

# Assistance on Liquefied Natural Gas Import Options for Myanmar Phase 1:

## Draft Report Presentation

MJMEnergy Ltd

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*serving the energy industry...*

# Section 1: Introduction

# The MJMEnergy Team

- MJMEnergy have developed a bespoke Project Team as follows:
- **MJMEnergy** is a UK-based firm providing technical and commercial consultancy throughout the world with a clear focus on natural gas and LNG related projects.
- **Penguin Energy Consultancy (PEC)** is a UK-based, independent energy industry techno-commercial consultancy and training provider. PEC has been involved in 46 LNG projects in 28 countries over 20 years, In addition PEC will be assisted by CA Metocean consultants
- **Economic Consulting Associates Limited (ECA)** was formed in 1997 to provide economic and regulatory consulting services to industry and government. ECA specialises in advising on economics, policy and regulatory issues in the utilities industries, with particular expertise in the gas sector.
- **Drennan Marine Consultancy Ltd** - is a LNG marine specialist with experience working in over 20 countries worldwide and is well used to ranking multiple locations in a structured and consistent way against relevant marine criteria including natural shelter, navigational risk and the capability of local services.

## Members of the consortium



# Section 2: Key Issues

# Key Issues – Schedule and duration

- Myanmar's economy has been growing and demands more electricity.
- Current hydroelectric capacity is limited.
- Gas fired power generation demand is growing.
- Significant quantities of Myanmar's gas is sold to Thailand and China.
- There is an impending gas shortage in Myanmar.
  
- MOGE is under considerable pressure to provide additional gas.
- Myanmar's upstream sector is exploring for new supplies but schedule is mid term to long.
- LNG is needed to provide a bridging solution.
- The need is urgent.
- The contract duration is uncertain depending on the success of offshore drilling.

## Key Points

There is considerable pressure on the MOGE to resolve its gas shortage quickly.

Whilst additional supplies of gas from Myanmar's upstream resources should be available this may take longer than expected.

LNG is needed as bridging solution but the duration of the supply is uncertain.

# Key Issues - Metocean environment

- Successful commercial operation requires the LNG facility to operate for a very high percentage of the year (typically >97%).
- This requires the LNG facility to
  - Remain connected to the gas export pipework Be able to offload LNG from LNG carriers on schedule.
- Metocean conditions (wind and wave) are the main external factor in determining availability and operability.
- Coastal waves were simulated using numerical modelling at each location.
  - 20 years long time series of wave height, wave direction, wave period, wind speed and wind direction were derived to assess the level of exposure.

## Key points

Met-ocean analysis is key to the site selection



# Key Issues - Social, cultural and environmental issues

- Also key in deciding the suitability of each site will be the inclusion of the following factors:
  - Impact on sensitive environmental areas such as national parks, marine reserves, coral and mangrove forests, etc.
  - Impact on community issues such as fishing grounds and tourist areas (revenue generation).
  - Impact on culturally sensitive sites such as temple complexes, sports stadia etc.
- Maps, internet resources and guide books have been consulted to establish headline impacts, if any.
- External project financing will be contingent on good environmental performance.

## Key Points

The Social, cultural and environment assessment is at a very high level and only uses publically available data.

Good environmental performance is key to project financing.



# Key Issues – Weather and geology

- Weather systems primarily come to the coast of Myanmar from the south west.
- The south west monsoon can produce high winds and flooding.
- Cyclones are a regular feature of Myanmar's weather.
  
- Myanmar sits on the borders of 3 tectonic plates.
- Earthquakes caused by plate movement and active faults are common.
- Some volcanic activity is also present.

## Key Points

Severe weather can be expected during the lifetime of the LNG facility.



A significant earthquake is possible during the lifetime of the LNG facility.



# Key Issues - Local infrastructure

- A LNG facility needs local infrastructure to be able to be constructed, maintained and operated efficiently:
  - Tugs able to move and position the LNG carrier at the LNG facility.
  - Roads or marine transport able to deliver construction equipment and material, operating consumables and provide access for staff and vendor representatives.
  - Availability of ports able to provide services such as pilotage, importation of equipment etc. and have appropriate rules and experience of hydrocarbon operations.
  - Access to skilled people to operate or support the LNG facility or the ability for expatriates to access the facility.

## Key Points

Myanmar has limited local infrastructure and much of the required capabilities are remote from the proposed site.



# Key Issues – Cost and ownership

- A LNG facility and the associated importation contract is likely to be the largest investment Myanmar has made.
- Some technology options may be leased rather than purchased to reduce impact.
  - Leasing reduces control.
  - BOT/BOOT options may be available.
- Capital investment in owned facilities may be large compared to the potential duration of the LNG import contract.
- Capital and operating (including leasing) costs need to be analysed on the same basis.

## Key Points

Capital and operating costs need to be analysed on the same basis.



# Key Issues – Storage capacity and vaporisation rates

- LNG delivery may be delayed by bad weather or gas vaporisation may exceed norms leading to a shortage of LNG.
- Some storage margin within the LNG facility to keep gas export/power generation running is important.
- Storage is expensive.
- Security of supply/Storage margins are a political issue and should be set by MOEE.
  
- Vaporisation capacity is relatively inexpensive and therefore not considered a key issue.

## Key Points

Security of supply needs to be set by MOEE.

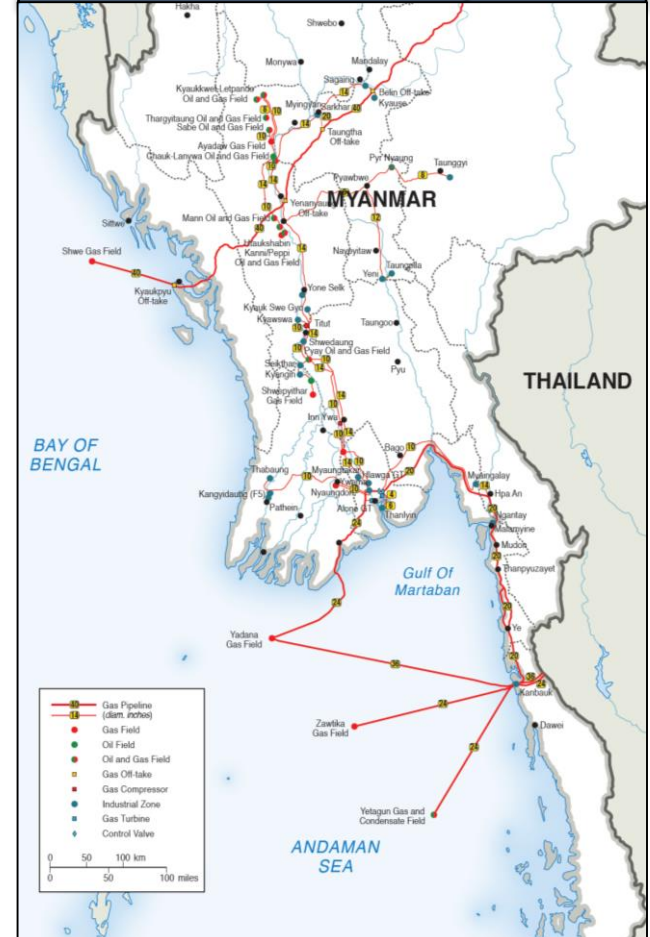
LNG storage is expensive.

Vaporisation capacity is inexpensive and not a key issue.

# Key issues – Pipelines

- Gas needs to be transported from the LNG facility to the power plants by gas transmission pipelines.
- Myanmar's pipeline network is old and is claimed to be in poor condition.
- This study has looked at laying new pipelines to connect into the existing pipeline network around Yangon.
- The existing pipeline network may need to be expanded or reinforced to cope with the additional demand – these costs are not included.

## Overview of gas pipeline infrastructure in Myanmar



# Section 3: Site Selection

# Methodology

A three level selection methodology has been used

- Stage 1 (Concept selection) - Technology concept selection is based on overriding system performance requirement. (Schedule and ownership, etc.)
- Stage 2 (Qualitative selection) – A qualitative tool based on traffic lights provides preliminary scoping of a range of sites.
- Stage 3 (Discounted expenditure selection) – k A simple discounted expenditure tool which allows both capital costs and operating costs to be compared simultaneously is used to provide the 3<sup>rd</sup> stage of selection.

## Key Points

3 level selection process which improves in granularity as it progresses.



# Site overview

- MOGE requested that 3 general areas were examined for suitable LNG import sites as shown below
- Kyuak Phyu in Rakhine state
  - 2 sites reviewed on the Madegyan River.
- Nga Yoke Kuang in Ayeyarwady state
  - 1 site onshore in Ngayok Bay.
  - 2 sites offshore in mid depth and deep water.
- Kalegauk Island in Mon state
  - 1 site onshore on the east of the island.
  - 1 site offshore in mid water to the northwest of the Island.

