University of Southern Queensland
Faculty of Engineering and Surveying

Potential Impact of Rising Sea Level on Land Ownership and Government Planning.

A dissertation submitted by

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Abstract

Climate change and consequent sea level rises over the next century will create major challenges for regulators determining land use. In excess of 150 million people worldwide live within one metre of mean high water mark (MHWM). Many populated areas in Australia will face challenges associated with rising sea levels in the next century.

This study seeks to model the potential impact of rising sea levels on two sample parcels of land in the Great Lakes and Lake Macquarie areas of New South Wales, based on anticipated changes to MHWM. It will also explore the consequences for land ownership where boundaries are defined by MHWM using the principles outlined in the Doctrine of Erosion and Accretion.

While there is a range of scientific opinion on the scope and speed of climate change, ranging from quite small to the catastrophic, this study has accepted the models developed by the Intergovernmental Panel on Climate Change (2007) and regional variations for the east coast of Australia proposed by the Commonwealth Scientific and Industrial Research Organisation.

Anticipated sea level rises will cause inundation of low-lying land in many areas of the world including Australia. There will be a landward migration of MHWM creating ownership issues for landowners and planning issues for government and regulatory bodies. Regulatory bodies will need to proceed cautiously with future land use to avoid legal liability for a foreseen event.

University of Southern Queensland
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List of Abbreviations

MHWM	Mean High Water Mark
CSIRO	Commonwealth Scientific & Industrial Research Organisation
IPCC	Intergovernmental Panel on Climate Change
DECC	Department of Environment & Climate Change
NSW	New South Wales
ppm	Parts per million
CO2	Carbon dioxide
cm	centimetres
DTM	Digital Terrain Models
AHD	Australian Height Datum
CRE	Cadastral Records Enquiry
DP	Deposited Plan

Chapter 1

1.1 Introduction

> *The maps of the world will have to be redrawn. (Sir David King, UK Science Adviser)*

Climate change is a dominant topic in both global and local politics. The implication of climate change for a planet with a rapidly expanding human population are at best challenging for the future of humanity and at worst, potentially catastrophic. While debate rages within scientific circles about the extent of climate change, there appears to be consensus that the Earth is warming and as a consequence sea levels are rising.

While it is not within the terms of reference of this paper, overwhelming scientific opinion suggests the causal effect of climate change is the elevation in carbon levels as a result of human activity, particularly since the industrial revolution (ref Garnaut report). The important aspect of climate change, and indeed the focus for this study, is based on the premise that the Earth is warming and that there will be consequential effects of this including, but not limited to, sea level rises. Although other scientific opinion exists regarding the causality of global warming including the views of geologist Ian Plimer, who refutes the contribution of carbon levels to changes in global temperature, there is little doubt in scientific circles that for whatever reason, the planet is warming. As Walker and King (2008, p.23) clearly state: "In summary, we know the world is warming."

Accepting this premise, this study will seek to identify the projections for sea level changes in the next 100 years and apply this information to two specific land parcels in the Lake Macquarie and Great Lakes areas of New South Wales that may be at risk. The study will explore the implications to the Doctrine of Erosion and Accretion in relation to changes in mean high water mark as a consequence of climate change. From the findings of the study the discussion will focus on the implications for planning and zoning in the future.

1.2 Project Aims

The focus of this paper is to:

1.1 examine the implications of sea level rises on land ownership, based on an analysis of scientific opinion on the extent of sea level changes expected over the next 100 years.

1.2 examine the concept of mean high water mark and the legal implications for landowners including the application of the doctrine of erosion and accretion in relation to changes in high water mark.

1.3 explore, based on the projected changes in sea level, the legal, social and planning implications for government in dealing with inundation

1.4 conduct a case study of two blocks of waterfront land of different topography and zoning in the Great Lakes and Lake Macquarie areas with the view to applying the findings in the above areas to their specific situations.

1.5 identify the issues for land ownership on the blocks identified in the study and explore the broader implications.

1.3 Project Objectives

This research project seeks to identify the effect of changes in mean high water mark (MHWM) as a result of climate change on land ownership and the legal, social and planning implications for the future. This will be achieved by targeting two case study land parcels abutting coastal areas in the Newcastle region. The case study parcels selected are topographically different and provide two useful perspectives of the effect of sea level rise on land ownership.

In the course of the study, the projected sea level rises over the next century will be examined. There is an extensive range of literature exploring models of climate change and consequent sea level rise. One key objective will be to identify a model of climate change that is broadly accepted as being based on the best evidence available and therefore a reasonable basis for planning. Climate change models are under constant review and refinement as a result of new data and better modelling techniques. This implies that predicted changes will also be revised which has substantial implications for planning authorities. The preparedness of government authorities, in particular the Great Lakes and Lake Macquarie Councils where the project land is located, will be explored set against the accepted climate change models.

The research methodology requires an understanding of the concept of MHWM and the way it is used to define coastal boundaries. The methodologies for defining MHWM will be reviewed and a justification for the study methodology provided.
The definition and concept of MHWM are critical aspects of this study. Apart from the obvious link to rising sea level, there is a large legal component particularly in relation to the Doctrine of Erosion and Accretion. The literature review will cite specific case studies involving changes to MHWM and the implications for land ownership including zoning regulations. Further, the broader implications for government authorities in dealing with such cases will be considered.

The study will also review government planning policies applying to climate change and in particular sea level change. This will include government at all levels and the

degree and importance of the link between the various levels of government. An examination of the possible responses to property affected by changes to MHWM will be conducted.

Two land areas have been identified as case study lots for this project. They are located in the Great Lakes and Lake Macquarie Shires of New South Wales, both in proximity to the Newcastle areas. The lots offer two perspectives on the affect of changes to MHWM due to their topography and current land use. Surveys will be conducted on the lots to ascertain current MHWM. Using survey plans and photographs, the consequential effects of sea level rise will be shown based on the findings identified in the literature review. The implications for the study lots will be examined from a local viewpoint and extrapolated to provide an insight into the national perspective.

1.4 Summary

The findings of this study will be used to review the practical and legal position of the landholders on the case study lots. The research will seek to identify the adequacy of government and planning policy for future development. The literature review that follows in the next chapter will explore each of the aforementioned issues, with the broad objective of reaching an acceptable model on which to base changes to MHWM over the course of the next century.

The outcomes of this study will provide a clear illustration of the need for a review of coastal lands in the local Newcastle region and indeed nationally. While there appears to be a broader acceptance of the reality of climate change and its consequent effects, there is a growing urgency to review land use in potentially at risk areas and consider the issues faced by landholders and the adequacy of current law to deal with the impending issues.

Chapter 2
Literature Review

2.1 Introduction

This chapter will review the literature to establish projections for changes in sea level over the next century. It will consider the range of views and seek to identify the most authoritative evidence at this point in the climate change debate. This will provide the basis for application to the case study land parcels. The literature review will also seek to establish and justify the methodology used in defining and establishing MHWM and its relationship to the doctrine of erosion and accretion. Government policies pertaining to coastal lands and climate change will be reviewed with reference to applicable case law.

2.2 Population

Over three billion people worldwide live within two hundred kilometres of a coastline. It is estimated that 150 million people worldwide live within an elevation of one metre from high tide level and 250 million within five metres (Commonwealth Scientific and Industrial Research Organisation (CSIRO) website, 2009). In Australia, most human habitation is in coastal areas and waterfront land has become a highly prized possession. Clearly changes to sea level will have a major impact on many people around the world.

2.3 Sea Level Rise Past, Present & Future

There is considerable debate in scientific circles about the extent of sea level rises. In the period from 1870 –2001 global sea level rose by 17 cm at a rate of 1.7mm per year (Church & White, 2006). It was further noted by the authors that sea level rises accelerated during the latter part of the 20th century. Walker and King (2008)

generally support this stating that for the twentieth century, the rise was 2 mm per year rising to 3 mm per year in the latter part of the century. They further suggest that this rate is still accelerating and state that even without calculating ocean inflows from melting ice sheets and glaciers, a rise of 10 cm is possible in the next few decades. Over half of the rises in sea level to date can be accounted for by expansion of the ocean volume due to warming. The full effect of melting glacial ice, melting of the Greenland and Antarctic ice shelves, and the reduced reflection of sunlight by the diminishing ice mass at the North Pole, has not been fully realised (Hansen, 2007).

There is a range of predictions about rises to sea level, from totally catastrophic estimates to more modest changes. The James Hanson Group at NASA Goddard Institute (cited in Gaia, 2009, p37) suggest a sea level rise in excess of five metres by 2100 based on their modelling. This is at odds with the more conservative estimates made by the Intergovernmental Panel on Climate Change (IPCC). The IPCC consists of leading climate scientists and government advisers from around the globe. While it is regarded as the definitive authority on climate change, it is generally considered conservative, possibly due to the wide range of views to be reflected (Walker & King 2008). IPCC reports from 2001 and 2007 (IPCC, 2001 & IPCC, 2007) suggest a range of possible sea level rises based on various greenhouse gas emission scenarios. The upper limit scenario has been adopted in the New South Wales Sea Level Rise Policy Statement (2009) based on the fact that the emission level on which it is based has already been exceeded. The upper limit scenario for 2100 is derived from the IPCC prediction of 59 cm. However this model fails to take account of glacial and ice sheet melt known as “dynamic melting of ice sheets” (Gore, 2006). The IPCC report (2007) states that if this melting were to grow in line with a rise in global temperature, the sea level rise would be a further 10 – 20 cm by 2100. The IPCC further cautions that these levels could be exceeded. Sea level rises will also have a regional impact due to oceanographic and atmospheric conditions at different places around the globe. The CSIRO in conjunction with the Department of Environment and Climate Change (DECC) suggests a New South Wales (NSW) regional variation of 8cm by 2030 and 12 cm by 2070. The DECC (2009) has extrapolated these figures to fit the 2050 and 2100 time frame creating regional increases above the model to be 10 cm and 14 cm respectively. This provides a benchmark of 40 cm for 2050 and 90cm for 2100.

2.4 The Range of Scientific Opinion

The Garnaut Climate Change Review (2008) has drawn attention to the emission levels adopted by the IPCC in developing climate models. The report suggests that unless rapid reductions in carbon levels can be achieved in the short term, which current trends do not indicate, the IPCC scenarios even at the highest end will be exceeded. The Garnaut Report models a number of emission scenarios, each of which is largely dependent on the global response to reducing carbon emissions. The report makes the following note on the level of human activity:

> *"The largest source of increased urgency is the unexpectedly high growth of the world economy in the early twenty first century, combined with unexpectedly high-energy intensity of that growth and continuing reliance on high emission fossil fuel as sources of energy." (Garnaut, 2008).*

Based on the uncertainty around the various climate change models that form the basis of much of the current policy formulation by government authorities in Australia, it is important to consider other credible sources where projections differ from the current wisdom. Rahmstorf, Cazenave, Church, Hansen, Keeling, Parker, Somerville (2007, p709) draw attention to the inadequacy of IPCC projected estimates in the 1993 –2006 period of 2mm/year. Satellite data for the period showed a linear trend of 3.3 mm/year. Further the rate of sea level rise for the last twenty years has been 25% faster than the rate of rise in any twenty-year period for the last 115 years. It is also interesting to note that the authors point out that the largest contributors to rising sea levels to date are ocean thermal expansion and melting from non-polar glaciers. They also point out that the contribution from ice sheet melt (that is Antarctica and Greenland) has thus far been small but expect that these areas will contribute far more in the future. In summary:

> *"projections, as summarised by the IPCC, have not exaggerated but may in some respects even have underestimated the change, in particular for sea level."* (Rahmsdorf et al, 2007, p709)

While Rahmsdorf and his colleagues query the adequacy of the IPCC models, there are a number of highly credible researchers in the climate change field who take an even more drastic view of sea level change. Hansen (2007) who heads the NASA's Goddard Institute for Space Studies, asserts that a 2 – 3 degree Celsius rise in temperature over the next century would result in sea level rises closer to five metres and rejects the linear approach to calculating melting ice sheet, particularly with an unclear future in regard to atmospheric carbon levels. He also suggests that the Earth is now believed to be within one degree Celsius of the warmest it has been in the last one million years. In historical terms, the Earth was last in a similar state climatically to the present about three million years ago. Carbon levels were similar, perhaps slightly higher and temperatures two to three degrees warmer. Sea levels were 10 to 25 metres higher than today. Hansen is also critical in his article of the research funding in this field, noting that moderate predictions are more likely to attract research dollars!

The complexities of climate change are immense and there is considerable disagreement amongst scientists and academics in this field other than the basic premise that the climate is warming as a result of human activity (Gore, 2006). The IPCC modelling and predictions have been widely used by government bodies in Australia to date. It should be carefully noted that there are predictions by creditable sources both above and below these estimates. There is concern that IPCC estimates are conservative (Walker & King , 2008).

Much of the key to climate change is linked to the levels of carbon in the atmosphere with temperature rises in the future adjusted accordingly. At the lower end predictions (450 parts per million (ppm) CO2) a temperature rise of 2.5 degrees Celsius is predicted (thought to be the lowest we can hope for). At the higher end (650 ppm CO2) there would be a likely temperature rise of 4 degrees Celsius (Walker & King 2008). Without immediate urgent action, it is anticipated that by 2035, CO2 will be at 550 ppm and by century's end over 1000 ppm, which would certainly flow dramatically into sea level rises and indeed rates of change. Walker and King (2008) are adamant that carbon levels are the key link in the global warming story stating:

"There are plenty of areas for debate in the global warming story but this is not one of them. If anybody tells you differently they either have a vested interest in ignoring the scientific arguments or they are a fool."

2.5 Conclusion and Adopted Model

The IPCC appears to be the most respected authority in the area of climate change and sea level rise. While there is credible debate around the extent of temperature increases linked to CO2 levels and the consequential sea level rises, major authorities in Australia including CSIRO and state and federal authorities working in this field tend to support the IPCC predictions as "the most robust" (CSIRO 2009). From the literature review to date, it appears (and the IPCC concedes) that the figures provided (90 centimetres (cm) rise by 2100), while at the upper end of their modelling, may still be exceeded. The modelling for this project will therefore be based around the upper and lower projections of the IPCC models, which reflects the likely views to be taken by authorities in Australia.

The table below outlines projected sea level rises for 2050 and 2100 based on the upper range scenario outlined by the IPCC and including a regional allowance derived from CSIRO modelling (2009, DECC).

Component	**Year 2050**	**Year 2100**
Sea level rise	30 cm	59 cm
Accelerated ice melt	(included in above value)	20 cm
Regional sea level rise variation	10 cm	14 cm
Rounding*	-	-3 cm
Total	40 cm	90 cm

Table 1. Projected Sea Level Rise for 2050 and 2100.

Figure 1 below illustrates the model projections made by the IPCC using a range of scenarios based on differing atmospheric carbon levels.

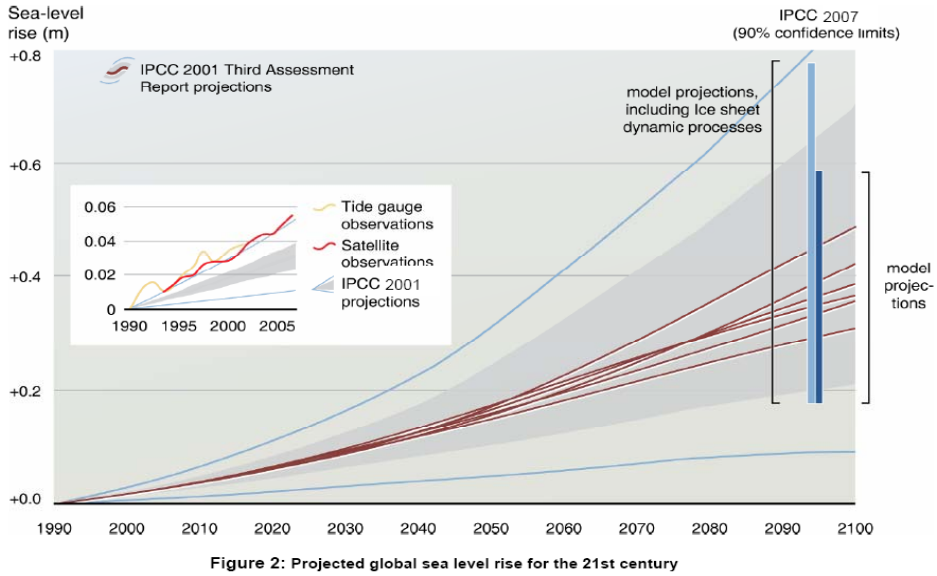

Figure 1. Projected Global Sea Level for the 21st Century.

