FINAL WAMSI NODE SUMMARY REPORT TEMPLATE

Node Details

Name of Node:	Ocean Science for Offshore and Coastal Engineering
Node Leader:	Professor Gregory Ivey

1. Node KPIs

Brief Description of "**why**" the research in the Node was undertaken. What were the key questions being addressed and were outlined in the original 2006 WAMSI Business Plan? [A listing of the Projects and Project Leaders and their Project staff, including students will form Annexure 1]

The research in this node was undertaken to enhance engineering design and operations through understanding and prediction of the physical oceanographic processes over the vast regions of operations, including the continental slope and down to the abyssal plain. The research is to support some of the largest ocean developments in the world in a hostile environment where there are many oceanographic unknowns. While the work considers much of the WA marine region, the prime focus is the North West Shelf which has a number of unique physical characteristics. It is an arid environment with little freshwater input. The region has input from the Indonesian Throughflow to the North and output to the Leeuwin Current to the south. There is complex shelf/slope topography, particularly in the northern regions. The Shelf is forced by some of the largest tidal motions in the world, in turn inducing internal waves and solitons, which, in many instances, are the dominant physical process in the marine environment and are thus often the dominant factor in engineering design criteria. Finally the region experiences intense tropical cyclones during the summer months. Further, the scale and intensity of these processes will likely evolve in response to climatic changes. There is thus a need for a comprehensive understanding of this complex and dynamic physical environment. Engineering priorities are for the research to understand these diverse processes and their interactions to provide design criteria for current and future developments in the region. This is particularly relevant to future expansion of the industry into more remote and deeper waters and, in all locations, not only near-surface conditions but also near the benthic boundary layer. More generally, quantifying the physical environment is essential if we are to understand the biological and chemical processes and hence sustainably manage the marine environment that is a focus of activity in other Nodes in WAMSI.

The following key questions were addressed:

Project 6.1:

- How do we manage current facilities and optimise the design of future facilities in West Australian coastal waters under the influence of climate change?

Project 6.2:

- How do we manage current facilities and optimise the design of future facilities on NWS and adjacent seas in the face of the intense forcing from tidally driven waves and currents?

Project 6.3:

- How do we use the new generation of instrument systems such as ocean gliders to obtain sustained observations of the ocean conditions in Western Australia?

2. Research Plan/Science Plan

Describe the high level "**Research Plan/ Science Plan**" for the Node in simple language [Note: the approved Science Plan for each Node will form Annexure 2]

The research plan of the Node is to understand, quantify and predict the physical oceanographic processes operating on the North West Shelf for the benefit of the offshore industry, for the coastal engineering industry, and for the community. A major driver of the research is recognition of the research needs of the offshore oil and gas industry in the Western Australian marine environment. The research tools and model outputs from the Node will be of direct relevance to offshore oil and gas industry and coastal engineering, and also to the fisheries industry, environmental issues, national strategic issues, and training/capacity building for the future. The activities in Node 6 provide benefits to many of the activities proposed in the other Nodes. As the oil and gas industry has its primary focus on the North West Shelf (NWS), this is also the only Node in WAMSI with primary focus on the marine waters from North West Cape to the Timor Sea. Some of the projects will, however, extend to more southerly parts of the WA marine environment.

There are 3 integrated projects covering:

6.1 Offshore and coastal engineering and the effects of climate change.
6.2 Impact of tides and internal waves on offshore engineering.
6.3 Ocean glider deployment as part of the West Australian Integrated Marine Observation System (WAIMOS).

3. Research Activities

1.

Describe the “**Research Activities**” for the Node in simple language. Please try and summarise the methodologies utilised as part of each Project in the Node [Note: the methods section of the approved Project Plans will form Annexure 3]

6.1 Offshore and coastal engineering and the effects of climate change

In Western Australia, similar to other coastal communities around the world, the combined effects of changes in the wind wave climate and the magnitude and frequency of storm surges, together with relative sea level rise due to of climate change could have important implications for coastal vulnerability. One of the major management questions is how will the coast respond to the combined action of waves, storm surges and mean sea level rise under a climate change. The main aim of this project was to address this question with an emphasis on the south west of Australia.

