out in such a manner that the distance from the LNG tanks to the coast is kept within one kilometre.

There is no infrastructure in the area of Wilson Point, and further studies would be required to confirm the possibility of constructing a road into the location. Consideration would be given to use of marine access through an offloading facility for import of heavy construction equipment. Wilson Point would be technically suitable from a marine standpoint.

2.3.5 North Kimberley: Koolan Island

TABLE 10

KOOLAN ISLAND LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	N	Y	Y	N	Y	Y
Multi Operator LNG Hub			N						
Gas Processing Hub			N						

Navigable Water for LNG Carriers & Port Suitability

The South side of Koolan Island presents suitable marine conditions and a breakwater or a long jetty would not be required. However, consultation with the iron ore mining Operator would be required to confirm the possibility of additional maritime traffic and berthing generated by the LNG operation, without disrupting current mining operations.

For the purposes of this study, GCA estimates this site would require a ~500 meter jetty.

Land Area Requirements

Koolan Island has an available area of more than 360 hectares, which would be sufficient for a Single Operator LNG Hub.

However, much of the land is reserved for hematite production, which recommenced in early 2007. The island is currently mined by Mount Gibson Iron (having taken over Aztec Resources in February 2007), which have a mining lease for ~12 years.

Site Elevation and Gradient

Koolan Island elevation increases to 150 meters within 2.3 kilometres from the coast, which would pose significant technical challenges for an LNG development.

Proximity to Gas Fields

The Cockatoo and Koolan Islands are located ~250 kilometres from the INPEX operated Ichthys field and ~300 kilometres from the Woodside operated Browse fields.

For the purposes of this study, GCA estimates the pipeline length to this site to be ~250 kilometres from the INPEX operated Ichthys field and ~310 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

The development could possibly be located within reasonable distance from the coastline on Koolan Island (less than one kilometre), but with large elevation changes this needs confirmation through surveys.

Pipeline Approach

The island's topography poses difficulties for pipeline approach. Substantial excavation and / or tunnelling are likely to be required.

Geotechnical Conditions

Koolan Island has cliffs and steep sloping ground. A large portion of the land is occupied by mining activities. Very significant earthworks would be required for this site to be used for an LNG development.

Proximity to Existing Infrastructure

Koolan Island is 5 kilometres east southeast of Cockatoo Island and a distance of ~170 kilometres north of Derby by sea. There is currently a mining operation on the island. Koolan Island is readily accessible by sea and has a functional port. The airstrip is in good condition and could be used for personnel transport. The port on the other hand may require upgrading of the wharf.

Summary Evaluation

There is sufficient area on Koolan Island for a Single Operator LNG Hub. However, this site would require significant earth works to be made suitable for the installation of LNG facilities because of the Island's rough terrain, high elevations and steep slopes. These technical difficulties are compounded by mining operations currently underway on the island. Koolan Island would be technically suitable from a marine standpoint.

2.3.6 North Kimberley: Cockatoo Island

TABLE 11

COCKATOO ISLAND LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	N	N	Y	NA	NA	NA	Y
Multi Operator LNG Hub			N						
Gas Processing Hub			N						

Navigable Water for LNG Carriers & Port Suitability

Cockatoo Island would be a suitable site from a marine standpoint. Dredging is likely to be needed for shallow area of 10 meter depth at the west end, otherwise deep water is close to shore. A breakwater or a long jetty would not be required

For the purposes of this study, GCA estimates this site would require a ~500 meter jetty.

Land Area Requirements

Cockatoo Island has an area of ~250 hectares, which is insufficient for an LNG development.

Land area is further constrained by mining currently underway on the island, which extends down to 30 meters below sea level, behind a sea wall. This seam is expected to be mined until 2011, after which the focus may shift to mining lower grade ore in centre of Island. There is usually about 80 mine staffs on Island.

Site Elevation and Gradient

Cockatoo Island elevation increases to 45 meters within 500 meters from the coast.

Proximity to Gas Fields

The Cockatoo and Koolan Islands are located ~250 kilometres from the INPEX operated Ichthys field and ~300 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

Not Applicable

Pipeline Approach

Not Applicable

Geotechnical Conditions

Not Applicable

There is almost no flat land on Cockatoo Island and any earth works is likely to require blasting.

Proximity to Existing Infrastructure

Cockatoo Island currently has an iron ore mining operation that is the only activity on the island. The island is currently served by a port and an airstrip which handles frequent charter flights. The island is readily accessible by sea and can be reached in 6 hours steaming time from Derby. All the logistical supplies for the mining operation are barged from Derby. In order to utilize the port and airstrip for the purposes of supporting an LNG project it would be necessary to upgrade the facilities. There is also an extensive road network on the island which was installed for the mining operations. This makes all parts of the island accessible by road. Cockatoo Island is a fly-in-fly-out operation, with normally ~80 people on the Island.

Summary Evaluation

There is insufficient available area on Cockatoo Island for an LNG development. This unsuitability is compounded by mining operations currently underway on the island. Cockatoo Island would be technically suitable from a marine standpoint.

2.3.7 South Kimberley: Cape Leveque

TABLE 12

CAPE LEVEQUE LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi Operator LNG Hub			Y						
Gas Processing Hub			Y						

Navigable Water for LNG Carriers & Port Suitability

Cape Leveque is exposed on the western side where there is deep water; it is sheltered to the east but would need dredging and / or a jetty of significant length.

For the purposes of this study, GCA estimates this site would require a ~1.5 kilometre jetty.

Land Area Requirements

Cape Leveque is a coastal site with over 950 hectares of available land. This would be adequate for the development of a gas processing Hub.

Site Elevation and Gradient

Elevations at the site range from ~15 to ~40 meters. The land rises from ~15 meters at the West boundary of the proposed site to a maximum height of ~40 meters at the mid point of the site and slope again to ~15 meters at the East boundary of the site. The site would be suitable for construction without large amounts of earth movement and the gradient would also allow movement of both heavy construction equipment and large modules.

Proximity to Gas Fields

Cape Leveque is situated ~280 kilometres from the INPEX operated Ichthys field and ~290 kilometres from the Woodside operated Browse fields. No technical issues are likely with the installation of the gas lines from the offshore fields.

For the purposes of this study, GCA has estimated the pipeline length to this site to be ~300 kilometres from the INPEX operated Ichthys field and ~290 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

The proposed plant site is located at the western boundary approximately 1.5 kilometres from the coast; at the South West boundary the distance to the coast decreases to one kilometre.

Pipeline Approach

To the West there are extensive sandy beaches. To the South West of the site there is a small cove with a less extensive beach where pipeline crossing could be made. It is likely that a both a single LNG plant scenario and a two LNG plant site could accommodate the gas inlet pipeline crossing by cutting the beach and carrying out the necessary remedial work. With a large gas processing hub and the much larger number of possible pipelines which would also cross the beach it may be necessary to develop an alternative type of crossing which obviates the need for continuous disruption of the beach.

Geotechnical Conditions

Cape Leveque is a relatively flat site, which would require minimum earthworks.

