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GROUND INVESTIGATION AND ARMOUR ROCK SUPPLY FOR THE MATERIAL OFFLOADING FACILITY ON BARROW ISLAND

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INGEOKRING SYMPOSIUM, TU DELFT

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INTRODUCTION

GORGON IS A MAJOR GAS FIELD THAT CAN PROVIDE AUSTRALIA AND ASIA WITH LNG GAS FOR AT LEAST 40 YEARS.

BARROW ISLAND WAS DESTINED TO HOUSE A HUGE LIQUEFYING GAS PLANT. FOR THE CONSTRUCTION OF THE PLANT A MATERIAL OFFLOAD FACILITY WAS NEEDED AND A JETTY FOR THE LNG VESSELS.

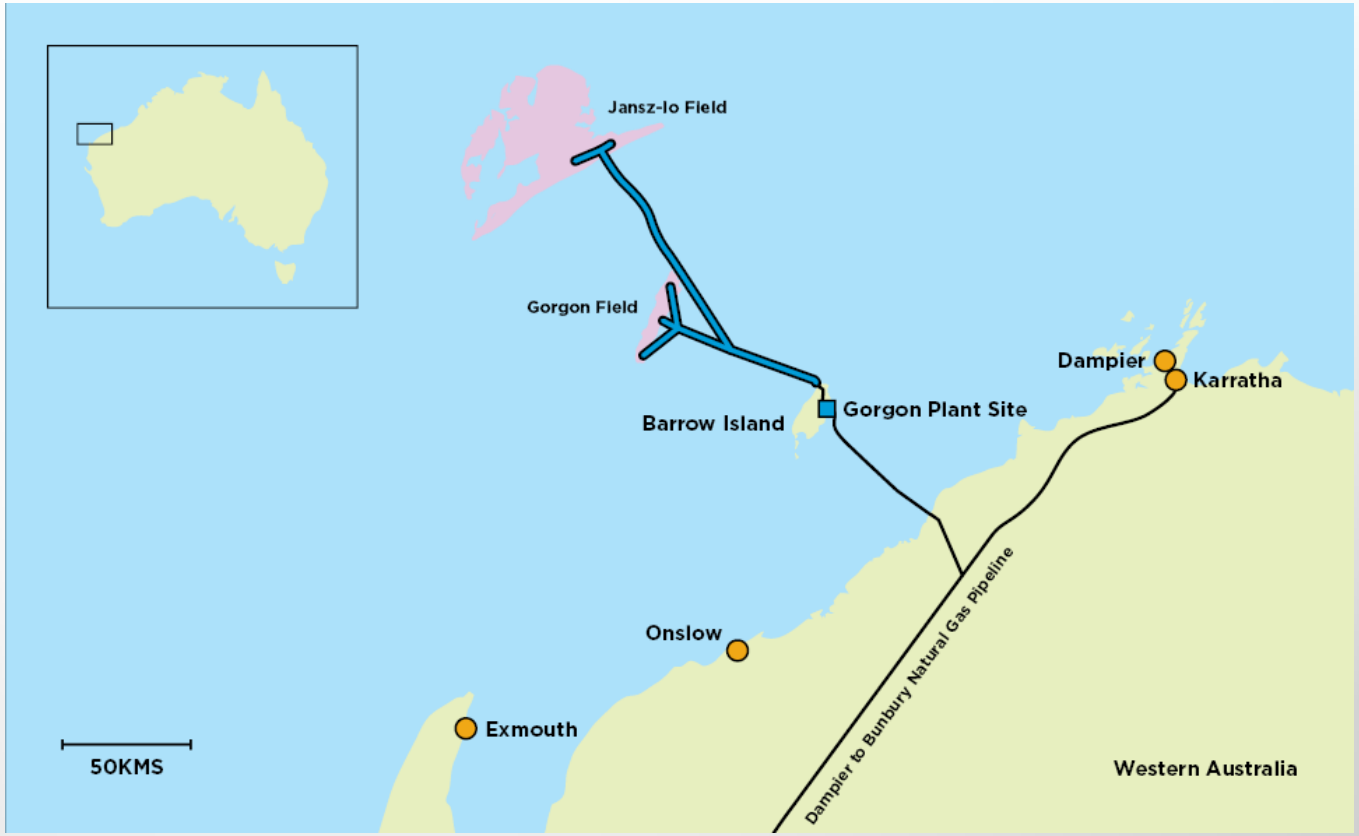
BARROW ISLAND IS A CLASS A NATURE RESERVE AND AT ALL COST CONTAMINATION OF FLORA AND FAUNA FROM THE MAIN LAND IS TO BE AVOIDED.

THIS WAS LEADING FOR THE PROJECT: NATURE PROTECTION AND SAFETY BEFORE ALL ELSE. A UNIQUE, HUGE PROJECT.

LAYOUT GORGON GAS PROJECT

A direct gas pipeline to the Australian mainland proved uneconomical

The placing of a Liquid Natural Gas plant on Barrow Island made the project feasible



https://australia.chevron.com/our-businesses/gorgon-project

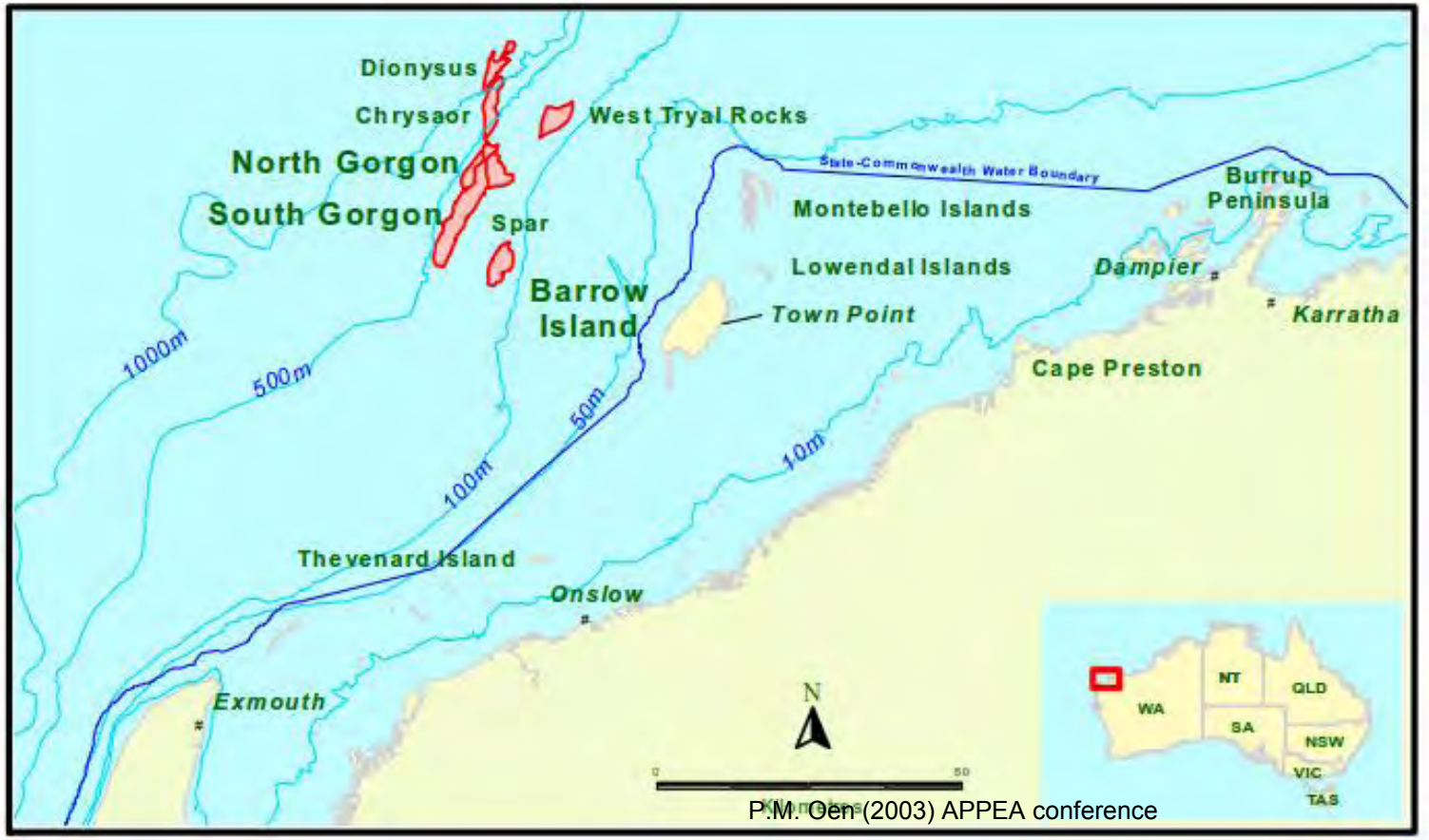
THE GORGON AND JANSZ-IO GAS FIELDS

200 kilometers from the coast

35.3 trillion cubic feet ($1{,}000 \times 10^9$ m^3) of natural gas

may have a lifespan of 60 years

(Chevron Australia 2018)



P.M. Oen (2003) APPEA conference

Note the bathymetry contours: Barrow Island is on the coastal platform

BARROW ISLAND

Despite the fact that Barrow Island is a Class A nature reserve since 1914, after an oil reserve was found in 1947, oil winning on the island occurs since 1964.