The project involved three main components:

The first component involved an assessment of the potential future changes to extreme still water levels, in particular storm surge magnitude and frequency, under different climate scenarios along the whole coastline of Western Australia. As a first step to considering future conditions, an assessment was made of the historic changes in extremes throughout the 20th century, to set projected future changes in an appropriate context. Extreme sea levels, exclusive of surface gravity waves, arise due to a combination of three main factors: mean sea level, tide, and storm surge. The variability and longer term changes in each of the individual components of sea level was examined before changes in the combined extreme sea levels were investigated. A detailed local assessment of the flooding implications of these potential future changes was undertaken for the Peel-Harvey Estuary.

The second component involved determining potential future changes in the surface wave climate around the coastline of Western Australia. Again, as a first step the present and historic wave climate and its variability was examined to provide context for future change because the order of magnitude of the present variability might be greater than the projected change.

Building on the first two components, the third component of the project considered the impact of these past and potential future changes in mean sea level, storm surges and waves on coastal stability. In particular, Yanchep Lagoon where the beach is defined as ‘perched’, was selected as the main study region. This site was chosen as representative of Western Australia because perched beaches are widespread throughout the entire State, from the wave-dominated beaches perched on calcarenite in the south, to the tide-dominated beaches fronted by fringing coral reefs in the north. In south west Western Australia, at least 25 % of the beaches in the Perth Metropolitan Region are perched due to the dominance of Quaternary limestone formations.

The project used a wide variety of data sources, developed a range of modelling tools and undertook extensive fieldwork at Yanchep over a cascade of temporal and spatial scales. The following data sources were analysed: tide gauge data, wave buoy data, meteorological re-analysis, tropical cyclone tracks, and aerial photographs. Five numerical modelling tools were used: Mike 21, Wave Watch III, SWAN, XBeach and SPHysics. Extensive fieldwork was undertaken at Yanchep Beach, and this included: regular beach surveys, current and wave measurements, sediment flux measurements and surface current drifter tracking.

6.2 Impact of tides and internal waves on offshore engineering

The Project research activities were designed to provide both a comprehensive understanding and predictive capability of the tidal motions and tidally driven internal wave climatology on the Australian North West Shelf. This covers the generation, propagation and dissipation of internal waves, and quantitative assessment of the intensity, spatial and temporal distribution of the currents and turbulence induced by these internal waves. The methods involved an integration of field measurements, the development and application of numerical ocean circulation models, and focussed laboratory and theoretical studies.

Field measurement programs were undertaken at physically diverse locations to determine the characteristics of tides and internal waves in the energetic tidally dominated environment of NW Western Australia. The three field sites and programs were:

1) North Rankin A area measurement/modelling program.

2) Browse Basin and Scott Reef measurement/modelling program.

3) Ningaloo Reef measurement program.

The main numerical modelling tool was ROMS (**R**egional **O**cean **M**odelling **S**ystem), an open source hydrostatic numerical circulation model developed with funds from the National Science Foundation and available freely. ROMS needs large-scale climatological ocean information to provide initial and boundary conditions, information obtained from the BLUELink model. In this application, ROMS is driven by the tidal forcing obtained from the TPXOv7.1 global tidal model and is applied to the North West Shelf with varying domain scales of up to approximately 2000 km by 800 km, and with horizontal spatial resolution down to scales of 1 km and with typically 50 sigma layers in the vertical. ROMS is typically run on timescales of a month. The model can then be used to set up a second model SUNTANS and this has been used mainly in the Browse Basin region. SUNTANS (**S**tanford **UN**s**T**ructured **A**daptive **Na**vier Stokes **S**olver) is a fully non-hydrostatic model and is run in unstructured domains of approximately 100 km by 100 km with horizontal spatial resolution down to scales of 75 m horizontally and up to 150 z-layers in the vertical. It is computationally intensive requiring large parallel machine computations and is able to resolve the high-energy non-hydrostatic flows and internal waves, which are seen at some locations on the NWS.