Proximity to Existing Infrastructure

Cape Leveque is located ~185 kilometres from Broome and ~150 kilometres from Derby. There is a small airstrip close to Cape Leveque which could perhaps be upgraded to allow the transportation of personnel and smaller equipment. There is a road from Cape Leveque to Broome. This road would require significant upgrading to be used to haul heavy equipment required for construction.

Summary Evaluation

From a technical perspective Cape Leveque would be a suitable site for any of the three possible installations (Single Operator LNG Hub, Multi Operator LNG Hub, Gas Processing Hub). The land area is adequate and the site elevation and topography are such that earth works would not be too extensive and the gradient would allow the transportation of large modules.

There is some infrastructure, which includes a dirt airstrip that could be upgraded and a road from Broome. The road would need considerable upgrading to allow transportation of heavy equipment and personnel.

Cape Leveque would be technically marginal from a marine standpoint. Further consideration and survey work would be needed to optimise the marine operations and berthing facilities.

2.3.8 South Kimberley: Lombadina (Packer Island)

TABLE 13

**LOMBADINA (PACKER ISLAND) FOR LNG SITE COMPARATIVE
TECHNICAL EVALUATION**

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi Operator LNG Hub			Y						
Gas Processing Hub			Y						

Navigable Water for LNG Carriers & Port Suitability

Lombadina (Packer Island) is wholly exposed to the weather and may require a significant breakwater to enclose the berth and probably the swing basin as well.

For the purposes of this study, GCA estimates this site would require a ~2 kilometre jetty.

Land Area Requirements

Lombadina has over 950 hectares of available land, adequate for the development of a gas processing Hub. The potential site could be located in several orientations due to the abundant land available. In the layout shown the distance from the coast has been kept to a minimum to reduce the length of the LNG loading lines which are very sensitive to cost.

Site Elevation and Gradient

The site elevation ranges of ~10 to ~25 meters and slopes downwards from the eastern boundary to the western boundary.

Proximity to Gas Fields

Lombadina is roughly equidistant from the INPEX operated Ichthys field and the Woodside operated Browse fields. Both are ~300 kilometres, in a straight line, from Lombadina.

For the purposes of this study, GCA estimates the pipeline length to this site to be ~310 kilometres from the INPEX operated Ichthys field and ~300 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

Assuming a minimum 10 meter elevation for a potential LNG site would result in a distance of approximately 2 kilometres from the coast to the proposed plant site, which is acceptable.

Pipeline Approach

To the North side of a potential plant site there is a small beach where pipeline crossings could take place. In the event a plan was established for a gas processing hub, then some minimally intrusive method could be developed for establishing multi pipeline crossing of beaches.

Geotechnical Conditions

Lombadina is characterized by relatively level and sandy ground, behind a rocky foreshore. Substantial earthworks are not required to render this site suitable for an LNG development.

Proximity to Existing Infrastructure

Lombadina is located ~140 kilometres from Derby and ~180 kilometres from Broome. There are port facilities and airports located in both Derby and Broome. Lombadina is also accessible by road from Broome. Some upgrading of the road would be necessary for access to an LNG site for transportation of materials during construction and personnel. There is also a sealed airstrip ~15 kilometres to the North of the potential site. This airstrip could be upgraded for use during construction and for normal operations.

Summary Evaluation

Lombadina has adequate land available and the gradient of the land would allow construction vehicles access without significant site preparation. The distance to the coast is no more than 2 kilometres which is well within the maximum of 5 kilometres for LNG loading lines.

There is also an existing road and airstrip which can be used. The road will require upgrading to accommodate construction and transportation vehicles in all seasons. The airstrip would probably require upgrading depending on the type of aircraft which will use the strip.

Lombadina (Packer Island) would be technically marginal from a marine standpoint.

2.3.9 South Kimberley: North Head / Perpendicular Head

TABLE 14

NORTH HEAD / PERPENDICULAR HEAD LNG SITE COMPARATIVE
TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi Operator LNG Hub			Y						
Gas Processing Hub			Y						

Navigable Water for LNG Carriers & Port Suitability

North Head is exposed to the weather and may require a jetty and breakwater of significant scale.

Perpendicular Head is exposed to the weather and may require a jetty of significant scale and possibly a breakwater as well. There is protected shallow water to the east in Pender Bay, where dredging and/or a long jetty would be needed.

For the purposes of this study, GCA estimates these sites would require a ~2 kilometre jetty.

Land Area Requirements

North Head and Perpendicular Head each have over 950 hectares of land available. This is sufficient land for the development of a gas processing Hub in the vicinity of North Head or Perpendicular Head.

Site Elevation and Gradient

North Head has an elevation range of ~10 to ~30 meters. The elevation increases from the coast in an easterly direction. The elevation does not pose a technical risk at this site.

Perpendicular Head has an elevation range of ~10 to ~40 meters. The terrain is steeper than the area at North Head. There are cliffs in the foreshore and some areas of steep slopes. Overall the cost of earthworks could be higher than North Head.

Proximity to Gas Fields

Both North Head and Perpendicular Head are located approximately 330 kilometres, in a straight line, from the INPEX operated Ichthys field. The distance from these potential sites to the Woodside operated Browse fields is approximately 300 kilometres.

For the purposes of this study, GCA estimates the pipeline length to this site to be ~370 kilometres from the INPEX operated Ichthys field and ~330 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

The plant site would be one kilometre from the coast at the closest point. Based on this short distance there would be no issue with the length of the LNG loading lines to the jetty.

Pipeline Approach

There are some wide beaches close to Perpendicular Head however pipeline crossings could be made at locations where there would be minimal beach depth thereby minimising any disruption to the environment. This is also the situation at North Head.

If a gas processing hub is selected as the desired development scenario then a method for passing multiple lines under the beach to prevent extensive cutting of the beach may be beneficial to reduce environmental impact.

Geotechnical Conditions

North Head has generally level ground, and limestone is expected to be found at relatively shallow depth. Perpendicular Head has an undulating ground with a number of gullies passing through the area.

Proximity to Existing Infrastructure

North Head is located approximately ~25 kilometres north of Beagle Bay and can be accessed by road from Broome. The distance to Broome is ~135 kilometres while to Derby it is 125 kilometres. Being accessible by road from Broome would be an asset when considering both transportation of construction materials and personnel. Some upgrading of the road will be required to make available for all seasons. There is no airstrip in the close vicinity.

Summary Evaluation

There is adequate land at both Perpendicular Head and North Head to develop a gas processing hub. Of the two sites, North Head probably has the more level ground and would be less costly when considering site preparation.

Both sites have access to Broome via the existing road however some upgrading of the road would be necessary. There is no airstrip in the vicinity; therefore it is likely some type of airstrip would require construction as part of any overall development.

Perpendicular Head and North Head would be technically marginal from a marine standpoint.