2.6 Mean High Water Mark

Butt (1996, p40) defines mean high-water mark (MHWM) in the following way:

> *"The mean high-water mark is the line of the medium high tide between the highest tide each lunar month (the springs) and the lowest tide each lunar months (the neaps), averaged out over the year."*

He further states that land below this level belongs to the Crown and includes the foreshore, that is, the land lying between high and low water marks.

Watson & Harcombe (2004) identify two types of waterfront boundaries in NSW, namely Right Line boundaries and ambulatory boundaries. In summary, the right line boundary is defined against survey monuments, linear measurements and adjoining boundaries. Ambulatory boundaries are boundaries that are subject to movement over time and are defined by rivers, streams, the shorelines of lakes and the sea (which

include the water boundaries of the target properties in this study). These boundaries are subject to change including the MHWM. Due to changes in global climate, oceanographic conditions or a range of other natural (and man made) phenomena, this measurement is less definitive at any point in time. Fifty thousand waterfront properties in NSW are defined by this mechanism.

2.7 Ambulatory (MHWM) Boundaries – The Doctrine of Erosion and Accretion

Ambulatory boundaries, in accordance with Common Law principles, give ownership rights to the MHWM (Lipman & Stokes, 2003). As stated, this boundary is subject to change. These boundaries are based on the doctrine of erosion and accretion. It is based on the principle that the sea and its foreshores should be held in trust by the Crown on behalf of its citizens (Gordon, cited in Watson & Harcombe, 2004). There is now considerable debate as to the application of this doctrine in the light of climate change (Lipman & Stokes, 2003).

The doctrine of accretion and erosion applies to where the boundary between land and water changes in a manner that it is not readily noticeable (Hughes Ed, 2007). Butt (1996) identifies two basic tests that apply to accretion and erosion. The slow and gradual test states that the change must be so slow and imperceptible to the naked eye as it occurs. The second test is that the changes must be from a natural process not from artificial sources such as reclamation by human intervention. In practice, this means that land added to belongs to the owner and land encroached upon by water belongs to the Crown. In the case of global warming and subsequent sea level rise, the process of divulation may occur. This refers to the encroachment of water and is the opposite of accretion (Department for Transport, Energy & Infrastructure, South Australia, 2009). Erosion also fits under this category.

2.8 Duty of Care

It has been well established so far that sea level rises as a result of climate change will impact on high water marks around the globe. Government authorities will be exposed to a range of pressures in the future regarding waterfront properties (Lipman & Stokes, 2003). In particular local councils may be exposed to legal action if their decisions on development do not show a duty of care. In July 2008 the Gippsland Coastal Board challenged South Gippsland Shire Council regarding permits issued for six single dwellings at risk of coastal subsidence and inundation due to sea level rises predicted by a commissioned CSIRO study. Section 60 (1) (e) of the Planning and Environment Act 1987 (Vic) states:

> *"before deciding on an application, the responsible authority must consider… any significant effects which the responsible authority considers the use or development may have on the environment* ***or*** *which the responsible authority considers the environment may have on the use or development."*

It was determined that a general consensus existed that climate change would create conditions that historical records could not adequately provide for in planning terms. It was also determined that there was an unacceptable and foreseeable risk of inundation. The approvals were overturned.

In NSW, the case of Walker v the Minister for Planning, also takes account of climate change and sea level rises. In this case Justice Peter Biscoe in 2007 overturned a decision by the NSW Planning Minister for a proposed residential development at Sandon Point, near Wollongong. Justice Biscoe stated in the decision that the Minister failed to take into account implied mandatory considerations including the principle of ecologically sustainable development and, in particular, impact of flooding and inundation of the project land that would ultimately be exacerbated by climate change.

The High Court of Australia in recent cases has examined 'salient factors' in determining whether a duty of care exists. They identify six key factors:

- Statutory Powers – do the powers exist for the relevant authority?
- Proximity – is the relationship between the parties one of neighbourhood?
- Control – does the authority have the power to control the situation that brought about harm?
- Knowledge – did the authority know, or ought to have known of an existing risk of harm?
- Vulnerability - is the claimant vulnerable in the sense that he or she could not safeguard her or himself?
- Reasonableness – is it reasonable in all the circumstances for the authority to show a duty or care. (Lipman & Stokes, 2003).

The Local Government Act 1993 Section 733(1) offers some protection to councils in relation to coastal erosion, provided decisions are made "in good faith." This implies that the council acts in accordance with guidelines such as the Coastline Management Manual 1990. Councils may also be exposed under the Civil Liability Act NSW 2002 although this act tries to restrict the liability of public authorities for issues such as personal injury or death as a result of coastal hazards, but the issue of property damage from coastal erosion is yet to be tested (Lipman & Stokes 2003). They also provide a range of scenarios where councils could be seriously compromised and liable in relation to the zoning and development consent provided to properties in at risk areas, based on our developing knowledge and understanding of climate change.

Lipman & Stokes (2003) make the point that traditional interpretations of the doctrines of accretion and erosion are incongruous with modern environmental policy because they do not adequately reflect the interests of the general population and their rights to securing public access to waterfront land. As most issues are now related to erosion and divulation rather than accretion on the NSW coast, coastal foreshore will become an issue of greater significance as the effects of sea level rise further impacts the coastline.

2.9 Government Policies

The NSW Government has released a Draft Sea Level Rise Policy Statement outlining policies, programs and legislation in relation to coastal hazards including rising sea levels. Fundamental to this statement is reference to the 1997 NSW Coastal Policy that seeks to guide the development of the coastal zone in an ecologically sustainable manner. It provides guidance to councils in the planning and management of coastal areas. Coupled with these policies, the Sea Level Rise Policy Statement considers the economic, social and environmental impacts of sea level rise, and outlines five policy principles:

- an adaptive, risk based approach
- provision of guidance to councils
- guide appropriate development on at risk land
- provision of emergency management support in floods and storms
- provision of up-to-date information on sea level rises

The NSW DECC has developed a draft technical note entitled the 'Scientific Basis of the 2009 Sea level Rise Benchmark.' This document essentially embraces the IPCC 2007 sea level model described above, including the CSIRO regional allowance. It is currently the basis for sea level rise advice in NSW.

The Lake Macquarie Council has adopted the NSW DECC recommendation for the upper limit sea level rise in determining "risk assessment, policy development, community empowerment, planning and development decisions" (Lake Macquarie Sea Level Rise Preparedness Adaptation, 2008). They have also made a commitment to review polices in light of changes of position by the NSW DECC as new information becomes available. This decision is wise in light of the legal implications outlined for government authorities in previous sections.

It is interesting to note that Great Lakes Council, the site of the Pindimar blocks targeted in this study, do not yet have a clear policy position such as the above from Lake Macquarie Council.

2.10 Conclusion

While there is an extensive range of scientific opinion on the magnitude of climate change and consequent sea level rise within the academic literature, the IPCC predictions and the CSIRO regional adjustments provide the most credible and widely agreed view at this time. However it is important to appreciate the complexity of the science associated with the Earth's climatic system and the potential for error in making predictions. The IPCC will no doubt take an adaptive approach to their predictions as more evidence comes to light and more reliable modeling techniques are developed. This factor is actually one of the greatest challenges for planning authorities in terms of deciding on what predictions to adopt. This study will use the IPCC and CSIRO models with the cautionary note that adaptations over time are inevitable.

The properties used in the case study parcels are defined by ambulatory boundaries. Based on the adopted projections, encroachment of water will take place as a result of changes to MHWM. The doctrine of erosion and accretion applies in the sense that the boundary between land and water change will be slow and imperceptible to the naked eye. However the second test, that is, it must be from natural processes, may open considerable debate if man made global warming is clearly established as the cause. Government authorities will be tested in terms of their duty of care, not only in terms of future land use, but whether they have acted "in good faith." Certainly a failure to act on the basis of information such as the IPCC projections, or other credible models, would seriously test this premise.

The following chapter detailing the methodology applies the findings in this chapter to the case study land parcels.

Chapter 3

Project Methodology/Justification & Resource Analysis

3.1 Introduction

In designing this project, it was decided to try and contrast the effects of sea level rise on different coastal areas by selecting land parcels with different topographical features. Lake Macquarie and Port Stephens are located in close proximity to Newcastle and have varying levels of exposure to sea level change. The topographical difference between the two land parcels establishes the effect of migrating MHWM on the overall loss of land and the implications for its future use. By applying the IPCC/CSIRO sea level models for 2050 and 2100, a clear picture of the effects on each land parcel can be displayed.

3.2 Defining the Case Study Land Areas

Two parcels of land that may be affected by rising sea levels have been selected for the purposes of this study. Both these parcels are bounded by tidal waters and are defined by Mean High Water Mark (MHWM). The identified sites provide examples of the contrasting effects that rising sea levels will have on the changing position of MHWM and the severity of impacts on the landowners.

The natural topography of the land, determines the level of impact of rising sea levels. A low-lying flat block of land will obviously be more affected than a block of land that is steep and higher in elevation.

3.3 Defining Future Sea Level Changes to Case Study Areas

Initially the study identified the current position of MHWM (see method description below) for both case study blocks. Using the IPCC/CSIRO estimates for sea level rise over the next 50 and 100 year periods, new MHWM levels were determined to illustrate the effects of specified sea level changes on the case study lots. This was simply calculated by adding the current MHWM supplied by Manly Hydraulics Laboratory to the IPCC predicted rises for the specified locations. Tables 2 and 3 below shows the changes to MHWM for both sites. 1

Year	MHWM (estimate)
2009	0.11
2050	0.51
2100	1.01

Table 2. Changes in MHWM at Brightwaters to 2100.

Year	MHWM (estimate)
2009	0.476
2050	0.876
2100	1.376

Table 3. Changes to MHWM at Pindimar to 2100.

A series of digital terrain models (DTM) were created for each lot illustrating the position of the estimated MHWM contour lines at each specified year in the above table.

3.4 Details of the Land Areas

3.4.1 Site 1 Brightwaters

Street Address: Buttaba Road

Locality: Brightwaters

Local Government Authority: Lake Macquarie

Parish: Morisset

County: Northumberland

Lot: 2

DP: 1058010

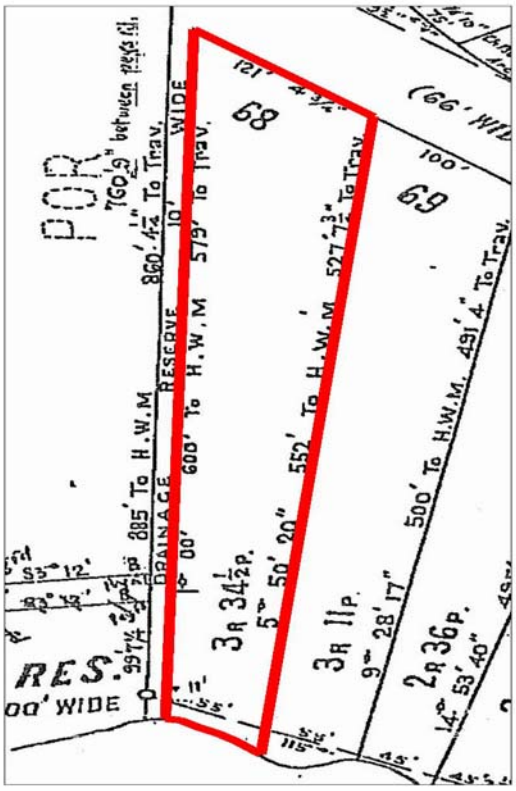

Figure 2. Section of Deposited Plan for Lot 68, DP8055 for Brightwaters.

*Explanatory Note: This lot was originally known as Lot 68, DP 8055. It has since been subdivided and now a Lake Macquarie Council reserve abuts the tidal boundary. For the purposes of this study, it will be assumed that it has not been sub-divided. The rationale for this is that it will be a significantly easier process to gain permission from Lake Macquarie Council rather than from a private owner to carry out survey work. However the block definition will be based on the most current deposited plan. The ownership issue is irrelevant to the purpose of this study.

The subject lot is on Buttaba Road and running parallel to Lake View Avenue. It abuts Lake Macquarie on the southern boundary. The property is surrounded by existing residential development including both new and older style residences. The

case study block is steep at the waterfront and gently sloping at the northern, road end. On surrounding properties there are multiple boatsheds and jetties built over Lake Macquarie.

Figure 3. Aerial Photograph of Brightwaters Land Parcel

3.4.2 Site 2 Pindimar

Street Name: Carruthers Avenue

Locality: Pindimar

Local Government Authority: Great Lakes

Parish: Coweambah

County: Gloucester

Lot: 15

DP: 10869

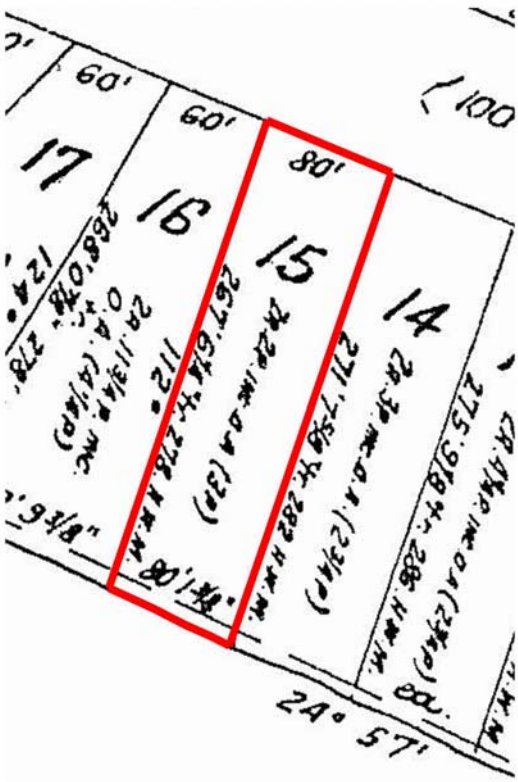

Figure 4. Section of DP 10869 Showing Lot 15 Pindimar

This case study lot is located at North Pindimar in Great Lakes Shire. It is located on the northern shores of Port Stephens approximately 70 kilometres north of Newcastle. The North Pindimar township is in an area of low lying land ranging between zero and three metres on the Australian Height Datum (AHD). The topography is flat and the soils is mainly sand. The land is mostly uncleared. Interestingly the village of Pindimar was sub-divided as a futuristic city with the intent of attracting returning troops after World War 1. On this basis a plan for small, rare blocks in a rural zoned area was registered.

Figure 5. Aerial Photograph of Pindimar Land Parcel

3.5 Collection of Historical Data and Search

Application was made to Manly Hydraulics Laboratory for the current MHWM level for each location. The results of these applications are included as Appendix B and C. Concurrently applications were made for information on the closest established permanent marks to the proposed sites. This information included location data and an accurate Australian Height Datum (AHD) level. AHD is a level datum, which is calculated by mean sea level. The relevant SCIMS documents are attached as Appendix D and E. Application to the NSW Department of Lands for a Cadastral Records Enquiry Report (CRE Search) for relevant plans for each land area was made prior to survey work. This information provided all relevant survey plans for each area and any new subdivisions or redefinitions done in the locations. These plans of survey are included as appendix H and I.

3.6 Description of Data Collection and Redefinition of Subject Lots

Using the current DP, existing boundary lines were re-defined by connecting into monuments (boundary marks). Using a permanent mark (for Brightwater location)

and state survey mark (for Pindimar location) with an AHD level, the current MHWM was reinstated. Levels were taken over both sites to produce digital terrain models on which contour lines were plotted. From this information, the resulting contour maps over the sites were used to predict MHWM positions, based on IPCC/CSIRO sea level rises.

