PHRT vulnerability

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COASTAL VULNERNERABILITY TO CLIMATE CHANGE – AN ASSESSMENT OF THE BURNETT MARY COAST

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Abstract

Coastal surveys form an important part of natural resource management planning. The coast, as the interface between land and ocean has dynamic geomorphic and ecological features. The geographic position of these features at any time is governed by relative sea level. On the tectonically stable east coast of Australia the coastline has migrated 30km to over 100km inland across the continental shelf with a sea level rise of some 120m at the end of the last Ice Age (17 000 years ago). For the last 6500 years sea level has been relatively stable and the coastal features we see today have formed. Tide gauge records for over 100 years and a trend from records in 1840 show the beginning of a slowly accelerating sea level rise consistent with climate models. The projections made by the IPCC 2007 suggest a slowly accelerating sea level rise over the next 100 years. If the projected maximum rise occurs, the most vulnerable sections of the Australian east coast would experience inland coastal movement. The management of the dynamic geomorphic and ecological coastal systems presents many problems that can be identified using vulnerability assessment. An example of the how vulnerability assessment methodology is developed in a coastal survey of the Burnett Mary coast. An area experiencing rapid population growth with some sections vulnerable changing coastal processes. Some of Australia's most sought after holiday destinations and most valuable property lie along this coast, particularly around Hervey Bay.

INTRODUCTION

Assessing coastal vulnerability to climate change a feature of the regional study of the Queensland coast, from south of Gladstone to Cooloola, including Hervey Bay and Fraser Island (referred to as the Burnett Mary coast). The study is being conducted by the Griffith Centre for Coastal Management for the Burnett Mary NRM. This paper describes how the principles for vulnerability assessment have been developed and how they will be applied to the Burnett Mary Coast.

Climate Change

Assessment of coastal vulnerability needs to be based on an understanding of the long term interaction between coasts and climate. As climate changes over time, sea level rises and falls (Figure 1) causing coastlines to migrate backwards and forwards across the continent shelf. Coastline features of beaches, dunes, spits and estuaries form and reform with narrow salt dominated ecosystems.

Figure 1 Ice age sea level cycle

On the tectonically stable east coast of Australia the coastline has migrated 30km to over 100km inland across the continental shelf with a sea level rise of some 120m at the end of the last Ice Age (17 000 years ago) (Figure 2).

Figure 2 The Burnett Mary coast and coastline position 17 000 years ago (on shelf image).

Following 10 000 years of rise sea level has been relative stable for the last 6 500 years and the coastal features we see today were formed. During the last 1 000 years sea level has been slightly falling (Helman 2007, and indicated by Jones and Mann 2004). This period ended around 1820, not long after European settlement (Helman 2007) of the Australian east coast.

For the last two hundred years long term tide gauge records show that sea level is commencing the accelerating rise first projected by IPCC in 1990 and reconfirmed in the latest report in 2007.

Differential warming of the global ocean

From the first observations on the east coast of Australia in the 1840's (Pugh and others 2002, Hunter and others 2003) sea level has risen slowly. The observed record (Sydney) from 1886 shows a similar long term trend. While Australian east coast sea levels have been below global average during this period (Lombard and others 2004) shows that this is due to the time lag for warming of the deep ocean. The North Atlantic shows significant warming of the deep ocean and the east coast of the USA sea level has risen well above the global average over the last century. Warming is expected to continue to spread through the world's oceans.

The influences of the different rates of sea level rise are discussed in three examples.

East Coast USA – sea level rise above global average
Titus (1998) shows a sea level rise of around 300mm/100 years for the south eastern US coast. This relatively rapid rise, much like the rise that is projected for the east coast of Australia over the next century, has seen the loss of many shoreline coastal developments (Figure 3) and a range of planning responses.

Figure 3 Houses on beach, USA (RT powerpoint)

After serious beach erosion Florida introduced legislation for coastal construction setback lines for sand beaches fronting the Atlantic Ocean and Gulf of Mexico in 1971 (Purpura 1972).

