REPORT ON LAND USE CHANGE AND SCENARIOS TECHNICAL WORKING GROUP FOR NERP PROJECT 9.4

"Conservation planning for a changing coastal zone"

National Environmental Research Program
TROPICAL ECOSYSTEMS *hub*

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ARC Centre of Excellence
Coral Reef Studies

The workshop was facilitated by Amélie Augé and Bob Pressey and gathered 18 researchers and stakeholders (see list in Appendix 1) at the Shoredrive Hotel meeting room in Townsville during a one-day meeting on 23 August 2012. It was organized by the ARC Centre of Excellence for Coral Reef Studies.

1. **Summary of project NERP 9.4**

This project is funded by the National Environment Research Program (NERP) Tropical Ecosystems Hub (Canberra) until December 2014.

Using a spatial conservation planning approach, NERP 9.4 project sets out to identify key priorities for protecting and restoring coastal ecosystems in the Great Barrier Reef World Heritage Area (GBRWHA). This project combines scenario planning to 25 years and land use change modelling. One part of the project will look at the entire GBR coast; another will look at case studies at a finer scale.

The steps of the project are:
- Spatial modelling of coastal development scenarios to 25 years
- Estimates of impacts for coastal ecosystems and selected species in each scenario
- Determination of conservation objectives
- Mainstreaming results into activities
- Governance analyses of the GBR coast

2. **Aim and organization of the workshop**

The objectives of this first technical workshop were to:
   a) Define the coastal zone
   b) Determine the main drivers of land use change
   c) Start discussing possible scenarios for the GBR coastal zone

Amélie presented a short introduction to NERP 9.4 project and what steps the technical workshop was covering. Participants introduced themselves and their field of expertise. Then,

discussion was started with participants on the various sections, using brainstorming, general discussion and specific responses from participants. During the day, several presentations were done to introduce the concepts and methods to the attendees at the start of a particular section.

3. **Definition of the coastal zone**

Various definitions previously used to define or describe the coastal zone were presented. These included the definitions from the Australian government ("includes coastal waters and those areas landwards of the coastal waters where there are processes or activities that affect the coast and its values") and from the Queensland government (extends over three nautical miles from the coastline and landwards… either five kms from the coastline or where land first reaches the height of 10m AHD whichever is further from the coast"). The general dictionary definition for coastal zone is usually " a spatial zone where interaction of the sea and land processes occurs" (Wikipedia).

Brainstormed ideas for boundary of the coastal zone at sea were:

- Extent of flood events as terrestrial inputs, can be 45km from shore (e.g. in the Burdekin)
- 3 nautical miles is legislative
- For water quality guidelines it varies a lot
- 10km offshore as arbitrary value

From this discussion, the most apparent and relevant boundary for the coastal zone at sea would be the flood plume maximum extent recorded as per study done by Michelle Devlin based on satellite imagery. These flood plume extents are highly variable along the coast but reflects hydrological phenomenon and hence how far terrestrial inputs have significant impacts. A 5km buffer along the coast may be combined with flood plume extent.

Brainstormed ideas for boundary of the coastal zone in land were:

- socio-economic boundaries; for instance including all of Townsville and Rockhampton
- 20m contours goes up to 40km inland but that is still coastal zone
- coastal plain: where alluvial stops, ranges start
- state and federal legislations sometimes boundary too close to shore due to terrain
- Use of the land: tilling, fertilisers, pesticides
- Need to know the goals to know what the boundary of the coastal zone is
- socio-economic: maybe can be input into coastal zone but no need to include it in physical boundary?
- SEQ, scenarios focused on urban, so define coast from the main drivers in scenarios

Each participant was then asked to give one answer to the question "What do you think of when I say "land coastal zone?". The answers were:
- Floodplain
- The surf
- Tidal interface
- Floodplains, catchments, scenic rim

- Tidal zone
- Floodplain, inshore waters
- Mangroves
- Coastal vegetation: dunes, mangroves, saltmarsh
- People: where we live and reside
- Sugarcane, horticulture
- People, communities using land and the coast: near the beach
- Intensive use both sea and land: urban, intensive agriculture, ports
- Coastal plain
- Ice cream
- Saltwater, estuaries, saltmarsh,
- Fishing, boating
- Beach

These answers can be summarized in four categories:
a) Intensive coastal agriculture
b) Geomorphologic characteristics
c) Coastal vegetation
d) Human presence and recreational activities

Based on this discussion, the coastal zone was defined as inclusive of all features that would fit in these four categories, and aligned with the main drivers of land use change that we identified later in the day.

4. <u>Drivers of land use change and coastal development in the GBR coast</u>

At the start of this section, Paul Groves from GBRMPA gave a short presentation on the coastal ecosystem work that his team is working on, focusing on coastal land use changes impacting ecosystems and their functions. This gave participants an understanding of how drivers of land use change can impact the coastal zone and the GBRWHA.

First, people were asked their opinion on what they thought the GBR coast may look like in 25 years. This started a brainstorming session with a range of discussions on policy decisions, agricultural practices, preference for people to live near the coast, knowledge, cane industry, forestry plantations, irrigation, urban expansion, aquaculture, mining, ports, social changes, change in knowledge and education, succession planning, economy, regulatory framework, migration and integration, sugar farms sold to big companies as children not taking over, shift from federal to state government in charge of coastal planning, run-offs, services, values, fishing, land ownership and sells, urban centers, sustainable living, policies, coastal planning, investment in research and development, climate change, price of sugar and beef, possible economy crash, tourism, diversification, guest houses, camps, stable framework for stronger industries, economic reforms, coordinated actions, off-sets, ecosystem services market, weeds and pest species, governance, cyclones, population spread, social factors, fragmentation, roads, dams, rails, development plans, enterprise size increases with fewer actors, Cape York, technological advancements in fertilisers, herbicides etc, transport corridors for mining, energy use and production, biofuels, solar energy, quality of life, legislation, hobby farms, rules and land management agreements.

During this discussion, the main factors of land use change that emerged were written on a white board for further discussion. These were:
- Economy
- Management
- Responsibility for environment
- Money
- Policy
- Urbanisation
- Energy
- Stability (political)
- Migration
- Education
- Values of people
- Prices/market
- Climate (more frequent cyclones, floods, drought + sea level rise)
- Politics
- Mining
- Food production

Everyone agreed that development will occur and that no scenario should have a decrease in economic activities or nil development. Some concluding statements were that drivers were related to business, politics, people and climate. These included mineral markets (no market = no mining), agriculture markets (food demand), values and priorities (driven by money), government and politics (that was later redefined as governance following Allan's talk).