## Site Options



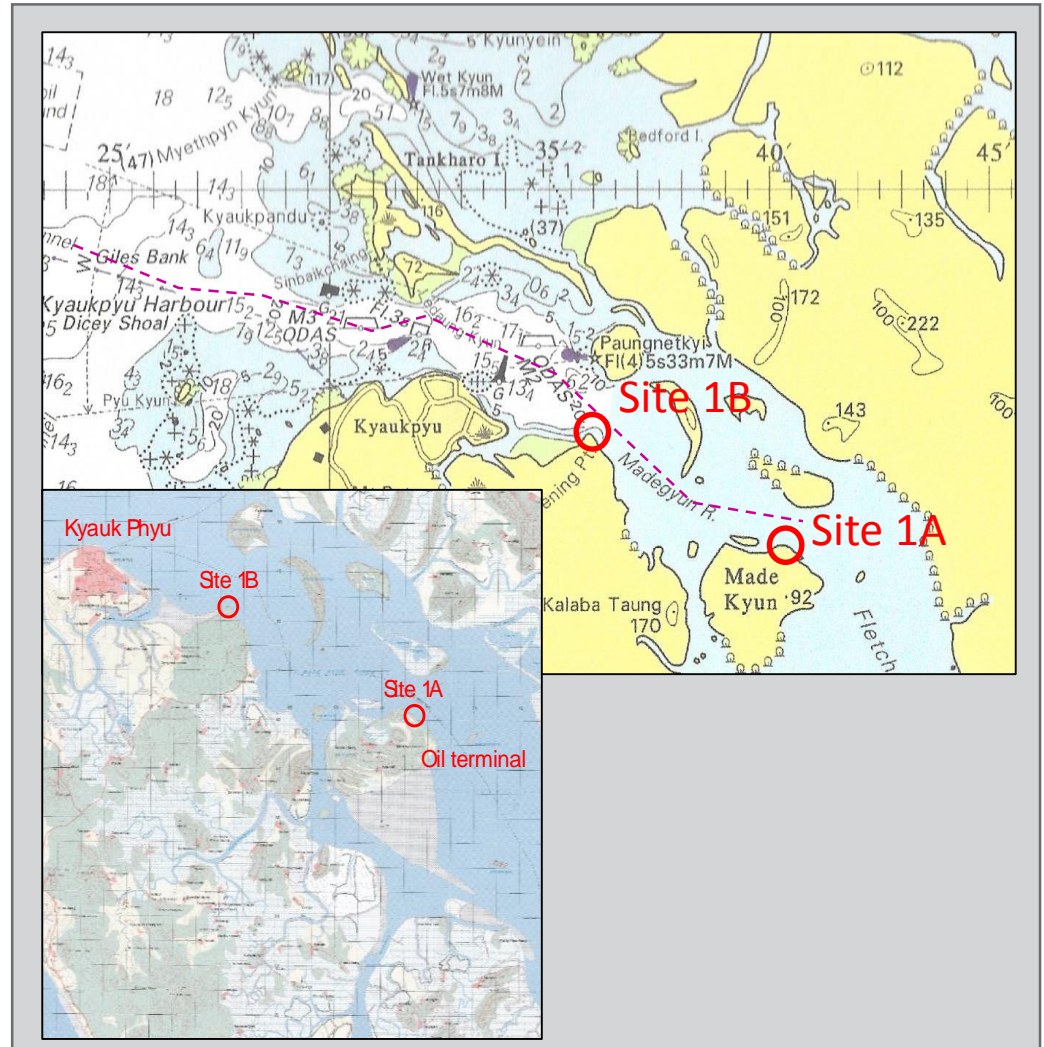
# Section 4: Site 1 Kyuak Phyu



# Site 1 – Kyauk Phyu overview

## Site locations

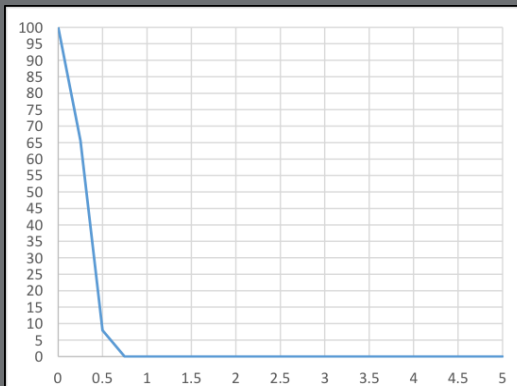
- Two sites considered on the Madegyan River to the south east of Kyauk Phyu
- Site 1A on Made Island close to or adjacent to the Shwe Oil Terminal.
- Site 1B on Ramree Island close to the Naval Base at Careening Point.



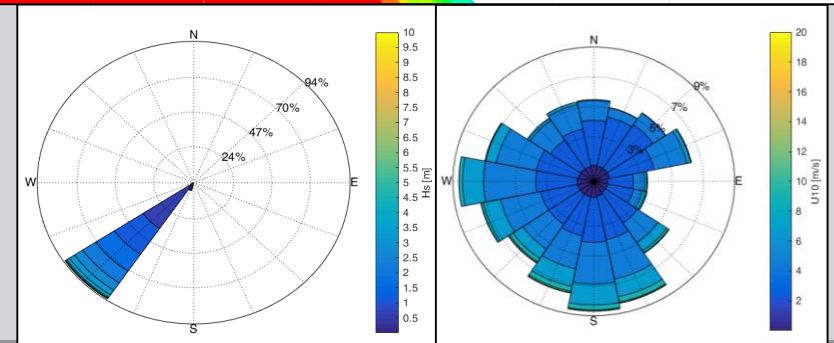
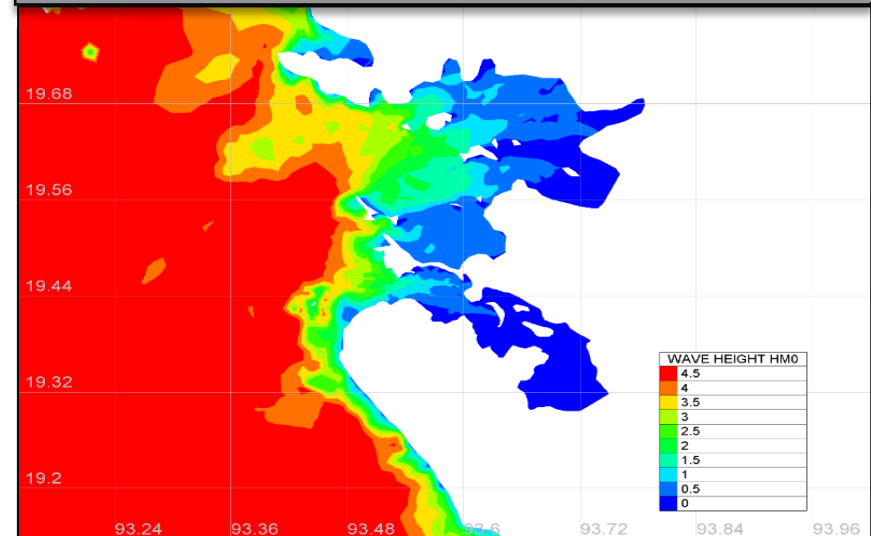
# Site 1 – Metocean analysis

- Both sites are well sheltered by Ramree Island from the prevailing SW wind and monsoon.
- Non cyclonic storms will not affect the LNG facility.
- Winds are insufficient to challenge LNG carrier mooring guidelines.
- A very good marine site.

*% Wave exceedance at the berth*



## Non Cyclonic Storm



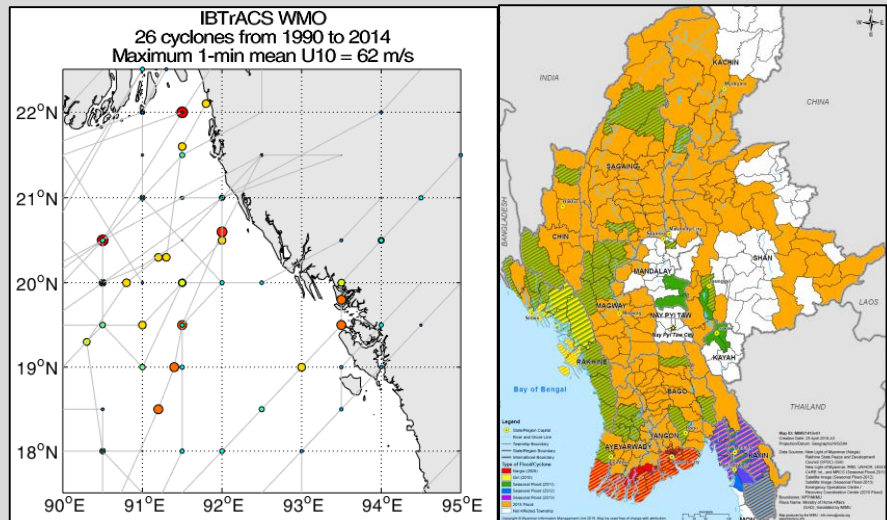
wave & wind rosettes

# Site 1: Weather & Geology

## Weather

- Cyclones are prevalent in Northern Myanmar and should be expected.
- Flooding has occurred twice since 2010.

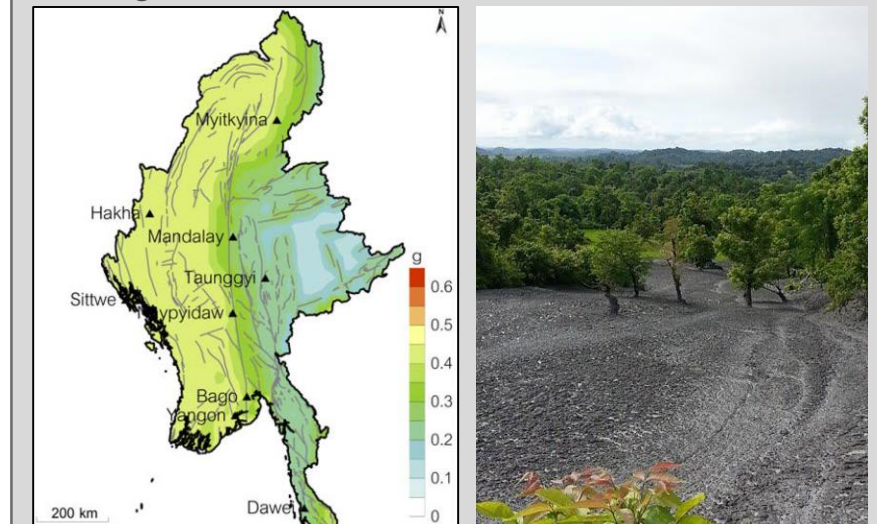
*Cyclone tracks & flooding events*



## Geology

- Magnitude 4 and 5 earthquakes have occurred nearby.
- High peak ground accelerations are anticipated (0.4 – 0.45g).
- Sai Krone mud volcano near site 1B.