3.7 Justification of Methodology

The methodology for re-defining boundaries is standard surveying practice and was done in accordance with surveying regulations.

There are a number of methodologies for defining MHWM. These include:

- **Levelling from a benchmark**: this method is commonly used in locations on the coast reasonably close to tide gauges and where the relationship between mean high water and Australian Height Datum is known. Newcastle is identified as an area suitable for this method (Mean High Water Mark and 100 feet reserves, NSW Institute of Surveyors, Sep 06).
- **Level from a local tide gauge**: studies suggest that this method requires observations over a twelve-month period or taking the mean of all high waters observed at a tide gauge over a lunation period of 29 days. This also requires that tide gauges are available and close enough to take readings.
- **The Range Ratio Method**: this method requires an automatic tide recorder and long-term values of the tidal planes. It requires the surveyor to take readings on one day of high and low water marks of consecutive tides and applying a formula to calculate mean high water. This method is most commonly used in streams and estuaries.

While these methodologies have limitations and accuracy issues in certain situations as discussed in the literature review, it was decided to use the **levelling from a benchmark** method. This method provided sufficient accuracy to meet the aims of the project.

3.8 Equipment/Resources Selection and Justification

Typical modern survey party equipment was used to carry out all field measurements. All field observations were made using a Leica TC 1105 Total Station. Traversing equipment included Leica Circular Prisms, adaptors, tri-brachs, tripods and range pole. A digital camera was used to photograph and document various aspects of the fieldwork.

The standardization of all field equipment including the total station, prisms, tri-brachs and ranging pole was done prior to commencement of each job. The total station calibration was undertaken on the University of Newcastle baseline (recommended in the Surveyors General's Directions for Survey Practice). All other equipment was standardized as required. A survey vehicle, personal protective equipment deemed suitable for the task and signage for safety issues around traffic areas were used. Safety protocols were followed, including a job safety analysis, risk assessment and a safe work methods statement.

For the calculations, such as the re-definition of the subject land parcels and plotting of the position of the MHWM contour lines, the software package, CivilCAD was used. Drafting of plans and plan presentation was done using AutoCAD (2008). Access was provided to computer hardware and the aforementioned software to carry out the fieldwork, plotters and printers for presentation of output data.

3.9 Investigation Protocols

As part of the practical component of the surveying work the following protocols were followed. All neighbouring property owners were informed of the purpose and dates of fieldwork. The owners of the land parcel at Pindimar were approached for approval to carry out the investigation and the associated fieldwork. All safety measures were outlined to the owners of the land. Lake Macquarie Council were approached for approval to carry out the survey work on the land at Brightwaters. Safety measures were again outlined. Both parties were briefed on the surveying guidelines and protocols used by the company Harper, Somers, O'Sullivan in

Newcastle as the equipment used was kindly provided by them. All safety protocols were followed.

3.10 Conclusion

From the activities outlined above, contour plans were developed for each land parcel showing current MHWM and the MHWM on the original survey. Both land parcel contour plans were then superimposed with the IPCC/CSIRO projections for 2050 and 2100 to show the landward migration of seawater. Cross sections were also developed and calculations made to show the percentage of land area lost to inundation.

Chapter 4

Results

4.1 Introduction

The results gathered on site were recorded in the field notes. They are included as Appendix F and G. They were collated and contour plans produced illustrating changes to sea level over the next century. The data collected is outlined below for each parcel of land.

4.2 Site 1 Brightwaters

Appendix H is a contour plan showing the position of the current MHWM. A smaller version is shown as Figure 5.

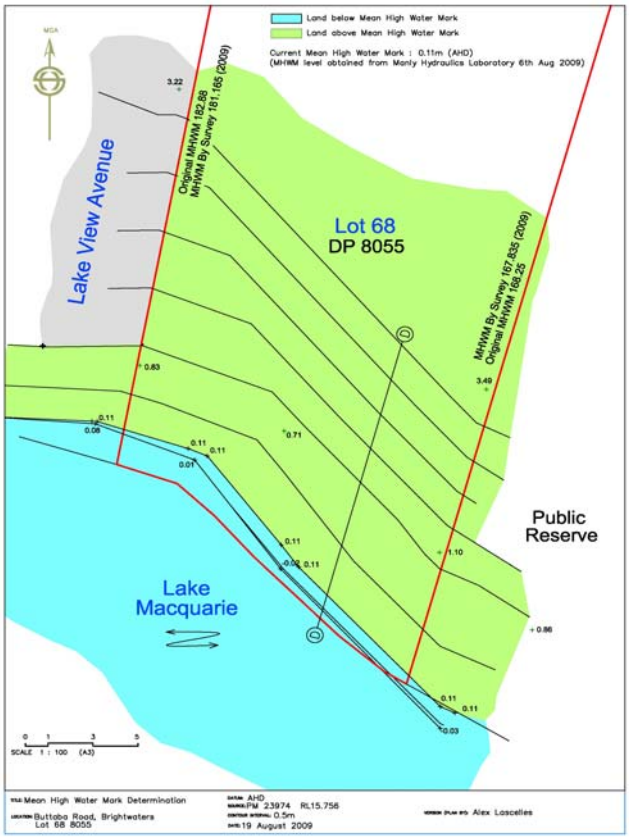

Figure 6. Contour Plan Showing Current MHWM Brightwater

The figure supplied by the Manly Hydraulics Laboratory is the RL 0.ll metres contour line. It can be seen as the colour change from blue to green on the contour plan. Blue on the plan indicates land below MHWM and the green indicates land above MHWM. The original survey on deposited plan 8055 (conducted in 1913) shows a distance of 182.88 m from the north-western corner of the lot to the MHWM specified in 1913. The figures obtained in this study (2009) indicate a landward migration of 1.715 m. In calculating these positions it was necessary to re-define all property boundary corners. The original eastern boundary line MHWM was 168.25m and the study recalculation (2009) was 167.835m showing a difference of 0.415 m.

Appendix I is again a contour plan showing the position of the estimated MHWM for the year 2050. A smaller version is shown as Figure 7.

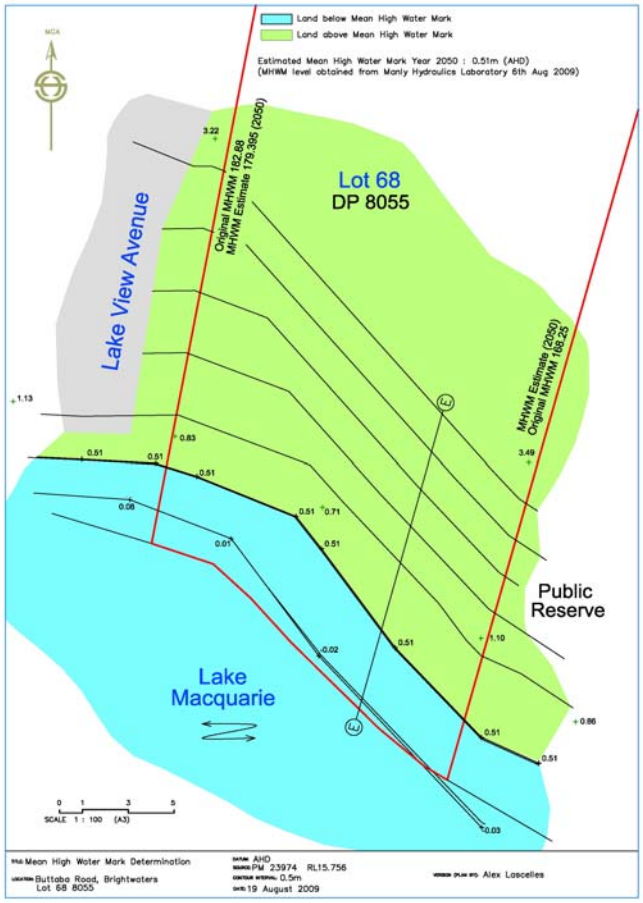

Figure 7. Contour Plan Showing Predicted MHWM for 2050 Brightwaters.

The western boundary indicates a landward migration of 3.485m set against the original MHWM calculated in 1913. The eastern boundary shows a landward migration of 2.79m. This means that the new MHWM value is RL0.51m.

Appendix J provides a contour plan for the estimated MHWM for 2100. A smaller version is shown below as Figure 8.

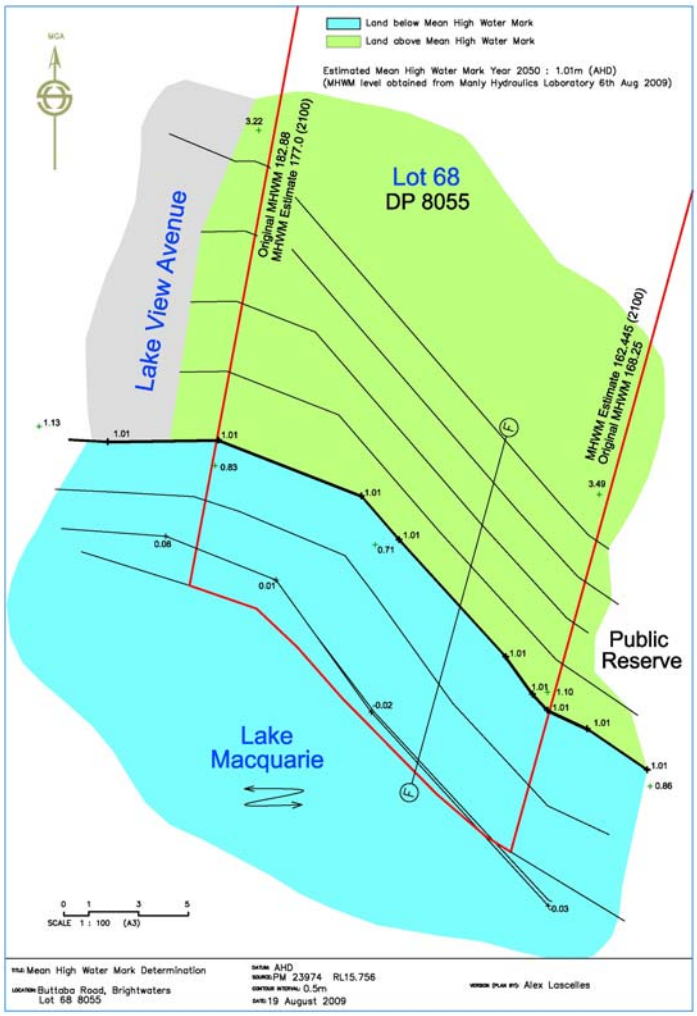

Figure 8. Contour Plan Showing Predicted MHWM for 2100 Brightwaters.

The western boundary is 5.88m landward of the original MHWM. The eastern boundary is 5.805m landward of the original MHWM.

Appendix K provides a cross section of the DTM using an exaggerated vertical scale for visual purposes. The cross sections show 2009, 2050 and 2100 estimates and indicate the changes in MHWM set against the topography of the lot.

The raw figures for the above information are presented in the following table and are shown in metres.

Year	Eastern Boundary	Western Boundary
1913 original	168.25	182.88
2009 study	167.835	181.165
2050 predicted	165.46	179.395
2100 predicted	162.445	177.0

Table 4. Changes in Eastern and Western Boundaries for Brightwaters.

Year	Eastern Boundary	Western Boundary
1913 original	168.25 MHWM	182.88 MHWM
2009 study	0.415	1.715
2050 predicted	2.79	3.485
2100 predicted	5.805	5.88

Table 5. Changes in metres from the original MHWM for Brightwaters.

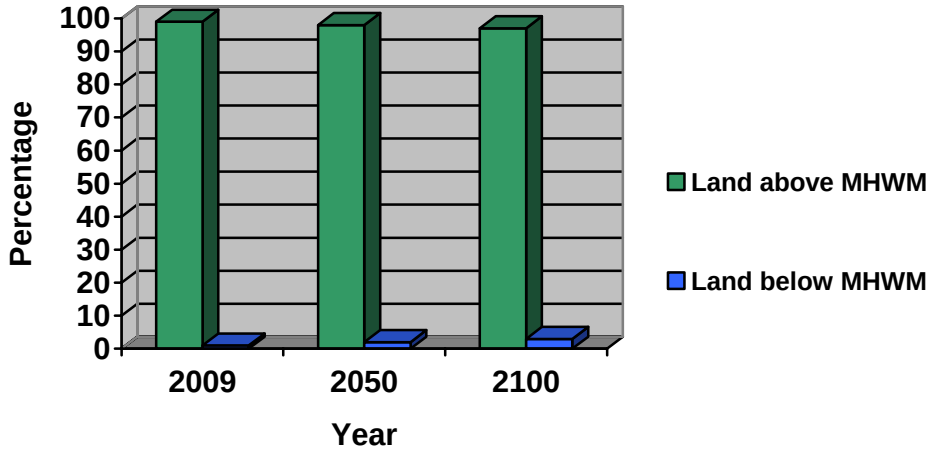

Table 6. Percentage of land lost to inundation at 2050 and 2100 Brightwaters.

The results indicate a landward migration from the original MHWM. The topography of this block is such that the incline from the waterfront is quite steep. The contour lines shown on the contour plan indicate an elevation rise of over 3 metres in the first 15 metres from MHWM.

Figure 9 and Figure 10 provide a photographic view of the Brightwaters site.

Figure 9. Photographic View of Brightwaters Site Showing Foreshore.

Figure 10. Photographic View of Brightwaters Site Showing Topographical Features.

4.3 Site 2 Pindimar

Appendix L is the current contour plan created in 2009 for the purpose of this study. Figure 11 provides a smaller view.

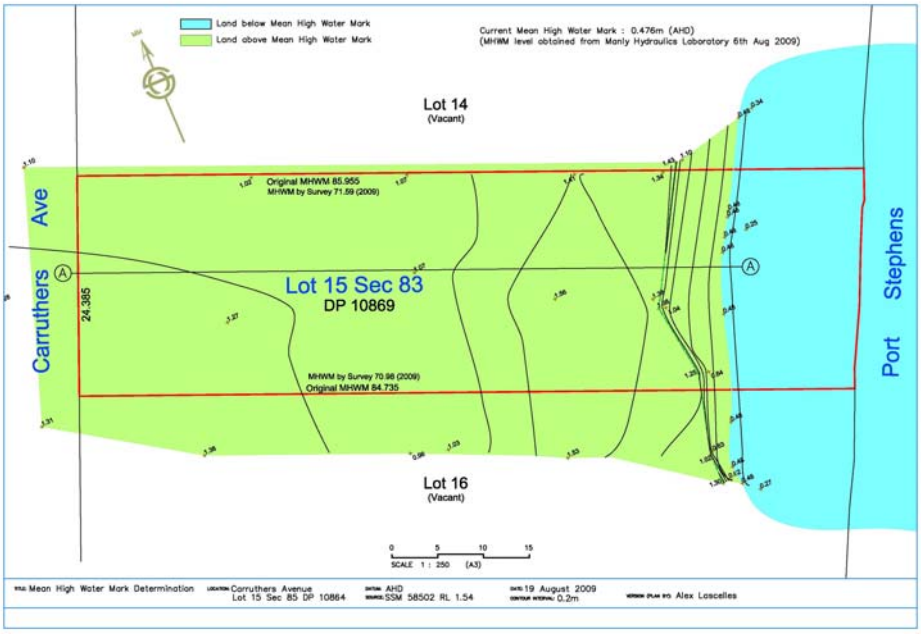

Figure 11. Contour Plan of Current MHWM at Pindimar.

On this site the northern and southern boundaries are the lines on which comparisons will be made. The original MHWM on DP 10869 for the northern boundary is 85.955m taken from the north west corner to the MHWM. The study measurement (2009) was 71.59m showing a landward migration of 14.365m. The original MHWM on the southern boundary was 84.735m compared to 70.98m for 2009, showing a landward migration of 13.755m.