5. **Scenarios**

The concept of scenario planning was explained in a brief presentation that included some examples of scenario planning exercises (e.g. Shell scenarios http://www.shell.com/home/content/future_energy/scenarios/ and Millennium Ecosystem Assessment http://www.maweb.org/en/index.aspx). An interesting and recommended reading is a paper about scenario planning (extracts can be found in Appendix 3):
Peterson, G. D., G. S. Cumming, et al. (2003). "Scenario planning: a tool for conservation in an uncertain world." Conservation biology 17(2): 358-366.

The main point about scenario planning is that it is not about predicting the future (current and past trends are not used) but scenarios are instead plausible alternative futures. They try to pin down the outer limits of what is plausible. The "real" future will be made of elements of each scenario but these scenarios can be used to understand the impacts of change so that managers can make decisions now. In project NERP 9.4, they will be used to understand the impacts of the different possible future GBR coasts to determine where protection of coastal ecosystems is required to ensure the health of the GBRWHA.

The scenarios in this project are to answer the specific question: "How can conservation planning ensure the resilience and health of the GBRWHA and its coastal zone in the light of future coastal development and land use change in the next 25 years?" Development is highly unpredictable and uncertain as it is strongly connected to economic factors, in particular from the future of Asian countries and their growth. Many different paths for the GBR coastal zone may unfold depending on how the identified drivers play out in the next decades. Using

scenario planning and looking at provocative alternative futures for the GBR coast to 2035 can make us understand how conservation actions should be undertaken now to ensure the future health of the GBRWHA whatever happens to the main drivers of coastal development and land use change.

The original idea for the scenarios was to have the traditional two-axes diagram, with the main drivers as "pressure" (due to amount of development) and "governance":

Pressure

Governance
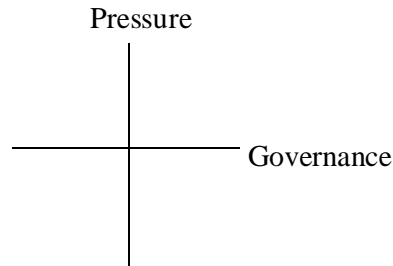
This was shown to the participants for discussion.

However, this workshop showed that more detailed drivers were needed. The use of spider web diagrams where a number of drivers can be visually quantified was suggested and adopted. Here is an example:

Driver 1

Driver 5   Driver 2

Driver 4   Driver 3
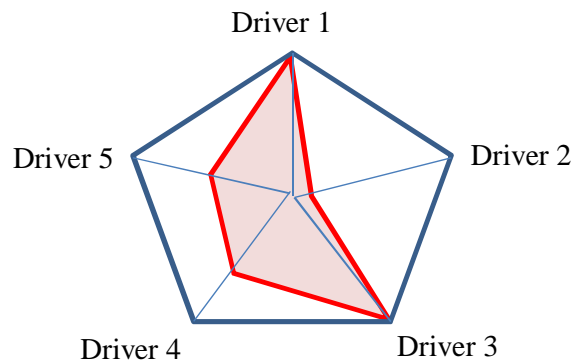
Brainstorming on possible scenarios brought to the table the following ideas:
-   Crashing economy
-   Immigration from Asia
-   Food security
-   Run-offs
-   Imports of bananas allowed
-   Water availability (e.g. water for Bowen proposal)
-   Aquaculture expansion as less areas become available to fishing
-   Competition with South East Asia
-   Population increase
-   Supercity versus dispersal

Final conclusions were that there are two options for scenarios. First, there are the 2 drivers as shown above with 4 resulting scenarios. Second, there are 4 to 7 drivers from which we can choose a combination of with different levels to produce 4 to 10 scenarios.

Further meetings with experts in economy showed that we have missed tourism whereas it is one of the major economic drivers in Queensland, in particular in the coastal area. This likely comes from the fact that we had no tourism representative in the working group. Tourism was mentioned but underestimated due to the prevalence of resource and agricultural representatives. Tourism was subsequently added in the driver list.

6. **Land use change modeling**

The next step in producing spatially-explicit scenarios is to determine the data available for modeling the land use change to 25 years in each scenario that will be described. The drivers of change are not explicitly spatial but we can transpose how they relate with what is happening on the ground. For instance a high market and demand for mineral resources involves new mines in the catchment that will mean development of transport corridors and ports for export but also increase urban areas for the fly in-fly out miners and their family living in the coastal zone etc.

Craig Shephard from the Remote Sensing Centre of the Queensland government presented the QLUMP (Queensland Land Use Mapping Program) data for the GBR catchments that were all updated to 2009 from the 1999 data, except for Cape York that is still only available for 1999. These data were publicly released in August 2012. He explained the land use classes and their levels used in QLUMP and how the mapping was done.

Sean Sloan from James Cook University later presented the land use change modeling method he used in one of his projects. He explained the land drivers (e.g. slope) he used and the variables and associated weights used in the GEOMOD part of the software Idrisi. Suitability maps are produced and used along with rules to determine where the change is to be attributed spatially based on a ranking of pixels. Method is fully described in his publication:
Sloan, S. and Pelletier, J.2012. How well may we project forest-cover change: A validation of a projected forest baseline for REDD+. *Global Environmental Change,* 22: 440-453.

QLUMP will be the basis of the land use change modeling for the scenarios. However, numerous adjustments and transformations will be needed (including reclassification and addition of further data). The amount of change will be dictated by the drivers and their attributes in each scenario. Idrisi will be used to spatially assign the changes and map the scenarios.

In the case of the GBR coast scenarios, several aspects of mapping and modeling were discussed including physical constraints for particular land uses (e.g. distance to mills for canes), centralized or decentralized urban growth based on the current urban centers (Townsville, Cairns), skills and labour constraints to expansion of particular land uses and availability of suitable soils and water availability.

An extensive discussion also covered the issue of competition and conflicts between land uses for available areas. For instance urban areas are developed on some of the best valuable soils for agriculture (e.g. Dalby). There is a similar conflict between mining expansion and agriculture land. Regional planning should be the method to sort this out (we later defined this planning as happening under "strong" governance"; see below).

7. Governance analysis of the GBR coast

This section was facilitated by Allan Dale from the Cairns Institute, co-leader in charge of the governance part of NERP 9.4. He gave a brief presentation on governance before starting a discussion on governance.

The outcome of his study is the health of the reef, with governance the way to get there. There are different levels of governance: international, state, local but also environmental, social etc The main question is what happens if governance fails so we can understand how to fix it.

Where does governance fit in the scenarios? How can it be incorporated? In a "healthy" governance scenario, development is guided to places where it is less detrimental to ecosystems and other values. With better governance, suitability of land becomes more important.

8. Coastal zone definition and draft scenarios and storylines

In the Appendix 2 of this report, you can find the description of the detailed process that we used to create the coastal zone for NERP project 9.4 along with maps showing its extent.