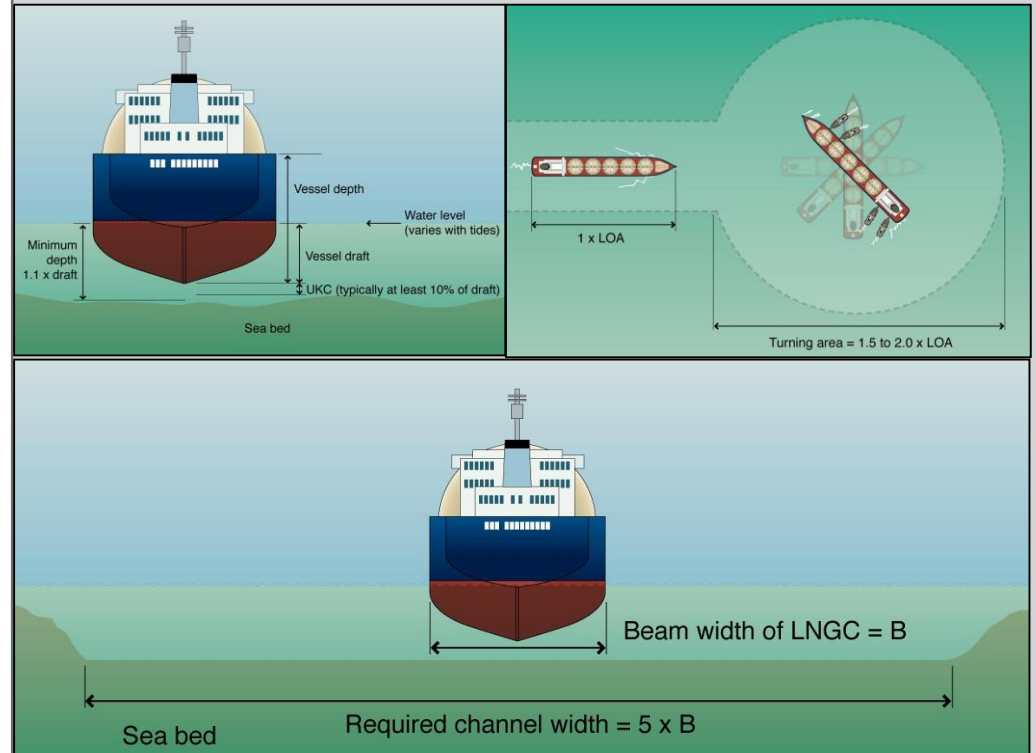
*Peak ground accelerations Sai Krone*



# Site 1: Navigation analysis

- A deep water channel to the oil terminal already exists and is large enough for LNG carriers.
- Jetty is relatively short but should be optimised with the minor dredging required to make a berth pocket out of the main channel.
- No wave protection required.
- A good marine site.

## Navigation requirements



# Site 1: Environmental, Social & Cultural Impact

- Mangrove is definitely present in Combermere Bay. Coral and seagrass may be present.
- Oil terminal has upset local residents who have made environmental and economic claims
- Protests against development should be expected.
- Anecdotal comments about issues around the oil and gas pipelines.

## Environmental impacts

*Mangrove areas around Kyauk Phyu*



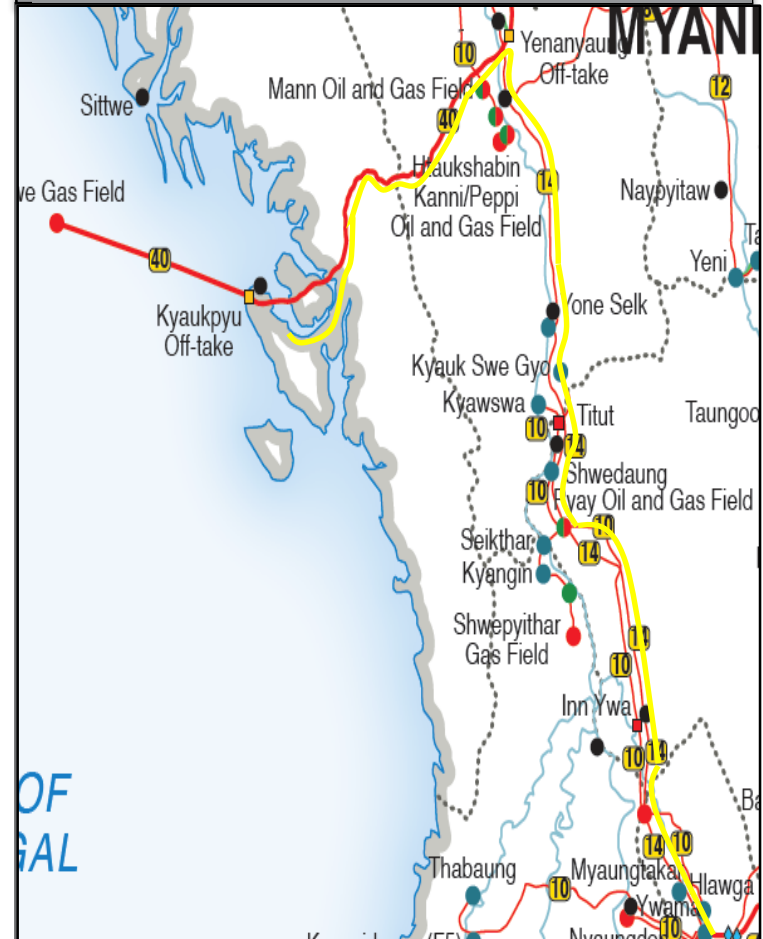
*pipeline & terminal protests*



# Site 1: Pipelines – re-use

- Negotiate access to the existing Shwe pipeline to Magway
- New 30" pipeline follows the existing route used by the 14" pipeline to Yangon
- No compressor station.
- Distance – Estimated at around 475km.

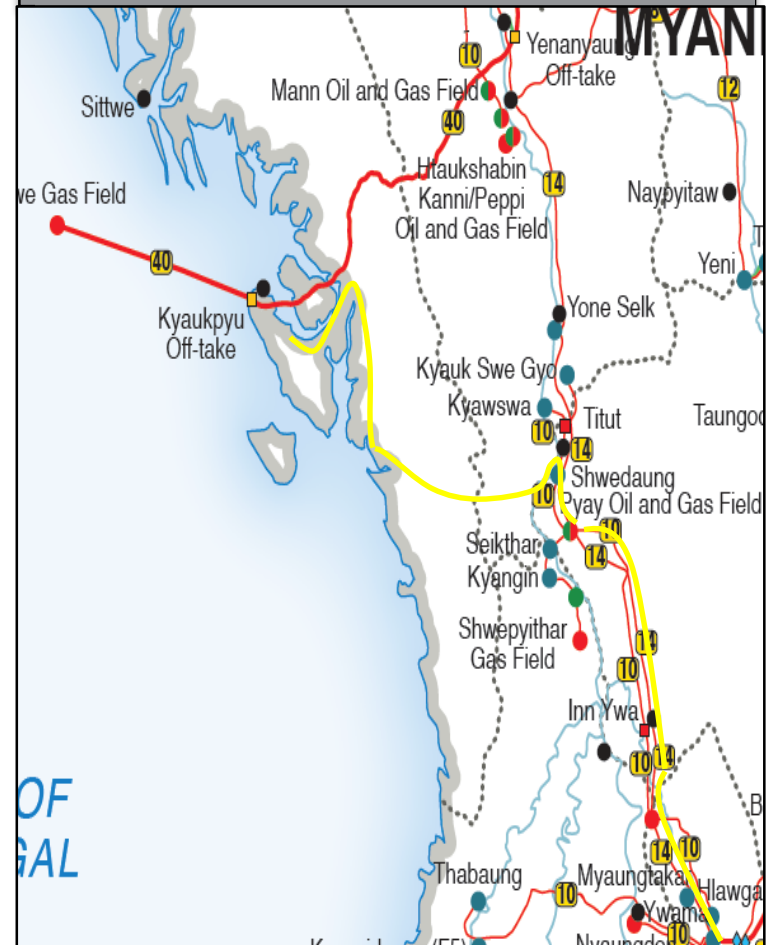
## Pipeline routes



# Site 1: Pipelines - new

- A new 290 km pipe to Pyay following the route of the current road.
- Starts with a new ROW in the road to Pyay and then follows the 14" pipeline to Yangon.
- Distance – Estimated at around 557km.
- All pipelines are 30 inch to avoid need for compressor stations.

## Pipeline routes



# Site 1: Local Infrastructure

- Suitable tugs available at oil terminal – availability uncertain.
- Unable to provide essential business services for foreign investors.
- Little industry and low skilled workforce.
- Health care underfunded and poorly equipped.
- No significant port infrastructure.
- Poor road connections.