Adopting the same procedure as for site 1, the 2050 and 2100 figures were extrapolated. The northern boundary measured 68.02m indicating a landward migration from the original measurement of 17.935m. The southern boundary was 68.42m indicating a landward migration of 16.315m. The figures for 2100 indicate an almost complete inundation of the lot. Only a small parcel remains above the estimated MHWM figure for 2100. A visual analysis further indicates that tidal activity, storm surges and erosion would probably destroy remaining land based on the topography and base materials (sand) on the lot. Appendix M shows changes to MHWM for 2050 at Pindimar. The figure below provides a reduced view of the original.

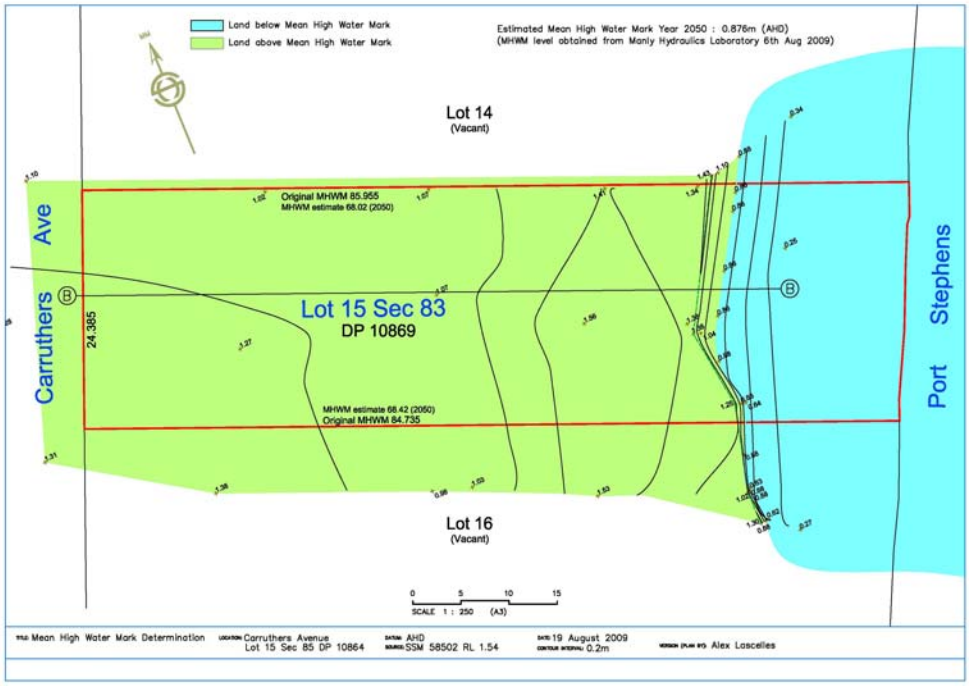

Figure 12. Contour Plan Showing Predicted MHWM for 2050 at Pindimar.

Appendix N shows an almost complete inundation by 2100. A reduced version is shown below in figure 13.

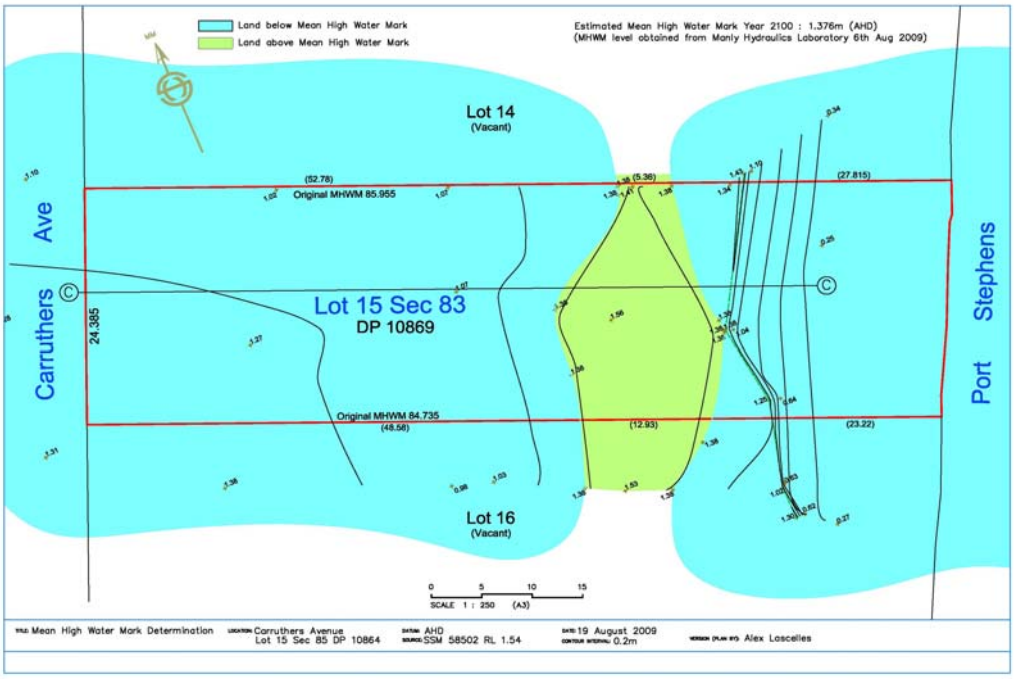

Figure 13. Contour Plan Showing Predicted MHWM for 2100 at Pindimar.

Evidence of current erosion, such as exposed tree roots and undercutting, suggest probable total inundation by 2100. Figure 14 is a recent photograph showing the already vulnerable nature of the foreshore.

Figure 14. Photograph of Evidence of Erosion and Undercutting at Pindimar.

Appendix O provides a cross section of the DTM using an exaggerated vertical scale for visual purposes. The cross sections show 2009, 2050 and 2100 estimates and provide further illustration of the probable total inundation by 2100.

The following table summarises the raw data on MHWM for the northern and southern boundaries for the specified periods. Values are in metres.

Year	Northern Boundary	Southern Boundary
Original	85.955	84.753
2009 study	71.59	70.98
2050 predicted	68.02	68.42
2100 predicted	Total inundation	Total inundation

Table 7. Changes in Northern and Southern Boundaries for Pindimar.

Changes from the original MHWM, shown in metres are shown in the following table.

Year	Northern Boundary	Southern Boundary
Original	85.955 MHWM	84.753 MHWM
2009 study	14.365	13.773
2050 predicted	17.935	16.333
2100 predicted	Total inundation	Total inundation

Table 8. Changes in Metres from Original MHWM Pindimar.

The following table outlines the percentage of land lost to inundation at 2050 and 2100.

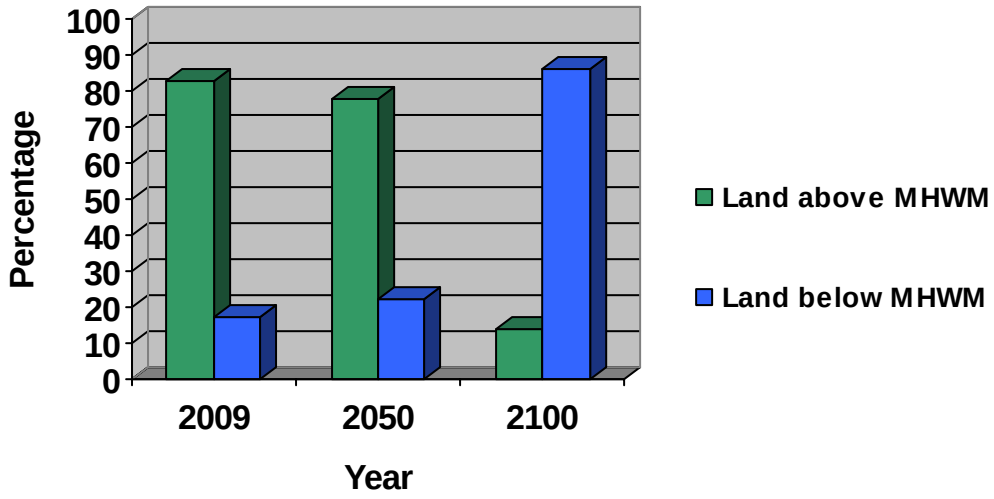

Table 9. Percentage of Land Lost to Inundation at 2050 and 2100 for Pindimar .

Figures 15 and 16 are site photographs illustrating the current status of the site including undercutting as already discussed. Figure 15 highlights the topographic proximity of the land parcel to the waters of Port Stephens.

Figure 15. Showing Proximity to Sea Level at Pindimar.

Figure 16. Showing Existing Topography and Vegetation at Pindimar.

4.4 Conclusion

The results illustrate the potential effect of sea level rise. In particular, the topography of the land abutting the sea will be fundamental to the percentage loss overall. The contrast between the two parcels of land, that is, one low lying, the other with a steep incline away from MHWM demonstrates this. This has substantial implications for areas of low lying land such as the Pindimar parcel where total inundation is a distinct possibility. Moreover, regulatory authorities will need to consider carefully their response to the types of activities that at-risk properties should be allowed to undertake. There is also a need to review the regulations surrounding land use at various levels of risk on the continuum from total inundation to more minor encroachment.

Chapter 5
Discussion

5.1 Implications for the Case Study Lots

There is a distinct contrast between the identified effects on both lots. The first lot at Brightwaters is less affected due to its steep topography. Despite losing some land to landward migration by sea water, there is enough elevation on the block to ensure the majority of the land is still usable and probably suitable for housing development, based on the IPCC/CSIRO estimates. On this particular lot, the land area due to the change in MHWM, would remain large enough to meet the requirements for its zoning, that is, 2(1) Residential under the Lake Macquarie LEP 2004. Although Lake Macquarie City Council has produced A 'Sea Level Rise Policy Factsheet,' it has not yet adopted a sea level rise prediction. However it does refer to the IPCC/CSIRO figures used in this paper. The lot is currently open to a range of residential developments including sub-division and residential building. More radical estimates of sea level change, should they prove to be correct, may change the level of impact on this lot.

Under the current laws, if application were made, the owners would lose the inundated land to the Crown in the 2050 and 2100 models. Even with the current 1913 to 2009 (current study) readings, it is likely that a redefinition would be required as part of a development consent. This is because the local authority would require it to comply with their developmental control plans, particularly in relation to building setbacks and land areas and floor levels. Due to the changes in MHWM, the lot size would be reduced. This would include the land between high and low water mark in addition to the inundated land. This assumes that the Doctrine of Erosion and Accretion applies. There are possible grounds for challenge here however. The Doctrine of Erosion and Accretion states that the change must be gradual and imperceptible. If sea level rises change in line with IPCC expectations, this may well be the case. However it also states that the process must be natural and not, for example, by a man made change such as reclamation. This may raise legal questions

about the extent to which global warming and subsequent sea level rise is man made. While it is quite clear from the literature review that current wisdom suggests this is the case, it may be more difficult to prove beyond doubt given the fact that world climate (certainly in the medium to long term) is known to fluctuate. The laws in this area may need to be reviewed in light of new and more definitive evidence.

The second case study lot at Pindimar is very different. The modelling carried out in this study suggests that the lot will be all but inundated by 2100 and possibly well before due to the affects of erosion and divulation. This lot is located in the Great Lakes Shire and is zoned 1(a) Rural under the Great Lakes Local Environment Plan 1996. The implications of the zoning and potential use of this lot is particularly relevant to this study. The zone aims to restrict development on the basis of the following development consents (Great Lakes Shire Website, 2009)

Zone No 1 (a) (Rural Zone)

1 What are the objectives of the zone?

The objective of the zone is to restrict development to those uses which are unlikely to:

(a) prejudice in a significant manner the agricultural production potential of land within the zone, and

(b) generate significant additional traffic, or create or increase a condition of ribbon development on any road, relative to the capacity and safety of the road, and

(c) have an adverse impact on the area's water resources, and

(d) create unreasonable or uneconomic demands for the provision or extension of public amenities or services.

2 What is permitted without development consent?

Development for the purpose of:

agriculture; bushfire hazard reduction.

3 What is permitted only with development consent?

Any development not included in Item 2 or 4.

4 What is prohibited?

Development for the purpose of:

boarding houses; bulky goods premises; commercial premises; hotels; medical centres; multiple dwellings; off-site promotional signs;

residential flat buildings; shops (other than convenience stores); vehicle body repair workshops; vehicle repair stations; warehouses.

While the area remains relatively undeveloped in terms of road infrastructure (although the road to the block is not formed it is a gazetted road), there is other evidence of development such as easements on the DP for services onto surrounding lots and existing overhead electricity. There is also a development consent for an abalone farm close to the case study lot which would require significant infrastructure including buildings. There are existing dwellings within 500 metres of the case study lot. From the Great Lakes Council website and the LEP quoted above, it appears that the construction of a dwelling or other non-precluded development would be possible with consent. Given the data gathered in this project and the models developed, it would appear that Great Lakes Council could place itself at considerable risk if such developments were approved on the basis of their duty of care. In particular, the salient factors identified by the High Court of Australia impose some level of responsibility on statutory authorities. The notion of knowledge – that is, did the authority know, or ought to have known of an existing risk of harm? No doubt there will be considerable debate in legal circles as to when it was a reasonable point in history to know about sea level rise. It should be noted that even the NSW Planning Minister has been overruled by the court in the case Walker v Minister for Planning on the basis that certain developments are prone to the effects of sea level changes.

5.2 Broader Implications

If one accepts the IPCC models for sea level rises over the next century, vast areas of the globe will be affected. The case study lots clearly illustrate the vulnerability of land in proximity to current sea level. However sea level rise is only part of a broader set of effects of climate change. Lake Macquarie Council in its "Sea Level Rise Policy Factsheet" identifies five general areas of impact from climate change. These include:

- Coastal and foreshore erosion, retreat and storm. This includes the risk of increased flooding, beach realignment, intrusion of saline water and increased storm surges and long term inundation.

- Ecological Impacts including changes to flora and fauna, and the distribution of wetlands and mangroves.
- Damage to infrastructure such as public and private housing, roads bridges and public utilities.
- Public Health issues and community well-being.
- Economic costs such as increased insurance premiums, mitigation measures, depreciation of land and assets and loss of tourism and recreational areas.

Lake Macquarie Council has identified these issues and possible responses. These include zoning restrictions, planned retreat, building setbacks, raised floor levels, dune protection and other protective works. While this at least identifies some of the associated issues with climate change a more coordinated national approach would be a better course of action. There are philosophical issues associated with the delegation of power throughout our community. However it must be recognised that local governments in many regions will not have the resources to make judgements about the extent and impact of climate change and consequent sea level rises. A national policy framework would offer local authorities the duty of care that may be a major issue in the future. The IPCC will continue to up-date its predictions and government at all levels will need to be adaptive. The most recent modelling by the IPCC attempts to provide worst case scenarios coupled with percentage chances of its occurrence. These models may provide the best basis for a national approach. The other advantage of a national approach using a higher than moderate sea level predictions is that a foreshore plan ensuring public access in the future could be accommodated. It is important to note that as with many other local government authorities, that the recognition of the potential impact of climate change has not yet translated into specific policy. Indeed this is the case with Lake Macquarie Council. Great Lakes Council appears to be further behind again.

It is important to review the duty of care and some of the salient factors identified by the High Court of Australia (2003) in relation to the liability of local authorities in these matters. In particular, do the powers exist for councils to account for climate change within their own policy framework? The Draft Sea Level Rise Policy Statement 2009 put out by the DECC of NSW provides information and support for

local councils in their decision making about climate change. This document adopts the IPCC model, but suggests that refinement of these figures over time should be anticipated. They recommend and 'adaptive, risk based approach.' The NSW Government has adopted a sea level rise planning benchmark that is designed to provide guidance on sea level rise impacts. It is designed to operate within current decision making frameworks including the Environmental Planning and Assessment Act 1979. However there is no regulatory or statutory requirement to comply. Local governments are currently guided by a range of policies and legislation to protect life and property from coastal hazards and flooding. The NSW Coastal Policy 1997 refers specifically to the possible effects of climate change. This policy applies the principles of ecologically sustainable development. The Local Government Act 1993 exempts councils from liability in relation to advice, action and omissions in relation to natural hazards in the coastal zone provided their decisions were taken in good faith. Good faith implies that the council has acted in accordance with guidelines such as the Coastline Management Manual (1990).