Setback lines were established on the basis of technical studies, including historical data and are reviewed every five years or sooner if proven necessary (Purpura 1972).
In the United States rolling easement policies have been implemented in the states of Maine, Rhode Island, Massachusetts and South Carolina to enable inland migration of wetlands and beaches (IPCC 2001c).

New Brunswick and other Canadian provinces have adopted setback policies based on future coastal retreat estimates (IPCC 2001c).

East Coast North Island, NZ – sea level rise at global average
Sea level rise at Auckland has been shown by (Goring and Bell 2001) as 180mm/100 years. An example at Gisborne where the policy of approved for the construction of retaining walls to prevent erosion was abandoned. A legal challenge by the coastline landholders to the Council's decision was resolved in the New Zealand High Court (Faulkner v Gisborne District Council, Barker J, 1995) where shorefront property owners sought to assert the common law right of the Crown to protect the shoreline from erosion. It was held that the

> … common law right of an owner to protect land from the inroads of the sea, although previously expressed in absolute terms, could no longer be asserted in direct opposition to a bona fide legislative policy of management on the coastline in the public interest. …. The right to protect one's property from the sea was inconsistent with the resource consent procedure envisaged by the Act (*Resource Management Act 1991)* (Barker 1995)

The coastline owners' application was dismissed. There are no equivalent statutory provisions in Australian States.

East Coast, Australia – sea level rise below global average
On the east coast of Australia Helman (2007) estimates a sea level rise of around 100mm/100 years (Figure 4).

Figure 4 Three centuries of sea level - East coast sea level trend
Estimated, observed and projected sea level 1830 to 2100 (after Helman 2007)
Sydney Helman 2007
Hobart after Pugh

Long term sea level trends (expressed) in periods of over 100 years can be used a measure of climate change. Over periods of less than a century sea level change due to climatic variability must also be considered and until the last few decades the influence on coastal process of this relatively slow sea level rise has been masked by decadal oscillation due to climate variability.

Climate Variability

Over the time scale of most coastline plans (several decades), the trend of sea level rise from climate change will continue but decadal and annual variations of sea level are important to coastal process. Over decades these sea level changes are related to oscillation of the Interdecadal Pacific Oscillation (IPO) (Helman 2007). It has been shown that during periods of negative IPO sea level rises at a faster rate than the long term trend (Goring and Bell 2001) (Figure 5) and is also higher (Figure 6) than the long term trend (Helman 2007) During these negative IPO phases storminess is generally high. The combination of high sea level and high energy corresponds to episodes of coastal erosion (Helman 2007). The longest period of negative IPO in the recent past has been from the late 1850's to the early 1890's and resulted in major changes to the coastline (Helman 2007).

Figure 5 Auckland after Goring and Bell

Figure 6 IPO and sea level (PH Ph D)

The current long (from the 1970's) positive phase of IPO has been characterised by periods of recurring drought and low storminess. Records show that inshore accretion of beaches and dunes during previous past positive IPO phases, in the early 1900's (Federation Drought) and the late 1930's drought has not occurred during recent decades. Helman (2007) attributes the lack of inshore accretion since the 1970's to the influence of long term trend of sea level rise.

It is considered, that during the next phase of negative IPO sea level will be above trend but will for the first time will be elevated by a significant component of the long term sea level rise (Goring and Bell 200X, Helman 2007). These features will contribute to coastal erosion and inland movement not previously experienced during the last two centuries of European settlement on the east coast of Australia (Helman 2007).