2.3.10 South Kimberley: Quondong Point

TABLE 15

QUONDONG POINT LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi Operator LNG Hub			Y						
Gas Processing Hub			Y						

Navigable Water for LNG Carriers & Port Suitability

Quondong Point is an exposed site which will probably require construction of a breakwater of significant length. There are potential issues with currents.

For the purposes of this study, GCA estimates this site would require a ~1.5 kilometre jetty.

Land Area Requirements

Quondong Point has over 950 hectares of land available which would make it suitable for a gas processing hub. The proposed site could however require the re-routing of the road that runs North from Broome.

Site Elevation and Gradient

There are some cliffs close to shore and thereafter a plateau extends to the east rising from 5 meters to 25 meters at the existing road. To the east of the road the elevation increases from 25 meters at the road to 35 meters at a distance of 4 kilometres to the east.

Proximity to Gas Fields

Quondong Point is located, in a straight line, ~425 kilometres from the INPEX operated Ichthys field and ~390 kilometres from the Woodside operated Browse fields.

For the purposes of this study, GCA estimates the pipeline length to this site to be ~470 kilometres from the INPEX operated Ichthys field and ~420 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

The distance to the coast could be within 2 kilometres. This distance, while technically suitable, could be reduced by re routing the road, which currently lies between the proposed plant site and the coast. The cost of LNG loading line could be as high as US\$25MM/km.

Pipeline Approach

There is at least a 5 meter elevation increase from the beach to the higher ground close to the beach, which will complicate the pipeline land fall. On the North site of the potential site there is a sandy beach where the pipeline crossings could be made. A large gas processing hub will require careful planning to handle multiple pipelines crossing the beach.

Geotechnical Conditions

The site is expected to be relatively level and require limited earthworks. However; visual reports of potential erosion may require further investigation.

Proximity to Existing Infrastructure

Quondong Point is located 45 kilometres from Broome where there is both a port and an airport. Quondong Point is accessible by road from Broome which is beneficial for both construction and personnel movement. Personnel employed at the LNG plant could live in Broome and commute to work. Some upgrading of the road will be required to make available for all seasons. There is an airstrip in the Broome vicinity.

Summary Evaluation

Quondong Point presents a suitable site on which to construct and develop a gas processing hub. There is considerable suitable land available. Final site selection could necessitate the relocation of the Broome road if the site closest to the coast is selected.

The site is further from the offshore gas fields than most other sites in the Kimberley; however it is closer to Broome where both a port and airport exist. Broome could also be used for staff housing with the staff commuting daily to the site.

Quondong Point would be technically marginal from a marine standpoint.

2.3.11 South Kimberley: Fisherman's bend

TABLE 16

FISHERMAN'S BEND LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi Operator LNG Hub			Y						
Gas Processing Hub			Y						

Navigable Water for LNG Carriers & Port Suitability

Fisherman Bend has shallow water, requiring significant capital and maintenance dredging. No breakwater would be required.

For the purposes of this study, GCA estimates this site would require a ~2 kilometre jetty.

Land Area Requirements

Fisherman's bend is a coastal location with over 950 hectares of available land. This would be a technically adequate site for the development of a gas processing Hub.

Site Elevation and Gradient

This potential site has an elevation range of 15 to 35 meters. The site is fairly level. There are cliffs at the edge of the beach. This site topography does not present any significant technical challenges.

Proximity to Gas Fields

Fisherman's Bend is significantly further from the offshore gas fields than other North and South Kimberley sites. The straight line distance to the INPEX operated Ichthys field is ~460 kilometres whereas the distance to the Woodside operated Browse fields is ~440 kilometres.

For the purposes of this study, GCA estimates the pipeline length to this site to be ~540 kilometres from the INPEX operated Ichthys field and ~480 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

Proximity of the site boundary to the coast is within 500 meters at the closest point. This short distance to the coast would result in minimum costs for the LNG loading lines.

Pipeline Approach

There are beaches close to the site and it appears pipeline landfall could be made at different points. There is a road running close to the coast so any pipeline landfall would require a road crossing to reach the intended site. Since this site could accommodate a full gas processing site there could be multiple pipeline crossing required. It would be very important to carefully plan where and how the beach crossings and the road crossings would be engineered. With potentially multiple pipelines coming ashore at one location a plan to minimise the disruption to the beach would be environmentally advantageous.

Geotechnical Conditions

This site is relatively level and extensive earthworks are not anticipated.

Proximity to Existing Infrastructure

Fisherman's Bend is located ~10 kilometres from Broome and as such has excellent access to both port facilities and an airport. There is also a potential for staff accommodation in Broome for both staff and their families, with significant potential cost benefits.

Summary Evaluation

From a technical view point, Fisherman's Bend would be a good location for a gas processing hub. There is adequate land with suitable topography.

Broome is ~10 kilometres away which would be a significant advantage from many respects. For example there is a port and airport in Broome which would significantly improve the efficiency of both the construction effort and the future operation of the plants in the gas processing hub. Staff could be housed in Broome, there are medical facilities etc in Broome which the staff and their families could benefit from.

There will be some challenges associated with the installation of the gas pipelines coming ashore since crossing the beach with minimum disruption and road crossing will require engineering and consultation with the local community.

Fisherman's Bend is significantly further from the offshore gas fields than other North and South Kimberley sites, which will have a substantial impact on offshore pipeline costs.

Fisherman's Bend would be technically marginal from a marine standpoint. The likely ongoing maintenance dredging will be an additional technical challenge associated with this site.

2.3.12 Offshore Kimberley: Scott Reef

TABLE 17

SCOTT REEF LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	NA	NA	NA	Y	NA	NA	NA	N
Multi Operator LNG Hub			NA						
Gas Processing Hub			NA						

Navigable Water for LNG Carriers & Port Suitability

Scott Reef is comprised of two separate coral reef structures: North Scott Reef is almost fully enclosed and contains sheltered waters between 10 and 20m deep; while South Scott Reef is crescent shaped with water depths ranging from 10 to 70m - both reefs are of a considerable size and partially exposed at low tide. Sandy Islet at the western tip of South Scott Reef is emergent at high tide.

The reef crest provides protection from the prevailing metocean conditions, but tidal currents are strong between the North and South reefs. Passage between the North and South reef is via a 1 mile wide passage, close to the south side of North reef.

Woodside's evaluation of the metocean conditions indicate that Scott Reef marine approaches are adequately surveyed and that no technical issues would be expected for navigation of LNG, LPG or condensate carriers. The water depth and currents associated with the narrow channels at the entrance to the North reef lagoons preclude a development within the Northern lagoon, but a development external to the North reef, or within the Southern lagoon would be technically feasible. GCA has not reviewed the analysis of metocean conditions conducted by Woodside.

Land Area Requirements

It is envisaged that all facilities will be located within the sheltered lagoonal areas of Scott Reef using a combination of gravity based structures constructed of either steel or concrete, or conventional jacket structures.

Site Elevation and Gradient

This is an offshore development with no land requirement.

Proximity to Gas Fields

Scott Reef is ~150 kilometres from the INPEX operated Ichthys field and is directly above the Woodside operated Torosa field.