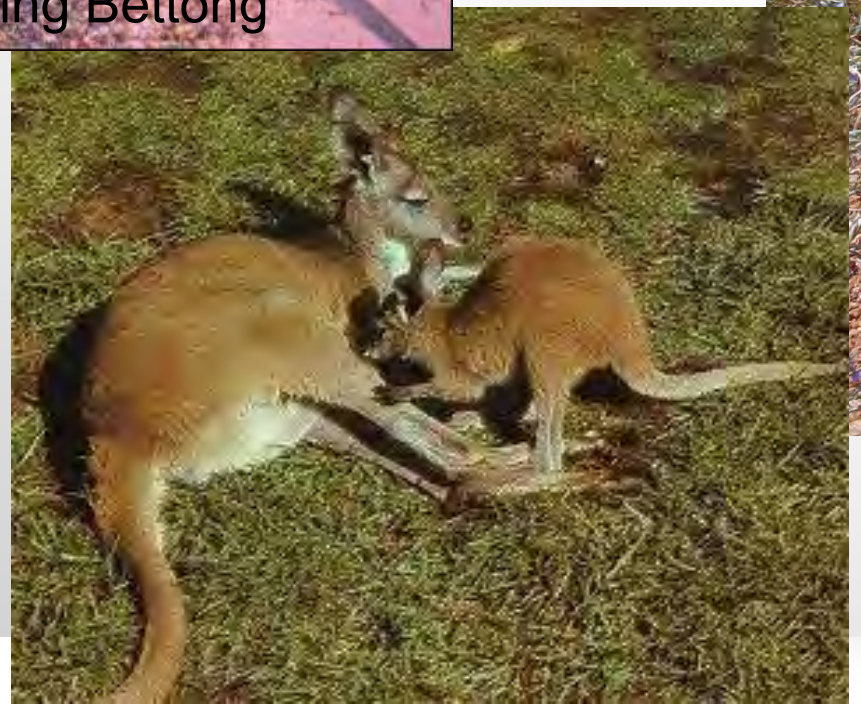
Infrastructure associated with oil production is found over much of the island

On the island strict measures are taken to prevent contamination with flora and fauna from the main land.

P.M. Oen (2003) APPEA conference

Endemic species of Barrow Island

Burrowing Bettong



Parentie Varane

Euro (Eastern Wallaroo)

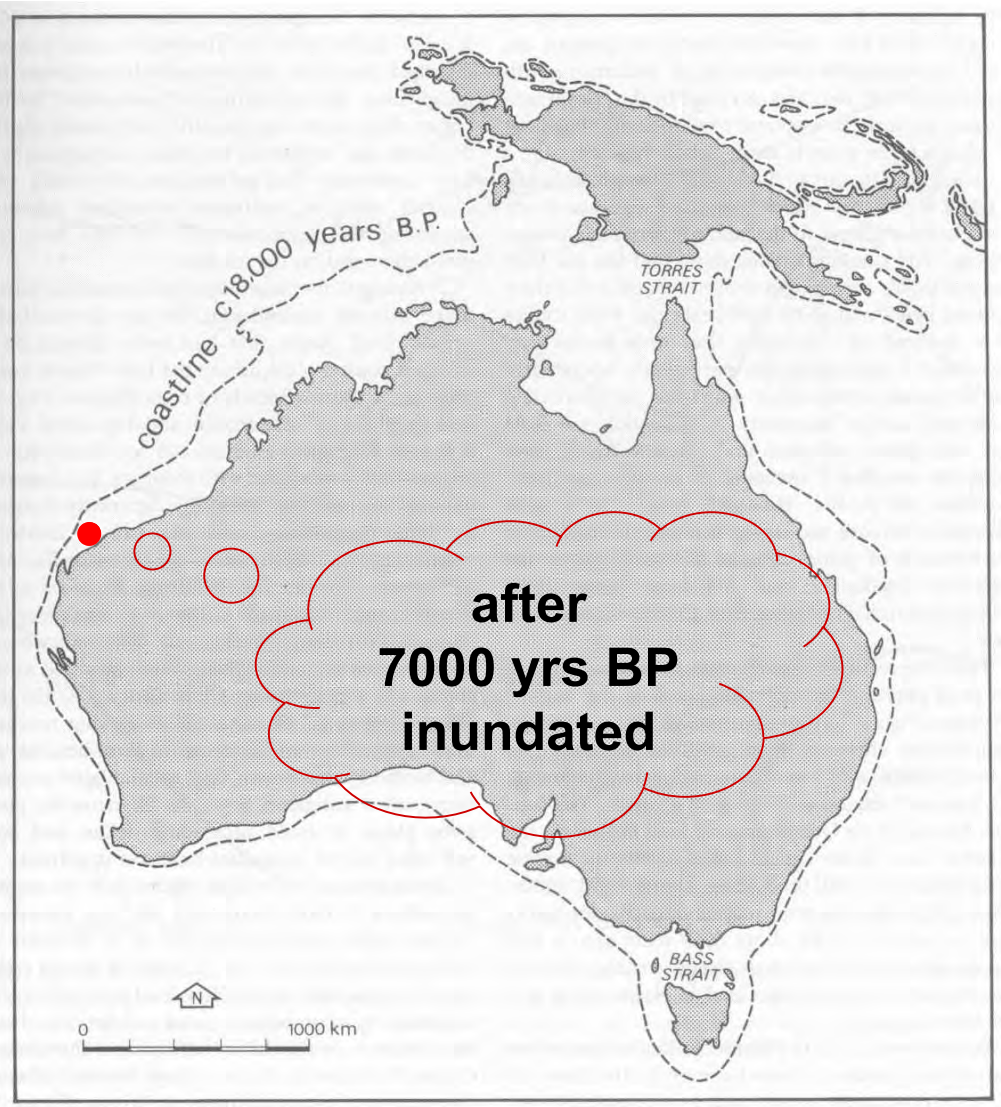
RECENT GEOLOGICAL HISTORY

Past 700.000 years: sealevel fluctuations

Rapid rise over past 10.000 years (from -130 m below present level)

Current sealevel is high point for past 130.000 years

Subaerial weathering took place for the past 130.000 years on the island



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BARROW ISLAND

In 2004 dredging contractors were invited to visit Barrow Island and examine the possible locations for the MOF and LNG terminal.

I visited the island in 2004, 2006 and 2009.

You can only enter the island with clean gear.

I was not allowed to bring in my own geological hammer for example.

But imagine: everything that enters the island has to be clean.

On the island inspection for pests including insects is continuously taking place.

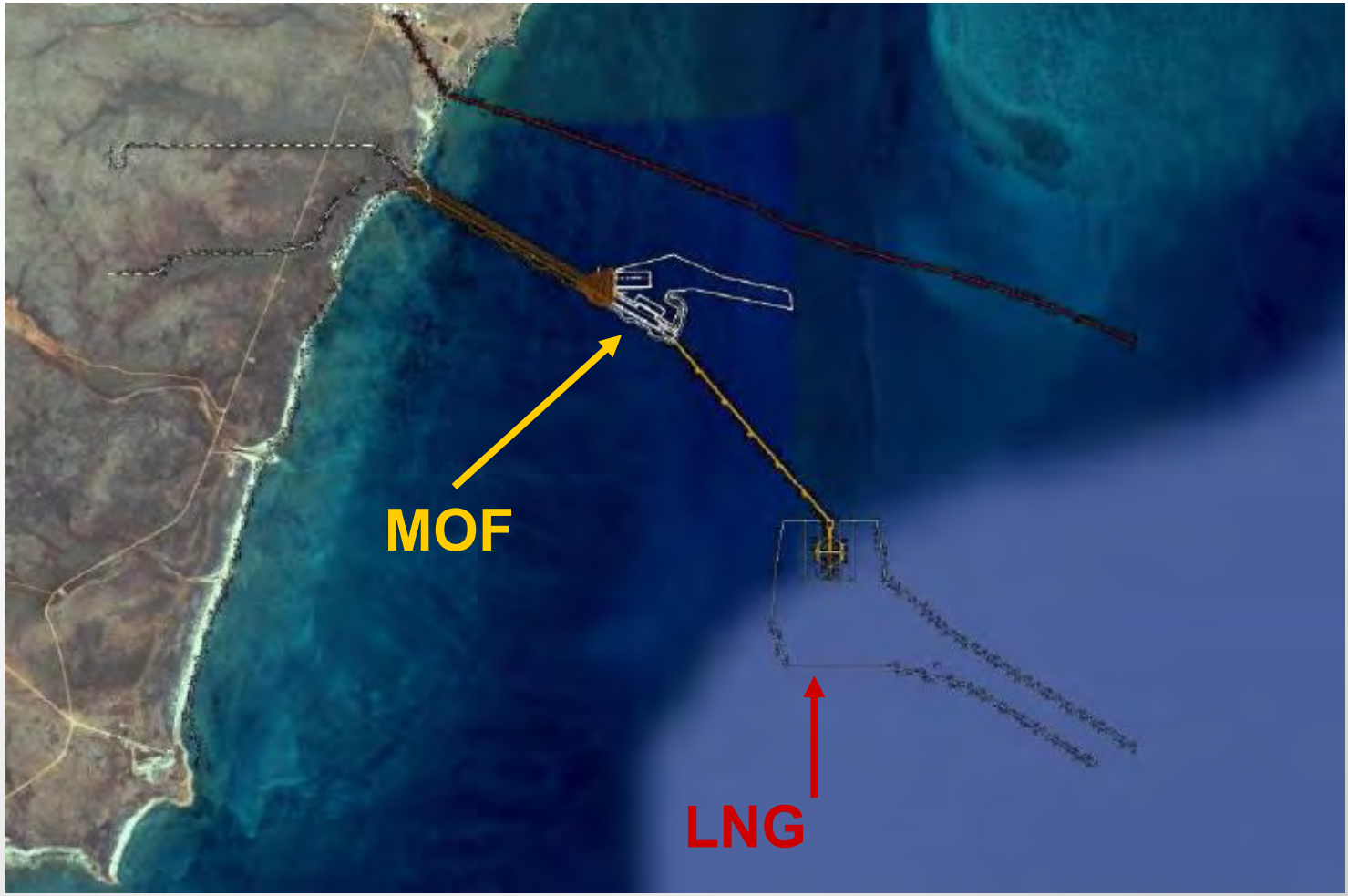
DREDGING PROJECT

The dredging work involved:

Dredging for the MOF area (about 1 Mm^3)

and the

LNG terminal and Access channel (about 6.3 Mm^3)