Data from the field sites was used to evaluate the model results and overall quality of the predictions, to test model descriptions of specific processes such as mixing intensity and energy fluxes and current speeds, and generally optimize model performance. Beyond this step, the model could then be used with confidence to predict ocean behavior at sites were no measurements were made or available. In essence, the models can then be used to forecast ocean behavior, and this method was used in both the Southern NWS region around North Rankin A and the Browse Basin region.

6.3 Deployment of Ocean Gliders as part of the West Australian Integrated Marine Observation System (WAIMOS)

The development of an integrated marine observing system (WAIMOS) for Western Australian was been funded through the National Collaborative Research Infrastructure Scheme (NCRIS) and EIF the Super Science as part of the Integrated Marine Observation System (IMOS) for Australia. In excess of $32 million has been invested in Western Australia. An emphasis is made on the multi-disciplinary real-time data to allow the development of each discipline and their integration. Under this project, multi-disciplinary marine data streams are be provided through the deployment of a range of instrumentation such as HF Radar, Ocean Gliders, Ocean moorings and acoustic observatories. This project was developed to provide funding to facilitate the deployment of ocean gliders in Western Australia and to provide a top-up for a PhD student (Thisara Welhena).

Ocean gliders are autonomous vehicles designed to operate in water depths up to 1000 m. By changing its buoyancy, the glider is able to descend and ascend. For WAIMOS, two different types of gliders are used. Both gliders have the same suite of sensors to measure conductivity (for salinity), temperature, dissolved oxygen, fluorescence, turbidity and CDOM (dissolved organic matter) with depth. The newer versions of shelf gliders also include downwelling light.

The Slocum glider, which has a maximum depth capability of 200m, was deployed off Two Rocks undertaking repeat transects since January 2009 to date (ongoing to June 2013. The aim was to traverse along the SRFME Two Rocks line past the IMOS mooring locations and transect into Perth canyon and then return through the axis of the canyon. A total of 20 Slocum deployments were completed between January 2009 and August 2011.

The Seaglider has a maximum depth of 1000m and an endurance of up to 4500km (up to 6 months). Deployments of Seaglider from Dampier was undertaken along the west coast between North-west Cape and Rottnest Island. A total of 10 Seaglider deployments were completed between January 2009 and August 2011.

4. Research Findings

Describe the "**Research Findings**" for the Node in simple language. Follow the sub-headings:

a. Overall research findings [very high level]
b. Specific research findings/ outputs [specific to the individual projects]
c. Intra-Nodal scientific outcomes [across the projects]
d. Inter-Nodal scientific outcomes [between this and another Node[s]
e. What wasn't addressed by the Node research, but is likely to be important from a scientific perspective?

[Note: the final Project Reports for the Node will form Annexure 4]

a. Overall research findings

6.1
Using data and numerical modelling, for the first time, there is a detailed map of the mean sea level, astronomical tide, storm surge, and wave climatology of Western Australia. An assessment has been made of the potential changes to the storm surge and wave climate under various climate change projections for Western Australia.

6.2
For the first time ever on the Australian North West Shelf (NWS), field measurements have been made of the rates of ocean mixing due to forcing by the large tides which dominate the oceanography of the NWS. Numerical models have been developed, and tested against the field measurements, which are able to both describe and forecast the ocean dynamics throughout the NWS dominated by tides and the internal waves they generate.