In the Appendix 4, you can find draft descriptions and storylines for the scenarios used to depict possible futures for the GBR coastal zone. I would encourage you to read the article I have mentioned earlier (Peterson et al., 2003) prior to looking at these scenarios, in particular if you have never worked on scenario planning. This will give you a good overview of scenario planning. I have copied the abstract and the most appropriate paragraphs of this article in Appendix 3.

Appendix 1: List of participants to the land use change working group

Name		Affiliation
Jorge	Alvarez-Romero	JCU
Amélie[1]	Augé	ARC CoE Coral Reef Studies
Jon**	Brodie	JCU
Paul	Burke	AgForce
Allan**	Dale	JCU Cairns Institute
Paul	Groves	GBRMPA
Matt	Kealley	Sugar Cane Growers
Mirjam[2]	Maughan	ARC CoE Coral Reef Studies
Morena	Mills	University of Queensland Global Change Institute
Bob*	Pressey	ARC CoE Coral Reef Studies
Craig	Shephard	DERM
Bob	Shepherd	FutureBeef Queensland
Sean	Sloan	Centre for Tropical Environmental and Sustainability Science
Natalie	Stoeckl	JCU School of Buisness
Peter	Wulf	NQ Bulk Ports
Hugh**	Yorkston	GBRMPA
Alana	O'Brien	DAFF
Donna	Turner	EHP Pallarenda

* Leader
** Co-leaders
[1] Postdoctoral research fellow
[2] GIS analyst project officer

Apologies from: Donna Audas (GBRMPA) and Neil Bennett (Townsville Port)

Appendix 2: Process used to create the terrestrial part of the coastal zone for project NERP 9.4 and maps showing the extent of this coastal zone.

By Amélie Augé (amelie.auge@jcu.edu.au) and Mirjam Maughan,
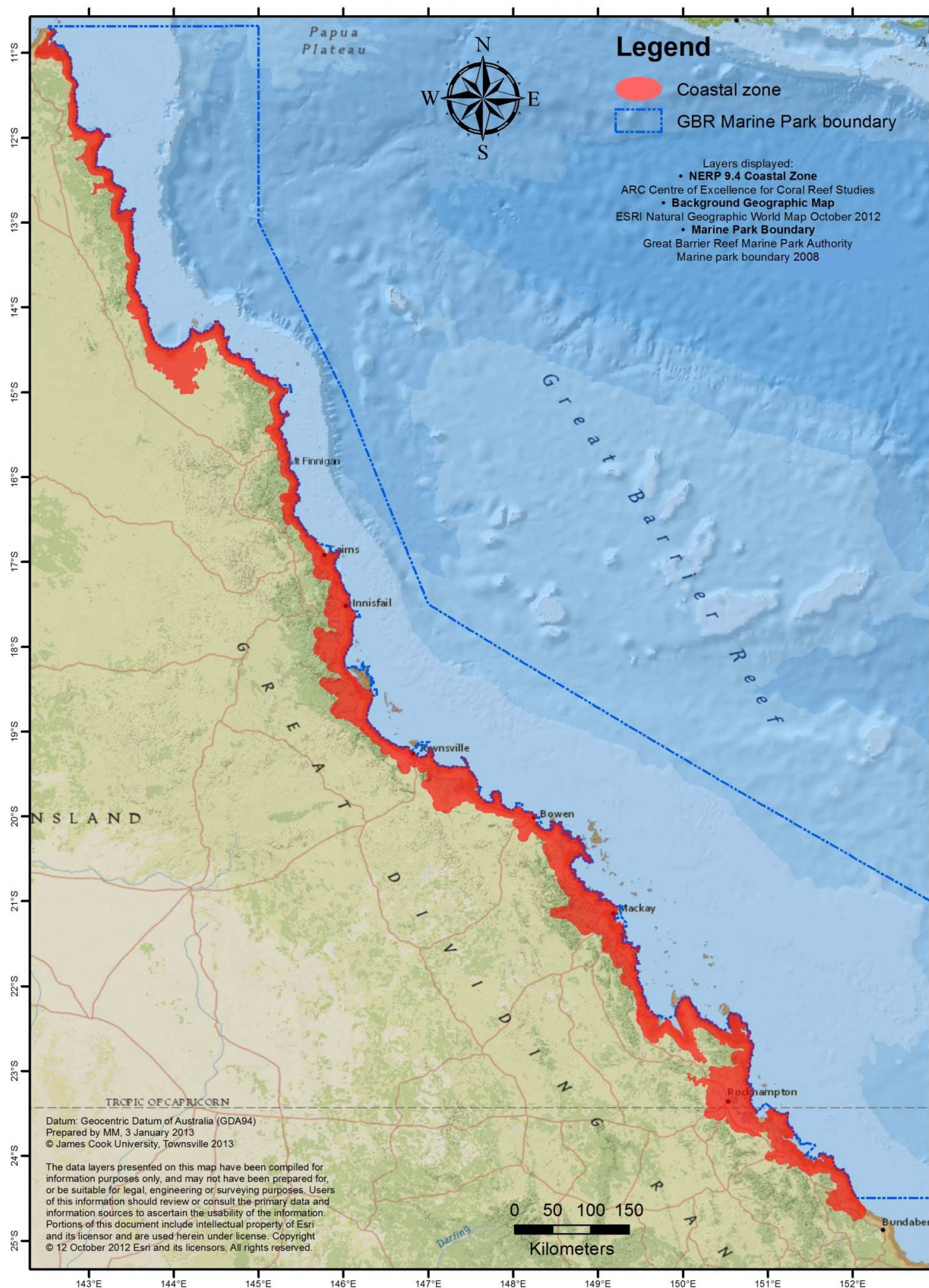ARC Centre of Excellence for Coral Reef Studies

Using a spatial conservation planning approach, NERP Project 9.4 sets out to identify key priorities for protecting and restoring coastal ecosystems in the Great Barrier Reef World Heritage Area (GBRWHA) in the light of possible future coastal development and land use change. Consequently, land use is an important factor that must be incorporated in the definition of the coastal zone. The coastal zone was defined based on stakeholders' consultation.

The GBR coastal zone spreads from the top of Cape York to the start of the Burnett Mary where the GBRMP stops. Landward, the boundary of this coastal zone was defined using a combination of buffers from the shore, elevation contours and inclusion of specific land uses and ecosystems. All islands, at the exception of Curtis Island where significant development will be found, were excluded from the coastal zone. All estuarine vegetation was included in the coastal zone. Below is the detailed process used to create the coastal zone. In brief, the coastal zone in NERP 9.4 can be summarised as any area within 10km from shore or within the 20m elevation contour from shore and any patch (and 5km around it) of area that is covered by either residential, industrial, sugar and horticulture land use found within 1km of the inland boundary created by the two previous descriptors.