There is clearly scope within the policy frameworks within NSW for local government to manage sea level rise through their own planning instruments. It would appear that local governments that are slow to respond and allow inappropriate developments could not claim that powers did not exist to allow them to respond. In relation to the case study blocks, it would be unwise on the basis of current knowledge for the Great Lakes Council to approve developments on the Pindimar parcel that might be vulnerable to sea level rise and other climate change consequences.

5.3 The Doctrine of Erosion and Accretion – Will it Suffice?

The selected lots illustrate the potentiality of sea level rises to affect coastal lands in different ways. The Brightwaters parcel, while affected, should remain viable in its current form with possible adaptations, such as building set backs and elevated floor levels. The issue of public access to waterfront land may be an issue on land similar in topography and elevation to this land parcel. Land such as this parcel, subject to

'gradual and imperceptible' change over time, could be dealt with under the current Doctrine of Erosion and Accretion, particularly if planning authorities make adaptive changes to regulations over time. Essentially the level of land loss will not fundamentally hinder the landholders capacity to make use of the land parcel. This is illustrated in the percentage loss of land for this parcel shown in Table 6.

The application of the Doctrine of Erosion and Accretion, if applied in its current form to the Pindimar land parcel, would result in a virtual total loss to the landholder. Applying the 2050 and 2100 sea levels changes nationally, there may be tens of thousands of land parcels and/or properties at risk of substantial or total inundation. It is vital that planning authorities initially at least, identify at risk areas, to warn planning authorities of the potential over the next century. Granting of development applications (without forewarning at least) in light of this information would place those authorities in breach of their duty of care. A national approach to this issue would potentially alleviate many legal and social problems in the future. However it does not offer protection to the owners of land parcels and property prior to the current time. The interpretation of the Doctrine of Erosion and Accretion in relation to these land parcels and properties, that is, the notion of man-made change, may be the only means of challenge for landholders. It raises the question as to whether the government (via the taxpayer) should foot the bill for loss of land and property, should the sea level changes unfold as currently predicted.

5.4 Project Contribution to Sustainability

The implications of this study should heighten awareness of the potential impact of global warming and consequent sea level change. Although it was clearly stated that the project would not try to determine the causes of global warming, other than to summarise general scientific opinion, the results of the study highlight the consequences of sea level change, albeit on the scale of the case study. The broader implications for sustainability in terms of the capacity of the human race to not only manage the change, but to positively reverse the trend can be drawn from a broader understanding of climate change and the role of human activity as the cause. The following matrix is based on the appendix in the Research Project Study Guide (2009)

and addresses the relevant sustainability issues. It is derived from a document put out by the Institution of Engineers, Australia, entitled *Towards Sustainable Engineering Practice: Engineering Frameworks for Sustainability*, Canberra, Australia (1997). The matrix is included as Appendix R and shows how the project takes account of the sustainability criteria for engineering work. It is important in a project of this nature, which is largely focused on environmental issues and how our society might respond, to include this appraisal.

Chapter 6
Conclusion & Recommendations

By its nature, science is evidence based. This implies that knowledge changes as new evidence comes to light. The current evidence suggests that man-made climate change will have a significant impact on global climate including a rise in sea level. While there is a range of predictions from experts in the field of climate science, ultimately a reasonable position has to be taken that reflects a consensus of expert opinion. The IPCC/CSIRO position used in this study is generally accepted as this benchmark. A flexible and adaptive approach, as suggested by the NSWDECC, will be required in the years ahead as new information comes to light. However it is reasonable to suggest that the upper level predictions in the IPCC models are tending to be a more accurate reflection of reality.

This scenario leaves government and planners little option other than to move ahead with policies that account for adaptations to changing climate and sea level. From the findings of this study come the following recommendations:

- Australia wide adoption of the upper IPCC predictions for sea level change as a basis for federal, state and local government policy and planning.
- Extensive coastal vulnerability modelling based on projected sea level rise using the IPCC projections and the CSIRO regional adjustments.
- A national policy framework for local government to ensure that duty of care is clearly established. This should include a national, evidence based position on sea level rise to promote a coordinated approach to planning and development.
- A review of the Doctrine of Erosion and Accretion and its application to the circumstances of man made climate change, to ensure that public access to foreshores is maintained and whether current at risk landholders will receive just treatment.
- A review of vulnerable coastal regions and a national response to the anticipated change in sea level and associated destructive forces.

In the words of UK Science Advisor, Sir David King:

"*The maps of the world will have to be redrawn.*"

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Appendix A

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

For: Alex Lascelles

Topic: Investigation into potential impacts caused by a rise in high water mark

Supervisor: Shane Simmons
Tony Proust, RPS HSO

Project Aim: This project seeks to investigate the potential impact of a rise in high on land ownership and local government planning schemes in Newcastle and Lake Macquarie city council.

Programme: (Issue A, 20 February 2009)

1. Research the science of global warming and the predicted potential impact.
2. Critically evaluate current models used by Newcastle and Lake Macquarie Council for anticipating sea level rises.
3. Evaluate legal aspects of boundary change as a result of changes in sea level and planning responses by the local governments.
4. Design and implement a model demonstrating impacts of rising sea levels in susceptible areas in Newcastle and Lake Macquarie.
5. Produce a plan clearly showing changes in high water mark and impacts on boundaries that are defined by high water mark. This plan will show changes in 20, 50 and 100 year periods.
6. Analyse data in terms of land use, planning policy and legal implications to land owners.

AGREED

Alex Lascelles (Student) _____ (Supervisor)

Date 22/3/09 Date 31/4/09

Examiner/Co-examiner: _____ 20/04/09

Appendix B

NSW Department of Commerce | Manly Hydraulics Laboratory

110b King Street
Manly Vale NSW 2093
Tel 02 9949 0200 Fax 02 9948 6185
ABN 54 625 095 406
www.mhl.nsw.gov.au

06 August 2009

Dear Alex,

RE: Mean High Water – Port Stephens, Tomaree

In accordance with the Surveyor General's Directions No. 6, Water as a Boundary Procedures March 2004 Version 5.5, the Mean High Water Mark is defined for the following location and period of record.

- Location: **Port Stephens, Tomaree**
- Period of data analysed: 1988 to June 2009
- The Mean High Water is 0.476*m AHD* +/- 0.05m

These numbers are an average level taken over 20 years of data, in the absence of 20 years of data the entire period of data will be analysed. In accordance with this 20-year cycle and sea level rise MHW levels will be updated each year. This level is current between 01/07/2009 – 30/06/2010.

If you have any further questions regarding this request, or other information held by MHL, please contact Sarah Hesse on 0299490265 or Mr Bronson McPherson on 0299490244 at the Laboratory.

Yours faithfully

Edward Couriel
Principal Engineer
Manly Hydraulics Laboratory

Appendix C

NSW Department of Commerce | Manly Hydraulics Laboratory

110b King Street
Manly Vale NSW 2093
Tel 02 9949 0200 Fax 02 9948 6185
ABN 54 625 095 406
www.mhl.nsw.gov.au

21 August 2009

Dear Alex,

RE: Mean High Water – Morisset, Lake Macquarie

In accordance with the Surveyor General's Directions No. 6, Water as a Boundary Procedures March 2004 Version 5.5, the Mean High Water Mark is defined for the following location and period of record.

- Location: **Morisset, Lake Macquarie**
- Period of data analysed: 1988 to June 2009
- The Mean High Water is 0.106*m AHD* +/- 0.05m

These numbers are an average level taken over 20 years of data, in the absence of 20 years of data the entire period of data will be analysed. In accordance with this 20-year cycle and sea level rise MHW levels will be updated each year. This level is current between 01/07/2009 – 30/06/2010.

If you have any further questions regarding this request, or other information held by MHL, please contact Sarah Hesse on 0299490265 or Mr Bronson McPherson on 0299490244 at the Laboratory.

Yours faithfully

Edward Couriel
Principal Engineer
Manly Hydraulics Laboratory

Appendix D

SCIMS
Mark Report

Department of Lands
Reliable from the ground up

Mark	Date	Time
SS 58502	06-MAR-2007	15:14:32

Station Name

Status

Alias

Location

GROUND LEVEL

Suburb

PINDIMAR

	Latitude	Longitude		Class	Order	Source	Date
GDA94	-32 40 57.41752	152 05 18.36110		C	3	227868	28-MAR-2002
	MGA Easting	**MGA Northing**	**MGA Zone**	**CSF**		**Convergence**	
	414540.179	6383530.270	56	0.999690		-0° 29' 32"	

	Latitude	Longitude		Class	Order	Source	Date
AGD66	-32 41 03.12488	152 05 14.29916		B	U	209767	23-FEB-2000
	AMG Easting	**AMG Northing**	**AMG Zone**	**CSF**		**Convergence**	
	414435.597	6383341.063	56	0.999690		-0° 29' 34"	
	ISG Easting	**ISG Northing**	**ISG Zone**	**CSF**		**Convergence**	
	214406.493	1382110.907	562	1.000030		-0° 29' 34"	

	Height	Class	Order	Source	Date
AHD71	1.54	D	4	209975	24-FEB-2000

Date Placed	Placed By	Monument Type
	NOT AVAILABLE	UNKNOWN

Witness Marks Print Page

Appendix E

SCIMS
Mark Report

Department of Lands
Reliable from the ground up

Mark	Date	Time
PM 23974	22-AUG-2009	08:56:24
Station Name		**Status**
Alias		
Location		**Suburb**
GROUND LEVEL		BRIGHTWATERS

GDA94	**Latitude**	**Longitude**		**Class**	**Order**	**Source**	**Date**
	-33 06 59.55803	151 32 46.52054		B	2	228831	07-APR-2004
	MGA Easting	**MGA Northing**	**MGA Zone**	**CSF**		**Convergence**	
	364370.175	6334852.683	56	0.999824		-0° 47' 39"	

AGD66	**Latitude**	**Longitude**		**Class**	**Order**	**Source**	**Date**
	-33 07 05.25014	151 32 42.41114		B	2	207033	16-MAY-1991
	AMG Easting	**AMG Northing**	**AMG Zone**	**CSF**		**Convergence**	
	364265.608	6334663.181	56	0.999825		-0° 47' 42"	
	ISG Easting	**ISG Northing**	**ISG Zone**	**CSF**		**Convergence**	
	350872.127	1334226.253	561	0.999969		0° 17' 52"	

AHD71	**Height**		**Class**	**Order**	**Source**	**Date**
	15.756		LB	L2	201411	26-JUN-1990

Date Placed	**Placed By**	**Monument Type**
	NOT AVAILABLE	UNKNOWN

Witness Marks Print Page

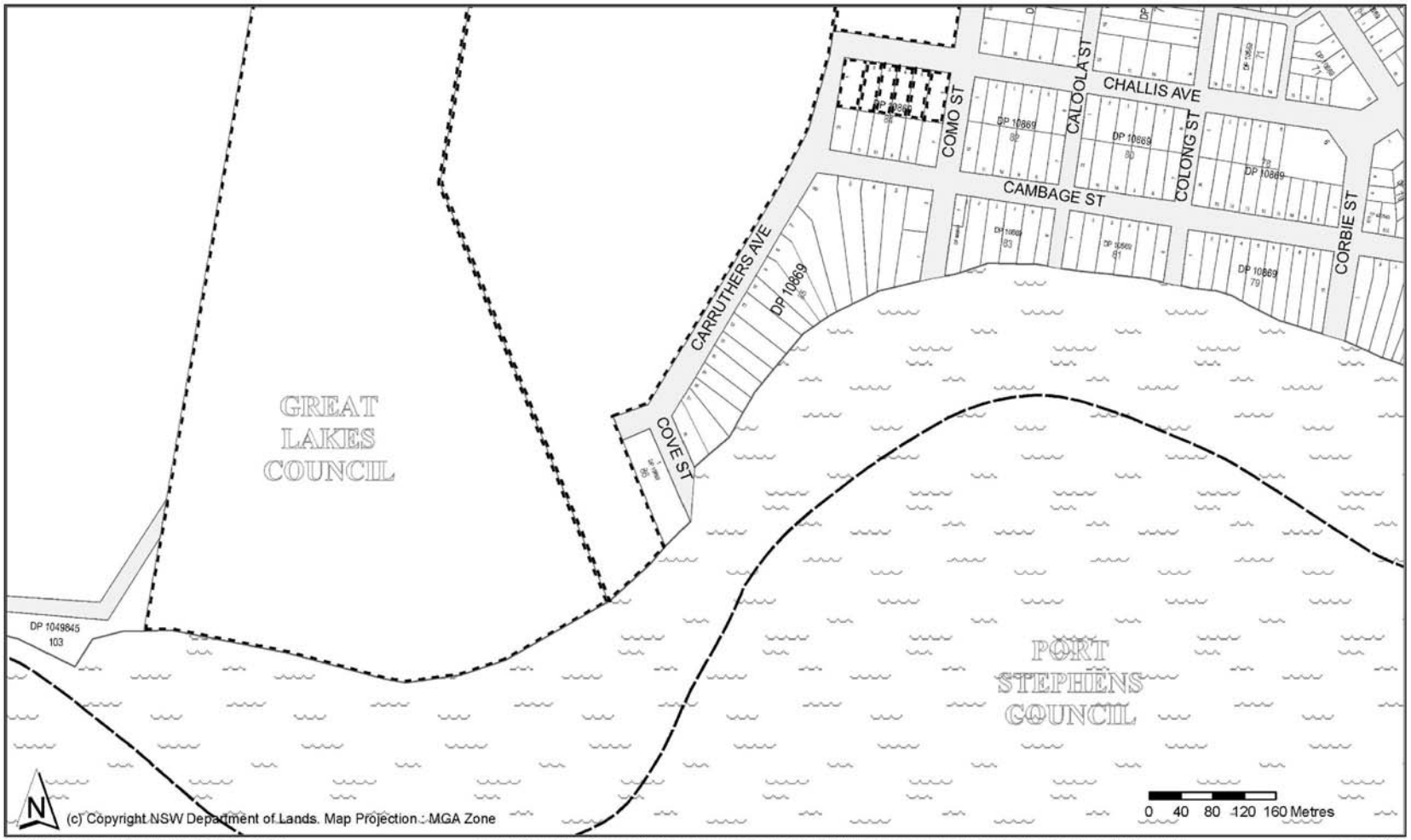
Department of Lands
Reliable from the ground up

Cadastral Records Enquiry Report

Ref : surv:epln-goodej

Requested Parcel : Lot 17 Section 85 DP 10869 **Identified Parcel :** Lot 17 Section 85 DP 10869