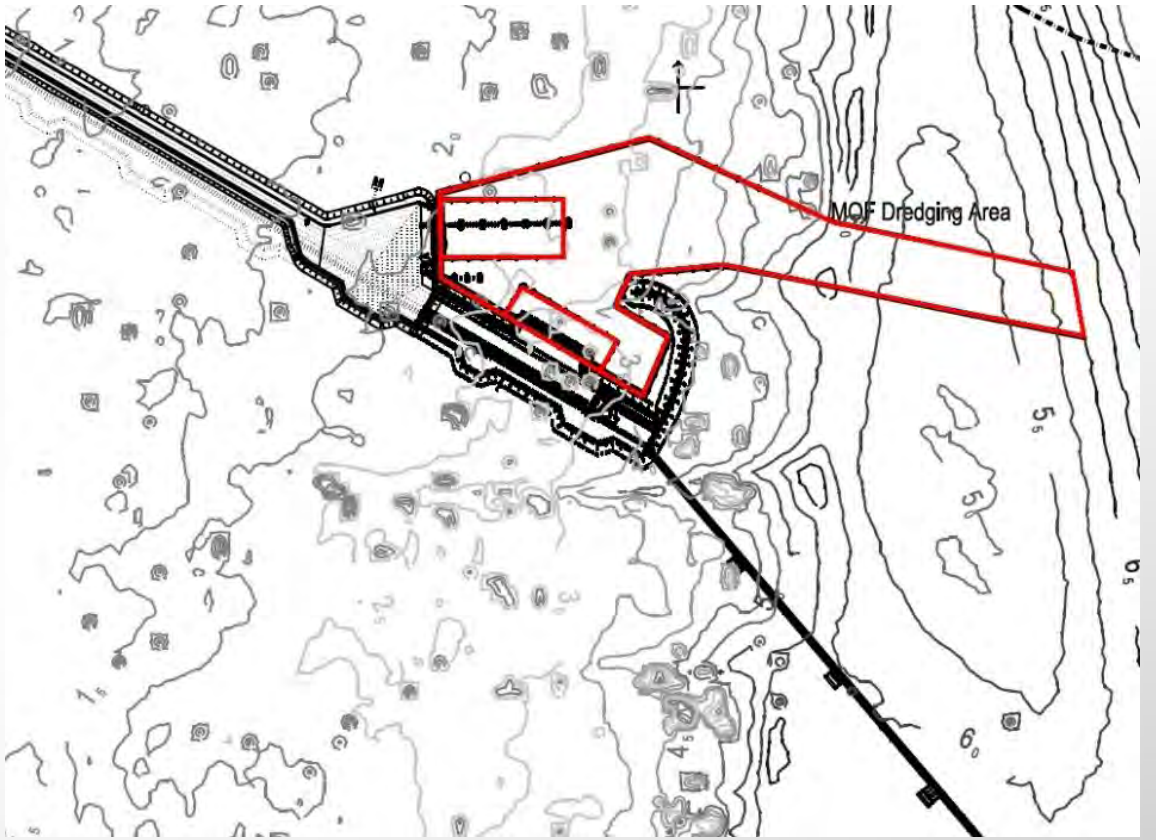


The project was tendered in 2006 and was awarded to Boskalis in 2009

SCOPE OF WORK

Dredging MOF Area

- Approach Channel
- Turning Basin
- Berth Pockets
  (0.7 million m^3)



SCOPE OF WORK

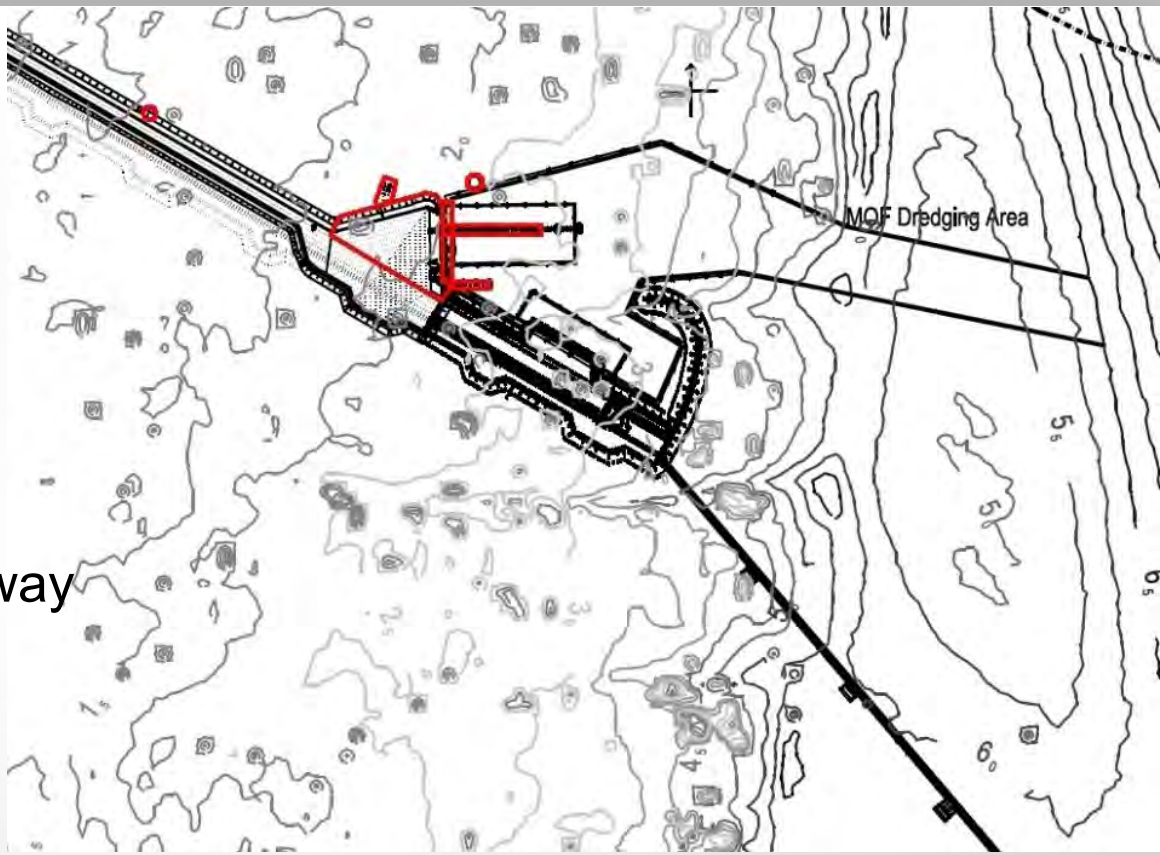
Design and construction of Pioneer MOF:

- Bunds & Reclamation (0.43 million m3)
- Rock Revetments (200,000 tons rock)
- Abutment Structures
- Berthing Dolphins & Access Walkway
- Small Craft Landing Pontoon

Extension of work:

Eastern MOF (EMOF):

- Rock Revetments (270,000 tons rock)
- 14,500 X-blocks.



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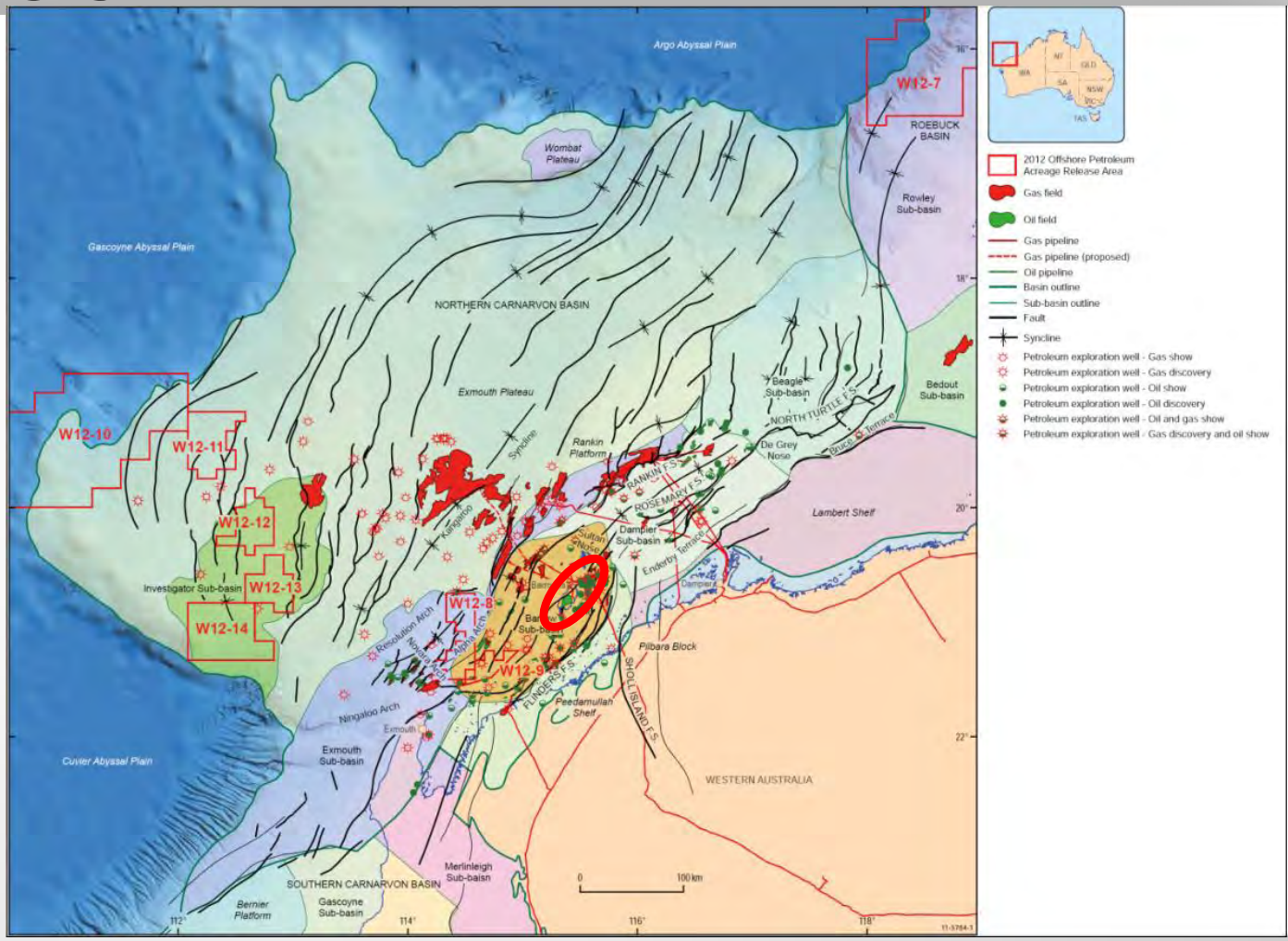
REGIONAL GEOLOGY