ASSESSING COASTAL VULNERABILITY

Coastal vulnerability has been considered for other coasts for example

Tasmania

A state wide coastal risk assessment was conducted by Sharples (2004) and more detailed assessment using the guidelines provided by Emergency Management Australia (Leaver 2005). Where risk assessment is defined as

…an appropriate balance between realising opportunities for gains while minimising losses…is an integral part of good management practice and an essential element of good corporate governance (Standards Australia and Standards New Zealand: AS/NZS 4360:2004, quoted in Leaver 2005)

Leaver (2005) argues that natural hazard risk reduction by risk based landuse planning contributes to community safety and sustainability. The impacts on infrastructure and on public and private property from climate change induced coastal hazards may be severe and must be considered in the planning process (Boyle 2002 quoted by Leaver 2005). By identifying areas in the coastal zone to prone to hazards Local Government can effectively reduce risk form climate change impacts (Leaver 2005).

Coastal hazards from rising sea levels include inundation (permanent and episodic) and erosion. Erodibility risk is determined by ‘Fundamental Vulnerability Factors’ identified by Sharples (2004) as shorelines with potential for erosion of unconsolidated sediment and shorelines backed by low-lying lands, of unconsolidated sediment (Leaver 2005).

Sandy beaches are in high demand for coastal developments, giving them a high priority for assessments of coastal vulnerability to sea level rise hazards (Walsh 2002, Sharples 2004).

All evidence suggests that sea level rise, from climate change and storm surge impacts from severe storms will *almost certainly increase* (Leaver 2005, Helman 2007).

THE BURNETT MARY STUDY

Past studies of coastal vulnerability have used the concept of risk. Risk implies that coastal change may occur (ie that this possibly an unlikely event) that that an appropriate balance can be realised between the opportunities for gains while minimising losses.

This view is challenged as an inappropriate strategy for sea level rise planning.

Based on the scientific evidence the ‘risk’ of sea level rise should be considered to be a ‘certainty’. The questions to be answered are by how much is it likely to rise, over what time scale might this occur and what is the likely coastline response.

The risk in coastline planning is that the decision makers, lulled by the long period of relatively low sea level and low storminess over the last three decades, may be reluctant to make prudent long term decisions that appreciate the lessons from the records of stormy periods and coastline erosion (Callaghan and Helman, in press). The impacts from these periods will increase when combined with a with a rising sea level trend.

Coastal Surveys

An extensive literature review reveals what is known about the coast. These include:

- History, including storm history from 1820 (from Helman 2007)
- Past Mapping
- Coastline Studies – especially previous Beach Protection Authority (BPA) studies

This information is used to describe the physical process and how past climate has influenced coastline response.

Coastal Inventory
Describing the present coast has three components:

- Coastal features (geomorphic)
- Ecosystems
- Existing development

The following features will be identified as key elements of an assessment of coastline vulnerability.

Bedrock
NSW Public Works 1978 (Byron Bay study) demonstrate the importance of bedrock mapping for coastal vulnerability assessment. Bedrock occurrence can be considered to reduce vulnerability to erosion as new headlands around which new coastline alignments might form. Where they can be deduced from previous geological mapping or drilling, bedrock surface contours can be used to determine the thickness of the coastal sediments.

Sediments
By definition, the remaining coast is mostly Quaternary (generally younger than 2 million years) and composed of unconsolidated sediments. Coffee rock will be mapped as a separate sub class from aerial photography when exposed by previous storm cuts on the beaches.

Surface sediments will be differentiated into age classes, namely:

- **Holocene** marine sands and muds
- **Pleistocene** Marine Sands and past estuarine and riverine sediments

Coastline landscape
Following assessment of the coastline geology and geomorphology the coastline landscape will be assessed as;

- Offshore - reefs, bars and sea bed to around 50m depth
- Open coast and estuarine shoreline - spits, beaches, tidal flats (classes to separate mud and sand substrates)
- Beach/Dunes – beach type, berm, foredunes, barrier dunes and dune dammed wetlands (also described in cross sections).

Coastline ecosystems
The dynamics of the coast forms the substrate providing the position and characteristics of the narrow linear coastal ecosystems and ecotones.

The classification of coastline ecosystems follows the classification of coastal geomorphic features and includes broad classes related to beach type, dune and hind dune characteristics and tidal flats.