Proximity of Plant Site to Coastline

Not Applicable

Pipeline Approach

The reef platform is characterised by a steep slope which drops from the shallow water of the reef lagoonal areas to water of ~400m water depth. The pipeline / umbilical crossing of the reef slope is a challenge for a Scott Reef based development.

Geotechnical Conditions

In 2006/2007 the Browse Joint Venture executed a geophysical and geotechnical survey programme comprising a number of bore holes on Scott Reef. Woodside has stated that these surveys have allowed the development of a preliminary geological model and indicate that both gravity base structures and piled jacket structures could be feasible.

Proximity to Existing Infrastructure

Scott Reef, like the Maret Islands, is a remote location with no existing infrastructure. The closest ports and airports are located at Derby – 220 kilometres and Broome 440 kilometres. All access and logistics would be managed as for an offshore operation.

Summary Evaluation

Scott Reef is an offshore development. To date, not even a small single train LNG plant has been installed in this type of environment and the technology for floating or even platform mounted LNG plants has yet to be demonstrated. Any proposal to move directly to a “hub” using barge mounted facilities should be seriously questioned.

2.3.13 Offshore Kimberley: Echuca Shoals

TABLE 18

ECHUCA SHOALS LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	?	NA	NA	NA	Y	NA	NA	NA	N
Multi Operator LNG Hub			NA						
Gas Processing Hub			NA						

Navigable Water for LNG Carriers & Port Suitability

Marine access would require further studies.

Land Area Requirements

This location is submerged therefore no land is available, requiring a similar development to Scott Reef.

Site Elevation and Gradient

Not Applicable

Proximity to Gas Fields

Echuca Shoals is located approximately 75 kilometres from the INPEX operated Ichthys field and ~200 kilometres from the Woodside operated Browse fields.

Proximity of Plant Site to Coastline

Not Applicable

Pipeline Approach

Not Applicable

Geotechnical Conditions

Not Applicable

Proximity to Existing Infrastructure

Echuca Shoals is located ~475 kilometres from Derby and ~520 kilometres from Broome. There are no facilities on the shoal and all future transportation would be by sea or helicopter.

Site Overview

Not Applicable

Summary Evaluation

Echuca Shoals is a submerged location with similar issues to Scott Reef. INPEX considered this site for its Ichthys project but ruled it out on the basis of the significant technical challenges presented.

2.3.14 Existing infrastructure: Burrup (NWS & Pluto)

TABLE 19

BURRUP LNG SITE COMPARATIVE TECHNICAL EVALUATION

	Navigable water for LNG carriers	Port suitability	Land area requirements	Site elevation and gradient	Proximity to gas fields	Proximity of plant site to coastline	Pipeline approach	Geotechnical conditions	Proximity to existing infrastructure
Single Operator LNG Hub	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi Operator LNG Hub			N						
Gas Processing Hub			N						

Navigable Water for LNG Carriers & Port Suitability

Burrup is a proven LNG site, and no marine complications are expected in the context of an additional development.

Land Area Requirements

It is acknowledged that development at the Burrup could either be a greenfield development, as discussed in this report, or an integrated development with the existing LNG plants which would be subject to commercial negotiations between the various interest holders. The scope of this study is purely the technical assessment of site suitability, and therefore excludes commentary on commercial matters.

In reviewing the available land in Burrup allocated for gas processing purposes it appears that Block "H" and "K" could be utilised for a stand alone LNG plant. There is sufficient land in these blocks on which to install a Single Operator LNG Hub. A Multi Operator LNG Hub or a Gas Processing Hub would require additional land.

At the time of this report it is understood that Woodside are evaluating the tie-back of the Browse Joint Venture gas fields to the North West Shelf gas plant.

Site Elevation and Gradient

It does not appear that site elevation would cause any significant technical issues.

Proximity to Gas Fields

Burrup is located ~1,020 kilometres from the INPEX operated Ichthys field and ~910 kilometres from the Woodside operated Browse gas fields.

Proximity of Plant Site to Coastline

There is no issue with the plant being close to the coast. This site has coastline as part of site boundary.

Pipeline Approach

The proposed site has coast line as a part of the site perimeter therefore gaining access to the sea for installation of a pipeline would not be problematic. The existing plants in Burrup have previously installed pipelines for gas supply so there exists a precedent for an acceptable method of bringing pipelines onshore. Similar techniques could be used for a new project. In an area where many pipelines come onshore, careful planning with all other stakeholders would be necessary.

Geotechnical Conditions

With the installation of other gas processing plants in this area the geotechnical conditions must be well known and any new plant constructor would have the benefit of that experience.

Proximity to Existing Infrastructure

Burrup is a gas processing area and there exists considerable infra structure that could be utilised by a company constructing a stand alone LNG plant.

Summary Evaluation

Single Operator LNG Hub could be built in the unallocated blocks "H" and "K". There is sufficient area for an LNG plant and being close to a well developed gas processing area there would be the benefits of existing infra structure which would be attractive to a new entrant to the area. The major downside to the Burrup location for an LNG plant to serve the Ichthys and Browse fields will be the significant distance from the fields to Burrup (~1,020 kilometres from the INPEX operated Ichthys field and ~910 kilometres from the Woodside operated Browse fields). This would not only impact pipeline costs, but could also cause schedule delays waiting delivery of large amounts of line pipe.

APPENDIX I

RFT DOIR2271107 - SCOPE OF SERVICES – Extract

RFT DOIR2271107 - SCOPE OF SERVICES – Extract**LNG Plant Site Selection Validation**

The objective of this area of the study is to review the site selection process undertaken by the various proponents, and provide commentary on the technical suitability of the various sites considered to date in the context of processing Browse Basin gas at an onshore hub location or locations.

The following studies are envisaged as part of the onshore site selection validation exercise:

Review LNG site selection process undertaken by industry.

- a. Comment on technical basis for screening / shortlisting of sites, including:
 - i. Port suitability (impact of metocean conditions and in particular currents on offloading availability);
 - ii. Land area requirements for infrastructure hub development (including allowance for construction operations)
 - iii. Site elevation (relative to storm surge) and gradient;
 - iv. Proximity to gas fields;
 - v. Distance to navigable water for LNG carriers;
 - vi. Proximity of plant site to coastline;
 - vii. Pipeline approach;
 - viii. Geotechnical conditions; and
 - ix. Proximity to existing infrastructure.
- b. Given the following shortlist of potential LNG hub locations, comment on the likely technical issues that could be envisaged at each of the following sites:
 - i. Kimberley – Maret Islands
 - ii. Kimberley – Wilson Point
 - iii. Kimberley – Scott Reef
 - iv. Kimberley – North Head / Perpendicular Head
 - v. Kimberley – Quondong Point
 - vi. Kimberley – Koolan / Cockatoo Islands
 - vii. Burrup – Tie in to existing NWS facilities / Pluto
- c. Provide an indication of possible infrastructure costs to the W.A. Government for onshore developments at each of the proposed locations, including costs associated with:
 - i. Potential upgrades to existing infrastructure (inc roads/airports etc);
 - ii. Requirement for expansion or provision of new support services and associated infrastructure including hospitals, utilities etc;
- d. Provide an assessment of the cost implications associated with the use of existing infrastructure (Burrup/Darwin) as opposed to a greenfield site in the Kimberley, this should include assessment of:
 - i. The relative cost associated with delivery of gas to sites in the Kimberley as opposed to Burrup / Darwin sites;
 - ii. Identification of potential cost savings attributable to evacuation of the Browse Basin gas via existing / planned assets at Burrup / Darwin sites; and
 - iii. Potential cost premium associated with construction at Kimberley sites (particularly for the remote sites).
- e. Provide commentary on the domestic gas potential for the sites under consideration.