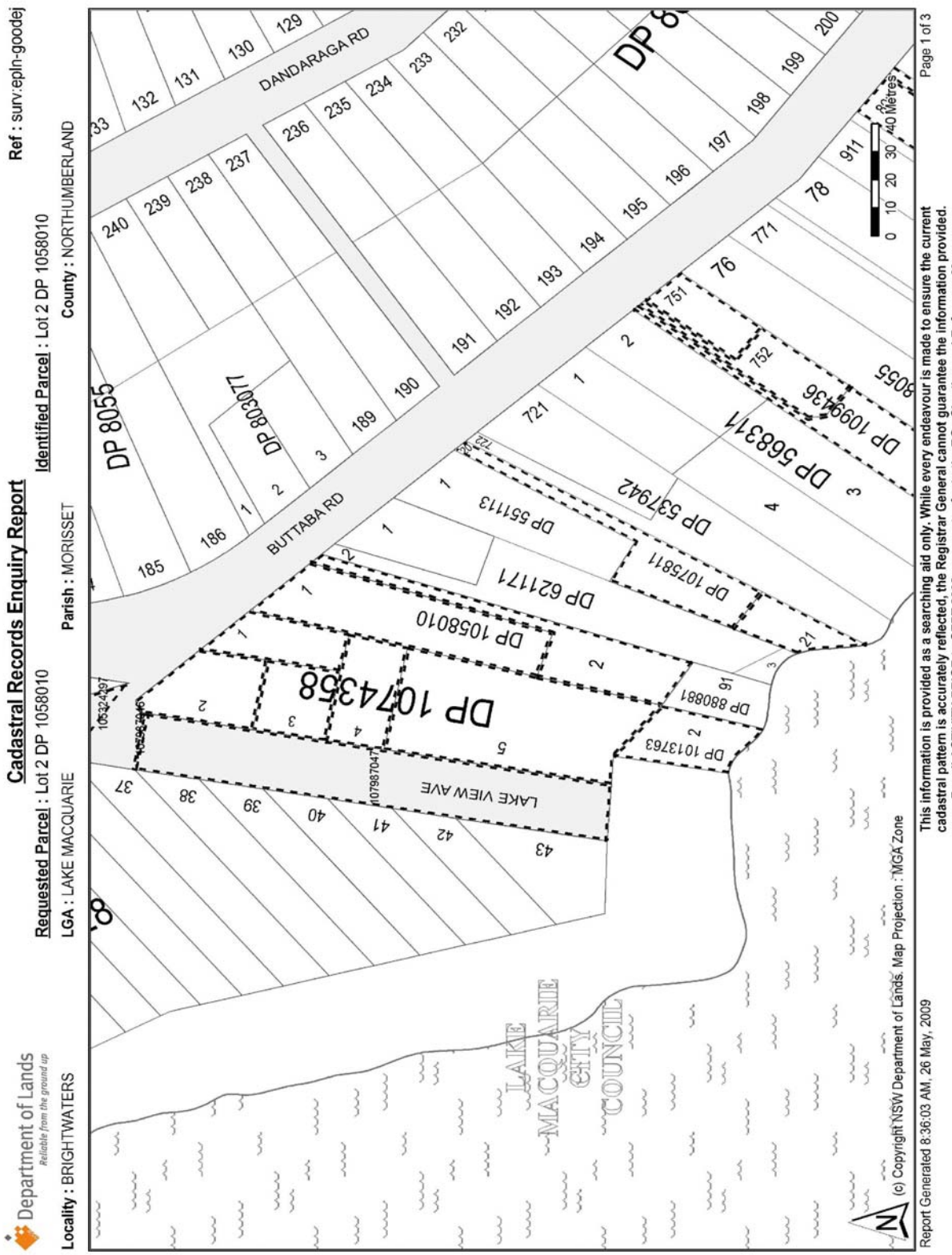
Locality : PINDIMAR **LGA :** GREAT LAKES **Parish :** COWEAMBAH **County :** GLOUCESTER



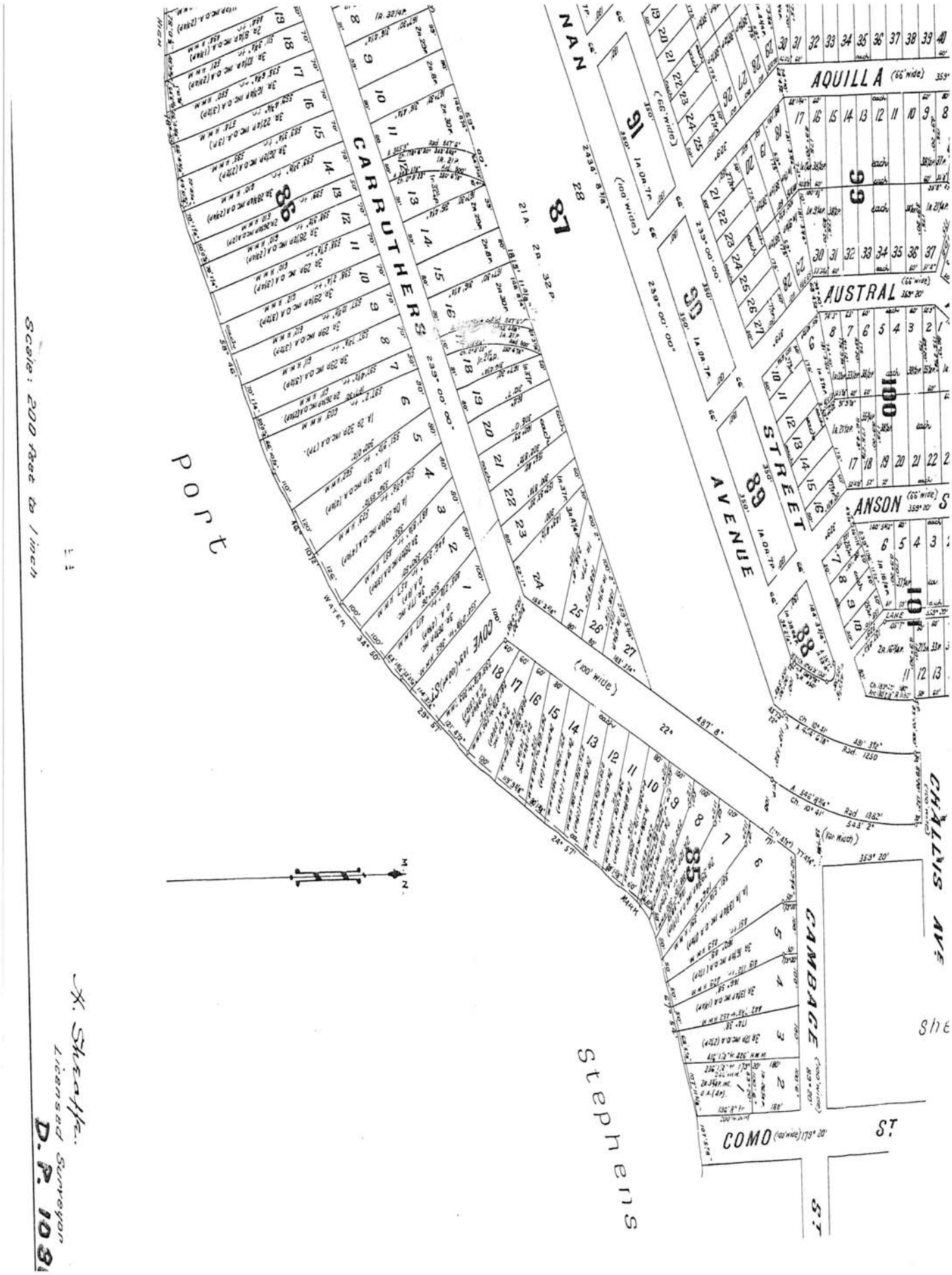
Report Generated 8:33:51 AM, 26 May, 2009

This information is provided as a searching aid only. While every endeavour is made to ensure the current cadastral pattern is accurately reflected, the Registrar General cannot guarantee the information provided. For all ACTIVITY PRIOR to SEPT 2002 you must refer to the RGs Charting and Reference Maps.

Appendix G

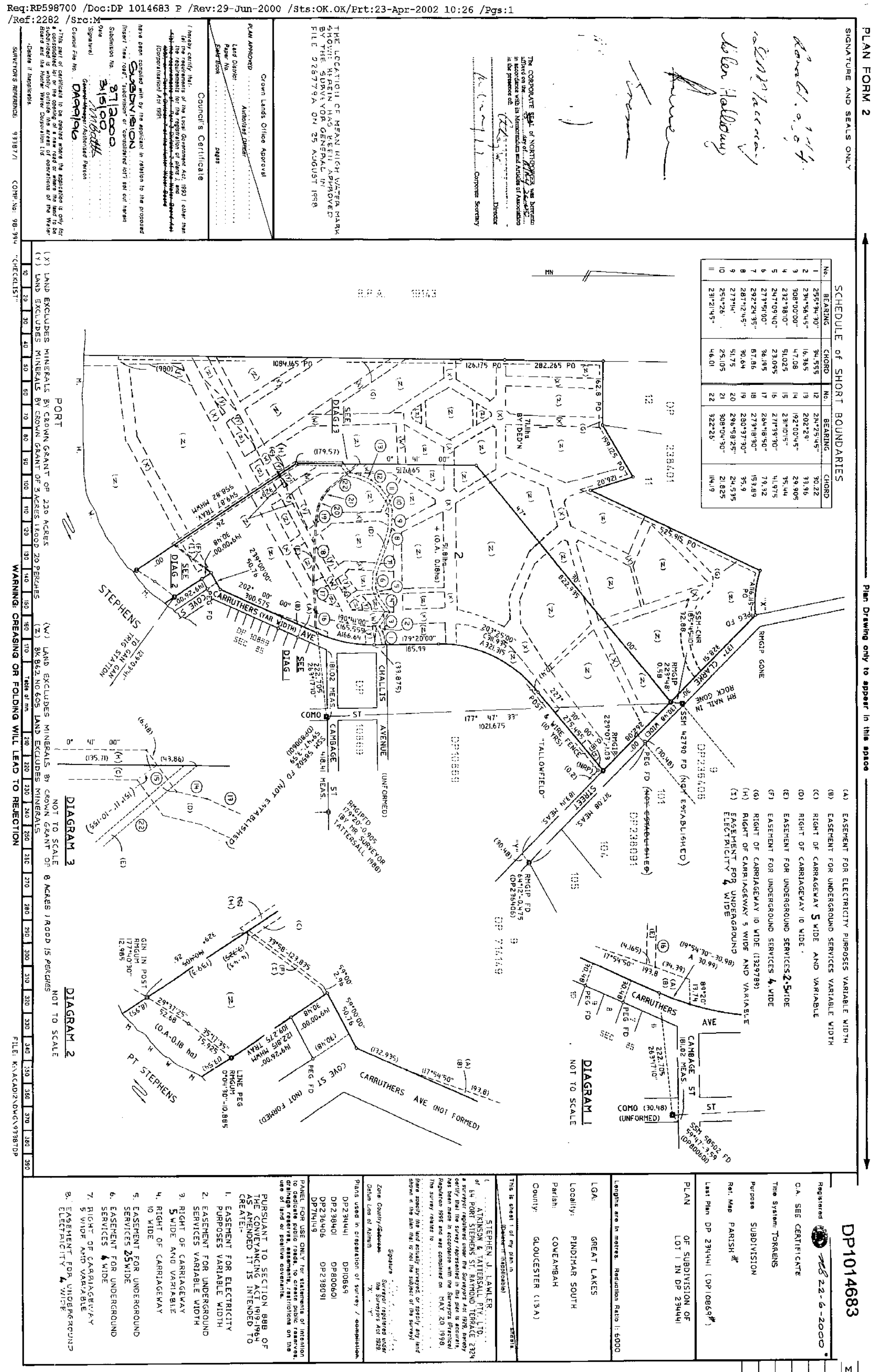

Cadastral Records Enquiry Report
Ref : surv:epln-goodej
Requested Parcel : Lot 2 DP 1058010
Identified Parcel : Lot 2 DP 1058010
LGA : LAKE MACQUARIE
Parish : MORISSET
County : NORTHUMBERLAND
Locality : BRIGHTWATERS
Department of Lands
Reliable from the ground up
DANDARAGA RD
BUTTABA RD
LAKE VIEW AVE
DP 8055
DP 803077
DP 1074358
DP 1058010
DP 621171
DP 551113
DP 537942
DP 1075811
DP 568311
DP 1099436
DP 880881
DP 1013763
LAKE MACQUARIE CITY COUNCIL
0 10 20 30 40 Metres
(c) Copyright NSW Department of Lands. Map Projection : MGA Zone
Report Generated 8:36:03 AM, 26 May, 2009
This information is provided as a searching aid only. While every endeavour is made to ensure the current cadastral pattern is accurately reflected, the Registrar General cannot guarantee the information provided. For all ACTIVITY PRIOR to SEPT 2002 you must refer to the RGs Charting and Reference Maps.
Page 1 of 3

Appendix H

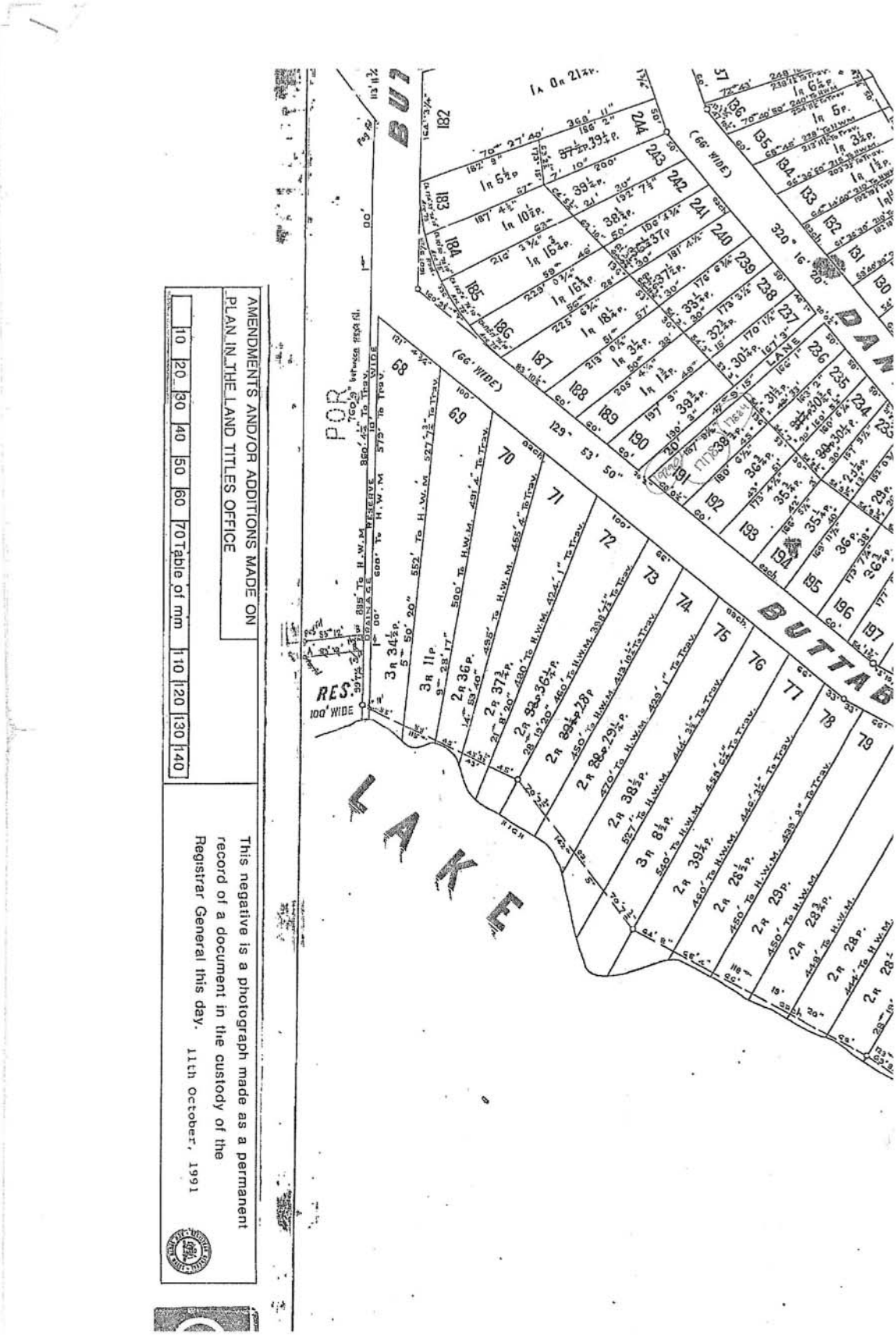

AQUILLA (66' wide)
AUSTRAL (66' wide)
ANSON (66' wide)
CARUTHERS
STREET
AVENUE
COVE
CAMBACE
COMO (66' wide)
CHALTIS AVE
Stephens
Port
Scale: 200 Feet to 1 inch
D.P. 108