Mapping

Regional Map
Map (small scale) shows rivers, catchments and low lying areas (1:1 000 000).

Coastal maps
Map series (large scale) shows coastline and bathymetry to 50m, geomorphic features interacting with coastlines using 1:100 000 AUSLIG 1997 base map and geological maps, cadastral, charts etc. Covers some 300 km of coast, requiring 15 A4 sheets for the study area coastline.

Detailed mapping
Critical areas (existing developments) mapped at 1:25 000 will show current developments. New mapping and model outputs will be combined into a comprehensive GIS data base. Including resurvey of COPE cross sections previously established by BPA

Vulnerability assessment - Future coastline

The important questions to be answered are:

- how will climate change and variability influence future coastlines;
- what changes could be expected to physical processes and ecological systems;
- what are the possible impacts on existing; and
- future coastal development?

Peer review

The review process will include the complete project from commencement to completion. Experience provided by the peer review panel throughout the project has the capacity to dramatically improve natural resource management outcomes. The goals of this review are:

- Review and critique the proposed field program, i.e. in terms of information to be recorded, recording methods and value to natural resource management
- Field inspection of coastline to critique coastline mapping and assessment
- Review draft report and NRM outcomes

DISCUSSION

Coastlines are vulnerable to long-term climate change but there is uncertainty about when and how this could occur. In developing a vulnerability assessment for the Burnett Mary coastline it is proposed to examine the following:

- Anticipated changes to climatic drivers
- Description of past climatic conditions (Sea level and storm history to described multi-decadal climatic variability, after Helman 2006).
- Projected regional coastal changes
- Response for coastal sub regions and individual sites based on historical information
- Coastal hazards and management issues

Projected future climate and anticipated coastline recession and realignment will depend on the nature of the bedrock geology, sediments and coastal landforms. The methodology for assessing the vulnerability to future climate drivers will be based on a qualitative synthesis of available information on past response and application of knowledge from other areas, and on a quantitative analysis using models for coastal recession due to sea-level rise such as the Bruun rule, and extreme event storm erosion models such as SBEACH (US Army, 1993). The SimCLIM model suite developed by the University of Waikato (Warwick et al, 2005) has some potential to quantify vulnerability for sea level rise and coastal inundation and other climate drivers. It is proposed to assess the suitability of the CoastCLIM component and to apply it in collaboration with our partners at the University of the Sunshine Coast. This combination of qualitative and quantitative analysis is important so as to avoid the shortcomings of some previous studies where coastal hazard lines are drawn for a particular event probability, which do not account for bedrock geology, essential infrastructure protection requirements or localised geomorphic variance.

Potential impacts will be defined at the key locations and will be classified according to whether they are:

- Developed areas,
- Coastline ecosystems, or
- Coastline recreational areas

Guidelines on how to put vulnerability lines on maps for various projections will be developed.

Unavoidable mitigation

The past subdivision of land near coastlines has exposed many existing coastal developments to the potential of severe erosion from a combination of more intense storms and surges, as well as increasing erosion associated with ongoing accelerating sea level rise. The initial impacts of these drivers of coastline change is likely to be experienced over the next few decades when the IPO phase changes to negative.

In addition to the return of the stormy IPO phase the possibility of a return of a catastrophic severe storm year, like or greater than 1967 that has not been linked to known climate parameters remains possible. Coastline plans over future decades to centuries need to include approaches that will address on going sea level rise and climatic variability.

While it is not possible, or desirable, to consider armouring the Australian coast at all developed sites, legal and economic forces may attempt to justify such a management option over the next few decades. For example, much of the Gold Coast has been armoured and the dunes rebuilt to retain beach amenity, these works must be accompanied by a range of costly and ongoing nourishment strategies. For many other settled areas along the coast the cost of armouring and nourishment could not be justified.

Strategic planning

Regardless of any short term measures put in place, in the long term some form of managed retreat will be necessary for the whole of the vulnerable ocean coast as well as some bay and estuary shorelines. Current planning schemes and the legal basis for any form of managed retreat remain problematic and will need to be addressed before managed retreat will be effective.