## Tug Infrastructure



*5 tugs at oil terminal*



# Site 1: Technology selection

- Any near shore solution based on a jetty.
- Mid water depth option is possible but significant additional dredging required so no advantage.
- Jetty moored FSRU is most flexible option with a short delivery timescale.
- Onshore terminal should be considered if LNG supply is for longer than 10 years or high levels of security of supply are required.

## Jetty moored FSRU



*FSRU Independence in Lithuania*

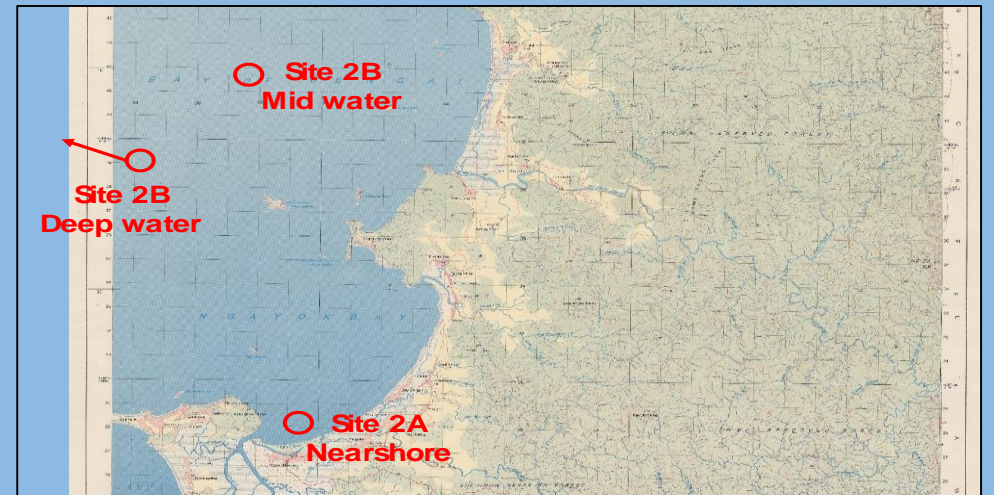
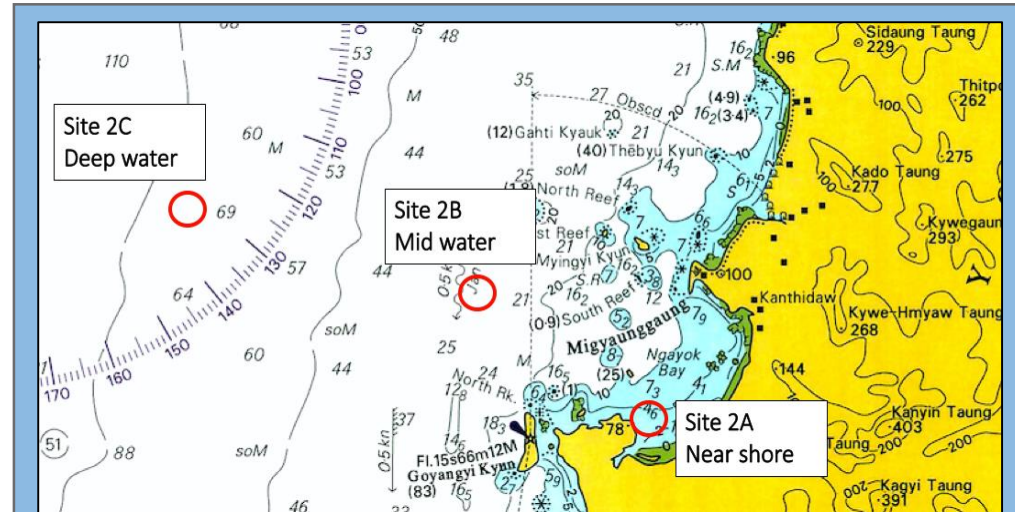
# Section 5: Site 2 Nga Yoke Kaung

# Site 2 – Overview

## Site Locations

Three sites considered as follows:

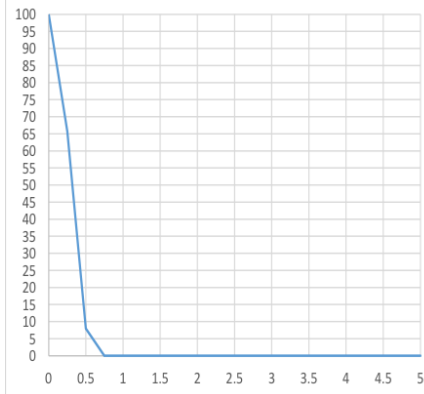
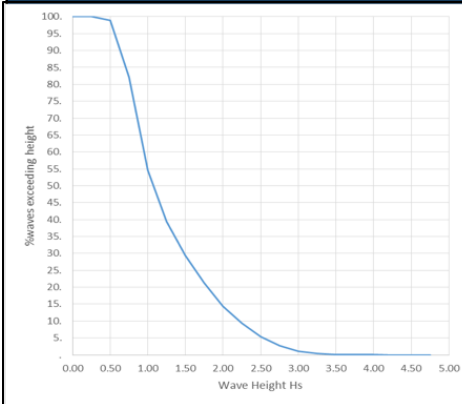
- Site 2A near the shore sheltered behind the headland to the south of Ngayok Bay.
- Site 2B in 20 m of water beyond the islands to the north end of Ngayok Bay about 10 – 15 km offshore.
- Site 2C in 80 m of water 30-40 km offshore of Ngayok Bay.



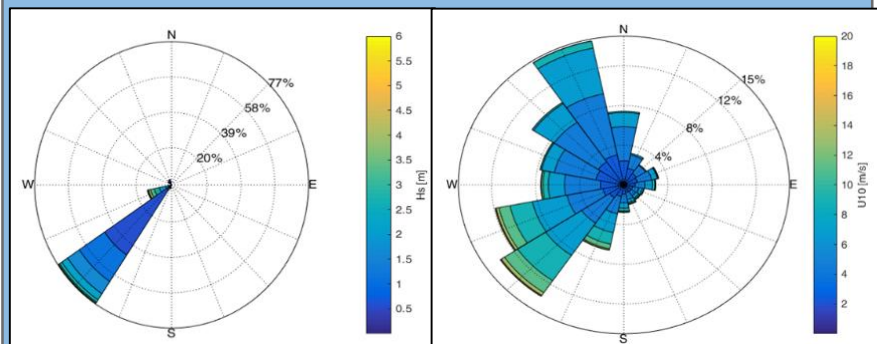
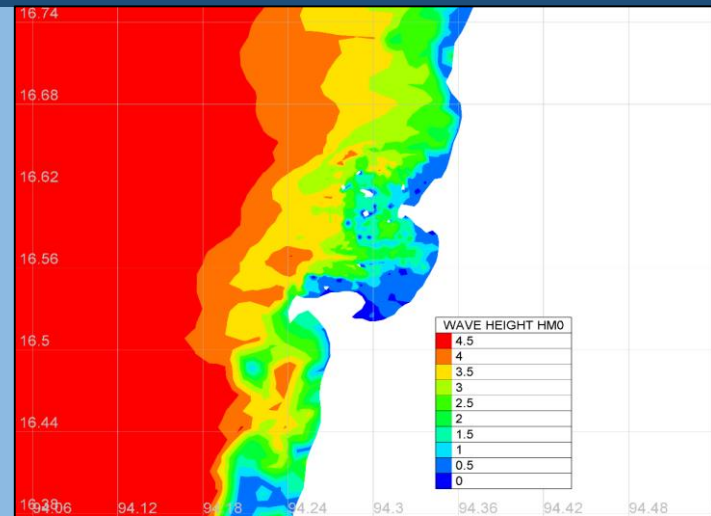
# Site 2 – Metocean analysis

- All three sites are exposed to SW winds and monsoon
- Site 2A has some shelter behind the headland
- Non cyclonic storms will impact operations at Sites 2B and 2C
- Winds are insufficient to challenge LNG carrier mooring guidelines

*% Wave exceedance*  
*Sites 2B & 2C*                      *Site 2A*



## Non Cyclonic Storm



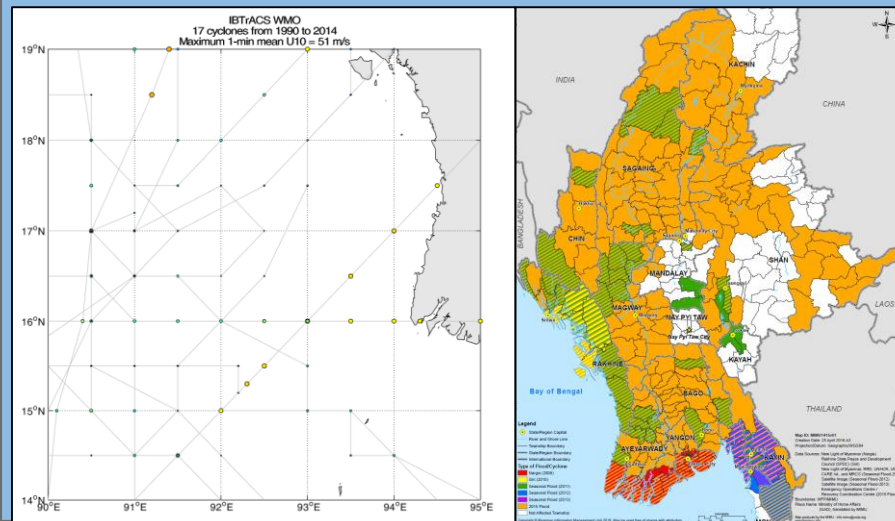
wave & wind rosettes

# Site 2 – Weather & Geology

## Weather

- Cyclones are prevalent in Northern Myanmar and should be expected.
- Flooding has occurred twice since 2010.