6.3
Ocean gliders have been successfully and continuously deployed for almost 3 years in the Perth region, and have identified new deep coastal flows cascading off the continental shelf

b. Specific Research findings

1) Project 6.1

- Analysis of data and successful completion of numerical modelling was used to provide, for the first time, a detailed map of the mean sea level, astronomical tide, storm surge, and wave climatology of Western Australia.
- A particular highlight of the research was the mapping of the inter-annual (18.6 and 4.4 year) tidal modulations, firstly for Western Australia and then on a global scale.
- An assessment of the potential changes to the storm surge and wave climate was inferred using numerical models for Western Australia.
- A detailed assessment of potential inundation areas around the Peel Harvey Estuary was conducted for various climate change projections over the 21st century.
- A detailed and successful set of field experiments over a cascade of temporal and spatial scales was conducted at Yanchep Lagoon revealing how beach behaviour response to different metocean forcing and how rock formations influence waves, currents and beach morphology.
- Local scale numerical modelling activities complement the field experiments and helped to provide a significantly improved understanding of the potential response of the coast around Yanchep to the combined action of waves, storm surges and mean sea level rise under a climate change
- 1 Post-Doctoral and 2 PhD students from UWA have been involved in the project. The two PhD students are due to complete their theses in 2012.

- One Final Year undergraduate Honours student has completed an individual research thesis over period 2007-2010.
- A total of 10 refereed journal and conference papers have been produced and an additional 6 journal papers are being prepared.
- A total of 17 presentations have been given at national and international conferences.
- A total of 19 presentations have been given at Workshops or invited seminars with national or international significance.

2) Project 6.2

- Successful field measurement programs were conducted at three separate field sites: Offshore North Rankin A (NRA), Browse Basin, and offshore of Ningaloo Reef
- Field experiments involved measurement of both mean flow quantities and, for the first time ever on the NWS, direct measurements of turbulent mixing
- Completion of numerical modelling was successfully undertaken, using both the ROMS and SUNTANS numerical models, for the NRA area and the Browse Basin area
- Laboratory and theoretical modelling was completed to complement the field and numerical modelling activities described above
- Four PhD students from UWA have been involved in the project; the first two completing theses in 2010 and 2011, and two more will complete theses by November 2011.
- Four Final Year undergraduate Honours students have completed individual research theses over period 2007-2010.
- A total of 11 refereed journal and conference papers have been produced
- A total of 13 presentations have been given at national and international conferences

3) Project 6.3

- Successful deployments of ocean gliders have been undertaken along the Two Rocks Transect (Slocum gliders) and along the deep waters off Western Australia monitoring the Leeuwin Current.
- A total of 20 Slocum and 10 Seaglider deployments were undertaken between January 2009 and August 2011.
- Discovery and documentation of the dense shelf water cascade along the Perth continental shelf.
- Two PhD students from UWA have been involved in the project;
- Three Final Year undergraduate Honours students have completed individual research theses over period 2007-2011.
- A total of 6 refereed journal and conference papers have been produced to date
- A total of 15 presentations have been given at national and international conferences and seminar series.

c. Intra-Nodal scientific outcomes

The 3 projects in this node were independent but geographically complementary in sense that 6.1 focused on the near coastal region (along almost all the WA coast) 6.2 focused on the offshore region in the NWS), and 6.3 on the near coastal region in the southern part of WA.

d. Inter-Nodal scientific outcomes

6.1: There is some complimentary work to that undertaken in Node 2.

6.2: The project scope of 6.2 complemented activities in Project 3.5 in Node 3.

6.3: Glider deployments were supplementary to activities in Node 1 (the PhD student co-funded through Node 1).

e. Issues not addressed but may be important

Project 6.1 investigation changes in storm surges and waves around the whole coastline of Western Australia, but had a focus on the south west. Hence while a detailed investigation was undertaken of the large storm surge and wave events generated by extra-tropical storms, tropical cyclones were only briefly considered. Further work on cyclone-induced surges and waves, particularly in relation to coastal flooding at key settlements along the north west coastline, should be investigated in more thoroughly.