Managed retreat

Managed retreat is designed to provide space between development and the dynamic shoreline. This avoids coastal hazards and prevents ecosystems being squeezed between rising seas and existing development (IPCC 2001c). Common managed retreat mechanisms include planning setbacks with a minimum distance from the shoreline (for new developments), density restrictions to limit new developments and rolling easements that permit development conditional on its removal when shorelines migrate landward (Titus 1998). Integrated coastal management policies may include all these strategies (IPCC 2001c).

Planning set back lines

Setbacks can be used as a managed retreat strategy where the setback is moved inland in line with shoreline recession over time (IPCC 2001c). The implementation of such a scheme will be difficult but not taking effective measures could be catastrophic.

Planning guidelines and interactive planning model

A specific adaptation to the Burnett Mary coast of generic guidelines developed by the Griffith Centre for Coastal Management (in co-operation with the former Coastal CRC – Helman and Tomlinson, 2006) will be prepared. These guidelines provide a best-practice framework (or first-order decision support system) for local authorities to address coastline vulnerability in their future planning and management strategies. The guidelines will incorporate the maps and other assessment undertaken throughout the project.

Communication of results

Training and workshops for Burnett Mary NRM and local government officers will focus on the use of the maps and the application of the vulnerability assessment tools and planning guidelines. Training sessions will involve the use of worked scenarios for targeted localities. These scenarios will demonstrate the basis and application of the guidelines using real data from the Burnett Mary region, enabling the implications of the project to be demonstrated effectively.

Community education will take the form of the dissemination of information sheets; the conduct of community workshops and the initiation of school information sessions.

CONCLUSIONS

The Griffith Centre for Coastal Management study will map and model the extensive coastline from Gladstone to Noosa to assess the impact of climate change on vulnerable coastal communities by providing essential baseline data for one of Queensland's most dynamic sections open coastline.

This area is experiencing rapid population growth, often in parts of the coast most vulnerable to coastal processes. Some of Australia's most sought after holiday destinations and most valuable property lie along this coast, particularly around Hervey Bay.

The relatively stable period of sea level during the last two hundred years of European settlements of the Australian continent is ending. Sea level has been slowly rising, is still rising, is projected to rise faster and will continue rising for centuries. This slowly accelerating sea level rise, observed on tide gauges, is now being expressed as a visible change in coastal features, the retreat of erosion faces and vegetation lines (Helman 2007).

We need to reorganise our approach to coastal planning, development and management to take account of the probability of long term sea level rise. This will require additions to present planning strategies of goals and policies that will endure for the centuries.

At some stage of sea level rise temporary mitigation measures involve increasing more expensive engineering works that cause disruption of coastal process and at this stage planning set backs to provide space for future dynamics is required.

Identifying coastal vulnerability involves the intersection of two pathways. One is geographic, identifying the sections of coast that have shared coastal dynamic features and the second is the relationship of these features to existing developments.

In annual to decadal planning time scales the influence of climate variability is likely to be more dominant.

Existing modelling tools don't take into account the effects of climate change, such as more frequent and severe storm and cyclonic activity and the flooding and erosion that accompany them, or the impact of predicted sea level rise.

This study will be used to create global information system map layers providing planners, governments, developers and the public with the most up-to-date information available on the state of the natural physical features of the coastline and how climate change will impact particular areas.

It will also pinpoint threats to the region's natural assets, which include the world's largest sand island, Fraser Island as well as well as many near-pristine estuarine systems. It will become a powerful tool for planning authorities to devise guidelines to shape future planning and natural resource management.