Process to create the polygon of the coastal zone in ArcGIS:

- Inland buffer from the coastline of 10km (dataset: Mainland GA 250k) → *polygon 1*
- 20m elevation contour from the coastline (dataset: 90m DEM) → *polygon 2*
- Union *polygon 1* and *polygon 2* and include all "holes" within the polygon → *polygon 3*
- Select all polygons of the following classes in QLUMP 2009 (1999 for Cape York):
  - ❖ Cropping/sugar
  - ❖ Irrigated cropping/irrigated sugar
  - ❖ Intensive horticulture
  - ❖ Irrigated perennial horticulture
  - ❖ Irrigated seasonal horticulture
  - ❖ Perennial horticulture
  - ❖ Seasonal horticulture
  - ❖ Manufacturing and industrial
  - ❖ Residential – only major and coastal towns (within 10km from shore)
- Create 1 km buffer around all these polygons → *polygon group A*
- Select all polygons from *polygon group A* that partly intersect *polygon 3* (excluding the Atherton Tablelands) and delete all others → *polygon group B*
- Create 5km buffer around *polygon group B* → *polygon 4*
- Union *polygon 3* and *polygon 4* → *polygon 5*
- Clip this dataset using the catchment boundaries between Jacky Creek catchment in the north to Baffle Creek Catchment in the south → *Polygon 6*
- Exclude all island but Curtis from *polygon 6* → polygon defining the inland area of the coastal zone for NERP 9.4

Coastal zone as defined by NERP project 9.4:
"Conservation planning for a changing coastal zone"

Legend

Coastal zone

GBR Marine Park boundary

Layers displayed:
• **NERP 9.4 Coastal Zone**
ARC Centre of Excellence for Coral Reef Studies
• **Background Geographic Map**
ESRI Natural Geographic World Map October 2012
• **Marine Park Boundary**
Great Barrier Reef Marine Park Authority
Marine park boundary 2008

Datum: Geocentric Datum of Australia (GDA94)
Prepared by MM, 3 January 2013
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0   50 100 150

Kilometers

Coastal zone as defined by NERP project 9.4: Gladstone region

	Coastal zone		Tourism
	Dry sugar cane		Urban
	Irrigated sugar Cane		Mining
	Dry cropping & horticulture		Aquaculture
	Irrigated cropping & horticulture		Grazing native pasture
	Conservation areas		Grazing improved pasture & dairy
	Ports		Wood production & plantations
	Infrastructure corridors		Other

Layers displayed:
• **NERP 9.4 Coastal Zone**
ARC Centre of Excellence for Coral Reef Studies
• **Topographic data**
Geoscience Australia
Geodata Topo 250k Series 3, 2006
• **Land use data**
Department of Science, Information Technology, Innovation and the Arts
Queensland Land Use Mapping Porgram 2009

Datum: Geocentric Datum of Australia (GDA94)
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YEPPOON
EMU PARK
KEPPEL SANDS
ROCKHAMPTON
GRACEMERE
BOULDERCOMBE
MOUNT MORGAN
MOUNT LARCOM
GLADSTONE
TANNUM SANDS
CALLIOPE

0 10 20 30
Kilometers

Coastal zone as defined by NERP project 9.4: Townsville region

	Coastal zone		Tourism
	Dry sugar cane		Urban
	Irrigated sugar Cane		Mining
	Dry cropping & horticulture		Aquaculture
	Irrigated cropping & horticulture		Grazing native pasture
	Conservation areas		Grazing improved pasture & dairy
	Ports		Wood production & plantations
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HORSESHOE BAY
SAUNDERS BEACH
NELLY BAY
PALLARENDA
MOUNT LOW
TOWNSVILLE
BOHLE PLAINS
ALICE RIVER
ALLIGATOR CREEK
CUNGULLA
GIRU
BRANDON
AYR
HOME HILL
BOWEN

0 10 20 30
Kilometers

Appendix 3: Extracts from the scientific publication
Peterson, G. D., G. S. Cumming, et al. (2003). "Scenario planning: a tool for conservation in an uncertain world." Conservation biology 17(2): 358-366.

Abstract: *Conservation decisions about how, when, and where to act are typically based on our expectations for the future. When the world is highly unpredictable and we are working from a limited range of expectations, however, our expectations will frequently be proved wrong. Scenario planning offers a framework for developing more resilient conservation policies when faced with uncontrollable, irreducible uncertainty. A scenario in this context is an account of a plausible future. Scenario planning consists of using a few contrasting scenarios to explore the uncertainty surrounding the future consequences of a decision. Ideally, scenarios should be constructed by a diverse group of people for a single, stated purpose. Scenario planning can incorporate a variety of quantitative and qualitative information in the decision-making process. Often, consideration of this diverse information in a systemic way leads to better decisions. Furthermore, the participation of a diverse group of people in a systemic process of collecting, discussing, and analyzing scenarios builds shared understanding. The robustness provided by the consideration of multiple possible futures has served several groups well; we present examples from business, government, and conservation planning that illustrate the value of scenario planning. For conservation, major benefits of using scenario planning are (1) increased understanding of key uncertainties, (2) incorporation of alternative perspectives into conservation planning, and (3) greater resilience of decisions to surprise.*

Traditional planning is frequently based upon the belief that the application of professional expertise to achieve well-defined goals will ensure efficient and effective management. However, such plans often fail to consider the variety of local conditions or the propensity for novel situations to create extraordinary surprises (Scott 1998). This blindness to variety and surprise, which is often accompanied by a false certainty about the efficacy of management, can lead to costly failures (Holling & Meffe 1996). We propose that scenario planning, a technique for making decisions in the face of uncontrollable, irreducible uncertainty, offers conservationists a method for developing more resilient conservation policies.

Scenario planning is a systemic method for thinking creatively about possible complex and uncertain futures. The central idea of scenario planning is to consider a variety of possible futures that include many of the important uncertainties in the system rather than to focus on the accurate prediction of a single outcome.

We define a scenario as a structured account of a possible future. Scenarios describe futures that could be rather than futures that will be (van der Heijden 1996; Raskin et al. 1998). In essence, scenarios are alternative, dynamic stories that capture key ingredients of our uncertainty about the future of a study system. Scenarios are constructed to provide insight into drivers of change, reveal the implications of current trajectories, and illuminate options for action.