Project 6.2 considered only the ocean response to forcing by tides, it did not consider the ocean response to forcing by cyclones, and these are important in parts of the NWS in the summer period from December to April. The ocean circulation models can be used to drive biogeochemical models of the ocean and the NWS in particular, and this is a logical extension of the current project.

6.3 None – the glider deployments are ongoing at least until June 2013.

5. Implications for Management (address the "So What")

a) What "management objectives" were being addressed by the research in this Node?

How do we manage current facilities and optimise the design of future facilities in West Australian coastal waters under the influence of climate change?

How do we manage current facilities and optimise the design of future facilities on NWS and adjacent seas in the face of the intense forcing from tidally driven waves and currents?

How to establish networks and data streams around marine observations at a national scale to address both short and long term research questions?

What is the background and natural variability in ocean conditions along the WA coastline

b) Who are the key management agency "beneficiaries" of the work in this Node?

Government and the community through the provision of information that underpins the government's initiatives associated with sustainable development and marine planning.

Industry by providing significant additional support to the ongoing development and international competitiveness of the offshore oil and gas industry

Particularly Dept of Fisheries and DEC for background and natural variability in ocean conditions along the WA coastline

c) What "management strategies" were being addressed by the research in this Node?

Policy for coastal zone under climate change

Development engineering design criteria for offshore oil and gas industry.

d) What "strategies and actions" are likely to be changed as a result of the research in this Node?

A better coastal management system and methodologies to assess the response of coastal regions to climate change.

In regard to 6.2, now developed sufficient knowledge internal waves that industry can assess first whether internal waves will be important in their geographical area of operation and second how strong the currents will be at a given location. Hence new industry standards for the design of engineering infrastructure to respond to the hazards associated with the internal waves.

e) Has the research in this Node improved "management effectiveness"?

6.1: Yes, the work has feed directly into revising the Western Australian Coastal planning policy.

6.2: Yes, now vastly better informed about the character of the physical environment of the NWS

6.3: Yes, Have discovered new process - Dense shelf water cascade – which has a significance for cross shore transport of water and suspended material.

f) Are the research findings "easily accessible" and in a format that allows for ease of interpretation and "take-up" by management agency staff? How has this "knowledge transfer" been facilitated to ensure the maximum value has been gained from the research?

The research findings are easily accessible as all results are published or shortly to be published in peer-reviewed open scientific literature. All metadata from project is available as per 7 below.

g) Has the research in this Node improved the overall management of the marine/ coastal environment in WA? How and give examples.

Yes, based on the research undertaken in 6.1 and expertise gained from the project, we were asked to peer review and contributed to the recent revision of the Western Australian Coastal planning policy. The group was also asked to provide a coastal assessment for the Yanchep lagoon to examine the possibilities for the relocation of surf lifesaving club.

Yes, as the numerical models developed in 6.2 have been used to assist in the planning and design phase of a number of either proposed projects or currently underway projects on NWS conducted by oil and gas industry.

Discovery of Dense Shelf Water Cascade needs to be considered when considering the nutrient budgets etc of the coastal region.

h) What are the longer-term likely impacts of the research for the State?

In regards to 6.1, on a practical level the research will great benefit the longer-term coastal management and planning of the state. From a research perspective we have become known internationally for our research on sea level variability and the implications of climate change and its impact on coastal stability. This has lead to collaborations with the National Oceanography Centre at the University of Southampton (UK) and the University of Seigen (Germany) and projects have been set up with the Australian Government Department of Climate Change and Energy Efficient and the Antarctic Climate and Ecosystems Cooperative Research Centre (Tasmania) to extend the work to the whole coastline of Australia.

In regard to 6.2, we have become globally known for our excellence of research and capabilities in the ocean dynamics and internal wave area in particular. This has led to new research projects and collaborations with MIT, Oregon State University, and a large project in period November 2011 to April 2012 with the US Naval Research Laboratory at Stennis Space Centre, Mississippi.The other significant output is the training of personal, both undergraduate and PhD, who will be directly employed by industry and government.