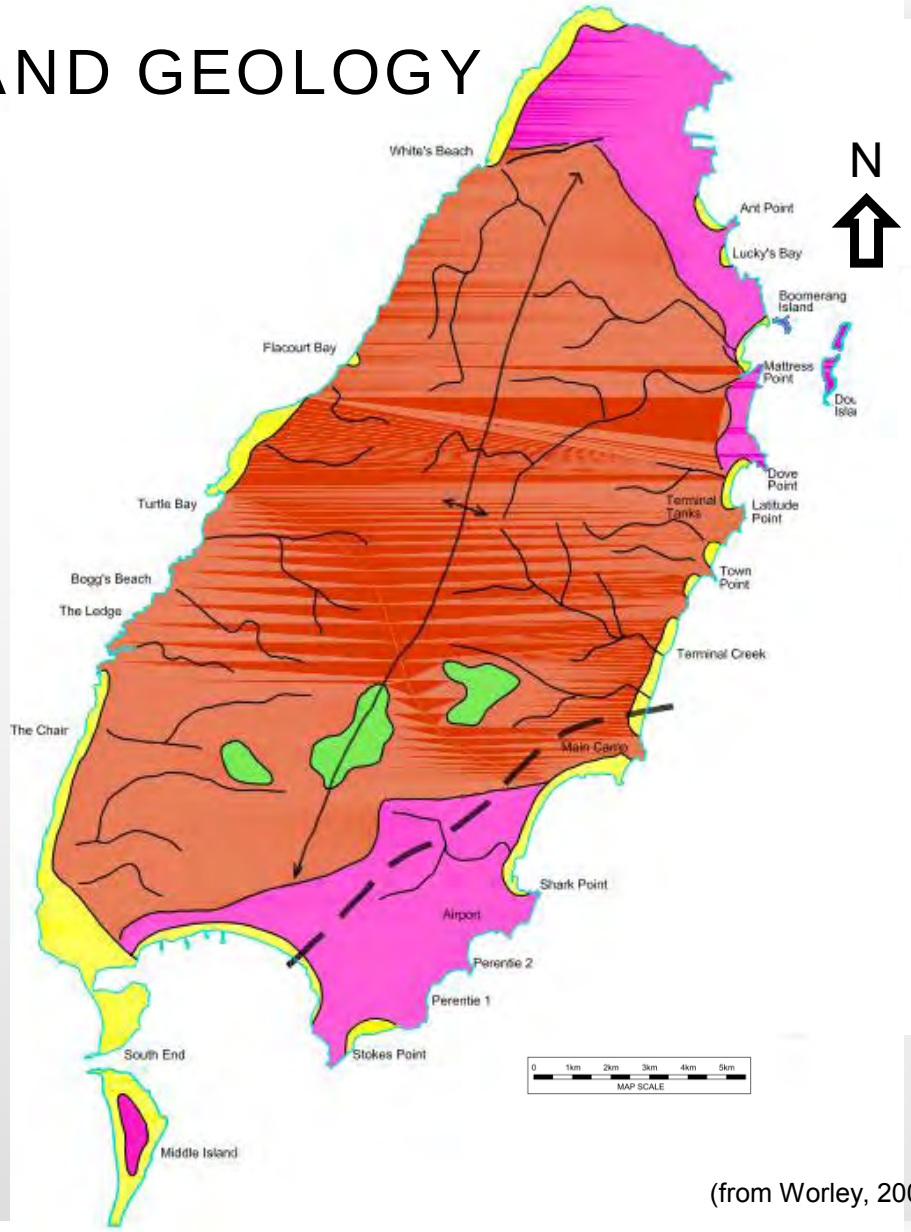
The Gorgon Gas field and Barrow Islands oil field are situated in the Northern Carnarvon Basin, characterized by open fold structures, with NE-SW trending axes

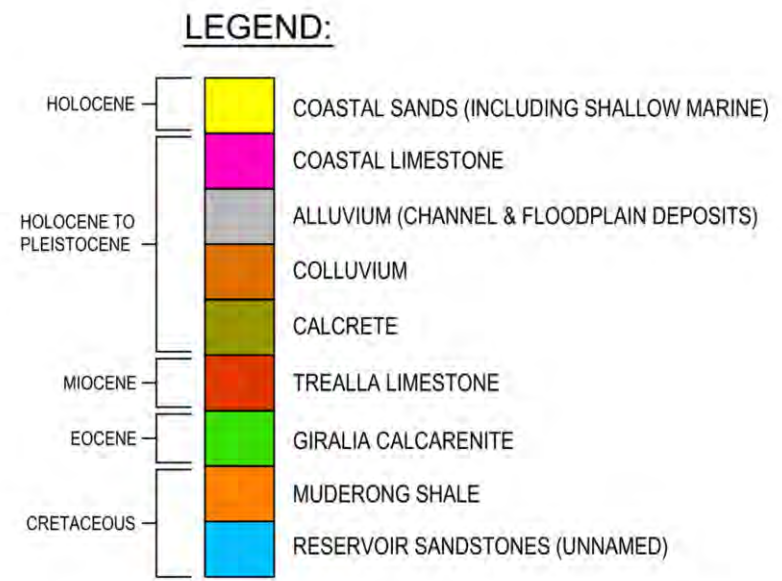
Barrow Island sits on an anticlinal structure

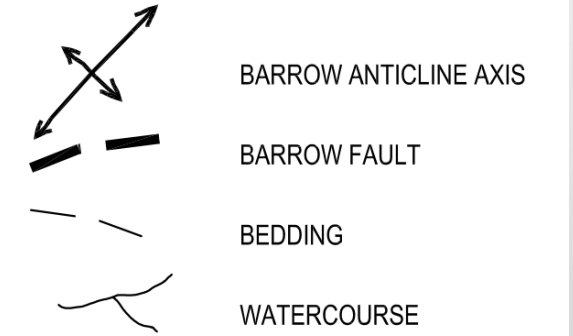


Australia 2012 Offshore Petroleum Exploration Acreage Release - Regional Geology of the Northern Carnarvon Basin. Australian Government - Department of Resources, Energy and Tourism - Geoscience Australia.

BARROW ISLAND GEOLOGY

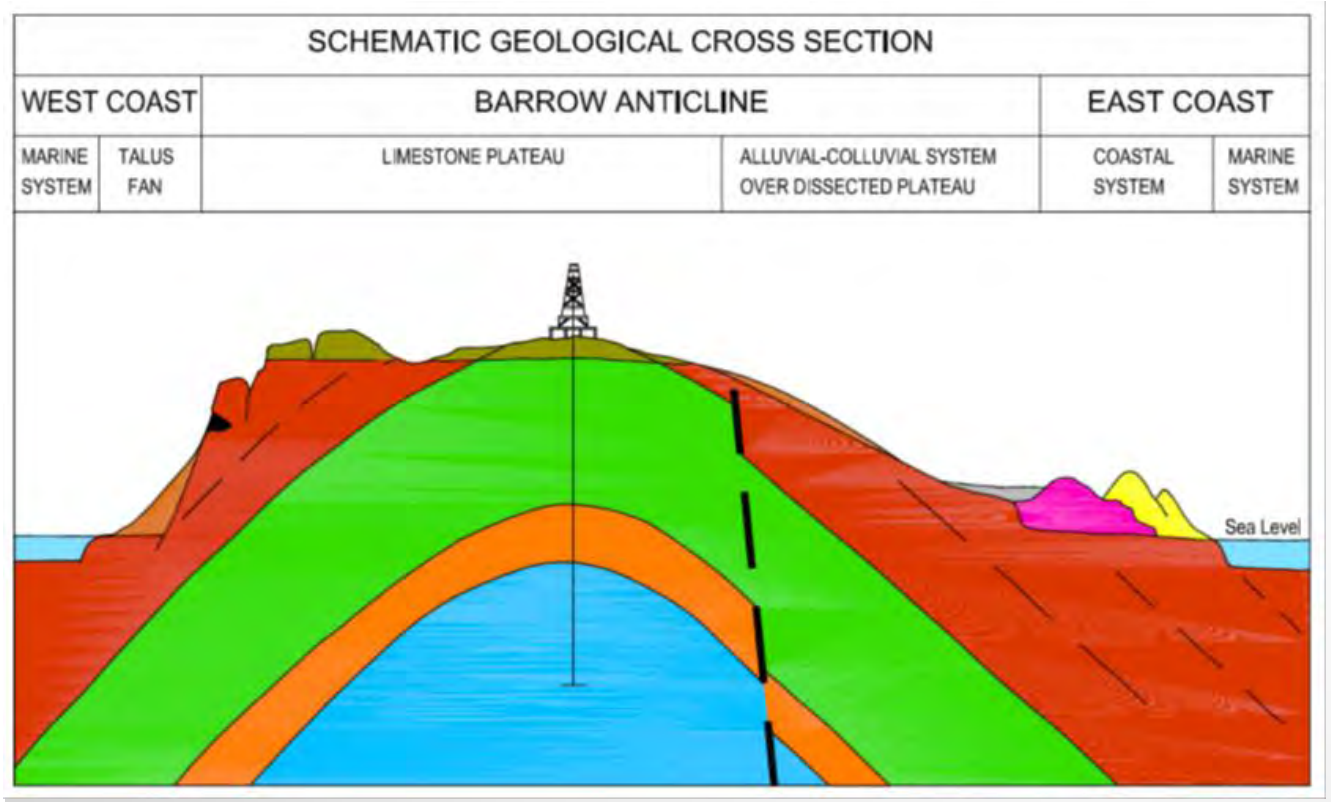


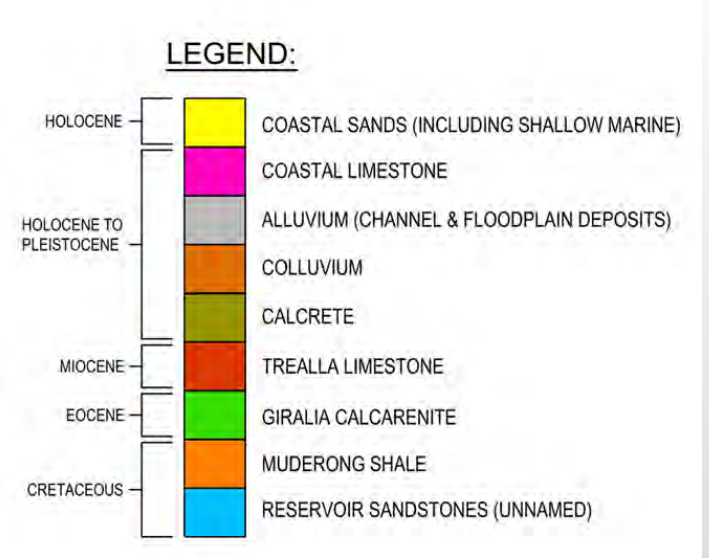




(from Worley, 2005: Geotechnical Investigation Gorgon Nearshore Development)