Unlike forecasts, scenarios stress irreducible uncertainties that are not controllable by the people making the decisions. Although trends, expert predictions, visions of the future, and models are all parts of scenario-building exercises, they should not be mistaken for scenarios themselves. Scenarios may encompass realistic projections of current trends, qualitative predictions, and quantitative models, but much of their value lies in incorporating both qualitative and quantitative understandings of the system and in stimulating people to evaluate and reassess their beliefs about the system (Greeuw et al. 2000). Useful scenarios incorporate imaginative speculation and a wide range of possibilities; those based only on what we currently know about the system have limited power because they do not help scenario users plan for the unpredictable.

The uncertainties chosen to define the alternatives should have differences that are directly related to the defining question or issue. They should imaginatively but plausibly push the boundaries of commonplace assumptions about the future. This set of alternatives provides a framework around which scenarios can be constructed.

Appendix 4: Draft descriptions and storylines of 8 scenarios for the Great Barrier Reef (GBR) coastal zone to 2035 to assess impacts on coastal ecosystems, GBR, and some focal species and produce conservation planning.

Five main drivers of land use change and development were identified in the Great Barrier Reef (GBR) coastal zone through stakeholders' consultation in the form of workshops and individual discussions:

-**Foreign demands for food and mineral resources:** Amount and price of food and mineral resources produced in the GBR catchments exported to foreign countries.
-Foreign demand for tourism: Amount of visitors from foreign countries coming to Queensland. The main increase in this demand will come from Asian countries in the next 25 years.
-Local demand for environmental services: Amount and strength of active local community demand for services provided by the environment such as clean water, conservation areas including for recreational activities, aesthetic values etc
-**Preference for coastal lifestyle:** Local inhabitants of the GBR catchment want a coastal lifestyle, including access to fishing spots, boat ramps, houses on or near the beach or with sea views etc
-**Innovation and technical advances:** Level at which industries and government funds innovative science research and its technological applications in the field of environmental management (run-offs, fertilizer uses) and environmentally-friendly energy production (solar and wind powered).

Four main streams of scenarios were produced based on combination of intensity of each of these drivers in plausible futures for the Queensland economy. These are:

- **FOOD AND MINERALS**: Foreign demands for food and minerals have increased significantly to some of the highest predictions made, in particular from Asia. Numerous mines have opened throughout the GBR catchments with large amount of transport, industrial and port infrastructure development in the coastal zone. Mine workers are all fly-in-fly-out and live near the sea in the coastal area. Tourism growth has slowed as the government has focussed on bringing money from agriculture and mining. There is little to no demand for environmental services from the population and people do not value the GBR, instead focusing on wealthy lifestyle. As agriculture and minerals are the pillars of the economy, large amount of money are given to innovations and technological research to improve exploitation.

- **TOURISM**: Expected foreign demands for food and minerals have decreased as Asia (in particular China) has turned to Africa to become its main producer. Due to this decrease, the Queensland government has managed the crisis that mining downturn has brought to the state's economy by boosting the tourism sector, mainly towards Asian tourists (needing high infrastructure standards and entertainments). Coastal Queensland becomes the playground of Asia. There is some demand for environmental services as some parts of the coastal area must be kept to a certain standard to allow tourism to thrive. Innovation and technological investments by the government are low and instead money is put forward to improve or develop transport corridors and amenities for tourists.

- **GREEN**: A wide-spread epidemic has started in Asia, originating from pollution due to industries in water supplies. Significant numbers of death and health problems mainly in Asia have now changed the face of the global market, in particular imports to Asia. Asian markets now require clean green fresh products to be imported as people want to eat safe products that cannot be produced where they live. Similarly, because coastal Queensland has promoted a clean image and the Queensland population realised the importance of keeping Queensland environment clean for health and well-being, tourism has turned into eco-tourism. Lifestyle choices by the local population are also environmentally friendly and there is a strong demand for environmental services.

- **BUSINESS AS USUAL**: This scenario is based on the land use change recorded within the last 10 years in the GBR coastal zone. The amount of land use change in the next 25 years is extrapolated through regression based on the current trends and past trends in the last decade.

Within each of these four scenario streams, the level of land use change (number of km^2 from one land use class to another) is similar. Governance (the process of decision-making and implementation), however, can play a significant role in mediating the distribution of land use change happening due to the main drivers. The spatial distribution of each land use class can vary and affect the impacts for ecosystems. In order to understand the level of impact of different governances, each scenario stream was modelled in two different governance contexts: with strong governance and with weak governance.

Strong governance in the Great Barrier Reef World Heritage Area (GBRWHA) coast would involve a coordinated collaborative state-society complex with influencing agendas and powerful actors ("champions") recognising the importance of planning for development in the coastal zone. Federal, state, regional and local governments would work together to produce policies in collaboration with NRMs and scientists. NRMs would also be well connected and all development set in the context of the overall GBRWHA for cumulative impacts. The main points of strong governance for land use change are:
- Development taking place in most suitable areas (following plans and regional ecosystems)
- No new ports but expansion of current major ports only
- Centralised organised growth
- Appropriate planning for climate change

Weak governance in the GBRWHA coast could be described as an uncoordinated state-society complex with the various governments contradicting each other with various mismatching weak policies and no clear or resilient agendas for planning for coastal development and cumulative impacts throughout the GBR coast. NRMs work in their own areas with little collaboration with others or government and scientists. The main points of weak governance for land use change are:
- Placement of development without planning or acknowledgement of regional ecosystems
- New ports developed in most appropriate sites from mines
- Decentralised and mixed growth
- No appropriate planning for climate change

In total, eight scenarios were produced, two for each stream. A summary description of these scenarios can be found on the next page, followed by the storylines of each scenario.
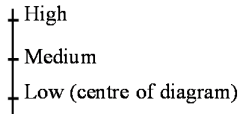
SCENARIO STREAMS = AMOUNT OF CHANGE
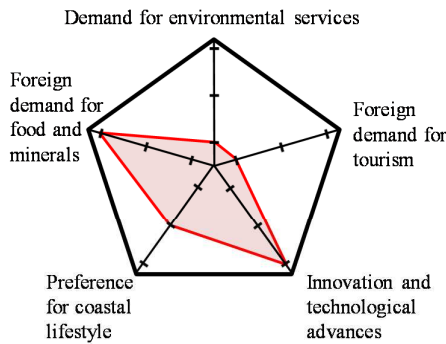
GOVERNANCE = SPATIAL ALLOCATION AND PRACTICES

<u>Strong governance</u> = coordinated collaborative state-society complex, influencing agendas, powerful actors ("champions"), recognised importance of planning for coastal development

<u>Weak governance</u> = uncoordinated state-society complex, various governments contradicting each others, mismatching weak agendas and no "champion" for planning for coastal development

SCENARIOS

Legend

High
Medium
Low (centre of diagram)

FOOD AND MINERALS

Demand for environmental services
Foreign demand for food and minerals
Foreign demand for tourism
Preference for coastal lifestyle
Innovation and technological advances