In regards to 6.3, WA has become one of only two places globally (other being off New Jersey, USA) which has undertaken multi-year repeat transects using ocean gliders to understand the continental shelf processes on seasonal and inter-annual timescales. The Ocean glider facility at UWA now forms one of the largest ocean glider facilities in the world and is considered a leader in the effective users of ocean glider technology globally. The IMOS funding will continue at least to June 2013 and recent funding by the WA State government will unable deployment of ocean glider along the north-west shelf of Australia.

6. Capacity Building

Detail the additional "capacity building" this Node has provided to WA. Considerations include Masters and PhD students, postdocs, technical support staff, research staff, equipment, facilities, building expertise and associated "knock-on" opportunities and income streams.

For Project 6.1:

- 1 Post-Doctoral and 2 PhD students from UWA have been involved in the project. The two PhD students are due to complete their theses in 2012.
- One Final Year undergraduate Honours student has completed an individual research thesis over period 2007-2010.
- Collaborations with staff and students at the National Oceanography Centre at the University of Southampton (UK), the University of Seigen (Germany) and the Antarctic Climate and Ecosystems Cooperative Research Centre (Tasmania).
- A project has been set up with the Australian Government Department of Climate Change and Energy Efficient and the Antarctic Climate and Ecosystems Cooperative Research Centre (Tasmania) to extend some of the methodologies applied in 6.1 to the whole coastline of Australia.

For Project 6.2:

- Four PhD students from UWA have been involved in the project; the first two completing theses in 2010 and 2011, and two more will complete theses by November 2011.
- Four Final Year undergraduate Honours students have completed individual research theses over period 2007-2010
- Two postdoctoral research Fellows over period 2007-2011.

For Project 6.3:

- Two PhD students from UWA have been involved in the project;
- Three Final Year undergraduate Honours students have completed individual research theses over period 2009-2011.
- The ocean glider facility employs 5 people and is the only such facility in Australia providing ocean glider capability for whole of Australia

7. Data Management

1.

Summarise the "Data and Information products" that have been generated by this Node.

For Project 6.1:
40 year (1970-2009) hindcasts of sea level and waves have been generated for the whole of Western Australia. These will provide valuable time series for coastal assessment in regions when no tide gauge or wave buoys are located.

For Project 6.2:
Physical oceanographic database from field measurement programs at diverse sites on NWS

For Project 6.3:
All data are available through the IMOS data portal without restriction.

8. Modelling

Describe [where applicable] the modeling tools that have been created by this Node. What are their strengths and limitations?

For Project 6.1:
A wide verity of numerical models has been setup covering a range of spatial and temporal scales. A tide/surge model of the whole of Western Australian was setup in Mike21 and simulated sea levels for the period 1970 to 2009. A wave model covering the whole of the Southern Indian Ocean was configured in Wave Watch III and produced wave hindcasts for the period 1970 to 2009. A local wave model of the Perth Metropolitan region was setup using SWAN. A local morphological model of Yanchep beach was configured using X Beach and SPHysics. A detailed tide/surge inundation model was setup for the Peel Harvey Estuary. All the models could be used in the future for a wide range of applications. Potentially the tide/surge and wave models of Western Australia could be used for forecasting purposes.

For Project 6.2:
Suite of multi-scale high resolution numerical ocean circulation models for ocean modelling and forecasting, widely applicable.

For Project 6.3:

None – this is a field observation project.

9. Societal Benefits

1.

Summarise the societal benefits of the research in the Node [suggest you summarise section 7 [*Benefits*] from the individual Project Reports]. Give a snapshot of where we were at the beginning of 2006 and where we are in mid 2011?

For Project 6.1:

- The research conducted in this project has considerable societal benefits. The work undertaken provides a much improved understand of the sea level and wave climatology of the region and coastal stability, and will help determine the scale and resources required for flood risk management and planning throughout the 21st century, including upgraded coastal protection and more accurate definition of coastal setbacks.