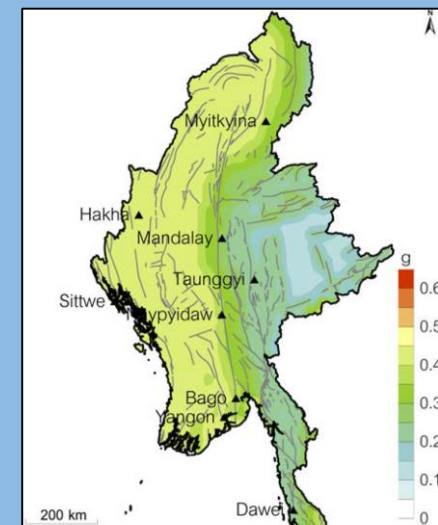
*Cyclone tracks & flooding events*



## Geology

- Magnitude 3 and 4 earthquakes have occurred nearby.
- High peak ground accelerations are anticipated (0.4 – 0.45g).

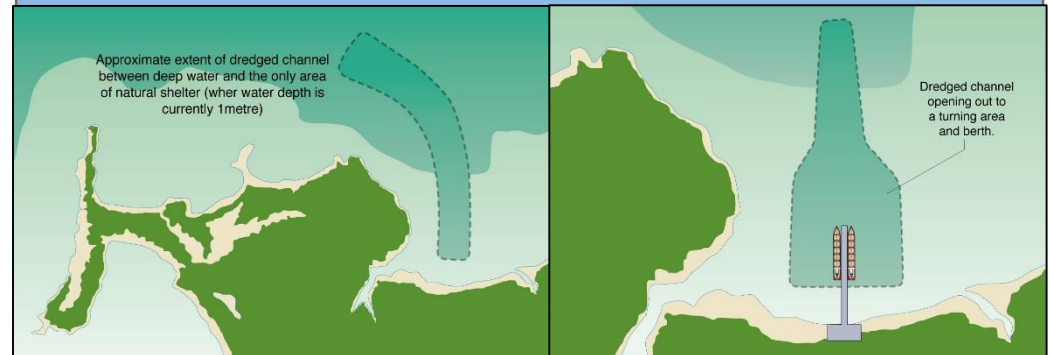
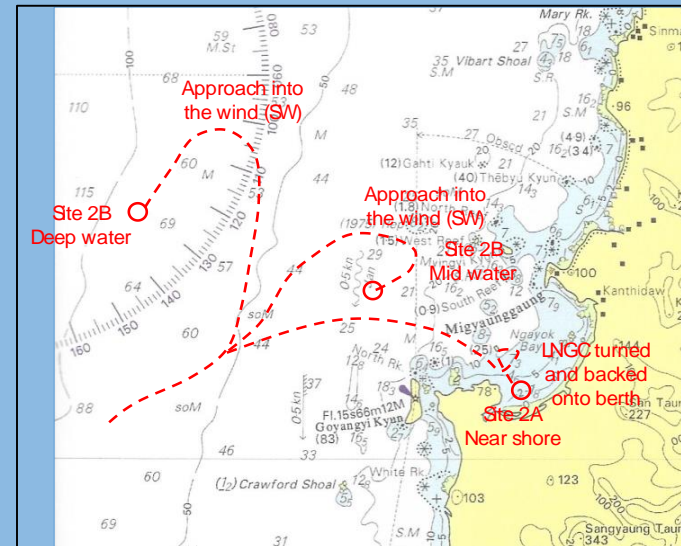
*Peak ground accelerations*



# Site 2: Navigational assessment

- Site 2A is in very shallow water (2m) and needs extensive dredging to 14 m for a LNG carrier to berth on a short jetty.
- Reducing the dredging by extending the jetty reduces and then eliminates the wave protection provided by the headland
- Offshore sites 2B and 2C are in deep water and present no navigational issues

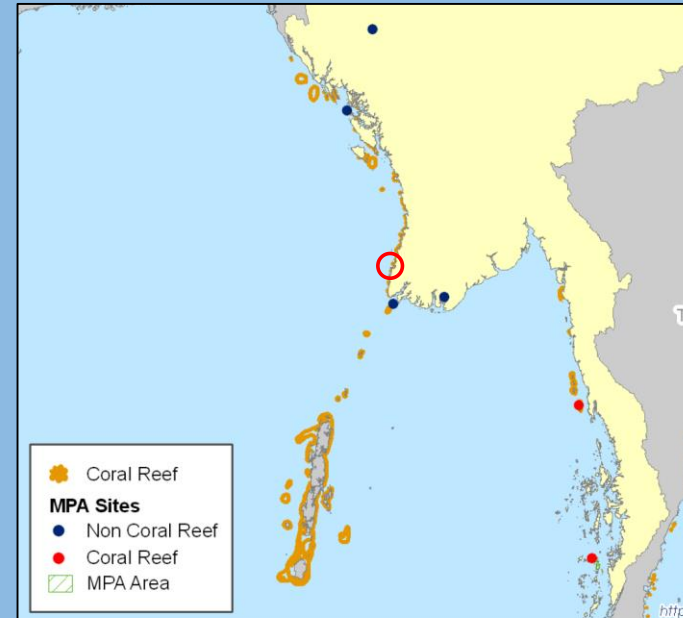
## Navigating to Site 2



# Site 2 – Environmental, Social & Cultural Impacts

- Coral and mangrove are definitely present. Seagrass and turtles may be present.
- Local tourist industry advertises snorkelling and diving.
- Beach resorts in the general area.
- Coal fired power plant in the bay rejected after local protests.
- Dredging would damage coral as would cold water/biocide return from vaporisation.
- Four local villages potentially impact by near shore terminal.

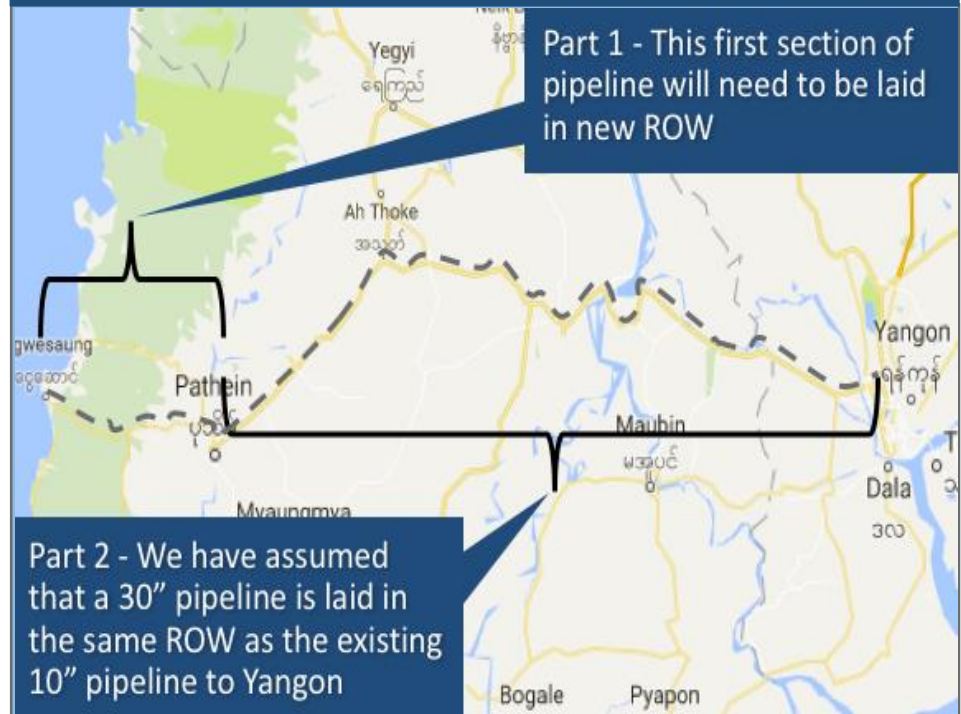
## Environmental impact



# Site 2 – Pipelines

- Background
  - Existing 10 inch pipeline to Yangon via Pathein to Thabaung is too small and low pressure for new flows.
- Main option
  - Lay new 30 inch pipeline in same wayleave.
  - Extend 30 inch pipeline from Pathein to the coast to link to LNG facility.
  - No reinforcement costs required unless gas is required for proposed power plant at Shwedaung.

## Pipeline route





# Site 2 – Local infrastructure

- No tugs, nearest tugs at Shwe oil terminal.
- No port or port authority.
- Pathein is only able to provide the most basic business services.
- Little industry and relatively low skill workforce.
- Technical and IT universities in Pathein should be able to provide some skills .
- Health care present.
- Large port at Pathein for river traffic but with no significant port infrastructure.
- Poor road connections.

## Pathein



# Site 2 – Technology selection

- Only mid or deep water options possible
- Near shore site too difficult environmentally
- Little difference in wave environment so deep water, buoy moored, FSRU preferred as more robust in extreme weather
- Poor road connections.