- Large increase in areas of agriculture (in particular sugar, horticulture), ports and infrastructure, infrastructure corridors and urban (incl. to accommodate fly-in-fly-out miners and family along the coast)
- No increase in conservation areas and small increase in tourism infrastructure
- Better agricultural practices and urban run-off management available
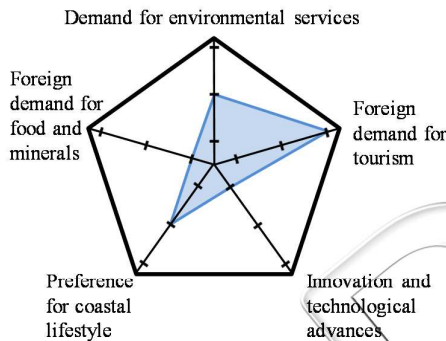
STRONG
- Development follows planning documents of most appropriate land use for specific areas
- Better practices are adopted and enforced hence land management improves (< run-off)
- Centralised growth around existing main urban centres but close to the coast
- Planning for sea level rise impact to 100 years

Export management

WEAK
- Uncoordinated development, planning made at very local scale with conflicts between different land uses
- Better practices are not adopted as technological advances are not supported
- Decentralised growth with fragmentation of landscape
- No planning for sea level rise
- Cape York is developed (ports and mines in particular)

Red tape cutting

TOURISM

Demand for environmental services
Foreign demand for food and minerals
Foreign demand for tourism
Preference for coastal lifestyle
Innovation and technological advances

- Large increase in areas for tourism, airports, marinas, highways, railways, tourist villages and resorts
- Trading ports transformed to accommodate cruiseships, with low resource exports but high imports
- Increase areas for horticulture with decrease in sugar
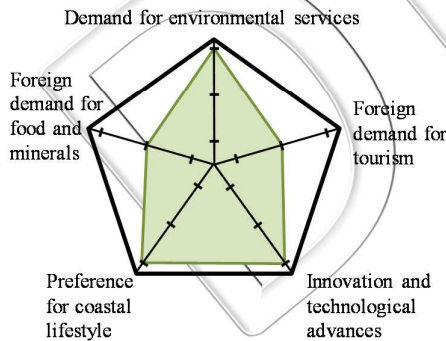- Some coastal areas receive protection

STRONG
- Development controlled under planning schemes with minimal impact rules on coastal geology; existing ports transformed for tourism and marinas expended
- Centralised growth with tourism centres defined
- New development to be resilient to expected sea level rise to 100 years
- Protected areas at most suitable sites for ecological values

Tourist heaven

WEAK
- Decentralised growth with tourism centres created all along the coast including in Cape York using cruiseship ports and airports to bring tourists (no roads above Princess Charlotte Bay)
- Numerous small and medium ports and marinas built
- No planning for sea level rise
- Protected areas designed for tourism, not for ecological values (eg recreational activities degrading ecological values are allowed)

Way for resorts

GREEN

Demand for environmental services
Foreign demand for food and minerals
Foreign demand for tourism
Preference for coastal lifestyle
Innovation and technological advances

- Medium increase of trading ports and infrastructure and agriculture areas but only for clean products (eg organic products, clean minerals, biofuels)
- Medium increase in eco- tourism with demand for pristine sites to visit
- People highly value coastal lifestyle
- Large increase in protected areas or improve status of existing ones
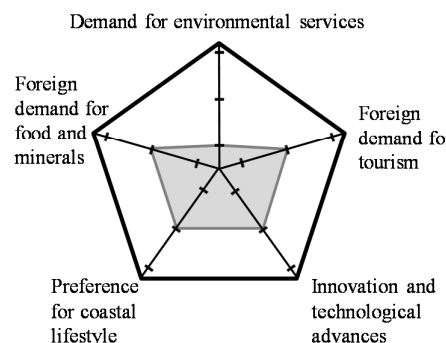
STRONG
- Development controlled under planning schemes with enforced standards for all impacts including run-off managed by innovative technologies
- Centralised growth with industrial, agricultural and tourism centres well defined
- New development to be resilient to expected sea level rise
- Protected areas at most suitable sites for ecological values

Eco-revolution

WEAK
- Uncoordinated development along the coast; protection of small unconnected patches of pristine areas for tourism
- Decentralised growth for all land use, no planning for sea level rise
- Technological advances are not implemented (> run off)
- Cape York becomes a favourite destination due to its pristine state with numerous development throughout

Green washing

BUSINESS AS USUAL

Demand for environmental services
Foreign demand for food and minerals
Foreign demand for tourism
Preference for coastal lifestyle
Innovation and technological advances

- Amount of change is extrapolated based on the trends seen in the last 10 years

STRONG
- Centralised growth
- Development follow plans for coastal management, including to accommodate for sea level rise to 100 years
- Protected areas at most suitable sites for ecological values and existing ones have their status increased

A twist on the trend

WEAK
- Predicted from the pattern of attribution seen in the last 10 years through land use change modelling using land drivers such as elevation, proximity to coast and cities etc

As we go

Scenario # 1: Export management

Storyline: Foreign demands and prices are high for mineral and food resources hence there is a high level of development in the coastal zone and adjacent catchments to sustain the demand for these two land uses. The governance has improved and there is coherent strong governance across the entire GBR coast that is unified and encompasses land and sea in the entire area (successful planning). This means new development and land use change is regulated and has occurred in the most appropriate areas ecologically. Demand for food has also increased to sustain the high population growth. Mining and most agriculture is owned by large national companies with a management that is more unified. The new generation of farmers shows a general lack of interest in taking over the farms of their parents due to the difficult and isolated way of life. However, farms that are still family-owned are now under the direction of a new generation of farmers that went to agricultural colleges and also use a better and more innovative management. Fisheries and aquaculture have increased but strong governance means that development has appropriate ecological assessments and cumulative impacts were studied. A healthy economy allows significant funds for innovation and technology research in the field of environmental sciences. This leads to better and more efficient agriculture practices with less run-off of sediments, nutrients and pesticides in the coastal zone and to the reef (potentially GM cane sugar or cotton plants are produced that require less or no pesticides and fertilizers). Mining for coal, natural gas and rare minerals increase and new mitigation methods to avoid sediments and chemical reaching water bodies are put in place and enforced by the government through legislation. These include treatment stations and some recycling of all water used in the mining process along with some sediment ponds created. Coal seam gas exploration was banned throughout Australia, due to strong governance and lobby by the farming companies owning areas of potential exploitation. This good economy and high number of development brings more people to the GBR coast, mainly through immigration from within Queensland (in particular SEQ) and Australia or overseas. Adequate governance manages where these people live and limits the number of new urban centres by increasing capacities and attractions (including for outdoor recreational activities through creation of urban parks, marinas, trips to the reef etc) of the already-established cities along the coast (centralised growth). International tourism increased slighty and national tourism also increases since the GBR coast's infrastructures are improved. No new ports are created along the GBRWHA and increase in export and shipping capacity is done through expansion of existing facilities, including of shipping routes. The increase in shipping in marine coastal areas is better managed and less dangerous due to technological advances. More railway lines are created to bring minerals to the ports throughout the coastal zone with a collaborative approach between different mining companies to minimise numbers and extent. Appropriate governance regulates competition between different land uses (agriculture, urban, mining, recreational, conservation) and the most adequate land uses are allowed in what are likely the most appropriate areas. Strong governance also directs development appropriately to plan for climate change and ensure resilience to extreme events and sea level rise to the medium predictions to 100 years. Because of higher incomes (and tax revenue) and strong governance, funding exists to manage land condition in natural ecosystems, parks and reserves. Weeds, feral animals and visitor impacts (camping, toilets and trails) are well managed.