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DRAFT FIGURES

Figure 1 Ice age cycle [graph to be scanned]

Figure 2 The present Burnett Mary coast and coastline position 17 000 years ago [past coastline drawn on continental shelf image]

Figure 3 Houses on beach after storm erosion and rapidly rising sea level on the east coast, USA

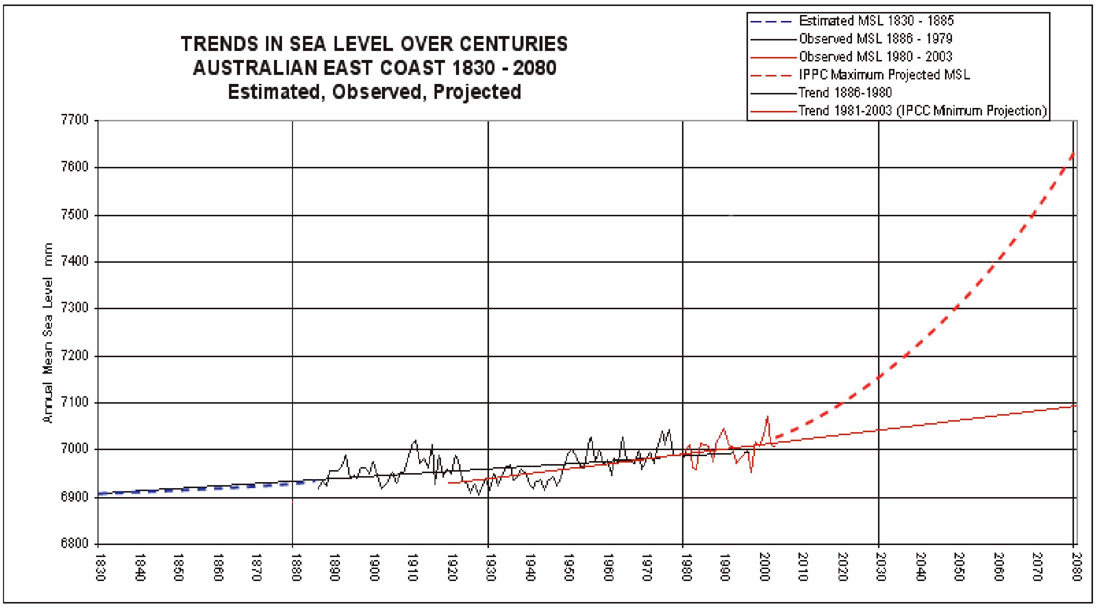

Figure 4 Three centuries of sea level - East coast sea level trends (estimated, observed and projected) from 1830 to 2100 (after Helman 2007).