BARROW ISLAND GEOLOGY

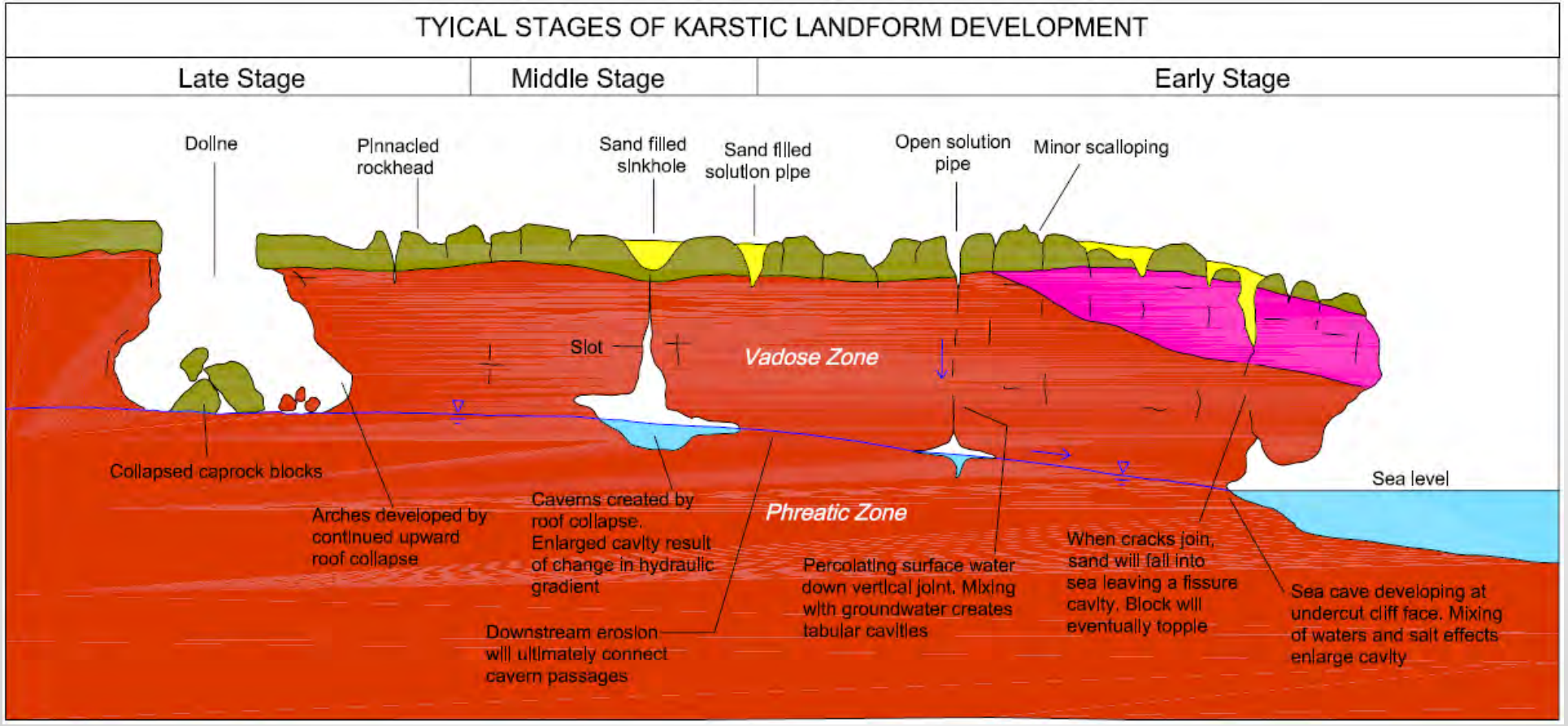




The island is shaped by an anticlinal fold structure, that also acts as a trap for the oil, which is arrested by the Muderong Shale, which underlies the Tertiary Limestone rock

(from Worley, 2005: Geotechnical Investigation Gorgon Nearshore Development)

COASTAL GEOLOGY



Weathering results in karst by dissolution. Rusty oxidation and clay weathering products occur. Also a duricrust (calcrete caprock) is developed.

(from Worley, 2005: Geotechnical Investigation Gorgon Nearshore Development)

DURICRUST FORMATION

COASTAL LIMESTONE

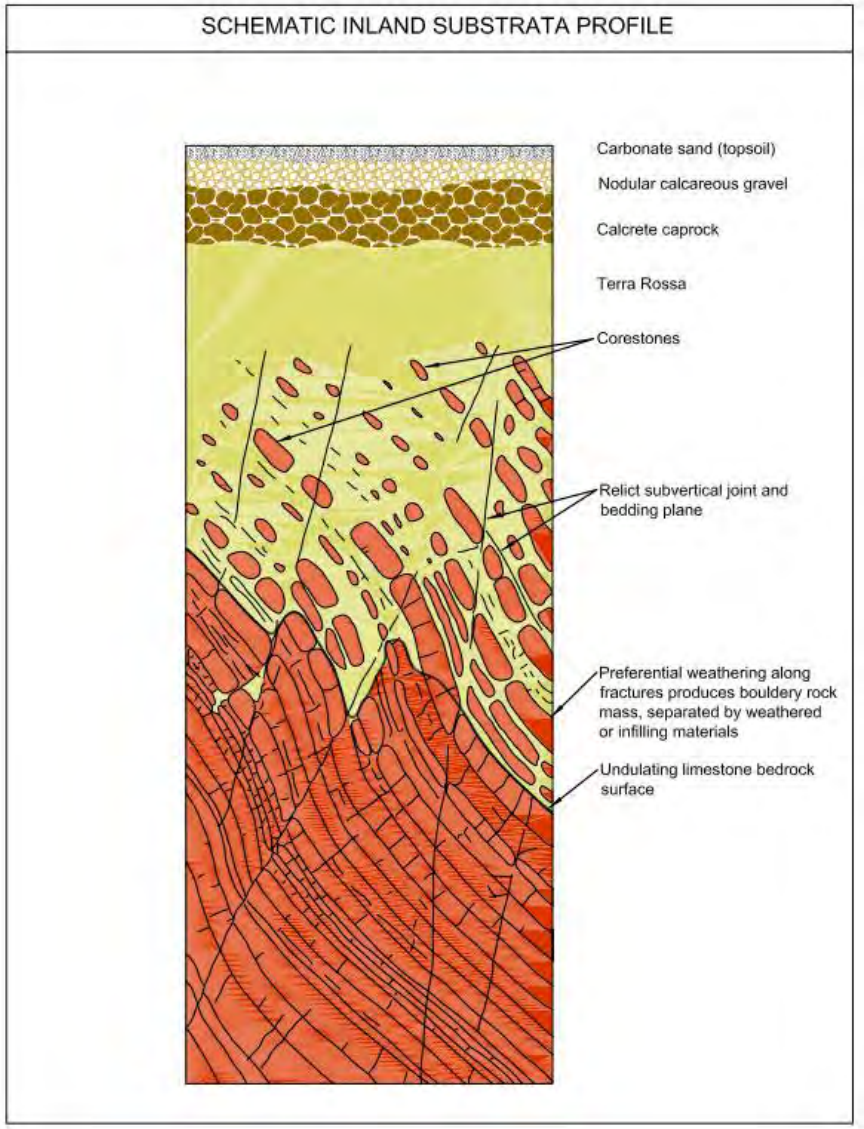
(Raised terraces and sea caves point to current uplift of island)

TREALLA LIMESTONE

Weathered Trealla Limestone in Creek Valley

Obe’s point Trealla Limestone Cliff

WEATHERED LIMESTONE



Additional Borehole LC-BH-04

Phase I Fugro borehole M5

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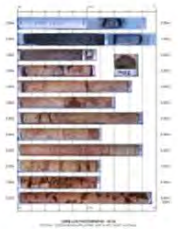
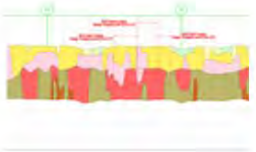
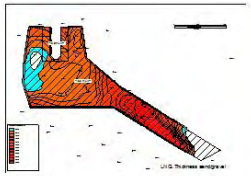
GROUNDMODEL