APPENDIX II

MARINE & METEOROLOGICAL CONDITIONS AT KING SOUND & POINT TORMENT

MARINE & METEOROLOGICAL CONDITIONS AT KING SOUND & POINT TORMENT

The coast between Hidden Island and Cape Leveque incorporates the entrance to King Sound, where numerous Shoal, reefs & islands extend up to 50 miles offshore. The currents and tidal streams in this area run between 6 and 10 knots with violent tide rips and eddies.

King Sound is bounded by the Buccaneer Archipelago, which lies in its NE approaches and consists of numerous islands, islets & rocks lying off the NW extremity of the peninsula separating Collier Bay from King Sound. The archipelago is divided into separate groups, the islands of which are connected to each other by reefs, which are dry at low water. This is due to the large variation in the strong spring tides which can have a range between high and low water of up to 11m.

King Sound is entered between the southern extremity of Hidden Island and Swan Point some 27 miles west and extends 60 miles SSE to the town of Derby at the entrance of the Fitzroy River. Depths of up to 16m lie in the fairway to about 20 miles from the headland. Thereafter the seabed Shoal gradually towards the shore in most places to NW of Point Torment, where the colour of the water is a discoloured dirty yellow, darkening to brown as Derby is approached, where it is filled with mud and sand. The area is presently unsurveyed in many parts and is currently not safe for entry by large deep draught vessels such as Q Flex and Q Max LNG tankers.

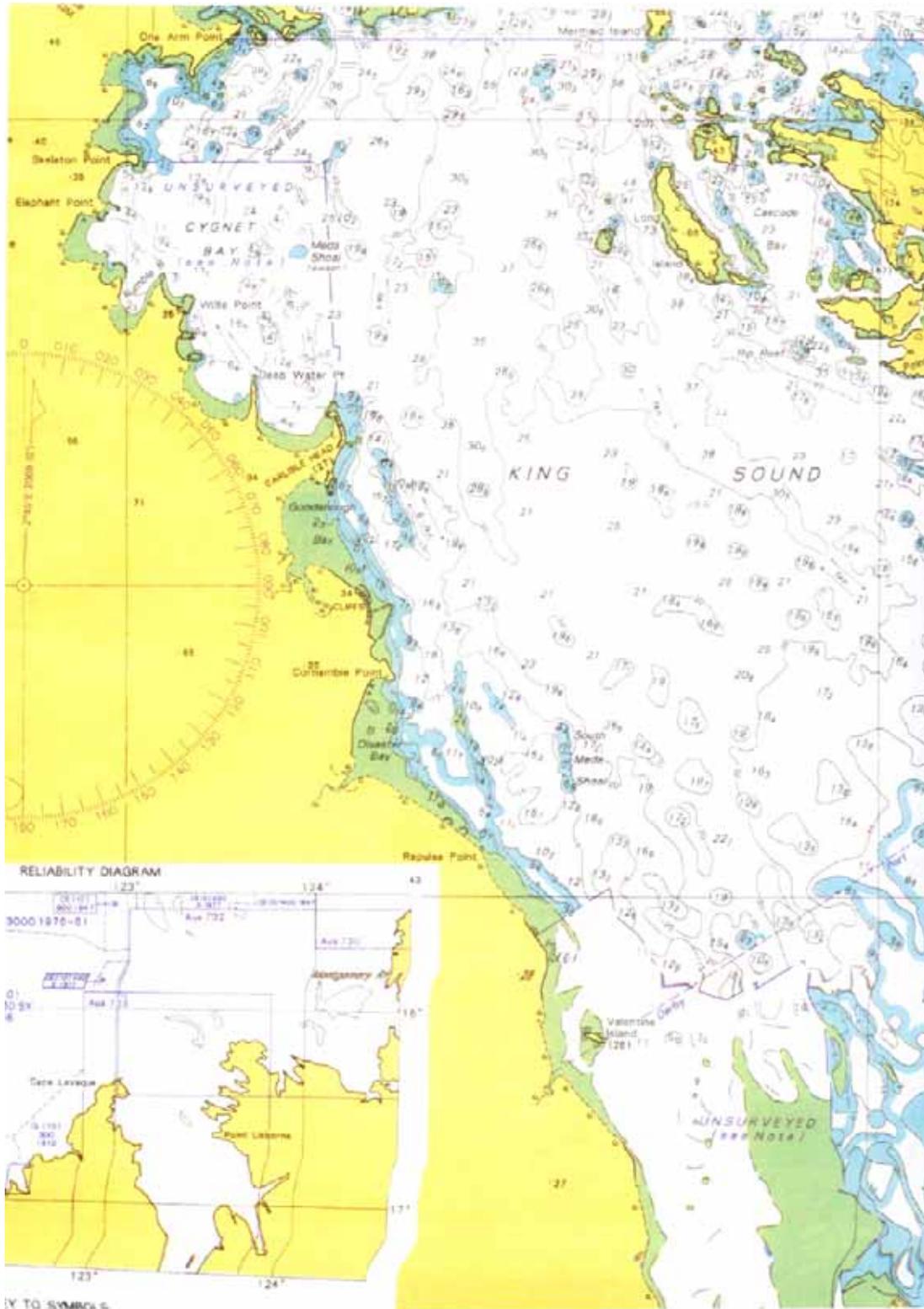
If any sites within King Sound are to be utilised, navigational safety would require that entry and exit from the Sound be confined to times of reasonable tidal flows and not be undertaken at night. This is in addition to the limitations that would be required for adverse wind conditions. Currently efficient navigational lights and buoy systems for LNG tankers are not provided.

In light of the above, King Sound is an area of very high risk for the navigation of large LNG & Condensate vessels. In addition there would almost certainly be significant delays that could not be built into forecast schedules. For these reasons Point Torment and all other sites in King Sound have been discarded as a likely LNG port for the purpose of this study.

TYPICAL CURRENTS AND TIDES OF THE KIMBERLEY AREAS CONSIDERED FOR LNG FACILITIES

	South Kimberley	North Kimberley	Offshore Kimberley	King Sound
Current range (knots)	0.5 to 5	1 to 5	NA	6 to 10
Tidal range (meters)	Up to 7.1	Up to 7.2	NA	Up to 11

Note: Information non available for Offshore Kimberley.