For Project 6.2:

- For the first time we have a comprehensive understanding of the physical oceanography of the Browse Basin in response to the macro-tidal forcing in the region. This is a necessary step before we can explain and understand the complex ecology of the region.
- Similarly, we have a comprehensive understanding of the physical oceanography in the southern part of the NWS in response to the moderate tidal forcing in the region.
- We have developed new instrument systems for use in the coastal ocean environment
- These models are being used to forecast the ocean environment in regions where there are currently no measurements but the oil and gas industry is proposing current and future developments.

For Project 6.3:

- The use of modern technology for sustained monitoring of the oceans at a reduced cost per measurement.

10. Future Research

Further work recommended. Outline what the next stage of the Node research should look like [if it was to continue] and where are the priority regions? Outline your hopes for the future as it relates to the ongoing uptake and maintenance of this work

For Project 6.1:

Further work on the north west coastline, particularly in relation to tropical cyclone induced storm surge and wave events.

Examples of projects already underway that build on research undertaken in 6.1:

2010-2011	ACE CRC Grant	National/tide surge modelling – Stage 1
2011-2012	DCCEE Grant	National/tide surge modelling – stage 2
2011-2012	WAMSI	Shark Bay - Effects of Rising Water Levels on the Faure Sill and Stromatolites

For Project 6.2
Examples already underway:

2010-2012	ARC Discovery Grant	Coastal circulation in the Kimberley
2011-2013	ARC Linkage Grant	Ocean response to tropical cyclone forcing

For Project 6.3:
IMOS funding continues at least until June 2013 with WA State Government funding extending deployment in the NW shelf to June 2014.

Sign off the Node report in your capacity as Node Leader.

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Annexures

Annexure 1: A listing of the Projects and Project Leaders and their Project staff, including students

Annexure 2: The approved *Science Plan* for the Node [2006 or 2007]

Annexure 3: The methods section of the approved *Project Plans*

Annexure 4: The final *Project Reports* for the Node

Annexure 5: Any other relevant information

Annexure 1: A listing of the Projects and Project Leaders and their Project staff, including students

6.1 Offshore and coastal engineering and the effects of climate change

Project Leader: Professor Chari Pattiaratchi, School Environmental Systems Engineering & UWA Oceans Institute, University Western Australia

Project Team: C. Pattiaratchi, I.D. Haigh (Post-doctoral researcher), Tanya Stul (Research Associate), C. Bosserelle (PhD student), S.L. Gallop (PhD student), L. MacPherson (Honours student).

6.2: Impact of tides and internal waves on offshore engineering

Project Leader: Professor Greg Ivey, School Environmental Systems Engineering & UWA Oceans Institute, University Western Australia

Project Team: G.N. Ivey, N.L Jones, M.Rayson, C.E. Bluteau (PhD student), P. van Gastel (PhD student), K. Lim (PhD student), M. Meuleners (Post-doctoral researcher)

6.3 West Australian Integrated Marine Observation System (WAIMOS)

Project Leader: Professor Chari Pattiaratchi, School Environmental Systems Engineering & UWA Oceans Institute, University Western Australia

Project Team: C. Pattiaratchi, C Hanson, Mun Woo (Post-doctoral researchers), Thisara Welhena (PhD student), Olga Bonderenko (PhD student), Anton Kuret (Honours student).

Annexure 2: The approved *Science Plan* for the Node [2006 or 2007]

See attached

Annexure 3: The methods section of the approved *Project Plans*

6.1 Offshore and coastal engineering and the effects of climate change

The objectives of this project were to predict changes in wind and wave climate along the West Australian coastline and together with storm surge and sediment transport models to determine coastal stability. A database of wind speeds and atmospheric pressure which was developed jointly by Woodside Energy Pty Ltd and University of Oklahoma was to be made available for this project but was not forthcoming. Thus the original methodology needed to be modified as follows:

- A 2D storm surge model (MIKE 21) was using to examine historical sea level variability and storm surge climatology over a 60 year period using NCEP atmospheric data fields. The model was initially developed for WA waters but has now extended to cover whole of Australia.