## Technology selection



# Section 6: Site 3 Kalegauk Island

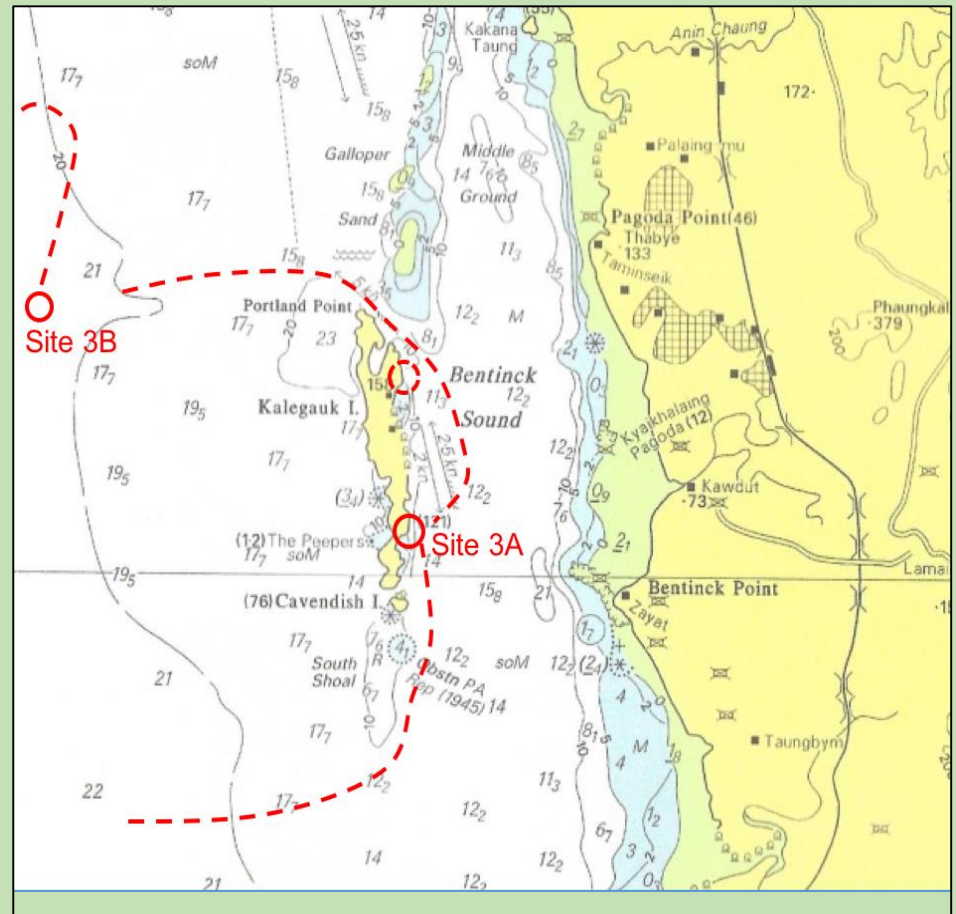
# Site 3 – Overview

Two sites considered

- Site 3A in Bentinck Sound to the east of Kalgauk Island. (NB: Two sites are possible but proximity to local populations favours the southern site – the northern site is not considered further.)
- Site 3B is located offshore in 20 m of water in the Andaman Sea to the northwest of Kalgauk Island.



## Site Locations



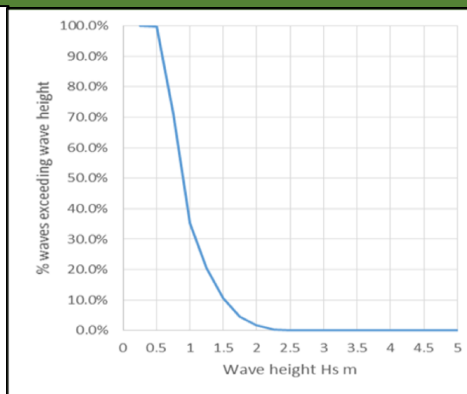
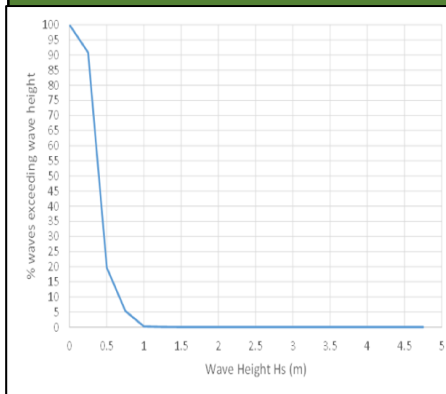
# Site 3 – Metocean Analysis

- Both sites are relatively sheltered from SW winds and monsoon by the Andaman Islands.
- Site 3A has additional protection from Kalegauk Island.
- Non cyclonic storms will impact operations at Sites 3B but are infrequent.
- Winds are insufficient to challenge LNG carrier mooring guidelines.

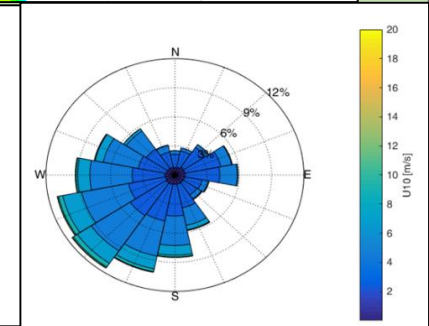
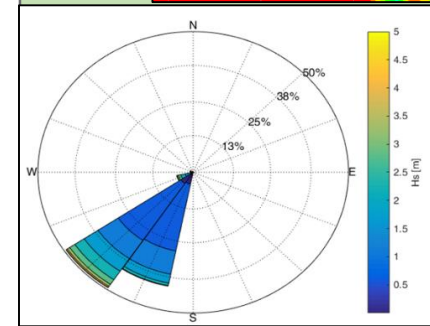
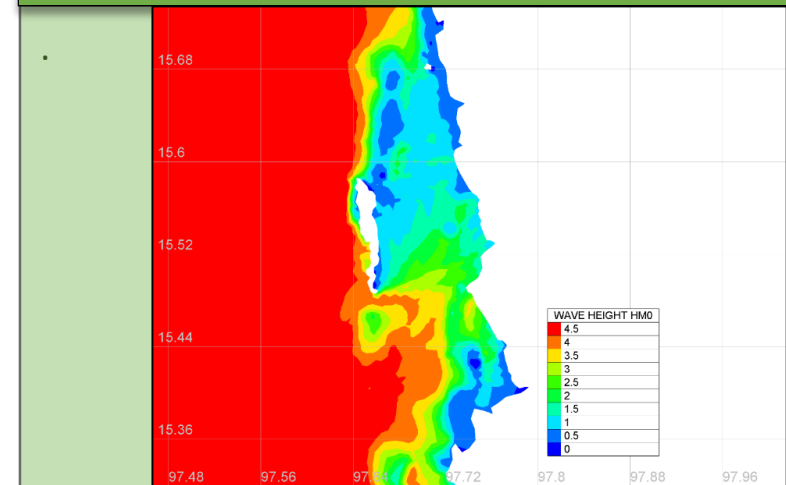
*% Wave exceedance*

*Sites 3A*

*Site 3B*



## Non cyclonic storm



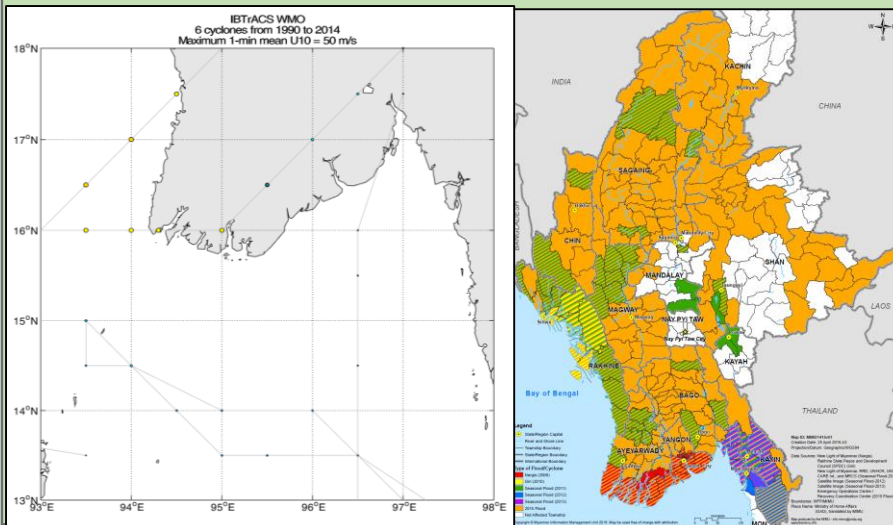
wind & wave rosettes

# Site 3 – Weather & Geology

## Weather

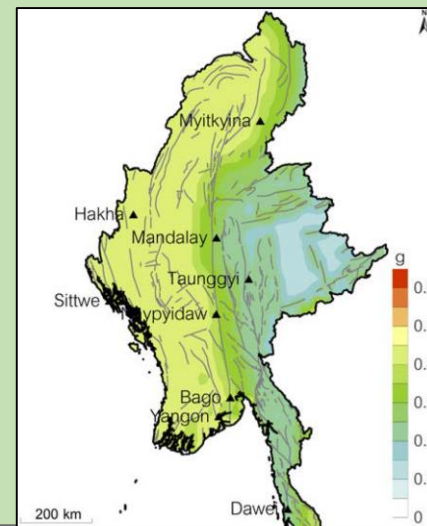
- Cyclones are infrequent in this part of Myanmar, cyclones are deflected by the Andaman Islands.
- Flooding occurs on a seasonal basis.