King Sound Chart

Proj. K1177 May08 | Checked: *mof* | Fig - 1

APPENDIX III
STUDY ASSUMPTIONS

Development Concept

- Gas dehydration can be done either onshore or offshore.
- In order to provide a basis for the comparison of costs to all sites, GCA has assumed that the condensate is treated and loaded offshore.
- LPGs extracted at the LNG plant.
- Offshore pipeline route from the field to the plant sites are considered to be in straight line. The impacts of unfavourable bathymetry on pipeline routes, which have not been studied in this report, could include longer pipeline lengths and slugging issues. However, no adverse bathymetry is anticipated in the area, which is expected to be typical continental shelf.

Area

- ~360 hectares required for a single company LNG development (i.e. single operator, who could possibly process the gas from different fields).
- ~660 hectares required for an LNG Hub development (i.e. operated by two companies with distinct facilities).
- >950 hectares required for a gas processing Hub (i.e. LNG Hub extending to incorporate gas processing facilities such as GTL, ammonia, methanol plants).
- A site elevation of at least 10 meters above sea level would typically be considered acceptable to be secure against storm surge.
- Fly in / fly out would be the preferred option.
- Power will be generated on-site to ensure sufficient plant reliability and uptime.

LNG Technology

- Each LNG train has a capacity ranging from 3.4 to 7.5 Mtpa.
- LNG process is air cooled.

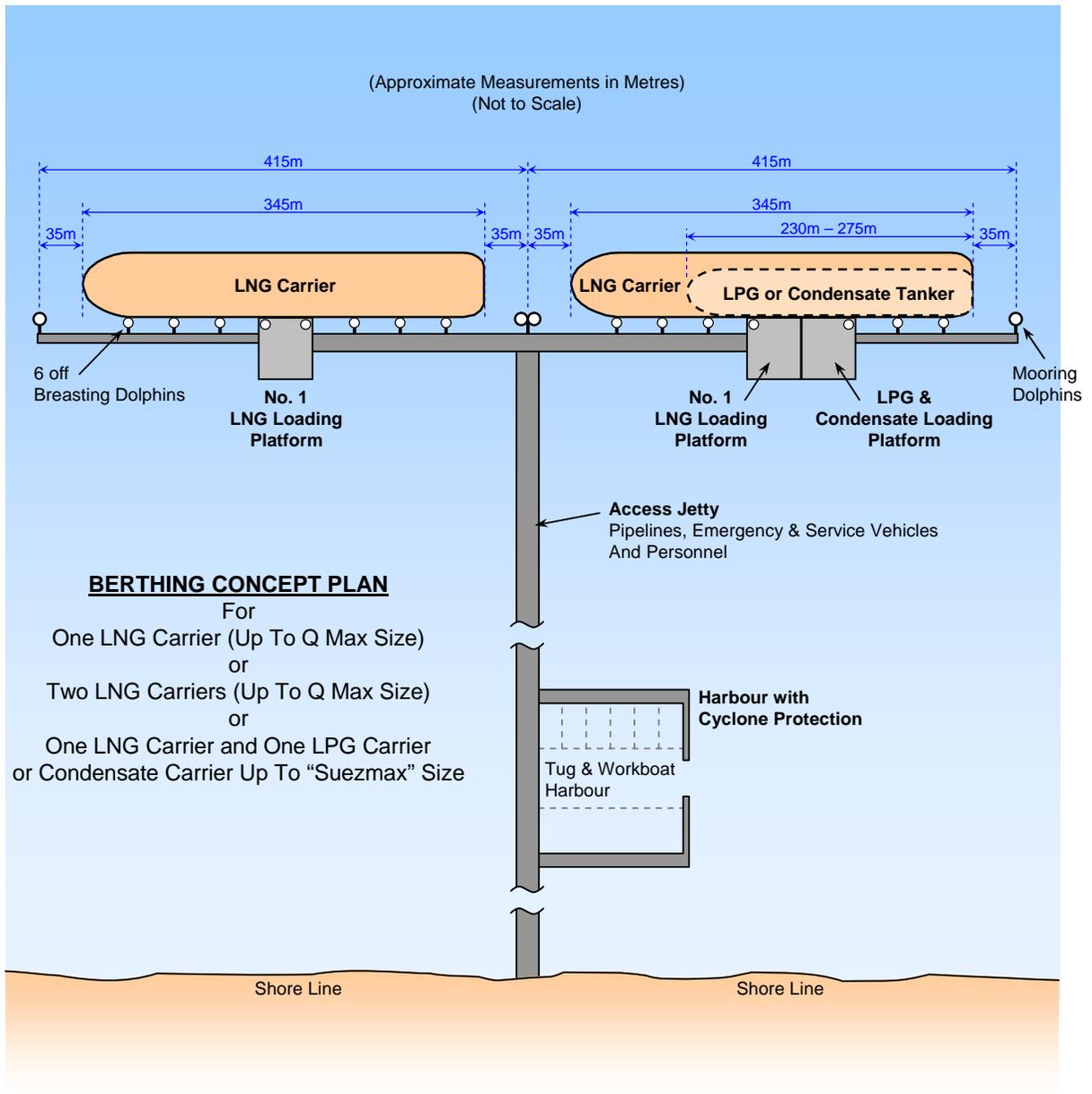
Construction Approach

- Construction can be done using either modular or non modular (with on-site construction) items.
- Area required for construction is included in LNG Plant requirement and represents up to 20% of the total area required.

Security and Legal Constraints

- LNG Plant should be able to withstand the “100 year storm” / major earthquake.
- LNG tanks are full containment.
- A security zone is required around the plant.