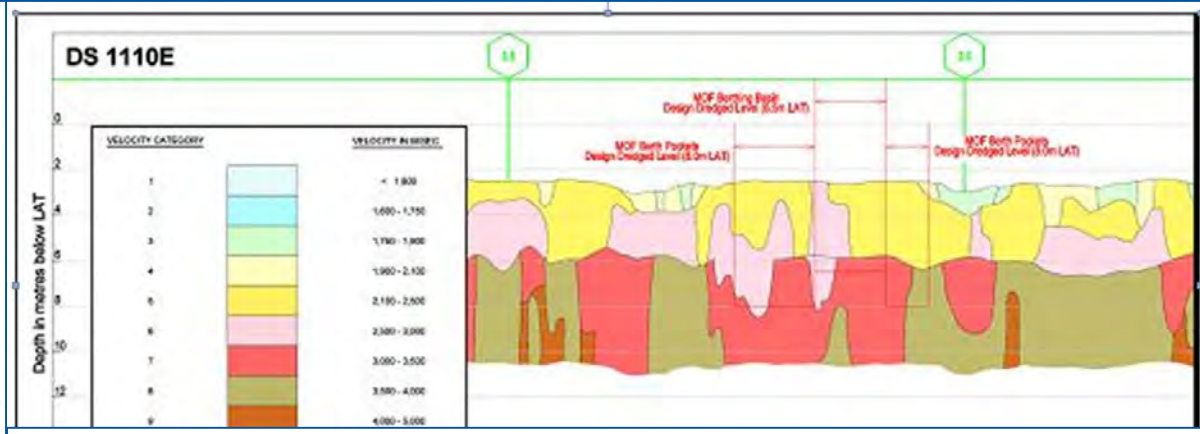


Gorgon Project
Interpretation of geotechnical data

Erik Schoute – Peter Verhoef Dredging Department

< 1600 m/s: granular top soil

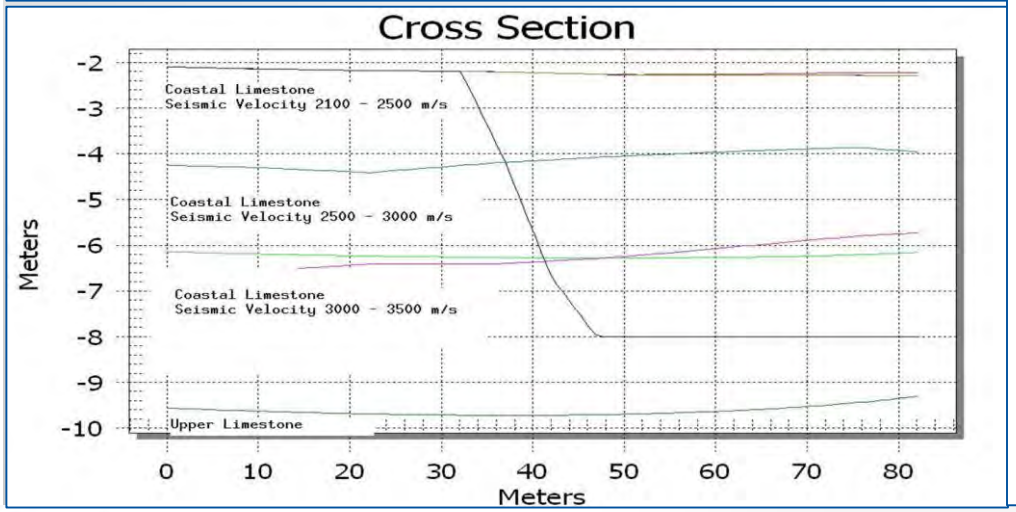
1600-2100 m/s: granular top soil, with cemented layers and gravels

Coastal Limestone:

2100-3000 m/s: rock, UCS=2-9 MPa, mean 6 MPa

Trealla Limestone:

3000-5000 m/s: rock, UCS=3-30 MPa, mean 15 MPa



ROCK MASS

< 1600 m/s: granular top soil

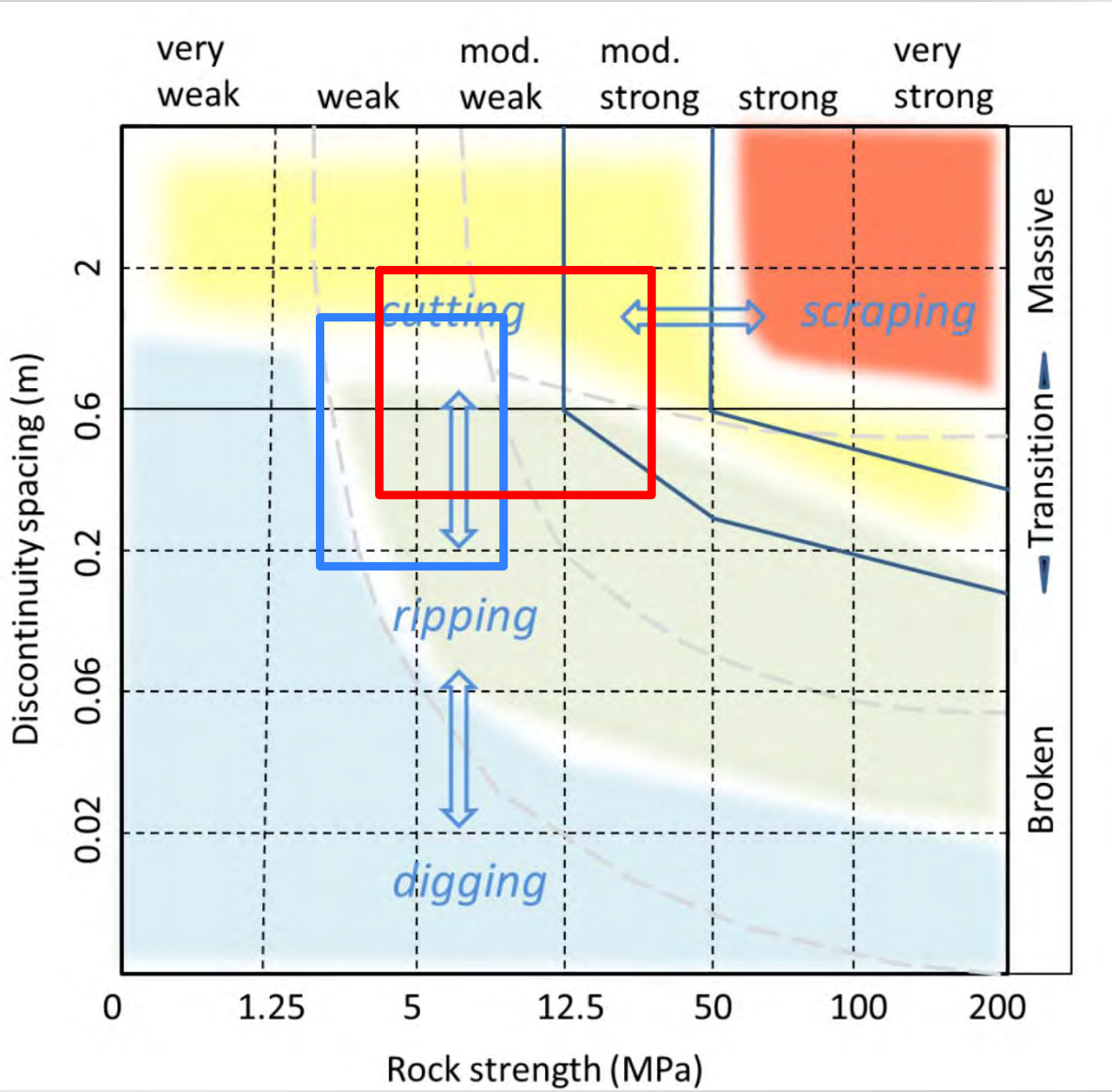
1600-2100 m/s: granular top soil, with cemented layers and gravels

Coastal Limestone:

2100-3000 m/s: rock, UCS=2-9 MPa, mean 6 MPa, Bulk density 2.4 Mg/m^3

Trealla Limestone:

3000-5000 m/s: rock, UCS=3-30 MPa, mean 15 MPa, Bulk density 2.4 Mg/m^3



DIRECT DREDGING BY BACKHOE

Direct dredging of the Coastal limestone by the newly built jumbo backhoe Baldur was successful. The top of the unit was expected to be stronger (calcrete / caprock), but the thickness of this caprock was higher than expected…..

HARD ROCK CRUSHED WITH CSD TAURUS

CRUSHING OF ROCK :

SUCTION MOUTH IS IN PLACE.

CRUSHING WITHOUT UNDER WATER PUMP

CRUSHED ROCK DREDGED BY BACKHOE DREDGER OR HOPPER DREDGER (TSHD)