Scenario # 2: Red tape cutting

Storyline: The foreign demands and prices for minerals increase leading to high development of mining activities in the catchment as well as in the coastal zone on land and at sea (eg oil and gas). Foreign food demand is also high and food production also increases. The governance is poor and uncoordinated leading to development occurring anywhere and with no overall governance for the entire GBR coastal zone. This weak governance also does not take into account future effects of climate change and development takes place without appropriate planning. Because of a change in legislation, reduced role of GBRMPA and pressure from mining companies, numerous ports, shipping channels, railway and road infrastructure are created throughout the coastal zone to increase capacity for easy export. Political short-term visions of cutting "red tape" and making profit have led to a change in legislation to make it easier for development to occur (eg the federal Environment Protection and Biodiversity Conservation Act, the Queensland Native Vegetation Act. Land Act, Water Act and Great Barrier Reef Protection Act were modified). All planned mining in Cape York go ahead, along with several new mining sites and a major port created in Princess Charlotte Bay. Offsets have been used to mitigate impacts of development but their implementations lacked of science and offset areas were designed without much ecological considerations. As population increases rapidly, through international immigration mainly, food supplies needed to increase and this is done without proper governance, hence leading to an uncontrolled increase in clearing for intensive agriculture in the coastal zone including new irrigation schemes and building of new dams. Grazing continues in the coastal catchments, and due to changes of legislation, vegetation clearing and sowing of introduced pasture species spreads to improve pasture productivity. Bores are drilled to supply water needs. Riparian areas are cleared and grazed. Seafood is derived from both fisheries and aquaculture, with little scientific considerations on fish stocks and ecological impacts of these practices. Immigrants that came to work in the mines value nature differently and hence further affect people's attitude towards the environment and the reef. People prefer to live along the coast, with sea views and proximity to coastal recreation, marinas and boat ramps being the most important factors for choosing a property. With weak governance, numerous small urban centres are created along the coast populated by families of fly-in-fly-out miners (decentralised growth). Science is well funded but mainly in the fields of geology and engineering to develop new technology to exploit mineral resources. Because of low demand for ecosystem services, no funding is allocated to manage land condition in natural ecosystems and reserves. Weeds and introduced pest animals spread due to lack of intervention and prevention, increased intensive agriculture and fertiliser use. Recreational uses are uncontrolled in coastal areas and conservation areas.

Scenario # 3: Tourism heaven

Storyline: The excepted increase in foreign demand for minerals and food has decreased as Asia, in particular China, turned to Africa as their primary producer. Consequently, many mines have closed and commercial ports are not expanded; existing ones have their activities slowed down. The economy is low but the environmental governance has improved and there is coherent governance across the entire GBR coast that is unified and encompasses land and sea in the entire area (successful planning). As a way of managing the economic crisis due to mining downturn, the Queensland government promotes Queensland, and in particular its

coast and the GBRWHA, as the prime vacation destination for the increasing tourism demand from Asian countries. As a result there are large numbers of tourism infrastructure projects developing all along the GBR coast, including tourist ports that are the industrial ports (most now unused) rebuilt to accommodate cruiseships and tourists, large resort complexes, tourist villages, local airports and tourist drives. All these developments are constrained by appropriate legislation and planning and are centralised leaving some parts of the coast untouched. They are also planned with climate change in mind as strong governance produces adequate plans to mitigate climate change predicted effects in the next 100 years, in particular, the increase in extreme meteorological events and sea level rise. Cape York is not developed for tourism more than it is at the exception of better access routes to some of the aboriginal communities. Because Asian tourists prefer man-made and controlled nature experiences, infrastructure and transport facilities are large and sophisticated. They allow Asian tourists to enjoy the natural wonders of the GBR coast in a safe and organised manner. Cultural tourism also increases as Asian tourists are attracted to spiritual sites; hence indigenous communities also benefit from this tourism by developing attractions. Tourists of other nationalities also benefit from these developments and numbers increase. All developments are well regulated in terms of ecological impacts by the healthy governance. Because the GBR coast and the GBR are such an important economic of Queensland, people value these more than previously. There is demand for environmental services for that reason and protection of key coastal sites and ecosystems is lobbied by the population. Speciality food, in particular seafood and vegetables, production increases for tourists' consumption mainly. Aquaculture sites are developed along the coast and sugar cane fields are mainly turned into horticulture. The remaining mining and commercial ports as well as agricultural land are well managed environmentally with strong governance as they are part of tourist attractions.

Scenario # 4: Way for resorts

Storyline: The expected increase in foreign demand for minerals and food has decreased as Asia, in particular China, turned to Africa as their primary producer. Consequently, many mines have closed and commercial ports are not expanded; existing ones have their activities slowed down. The economy is lower. A weak governance makes it difficult for the state to determine a strategy to overcome the issue. The Queensland government is trying to lift the economy at all costs and as a consequence environmental standards are lowered for all kind of land use. Some mines still operate and the ports that are still in use have lowered their environmental standards due to the lack of money. Governance is weak and politics focuses on keeping the economy running by encouraging building and development in the coastal zone, in particular to attract the increasing number of potential Asian tourists, leading to large resort development in the best scenic spots. Hence, clearing of land is made easier to allow for new industries to develop (the federal Environment Protection and Biodiversity Conservation Act, the Queensland Native Vegetation Act. Land Act, Water Act and Great Barrier Reef Protection Act are repealed). Imports are expensive and Australia needs to rely on its own resources. The foreign demand for seafood and aquaculture exports decreases as this becomes expensive but fishing increases in the GBRWHA to supply the national and tourist demands. Aquaculture is not developed as it is expensive to run. There are unregulated small developments of urban, industrial and agricultural areas which lead to fragmentation of the landscape, with weak governance. Tourism development is also unplanned and flourish all along the coast including in the south of Cape York where the government funded road