### *Cyclone tracks & flooding events*



## Geology

- There have been no recorded earthquakes in the vicinity of Kalegauk Island. There have been several Magnitude 4 – 5 earthquakes in the Andaman Sea to the west.
- Moderate peak ground accelerations are anticipated (<0.2g).



### *Peak ground accelerations*

# Site 3 – Navigational assessment

- Site 3A is in 12 m of water + tides.
- No dredging is required if LNG transit times are controlled to high slack water.
- A dredged berthing pocket to 14 m sufficient for a LNG carrier to escape and incident will be required.
- Offshore site 3B is in a water depth of 20 m and present no navigational issues.

## Key Points



Heights In Metres Above Chart Datum

Tidal Condition	Mean High Water Spring Tides	Mean High Water Neap Tides	Mean Low Water Neap Tides	Mean Low Water Spring Tides
Tidal Height, m	5.5	3.9	2.5	0.9

# Site 3 – Environmental, Social & Cultural Impacts

- Kalgauk Island has 2 villages and 2 smaller settlements. Avoiding hazards and impacts is possible but restricts the space available.
- Fishing is important to Mon state but the muddy seabed here is probably of lower value than further south.

## Key Points

“Pristine” coast but development starting  
Foreigners had no access until recently  
Some deforestation by rubber plantations



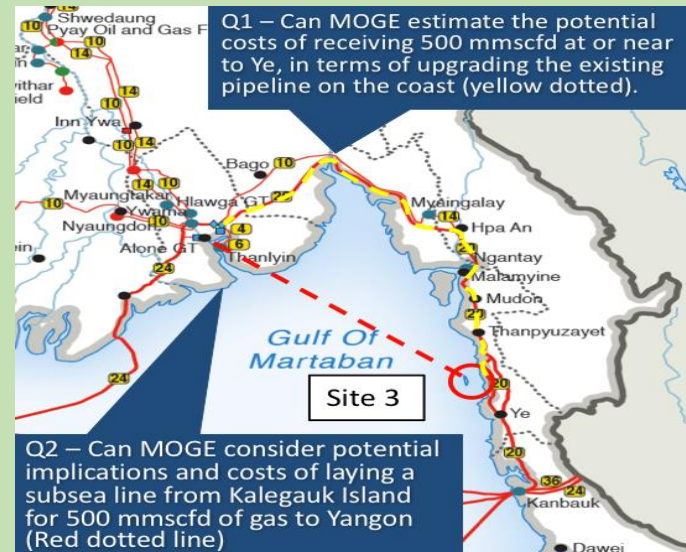
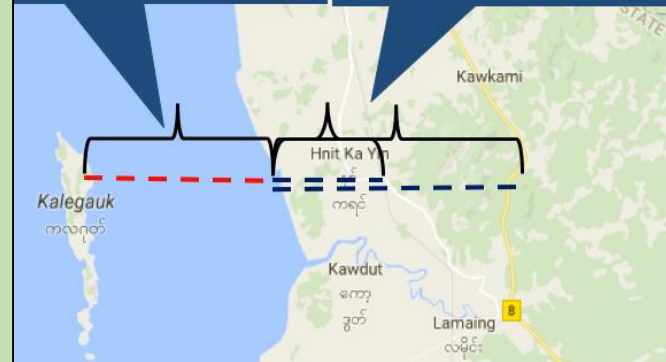


# Site 3 – Pipelines

- An existing pipeline connects Kaunbauk to Yangon via the power stations at Mawlamyine.
- Reinforcement is currently underway but making slow progress.
- Three pipeline options
  - Reinforce whole pipeline from Kalegauk to Yangon.
  - Lay new 30 inch pipeline in same wayleave as existing pipeline.
  - Lay a 30 inch subsea pipeline directly to Yangon across the Gulf of Martaban.

Offshore connection of 10 km in length depending on the landing point

Two options for onshore connection of 8-16 km depending on which of the two 20" pipelines is best to connect to.



Q1 – Can MOGE estimate the potential costs of receiving 500 mmscfd at or near to Ye, in terms of upgrading the existing pipeline on the coast (yellow dotted).

Q2 – Can MOGE consider potential implications and costs of laying a subsea line from Kalegauk Island for 500 mmscfd of gas to Yangon (Red dotted line)

# Site 3 – Local infrastructure

- No tugs, nearest tugs at Shwe oil terminal.
- No port or port authority.
- Ye is the nearest town but is unable to provide the most basic business services.
- Little industry and relatively low skill workforce.
- Mawlamyine has higher education establishments.
- Health care at Ye is seen as poor
- Port at Mawlamyine for river traffic but with no significant port infrastructure.
- Good road & rail connections but these may be in poor condition.

## Key Points

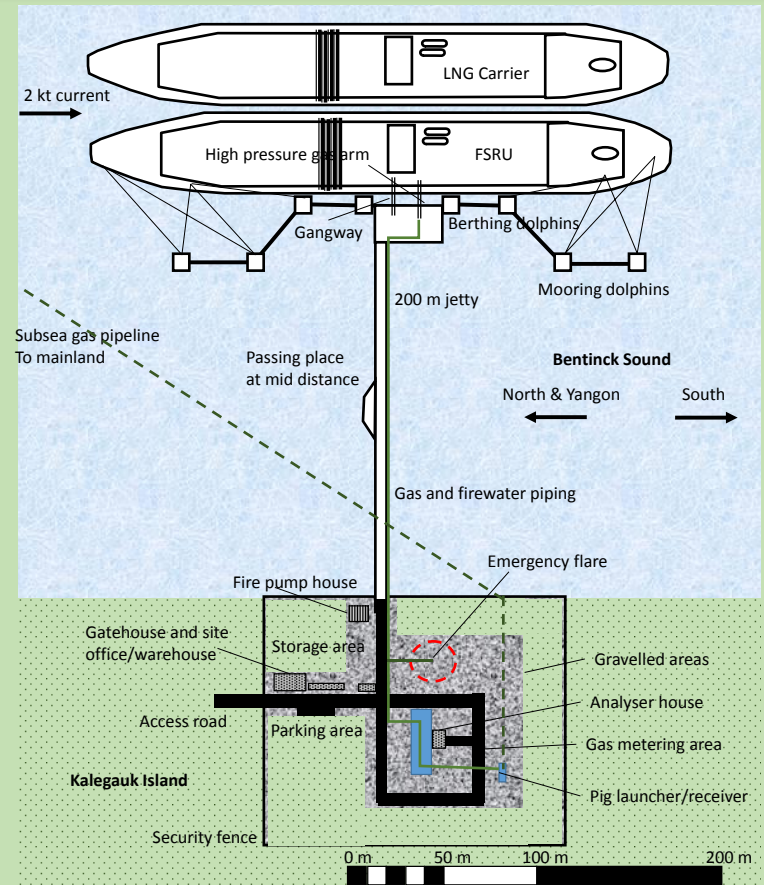
Ye – very limited infrastructure



# Site 3A – Technology Selection

- Any near shore solution based on a jetty.
- Mid water depth option is possible but significant additional dredging required so no advantage.
- Limited space on the island away from people which will make an onshore terminal challenging but its potential cannot be ruled out at this stage.
- Jetty moored FSRU is most flexible option with a short delivery timescale.

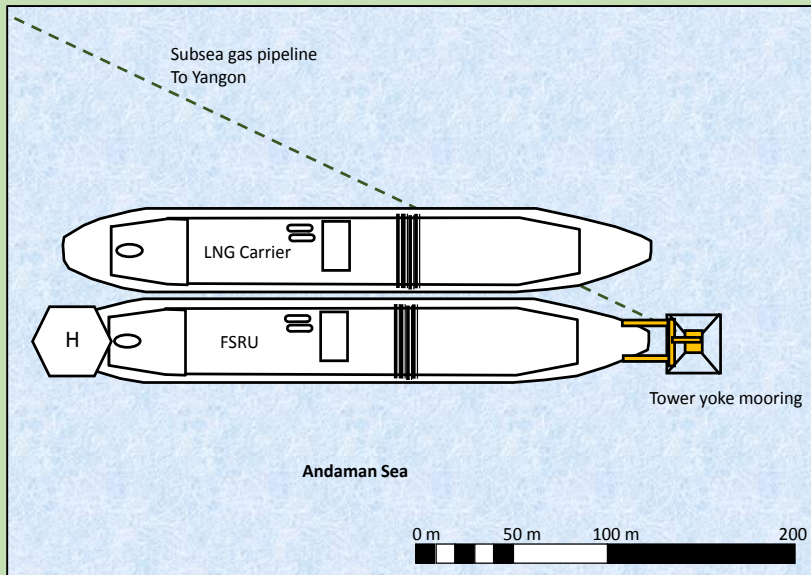
## Technology selection



# Site 3B – Technology Selection

## Technology selection

- The variability in wave direction is small so an island jetty may be possible although wave heights will marginally limit availability.



## Technology selection

- Water depth is about 20 m and relatively exposed so a tower yoke mooring is preferred.