- Wave generation model (WAVEWATCH 3) was using to examine historical surface gravity wave climatology for the Indian Ocean region over a 40 year period using NCEP atmospheric data fields.

- Wave generation model (SWAN) was used to downscale the coars WAVEWATCH3 models to the continental shelf region

- Morphological model (XBEACH) was used to examine the response of the nearshore to the combined action of waves, storm surge and mean sea level rise.

6.2: Impact of tides and internal waves on offshore engineering

Methods

The work over the period 2004-7 has thus focussed on one specific site on the North West Shelf in vicinity of NRA. This is location where large amplitude internal waves are known to propgate, but the waves themselves form in much deeper water some 100 km away on the shelf break and evolve considerably before reaching NRA hTwo further field sites are needed to capture the diverse character of internal waves on the NWS. Firstly, a deep water site in approximately 500 m of water 100 km North West of North Rankin is the proposed site of a field program in early 2008 and 2009. While not an area of industry activity, this area appears a prime location for the generation of internal waves and an experiment to examine the benthic generation of internal waves is proposed at this location in 2008 and 2009. This experiment would involve fixed measurement arrays and flying ocean gliders from offshore and into shallow waters around North Rankin. The second proposed site would be near Scott Reef in the far north. This area is a site of current industry activity and the proposal is to augment this on-going measurement program in late 2008 with a specialist benthic array experiment to quantify and to fly ocean gliders in the vicinity at the time to obtain spatial pictures of the ocean conditions in the region. These three diverse experimental sites would provide high quality temporal and spatial information about the internal wave dynamics and this is essential for the development and testing of the numerical modelling aspect of the project.

In summary the objectives are to undertake field measurement arrays at physically diverse locations to determine characteristics of tides and internal waves in the energetic tidal-dominated environment of NW Western Australia.

<u>6.2.1 North Rankin measurement/modelling program</u>.

The focus will be a tidally-driven internal wave generation at a field site to the north west of North Rankin. The region is outside the geographic area of current measurements made by any oil company. It will involve a dedicated benthic boundary layer experiment to directly measure dynamics in generation region, then tracking and evolution of internal waves, using a combination of vessels, gliders and fixed measurements, as waves propagate some 100 km towards North Rankin platform where continuous monitoring is conducted by Woodside. Numerical modelling will then be conducted.

<u>6.2.2 Scott Reef measurement/modelling program</u>.

A second field site will be the vicinity of Scott Reef. It will involve a dedicated benthic boundary layer experiment to directly measure dynamics in generation regions around Scott Reef, then tracking and evolution of internal waves, using combination vessels, gliders and fixed measurements, as waves propagate east onto relatively shallow continental Shelf stretching to Kimberleys. Numerical modelling will then be conducted.

Outcomes of both major programs at these very different sites are to develop and refine multiply nested or hybrid predictive ocean circulation models capable of resolving fine scale features of the physical ocean environment. A major outcome will be understanding processes operative on the NWS and predictive capacity of internal wave and physical oceanographic environment at high spatial and temporal resolution. This project will accomplish technology transfer of oceanographic measurement data transfer from industry to University. It will also accomplish enhanced international research collaboration, already started due to the collaboration between UWA, Stanford University and Scripps Institute of Oceanography. Capacity building has already occurred at UWA with two researchers and two PHD students now full time on this project, a complex and unique hybrid model is now under development, and this model can be used as a research tool anywhere in the WA marine environment.

6.3 Ocean glider deployment as part of the West Australian Integrated Marine Observation System (WAIMOS).

Deployment of Ocean gliders.

Annexure 4: The final *Project Reports* for the Node