improvements and airports to bring tourists to the resorts built there. Due to the government push, Asian tourism increases and is mostly orientated towards cities, resorts and culture rather than natural wonders, unless they are coupled with high-tech facilities and transport is made easy. The lack of strong governance leads to the failure of potential cultural tourism as it is only conducted within resorts and not in aboriginal communities. Consequently, the GBR itself is only used for fishing, and does not bring much tourism money to the economy at the exception of a few definite sites. Actions to protect the GBR or other significant natural areas that could attract tourism are dismissed. Science funding is low and technical improvements are slow. Cities expand their infrastructure to try to benefit from this new tourism with no improvement in urban run-off management. The science is available but the technology is not developed or adopted due to a lack of support from the government. Population in the GBR coast and catchment is only lightly increasing as mining jobs are lost and this forces some people to migrate to large economic centres such as Brisbane or out of the state; immigration is low. People who choose to stay tend to agglomerate in the coastal cities or around coastal towns close to tourist resorts where facilities and work opportunities are within the tourism industries. New tourism centres and associated infrastructure (airports, marinas, entertainment parks, golf courses etc) are created all along the coastline where the best scenic values are found for Asian tourists (similar to the Gold Coast). Highways and main roads are updated to allow better tourist transport between the resorts. Agriculture and remnant mining areas are poorly managed and their environmental impacts worsen. Natural ecosystems are only maintained near tourism centres in areas called "protected areas", and because of lack of money and interest, neglected elsewhere.

Scenario # 5: Eco revolution

Storyline: The foreign demand for food and minerals is moderate (equivalent to medium current predictions) but there has been a shift in the market following an epidemic that started in China due to industrial pollution of the riverways. Significant numbers of death and health problems, mainly in Asia but that have spread worldwide before a cure was found, have now changed the face of the global market, in particular imports to Asia. Asian markets now require clean, green and fresh products to be imported as people want to eat safe products that cannot be produced where they live. This trend is also significant to most developed countries. Following the epidemic, Queensland people's values towards sustainable resources and to protect the land from pollution for them and the future generations also increased. Mining development is minimal, only extracting necessary minerals where no alternative exists. Bio-fuel (including from agriculture such as sugar cane) and environmentally friendly power production (eg solar power, windmills) increase. More land is needed for bio-fuels and food production but good governance and scientific advances limit ecological impacts. The focus on reducing carbon footprint means consumers prefer locally grown products, and there is a diversification of local agriculture. The use of native species in food production increases (eg bush food), requiring less water. Fishing is regulated and aquaculture developments require advanced treatment of run-off water. Due to well-functioning governance, recycling water stations and desalinisation plants are built for both agriculture and domestic use, and regulation requires new residential development to implement water-saving technologies including compulsory rain water tanks. Due to this sustainable water management, some dams can be taken down to restore natural flow of water. Science funding is high particularly to develop improved agriculture methods that allow reduced uses of fertilisers and pesticides. Riparian vegetation is fully restored throughout catchments. Eco-tourism is an important

economic revenue and large developments are created to accommodate tourists along the sea to enjoy the coast and the reef. Due to unified and effective governance for the GBR coast, these developments (including tourist ports, lodges, resorts) were conducted with high environmental considerations and spatially centralised. Existing commercial ports and infrastructure are expanded to increase export capacity with no new port created. These are also expanded to accommodate cruiseships and tourists. People value their way of life, the opportunity to visit a natural area for the weekend and like having some land. Small hobby farms are popular in outer suburbs. Population increases reasonably with a centralised growth along the coast. People value these coastal towns for the quality of life for themselves and their children. Because of an eco-focus, high level of ecosystem services demand and strong governance, the will and funding exists to manage land condition in natural ecosystems and reserves. Weeds, feral animals and visitor impacts are well managed.

Scenario # 6: Green washing

Storyline: The foreign demand for food and minerals is high but there has been a shift in the market following an epidemic that started in China due to industrial pollution of the riverways. Significant numbers of death and health problems, mainly in Asia but that have spread worldwide before a cure was found, have now changed the face of the global market, in particular imports to Asia. Asian markets now require clean, green and fresh products to be imported as people want to eat safe products that cannot be produced where they live. Bio-fuels are also sought after to reduce pollution in large cities. This trend is also significant to most developed countries. Following the epidemic, Queensland people´s values towards protecting the land from pollution for them and the future generations also increased. Mining development exists but only extracting necessary minerals where no alternative exists. There is a high local and foreign demand for clean energy, including sugar cane-based bio-fuel and environmentally friendly power production (eg solar power, windmills). More land is consequently needed for bio-fuels and food production and several ports are created close to the bio-fuel centres to allow easy export. A weak governance does not allow proper spatial planning and, although there is high demand for ecological services, development occurs without proper planning in a decentralised manner. The local population recognises the importance of clean mining and agriculture so that fresh water and food products are safe to drink and eat. However, weak governance without coordination throughout the coastal zone means that developments such as ports and land clearing occur in any areas. Fishing is seen as a "green" way of obtaining food and increases without proper regulations due to weak governance. Aquaculture develops. To increase sugar cane areas, water needs are obtained from extra dams with poor ecological assessment. Science funding is high particularly to develop improved agriculture methods that allow reduced run-offs. However, these scientific advances are often not taken up by companies or farmers due to a lack of support for technology advances on the ground in consequence of the weak governance. Eco-tourism is an important economic revenue and numerous small developments are created all along the coast to accommodate tourists along the sea to enjoy the coast and the reef. Cape York with its pristine clean environment is praised by tourists and some development occurs along the coast. Population increases reasonably in the coastal zone with a decentralised growth as new coastal towns are created. People value these coastal towns for the quality of life for themselves and their children. Because of weak governance, management of land condition in natural ecosystems and reserves is inexistent and most protected areas are open for tourism. Weeds and feral animals spread in protected areas that are not used for tourism.

Scenario # 7: As we go

Storyline: Based on current trends without changes to any main drivers to what has been occurring in the last 10 years for both the amount of land use change and its spatial allocation to model the current weak governance in the GBR coastal zone. Ports and their infrastructure are expanded based on current available plans.

Scenario # 8: A twist on the trend

Storyline: Based on current trends without changes to any main drivers to what has been occurring in the last 10 years for the amount of land use change. In this scenario, the trend in amount of change is similar to Scenario #7 but strong governance is used to assign the spatial allocation of changes. Hence spatial attribution of land use change is dictated by the Queensland coastal plan with centralised growth and conservation areas being placed in areas of ecological values that are at risk. Planning includes adjustments to coastal development for resilience to medium sea level rise prediction to 100 years.