APPENDIX IV
BERTH CONCEPT PLAN

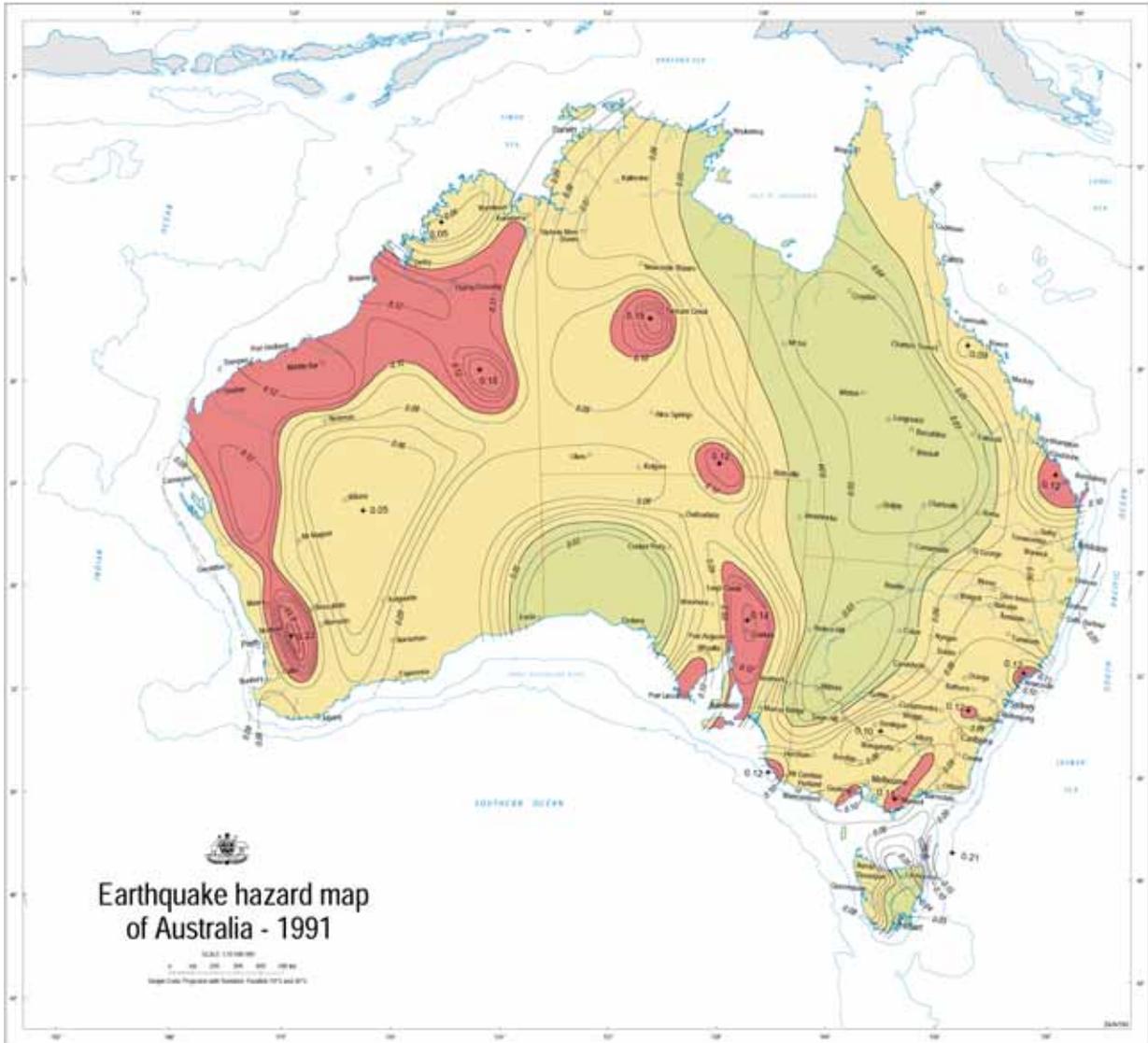


BERTHING CONCEPT PLAN
For
One LNG Carrier (Up To Q Max Size)
or
Two LNG Carriers (Up To Q Max Size)
or
One LNG Carrier and One LPG Carrier
or Condensate Carrier Up To "Suezmax" Size

Berthing Concept Plan

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APPENDIX V
SEISMICITY OF AUSTRALIA



Earthquake hazard map of Australia - 1991

SCALE 1:1000000
Major Cities Projection with Boundaries Possible 10% and 50%

EXPLANATORY NOTES

The map was prepared by members of the Standards Australia Working Group (SAWG) based on the report prepared by David McPherson, 1991. The authorisation contained therein. Copyright © Gaffney, Cline & Associates, Inc. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or by any information storage and retrieval system, without the prior written permission of Gaffney, Cline & Associates, Inc.

REFERENCES
 David McPherson, 1991, *Earthquake Hazard in Australia*, Australian Journal of Earthquake Engineering, 21, 103-107.
 Commonwealth of Australia, 1980.
 The Commonwealth does not warrant that this map is accurate, nor free of errors and does not accept liability for any loss or damage of any kind arising from reliance on information presented herein.

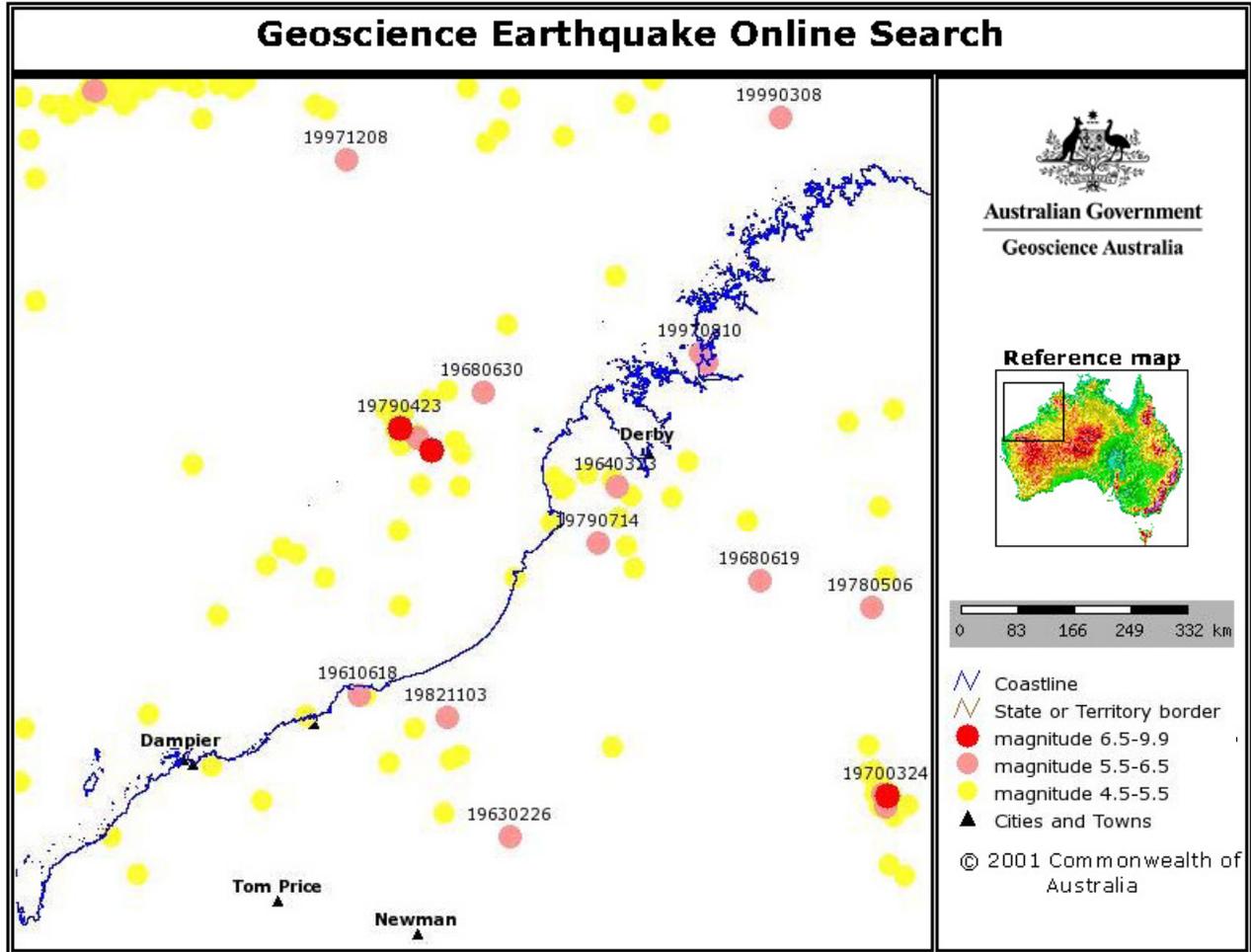
**Acceleration coefficient (a)
10% chance of being exceeded in 50 years**