Appendix H

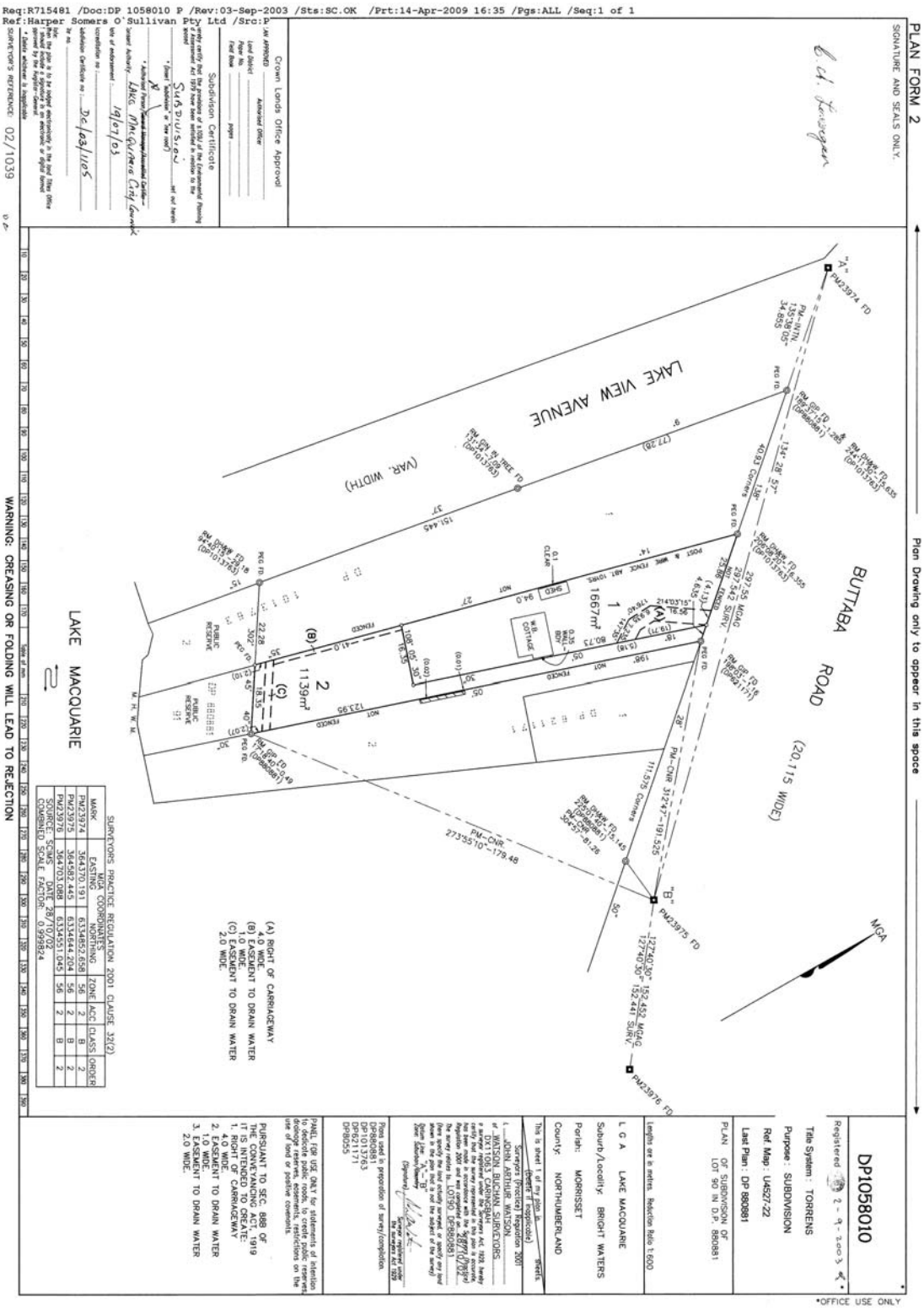
Req:RP598700 /Doc:DP 1014683 P /Rev:29-Jun-2000 /Sts:OK.OK/Prt:23-Apr-2002 10:26 /Pgs:1
/Ref:2282 /Src:M



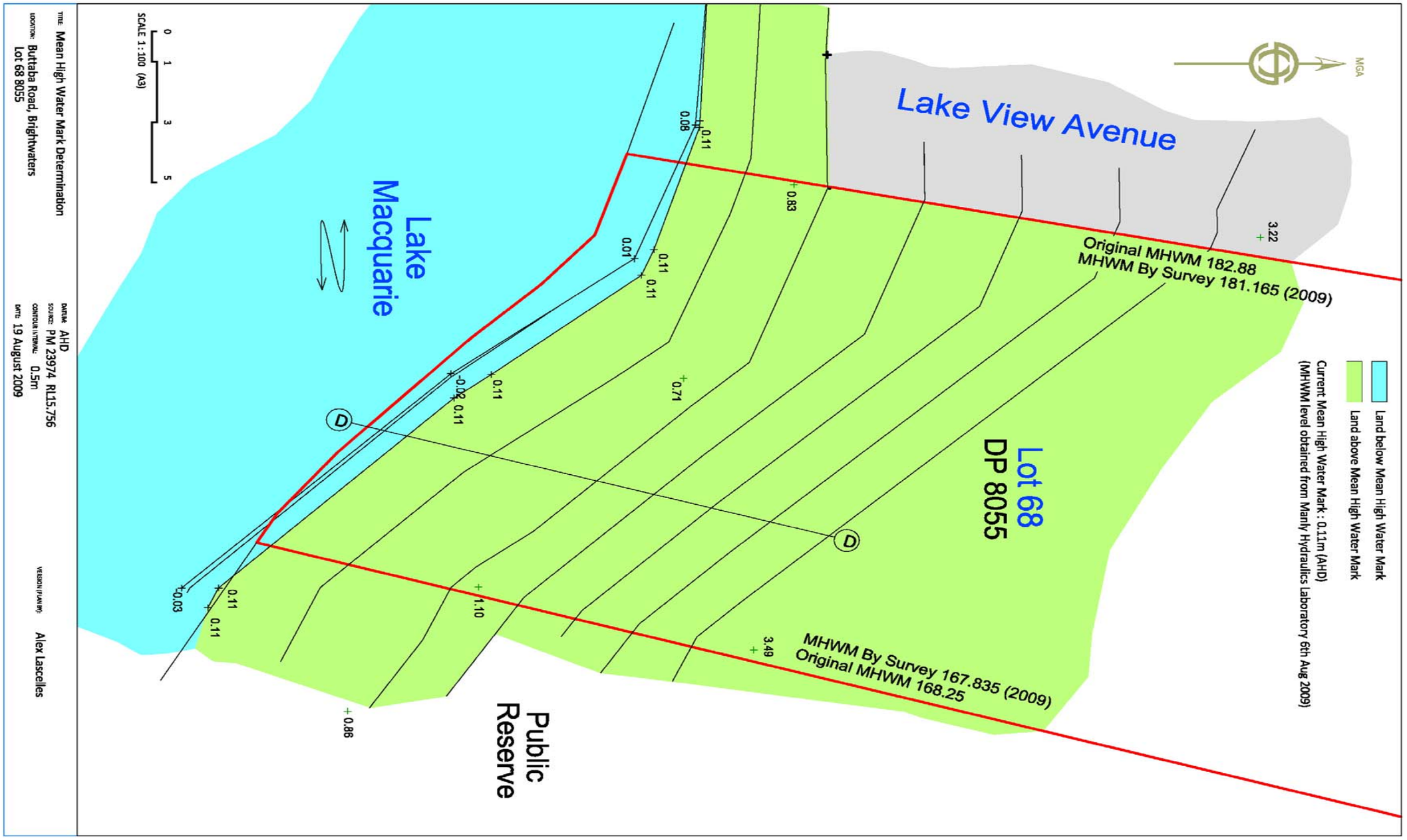
Appendix I


AMENDMENTS AND/OR ADDITIONS MADE ON PLAN IN THE LAND TITLES OFFICE
10 20 30 40 50 60 70 Table of mm 110 120 130 140
This negative is a photograph made as a permanent record of a document in the custody of the Registrar General this day. 11th October, 1991
LAKE
BUTTA
DAN
(66' WIDE)
LANE
RES.
100' WIDE

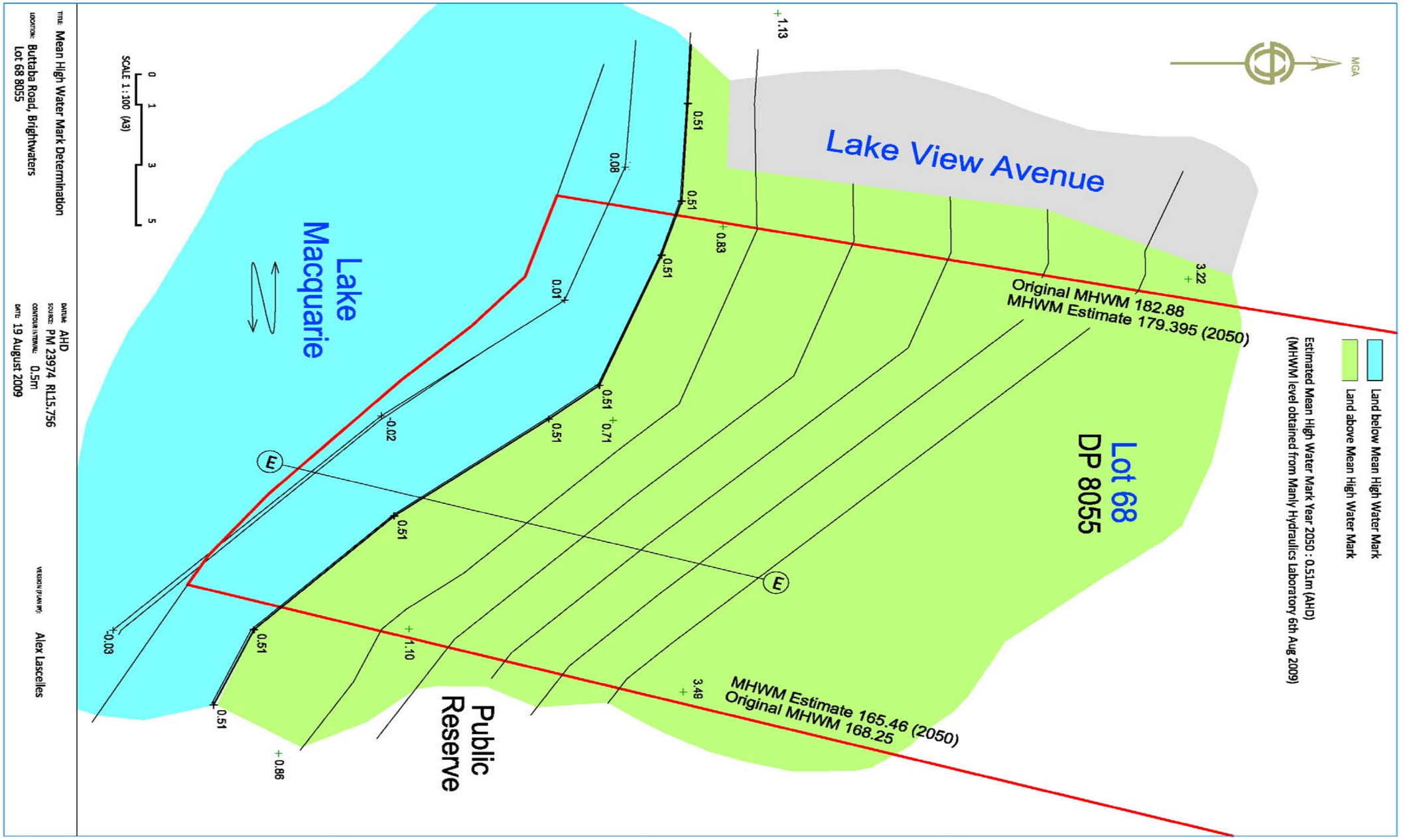
Appendix I


Req:R715481 /Doc:DP 1058010 P /Rev:03-Sep-2003 /Sts:SC.OK /Prt:14-Apr-2009 16:35 /Pgs:ALL /Seq:1 of 1
Ref:Harper Somers O'Sullivan Pty Ltd /Src:P
PLAN FORM 2
SIGNATURE AND SEALS ONLY.
Plan Drawing only to appear in this space
DP1058010
Registered 2-9-2003
Title System: TORRENS
Purpose: SUBDIVISION
Ref Map: U4527-22
Last Plan: DP 880881
PLAN OF SUBDIVISION OF LOT 90 IN D.P. 880881
Lengths are in metres. Reduction Ratio 1:600
L G A LAKE MACQUARIE
Suburb/Locality: BRIGHT WATERS
Parish: MORRISSET
County: NORTHUMBERLAND
Crown Lands Office Approval
Subdivision Certificate
Surveyors Practice Regulation 2001 Clause 33(2)
I, JOHN ARTHUR WATSON of WATSON BUCHAN SURVEYORS
Parcels created in preparation of survey/completion
DP1013763
DP621171
DP8055
PANEL FOR USE ONLY for statements of intention to dedicate public roads, to create public reserves, drainage reserves, easements, restrictions on the use of land or positive covenants.
PURSUANT TO SEC. 88B OF THE CONVEYANCING ACT 1919
IT IS INTENDED TO CREATE:
1. RIGHT OF CARRIAGEWAY 4.0 WIDE.
2. EASEMENT TO DRAIN WATER 10 WIDE.
3. EASEMENT TO DRAIN WATER 2.0 WIDE.
BUTTABA ROAD
(20.115 WIDE)
LAKE VIEW AVENUE
(VAR. WIDTH)
LAKE MACQUARIE
MGA
"A" PM23974 FD
"B" PM23975 FD
PM23976 FD
1667m²
1139m²
(A) RIGHT OF CARRIAGEWAY 4.0 WIDE.
(B) EASEMENT TO DRAIN WATER 10 WIDE.
(C) EASEMENT TO DRAIN WATER 2.0 WIDE.
MARK | EASTING | NORTHING | ZONE | ACC. CLASS | ORDER
PM23974 | 364370.191 | 6334852.658 | 56 | 2 | B | 2
PM23975 | 364582.445 | 6334644.204 | 56 | 2 | B | 2
PM23976 | 364703.088 | 6334551.045 | 56 | 2 | B | 2
SOURCE: SCIMS DATE: 28/10/02
COMBINED SCALE FACTOR: 0.999824
WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION
*OFFICE USE ONLY