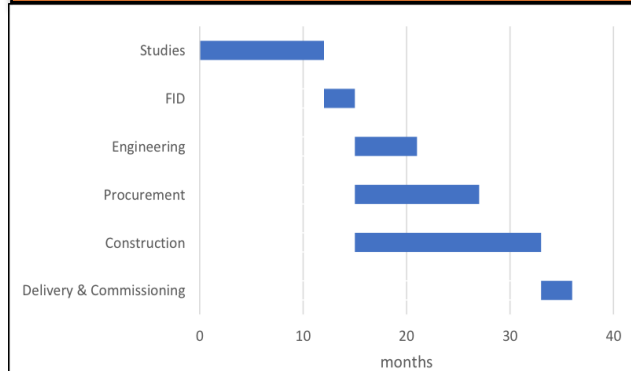
# Section 7: Conclusions & Way Forward

# Schedule

All sites similar in terms of schedule

- LNG supply possible in 3 years includes
  - 1 year of studies, permitting and financing.
  - 2 years of engineering, procurement and construction.
- Engineering, procurement & construction
  - FSRU 18 -24 months
  - Marine jetty/dredging 18 – 24 months
  - Gas pipeline 24 months
- Schedule should coincide with newbuild FSRU current under consideration coming to market

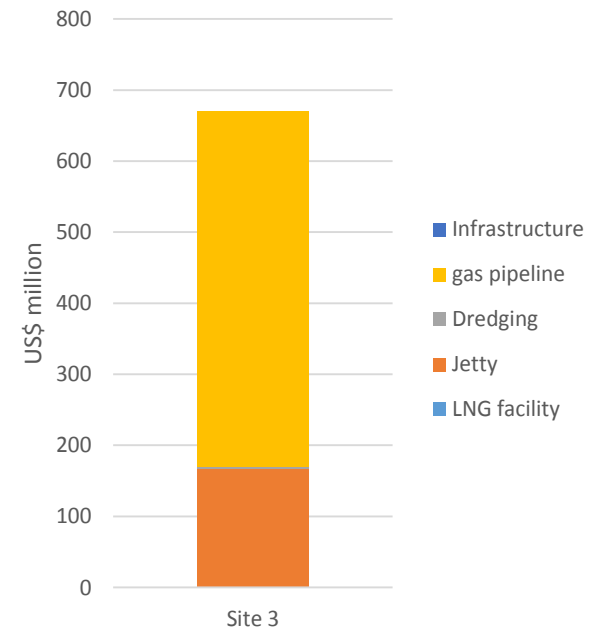
## Schedule



# Capital Investment

- The FSRU is presumed to be on a leased basis
- Capital investment required for
  - Marine facilities  
(May include in FSRU package)
  - Gas pipelines
- Operating costs are anticipated to be US\$ 60 - 70 million pa including the FSRU lease
- US\$ 140,000 per day assumed for lease (US\$ 51 million pa)

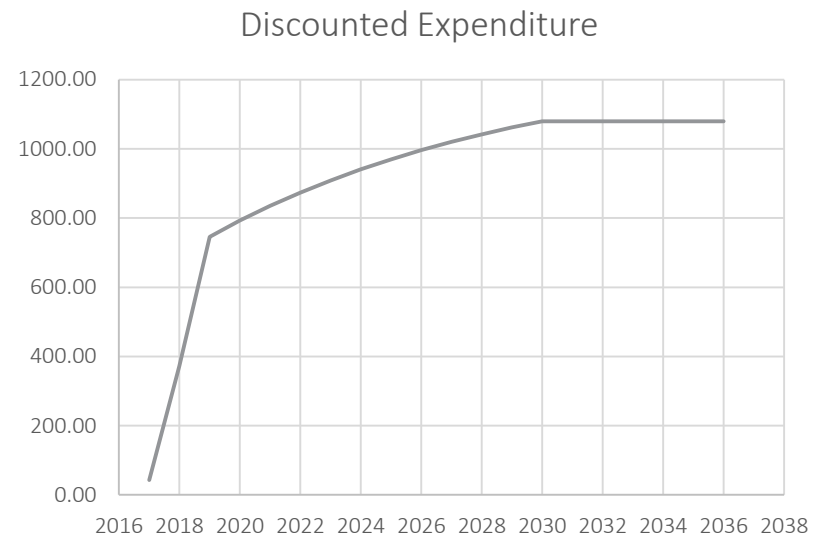
## Capex breakdown



# Discounted Expenditure

- To compare capital costs with operating costs over the lifetime of the LNG lease/import contract a NPV model has been used
- As no LNG price/sales income estimates are part of the scope of work a view can only be taken of discounted expenditure

## Cash flow model





# Site comparison

Schedules and costs (+/-50%) for each site examined are shown in the table

Site	Location	LNG technology	Gas pipeline length km	Implementation Schedule years	Capital cost US\$ million	Operating cost US\$ million	Discounted Expenditure US\$ million
1A	Kyauk Phyu	FSRU on jetty	557 new pipe 475 use Shwe	3 3	815 716	62 62	1040 960
2C	Ngayok Bay	Buoy moored FSRU	235	3.5	502	71	815
3A	Kalgauk Island	FSRU on jetty	410	3	670	69	950
3B	Kalgauk Island	Tower yoke moored FSRU	225 subsea	3.5	436	69	750

Notes:

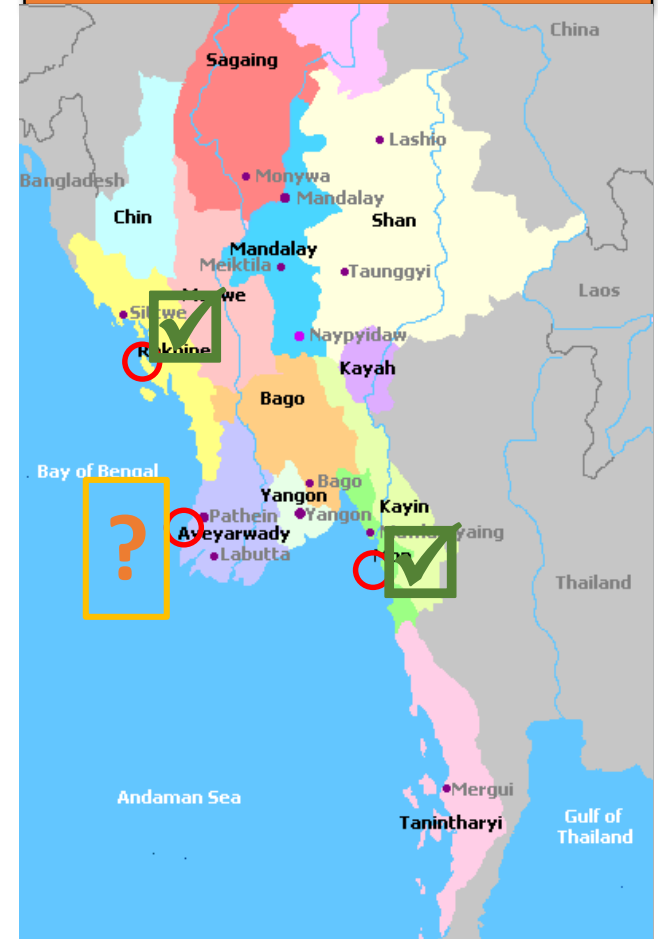
- Site 1A new pipeline from Magway to Yangon (via Shwe) or direct to Yangon
- Site 2C has a relatively low metocean availability of 85%
- Site 2C needs to find a solution to getting a subsea pipeline past coral
- Site 3A could use a subsea pipeline direct to Yangon which improves economics

# Site selection conclusions

Three sites were shortlisted and examined in more detail.

- *Option 1* - Site 1A looks a good site but pipeline is long.
- *Option 2* – Site 3A looks the best marine site but an onshore pipeline route to Yangon is long.
- *Option 3* – Site 3B is a compromise but the subsea pipeline option across the Gulf of Martaban looks promising (NB: The Site 3B subsea pipeline could be combined with site 3A).
- Site 2 presents challenges

## Site options



# Schedule Conclusions

- LNG infrastructure is on the critical path for most options
  - There are no unchartered FSRUs available until 2019-20
- Marine facilities (dredging/jetties etc) can be on the critical path but are always close to the critical schedule
- Gas pipelines can be on the critical path but are always close to the critical schedule
  - Marine facilities and gas pipelines can be accelerated by working on multiple fronts but this may have a cost impact
  - Procurement of material/equipment is a key issue and although schedules are improving still represents a bottleneck

## Key Points

Permitting and financing will take longer than engineering pre FID



# Cost Conclusions

- All options use a FSRU
  - This is assumed to be leased for a period (10 years)
  - There is no capital expenditure associated with the FSRU
- All capital expenditure is for onshore/shoreline facilities
  - Pipeline expenditure dominates capital investment
- Operating costs are dominated by fuel/electricity
- Towage costs will be high if tugs need to travel some distance to the LNG facility

## Lease rates

Lease rates become significant over the charter lifetime.

A rate of US\$ 140,000/day has been used.

This is the upper end of the current range but FSRUs are in short supply so rates may rise further

# Future work

- This is a high level, desk top, study – it helps decision making but is only the first stage of a process
- This study should not be used to select a site and/or technology without more detailed assessments including
  - Site visits
  - Bathymetric and topological surveys
  - Calibrated metocean assessments preferably using measured wave data
  - LNG volume to be imported and rate and range of vaporisation rates required
  - Design feasibility studies for FSRU and pipeline
  - Environmental and social impact studies

## A future study should consist of the following

Site visits

Bathymetric and topological surveys

Calibrated metocean assessments preferably using measured wave data

LNG volume to be imported and rate and range of vaporisation rates required

Design feasibility studies for FSRU and pipeline

Environmental and social impact studies

# Thank you

## Any questions?

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