	< 0.05
	0.05 - 0.10
	> 0.10

• 0.12 Peak coefficient value
 - - - Bathymetric contour (m)

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Earthquake Hazard Map of Australia		
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Kimberley Region Earthquake Records

Proj. K1177 May08 | Checked: *mof* | Appx V-2

APPENDIX VI

BROWSE BASIN WOODSIDE AND INPEX OPERATED FIELDS OVERVIEW

(Source: Deloitte PetroView – as of 19 February 2008)

BROWSE BASIN WOODSIDE AND INPEX OPERATED FIELDS OVERVIEW

Woodside CALLIANCE

- Operator: WOODSIDE PET LTD
- Status: Appraisal
- Discovery date: 2000.08.27
- Production start date (target): 2011.07.01
- Partners:
 - BHP BILLITON LTD (14.16%)
 - BP PLC (18.34%)
 - CHEVRON CORPORATION (18.34%)
 - ROYAL DUTCH SHELL (11.66%)
 - WOODSIDE PET LTD (37.50%)
- Reserves:
 - Initial Oil MMB 86.8
 - Initial Oil MCM 13800.1
 - Initial Oil Equiv MMB 771.2
 - Initial Oil Equiv MCM 122615.9
 - Initial Gas BCF 3969.7
 - Initial Gas BCM 112.4

Woodside BRECKNOCK

- Operator: WOODSIDE PET LTD
- Status: Appraisal
- Discovery date: 1979.12.12
- Production start date (target): 2011.07.01
- Partners:
 - BHP BILLITON LTD (8.33%)
 - BP PLC (16.67%)
 - CHEVRON CORPORATION (16.67%)
 - ROYAL DUTCH SHELL (8.33%)
 - WOODSIDE PET LTD (50.00%)
- Reserves:
 - Initial Oil MMB 115
 - Initial Oil MCM 18283.5
 - Initial Oil Equiv MMB 1028.8
 - Initial Oil Equiv MCM 163565
 - Initial Gas BCF 5300
 - Initial Gas BCM 150.1

Woodside TOROSA

- Operator: WOODSIDE PET LTD
- Status: Appraisal
- Discovery date: 1971.06.10
- Partners:
 - BHP BILLITON LTD (8.33%)
 - BP PLC (16.67%)
 - CHEVRON CORPORATION (16.67%)
 - ROYAL DUTCH SHELL (8.33%)
 - WOODSIDE PET LTD (50.00%)
- Reserves:
 - Initial Oil MMB 113
 - Initial Oil MCM 17965.6
 - Initial Oil Equiv MMB 2095.8
 - Initial Oil Equiv MCM 333199
 - Initial Gas BCF 11500
 - Initial Gas BCM 325.6

INPEX ICHTHYS

- Operator: INPEX HOLDINGS INC
- Status: Appraisal
- Discovery date: 1980.12.16
- Production start date (target): 2012.07.01
- Partners:
 - INPEX HOLDINGS INC (76.00%)
 - TOTAL SA (24.00%)
- Reserves:
 - Initial Oil MMB 312
 - Initial Oil MCM 49604
 - Initial Oil Equiv MMB 1949.9
 - Initial Oil Equiv MCM 310003.3
 - Initial Gas BCF 9499.6
 - Initial Gas BCM 269

APPENDIX VII
GLOSSARY

GLOSSARY

ALSOC	Australian LNG Ship. operating Company Ltd.
bar	The bar (symbol bar), decibar (symbol dbar) and the millibar (symbol mbar, also mb) are units of pressure. The bar is still widely used in descriptions of pressure because it is about the same as atmospheric pressure.
Btu	The British thermal unit (BTU or Btu) is a unit of energy used in the power, steam generation, and heating and air conditioning industries. One BTU is approximately 1,054—1,060 kJ (kilojoules).
CGR	Condensate to Gas Ratio
DWT	DWT, for deadweight tones, is the displacement at any loaded condition minus the lightship weight. It includes the crew, passengers, cargo, fuel, water, and stores. Like Displacement, it is often expressed in long tons or in metric tons.
GCA	Gaffney, Cline & Associates
ha	A hectare (symbol ha) is a unit of area equal to 10,000 square meters, or one square hectometer, and commonly used for measuring land area. A 100 m square is one ha.
km	Kilometre(s)
LNG	LNG is natural gas that has been converted to liquid form for ease of storage or transport. Liquefied natural gas takes up about 1/600th the volume of natural gas at a stove burner tip. It is odorless, colorless, non-corrosive, and non-toxic. The liquefaction process involves removal of certain components, such as dust, helium, water, and heavy hydrocarbons, which could cause difficulty downstream, and then condensation into a liquid at close to atmospheric pressure (Maximum Transport Pressure set around 25 kPa (3.6psi)) by cooling it to approximately -163 °C (-260 °F).
LOA	Length Over All, commonly used to indicate maximum hull length of a vessel. LOA is the most commonly-used way of expressing the size of a boat.
LPG	Liquefied petroleum gas (also called LPG, LP Gas, or autogas) is a mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles, as well as as an aerosol propellant and a refrigerant. Varieties of LPG bought and sold include mixes that are primarily propane, mixes that are primarily butane, and the more common, mixes including both propane (60%) and butane (40%).
Mtpa	Million tones per annum
PPP	Public-Private Partnership, the operation of a service in the partnership of government and the private sector. In some types of PPP, the government uses tax revenue to provide capital for investment, with operations run jointly with the private sector or under contract (see contracting out). In other types (notably the Private Finance Initiative), capital investment is made by the private sector on the strength of a contract with government to provide agreed services. Government contributions to a PPP may also be in kind (notably the transfer of existing assets).
psi	The pound per square inch or, more accurately, pound-force per square inch (symbol: psi or lbf/in ² or lbf/in ²) is a unit of pressure or of stress. It is the pressure resulting from a force of one pound-force applied to an area of one square inch: 1 psi (6.894757 kPa) : Pascal (Pa) is the SI unit of pressure
SPM	Single Point Mooring are loading Buoys anchored offshore, which serve as a mooring point for tankers to (off)load gas or fluid products. They are the link between the geostatic subsea manifold connections and the weathervaning tanker. The main purpose of the buoy is to transfer fluids between onshore or offshore facilities and the moored tanker.

SRTM The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA).

Tcf Trillion cubic feet

TCS Thompson Clarke Shipping

WEL Woodside Energy Limited