The Baldur BHD started in May 2010 with dredging for the Pioneer MOF

Early 2012 the MOF was ready

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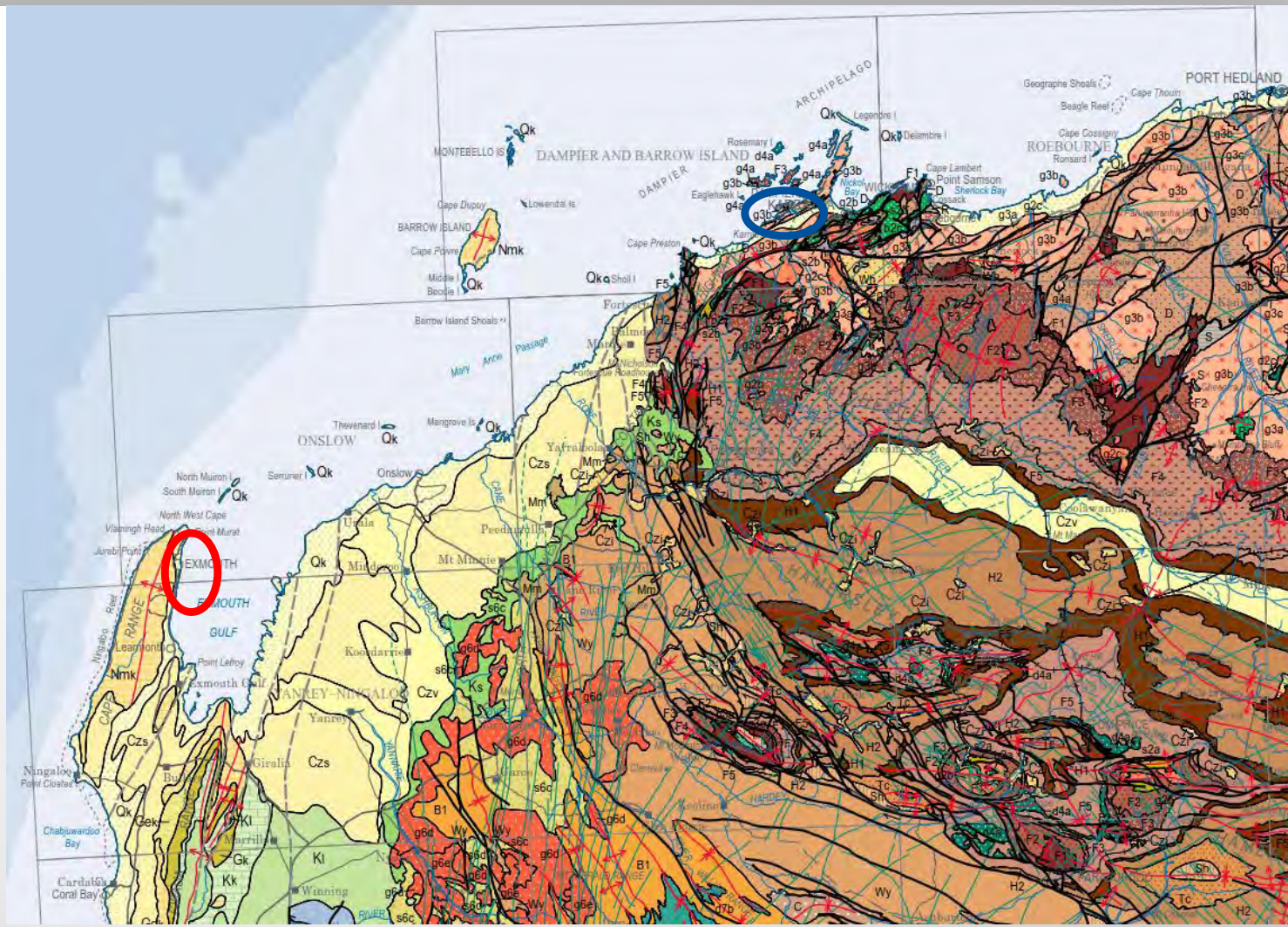
ARMOURSTONE FOR MOF REVETMENT

Similar rock to the Trealla Limestone on Barrow Island is found at Exmouth

An other obvious location is the hard gabbro and granitic rocks at Dampier

Both possibilities were investigated. Logistics problems ruled out the Dampier option



http://dmpbookshop.eruditetechnologies.com.au/product/geological-map-of-western-australia-12-500-000-2015.do

EXMOUTH ROCK QUARRY

The quarry is in Trealla Limestone

QUARRY INSPECTION

Inspection visit allowed assessment of armourstone quality and impression of the quantity of large rock blocks available. There were doubts if enough thick layers were available. The rock is locally brecciated, fractured and weathered.

EXMOUTH BREAKWATER

The breakwater consists of large armourstone blocks, locally brecciated and fractured.

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ARMOURSTONE PRODUCTION NEAR PERTH

Final selection of armourstone source in the Darling Ranges near Perth.

Although 1500 km from Barrow Island there are

- Excellent quality granites
- Several large aggregate pits
- Relatively easy project control and logistics
- Deepwater port facilities

ARMOURSTONE PRODUCTION NEAR PERTH

Rock was sourced with 4 different suppliers, multiple quarries. The way they achieved to produce a compliant end-product differed significantly based on geology, rock mass properties, blasting performance and rock selection methods.

ARMOURSTONE QUANTITIES

Rock Grading	Quantity delivered to BWI
Selected Quarry Run	142,180
25 kg	1,201
250 kg	1,992
300-1,000 kg	76,528
1,000-3,000 kg	153,025
3,000-6,000 kg	47,850
4,000-8,000 kg	22,091
6,000-10,000kg	20,049
TOTAL	464,916

221,901 tonnes

243,015 tonnes

Challenge: quarry owners consistently overestimate armourstone yield
Yield > 1 ton = 20%
then Total blasted quantity required = 243,015 / 0.20 = 1,2 M tonnes of rock
Yield > 1 ton = 15%
Then Total blasted quantity required = 243,015 / 0.15 = 1,6 M tonnes of rock

QUALITY CONTROL

Rock Material Property testing frequency 1/40,000 tonnes, Grading and shape 1/20,000 tonnes.

QUALITY CONTROL

No blast holes…

…clean stockpiles

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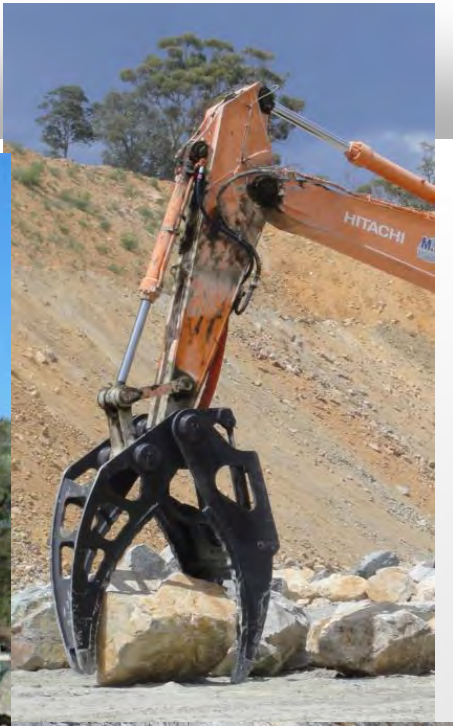
ARMOURSTONE TRANSPORT

QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING



Loading by grapple or forks to minimize dirt

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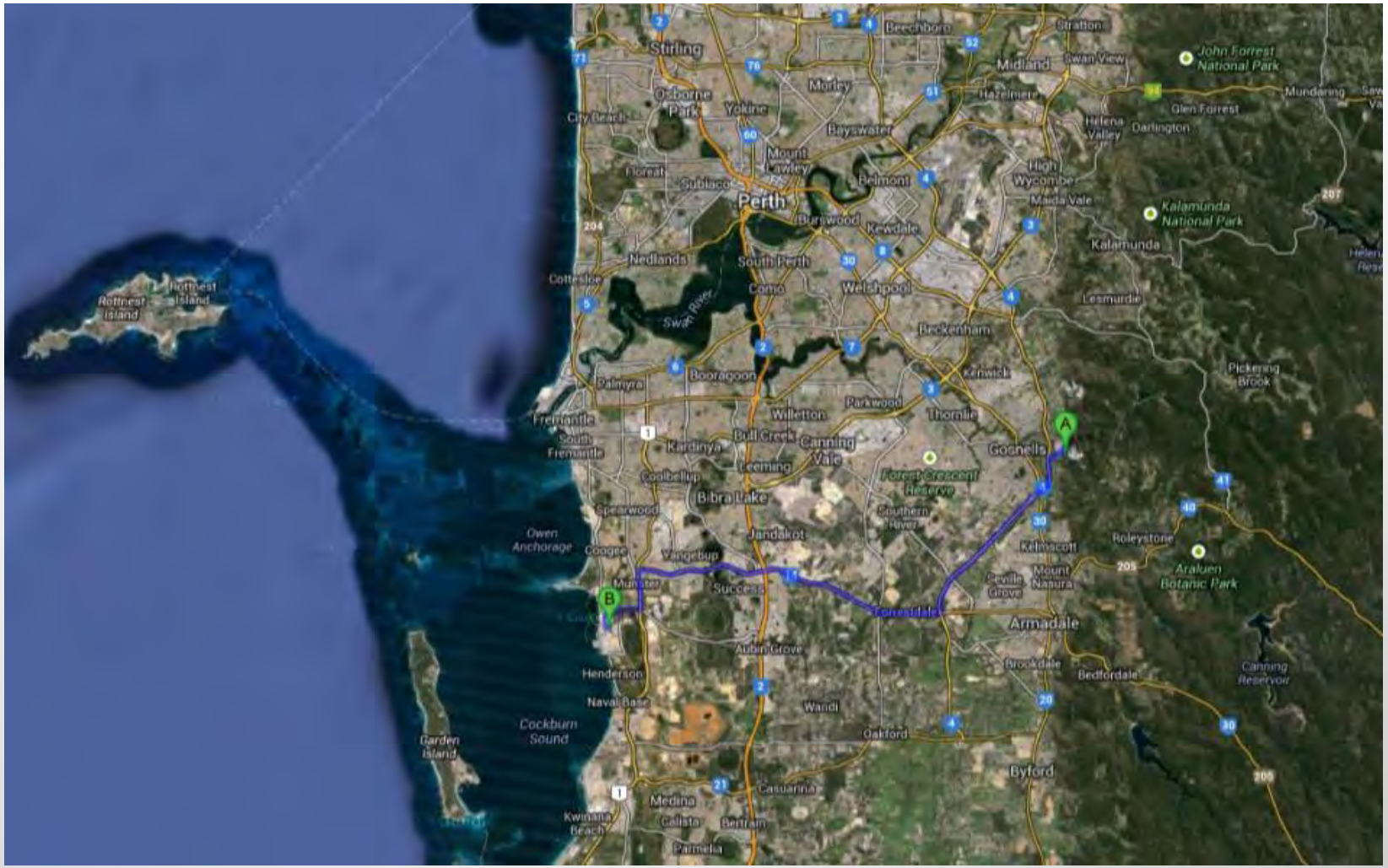
ARMOURSTONE TRANSPORT

QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING



ARMOURSTONE TRANSPORT

QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING

Offloading at the Henderson yard

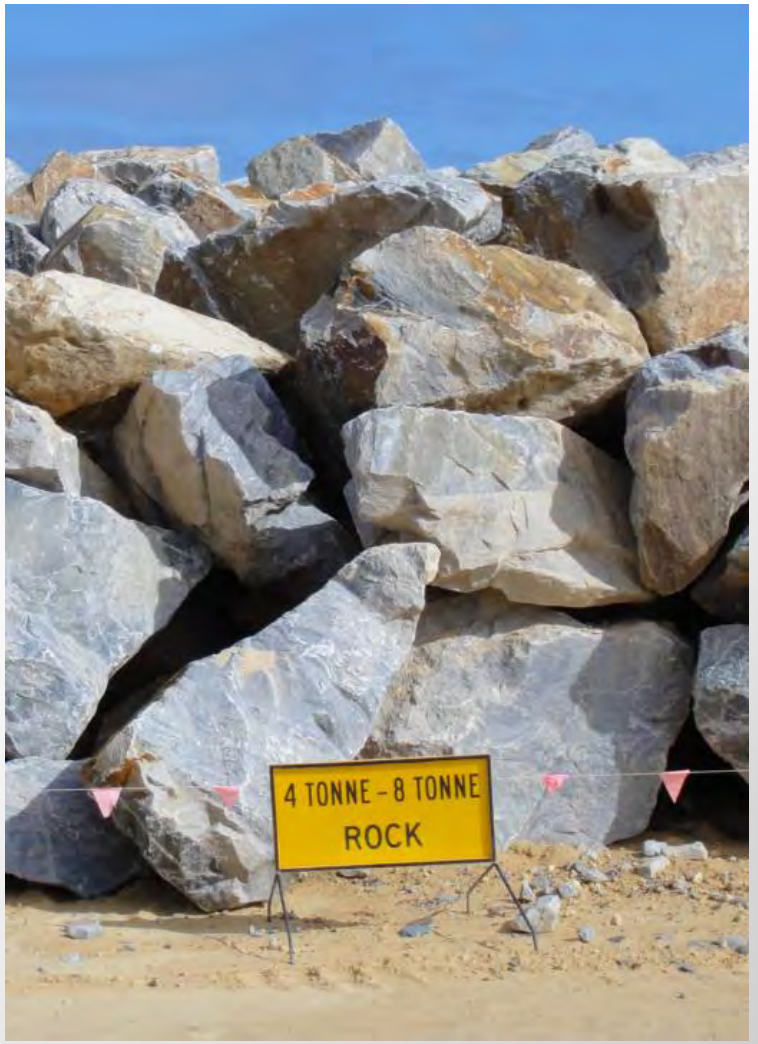
ARMOURSTONE TRANSPORT

QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING



ARMOURSTONE TRANSPORT

QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING

ARMOURSTONE TRANSPORT

QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING

IMPACT PLATE INNOVATION

QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING

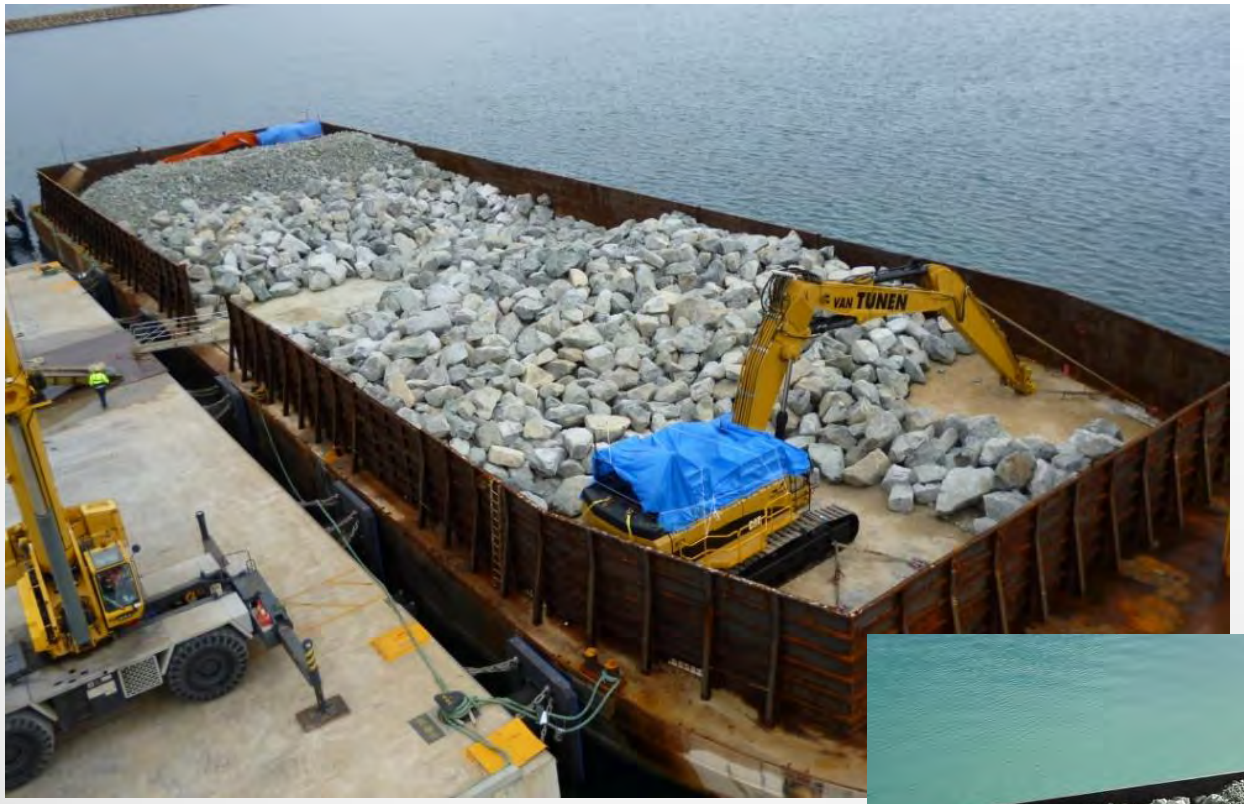
BARGE LOADING AT HENDERSON (PERTH)

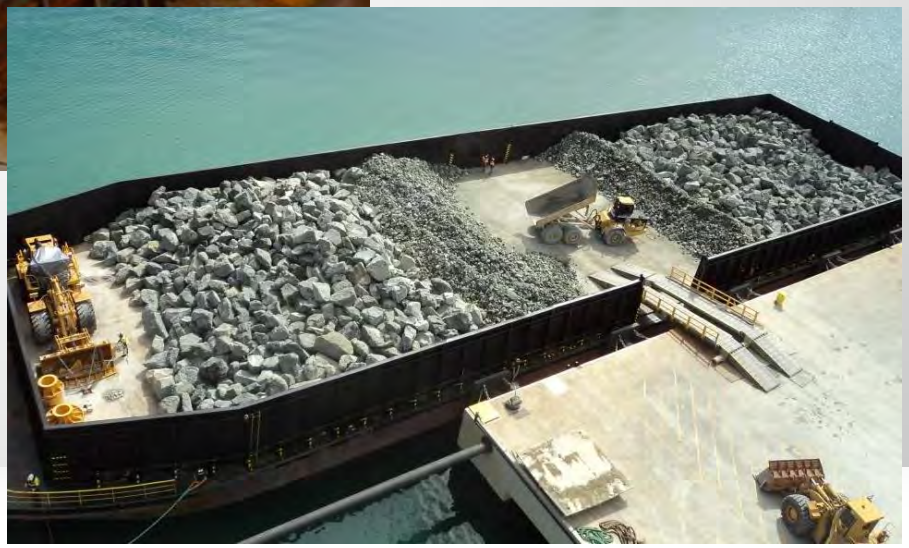
QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING





Often loads with multiple gradings and equipment – lowering barge capacity

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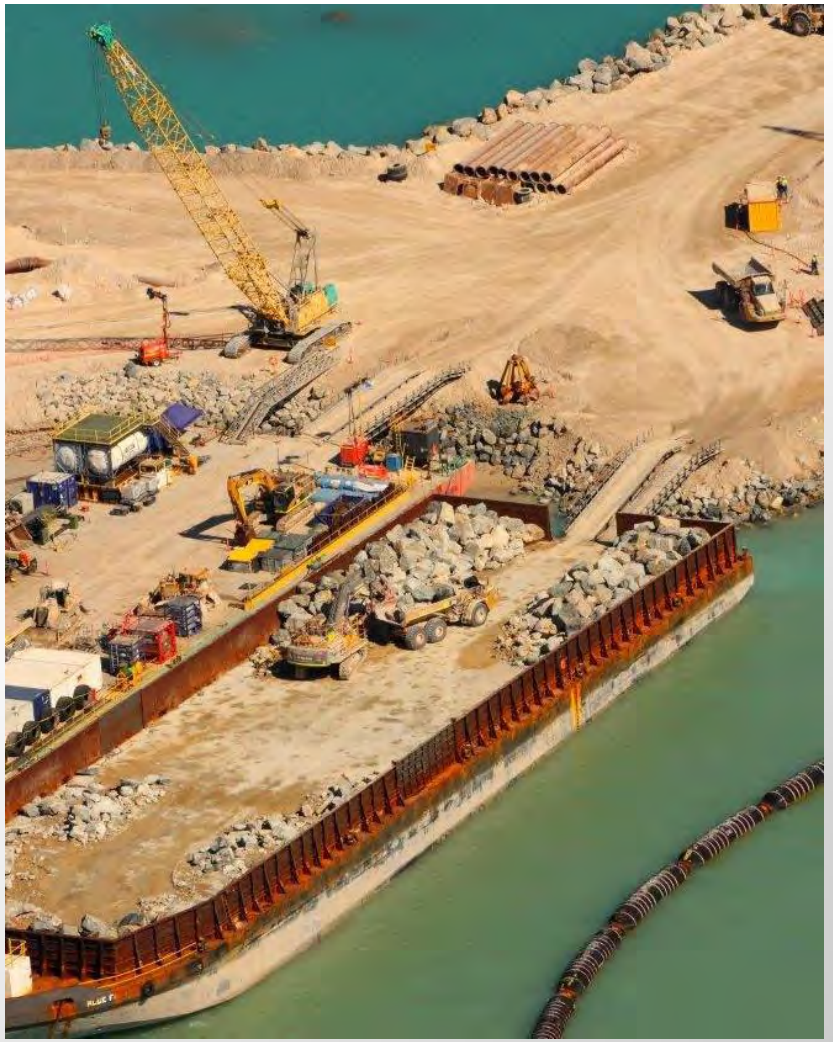
MARINE TRANSPORT

QUARRY

HENDERSON STOCKPILE

BARGE LOADING

BARGE OFFLOADING



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