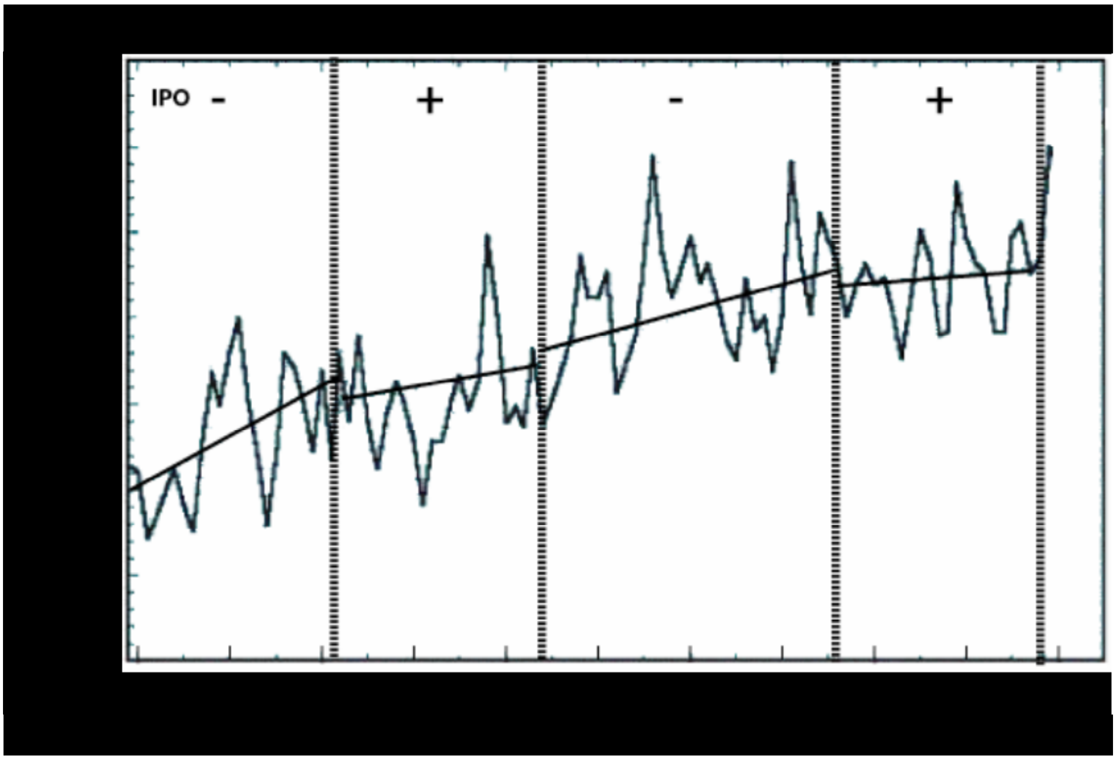

Figure 5 IPO phases and rates of sea level rise Auckland, from Goring and Bell (2001), showing sea level rising faster during negative phases of IPO.

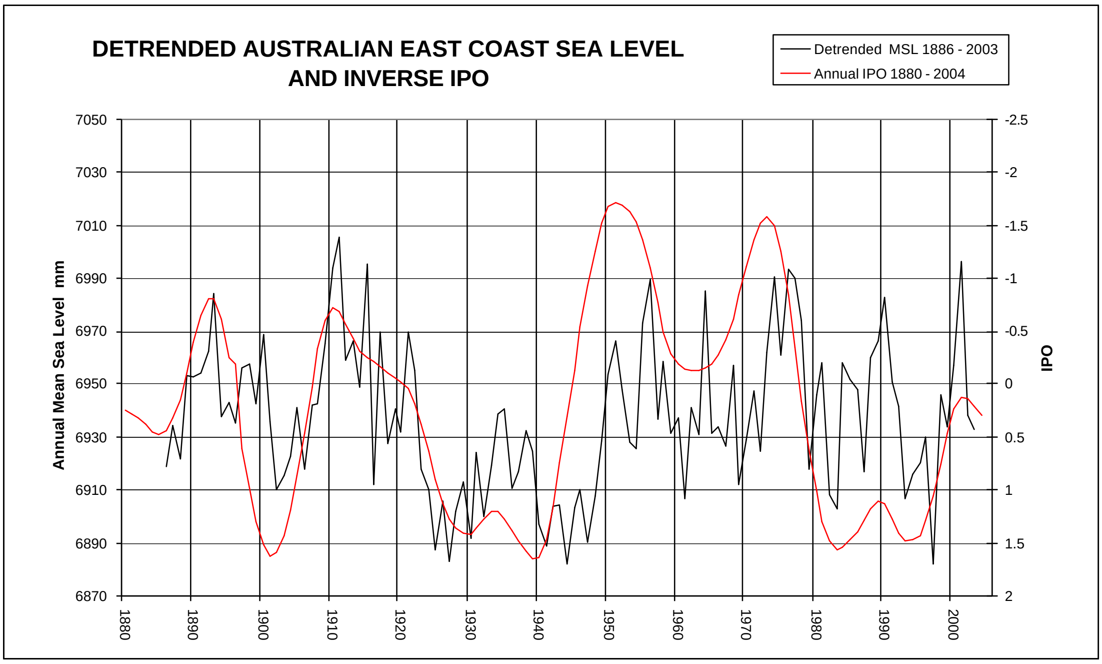

Figure 6 Episodic oscillation of IPO and detrended Sydney sea level from 1886. IPO plotted inverse (Helman 2007).