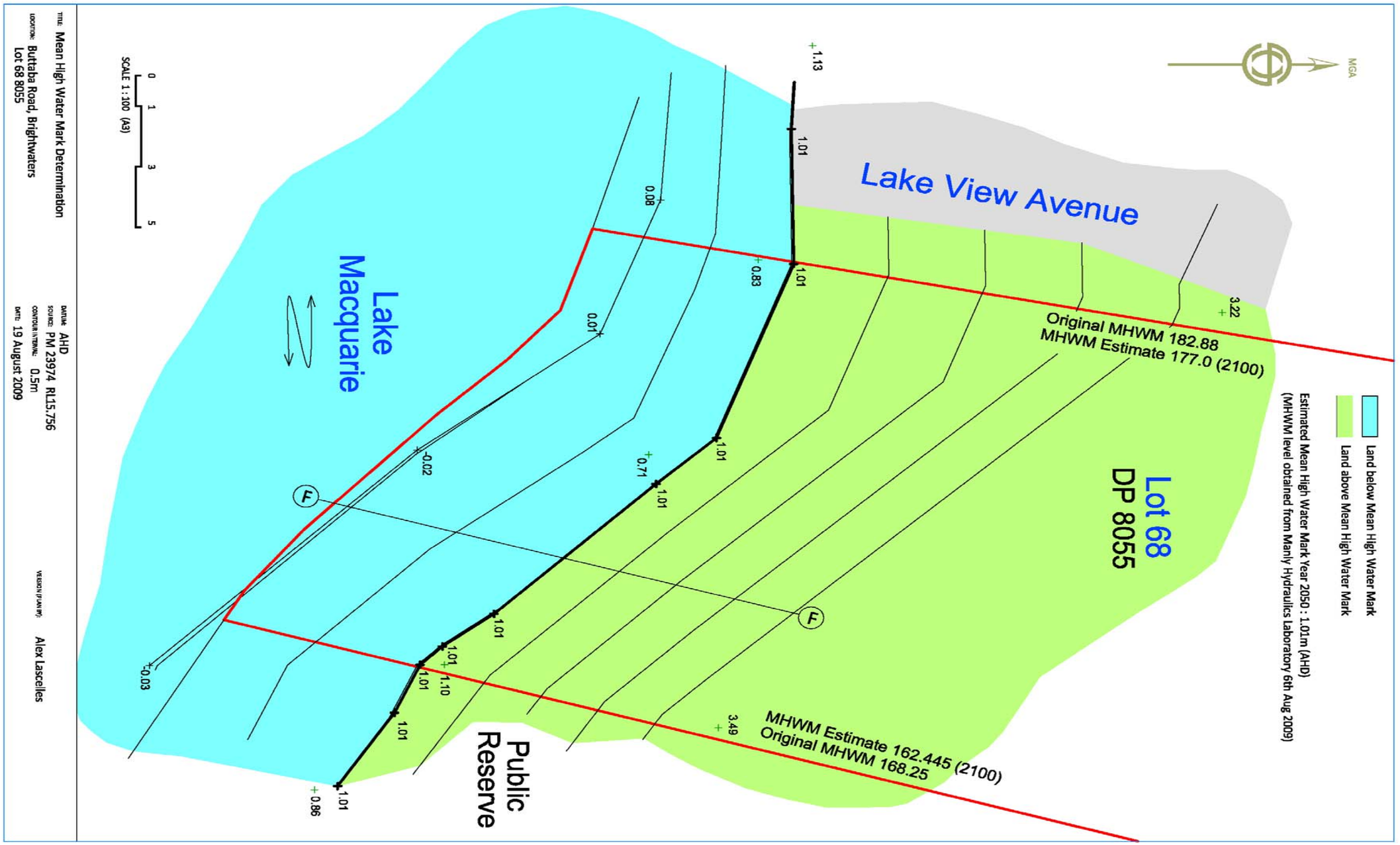
Appendix J


MGA
Lake View Avenue
Original MHWM 182.88
MHWM By Survey 181.165 (2009)
Land below Mean High Water Mark
Land above Mean High Water Mark
Current Mean High Water Mark : 0.11m (AHD)
(MHWM level obtained from Manly Hydraulics Laboratory 6th Aug 2009)
Lake Macquarie
Lot 68
DP 8055
Public Reserve
MHWM By Survey 167.835 (2009)
Original MHWM 168.25
3.22
0.83
0.08
0.11
0.01
0.11
0.11
0.71
0.11
0.02
0.11
1.10
3.49
0.86
0.03
0.11
0.11
D
SCALE 1:100 (A3)
0 1 3 5
TITLE: Mean High Water Mark Determination
LOCATION: Buttaba Road, Brightwaters
Lot 68 8055
DATUM: AHD
SOURCE: PM 23974 RL15.756
CONTOUR INTERVAL: 0.5m
DATE: 19 August 2009
VERSION (PLAN №): Alex Lascelles

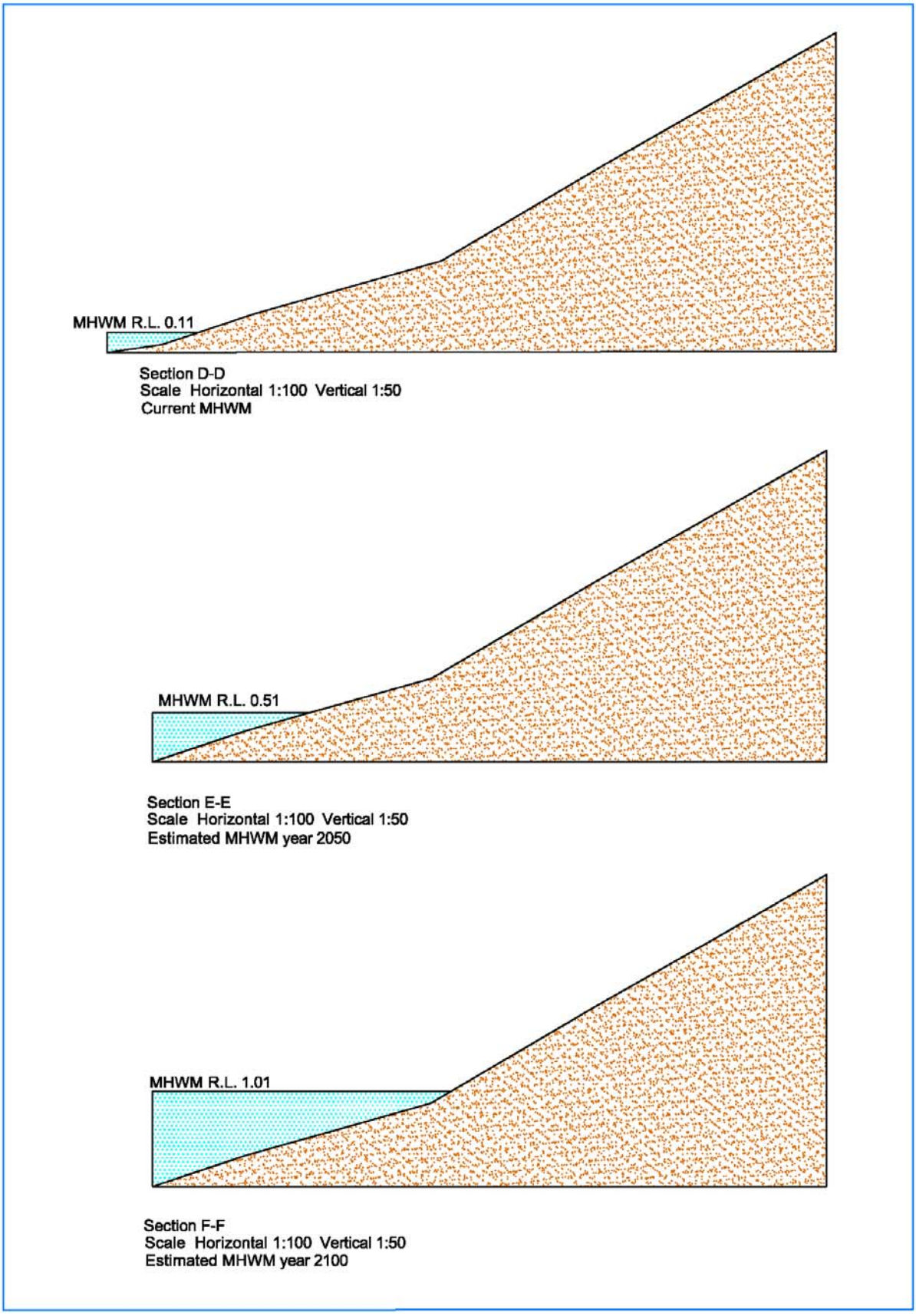
Appendix K


Land below Mean High Water Mark
Land above Mean High Water Mark
Estimated Mean High Water Mark Year 2050 : 0.51m (AHD)
(MHWM level obtained from Manly Hydraulics Laboratory 6th Aug 2009)
MGA
Lake View Avenue
Original MHWM 182.88
MHWM Estimate 179.395 (2050)
Lot 68
DP 8055
Lake
Macquarie
Public
Reserve
MHWM Estimate 165.46 (2050)
Original MHWM 168.25
1.13
0.51
0.08
0.51
0.83
0.51
3.22
0.01
0.51
0.71
0.51
-0.02
E
E
0.51
1.10
3.49
0.51
0.86
0.51
-0.03
SCALE 1:100 (A3)
0 1 3 5
TITLE: Mean High Water Mark Determination
LOCATION: Buttaba Road, Brightwaters
Lot 68 8055
DATUM: AHD
SOURCE: PM 23974 RL15.756
CONTOUR INTERVAL: 0.5m
DATE: 19 August 2009
VERSION (PLAN №): Alex Lascelles

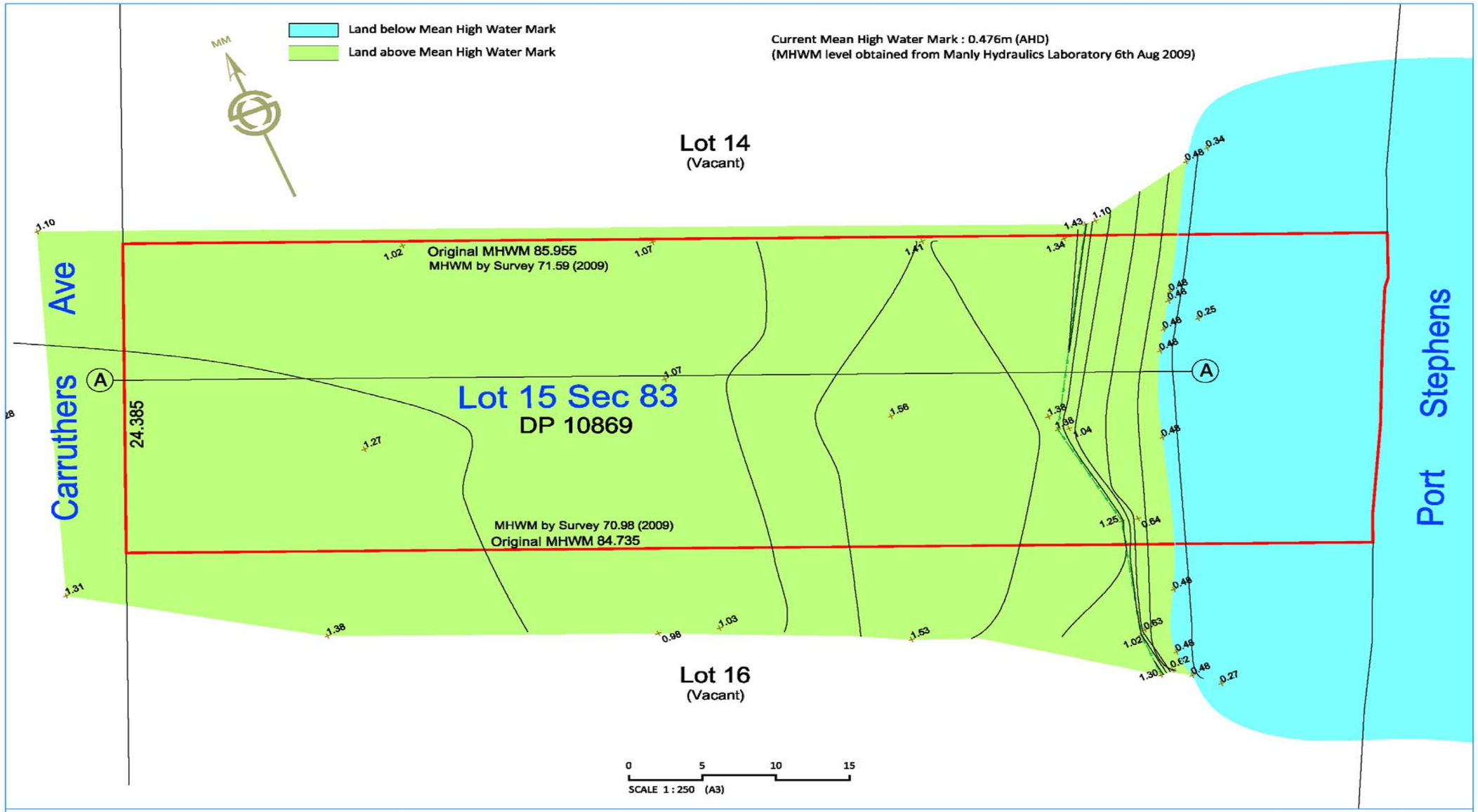
Appendix L


MGA
Lake View Avenue
Lake Macquarie
Lot 68
DP 8055
Public Reserve
Original MHWM 182.88
MHWM Estimate 177.0 (2100)
MHWM Estimate 162.445 (2100)
Original MHWM 168.25
Land below Mean High Water Mark
Land above Mean High Water Mark
Estimated Mean High Water Mark Year 2050 : 1.01m (AHD)
(MHWM level obtained from Manly Hydraulics Laboratory 6th Aug 2009)
SCALE 1 : 100 (A3)
0 1 3 5
TITLE: Mean High Water Mark Determination
LOCATION: Buttaba Road, Brightwaters
Lot 68 8055
DATUM: AHD
SOURCE: PM 23974 RL15.756
CONTOUR INTERVAL: 0.5m
DATE: 19 August 2009
VERSION (PLAN NO): Alex Lascelles

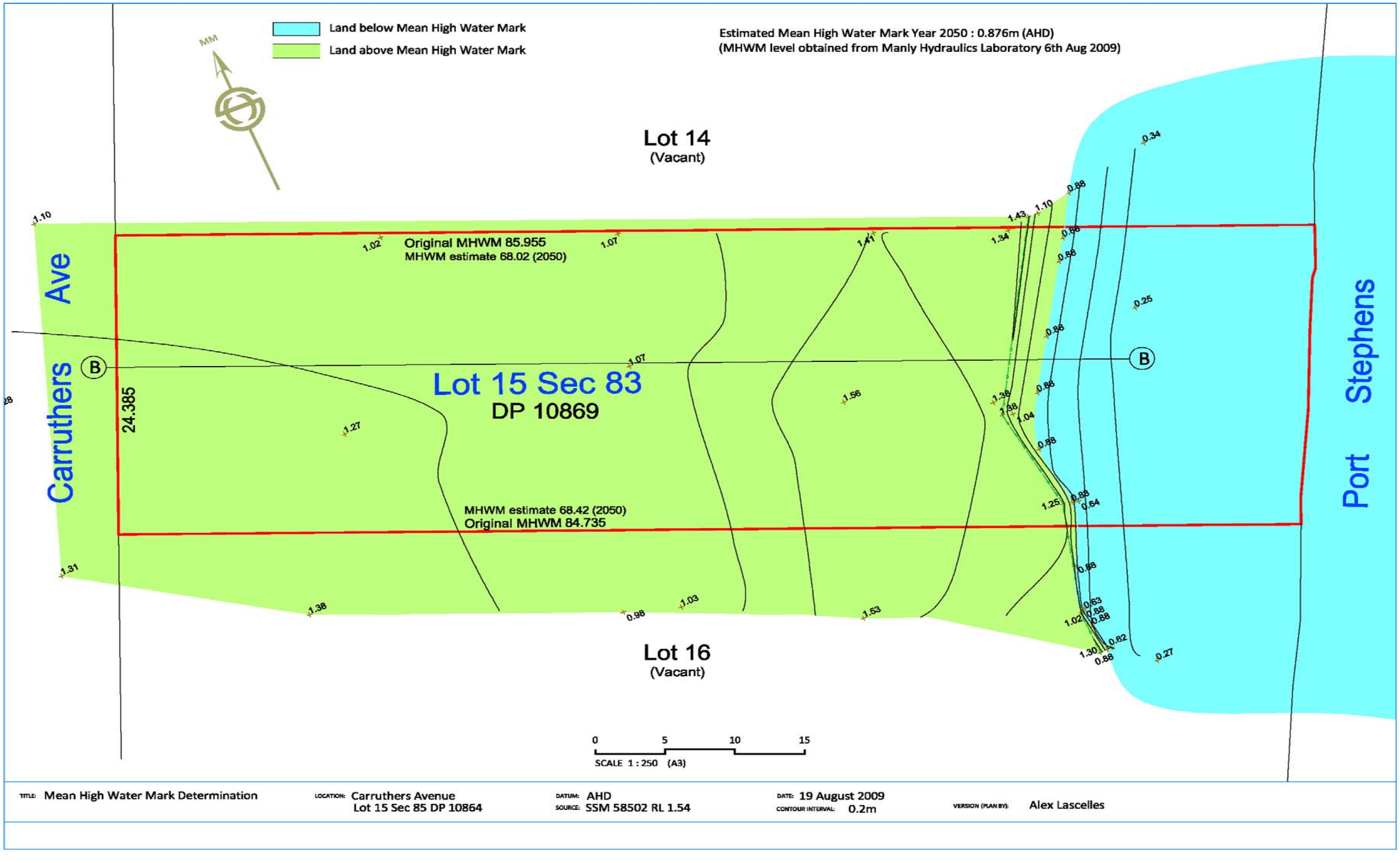
Appendix M


MHWM R.L. 0.11
Section D-D
Scale Horizontal 1:100 Vertical 1:50
Current MHWM
MHWM R.L. 0.51
Section E-E
Scale Horizontal 1:100 Vertical 1:50
Estimated MHWM year 2050
MHWM R.L. 1.01
Section F-F
Scale Horizontal 1:100 Vertical 1:50
Estimated MHWM year 2100

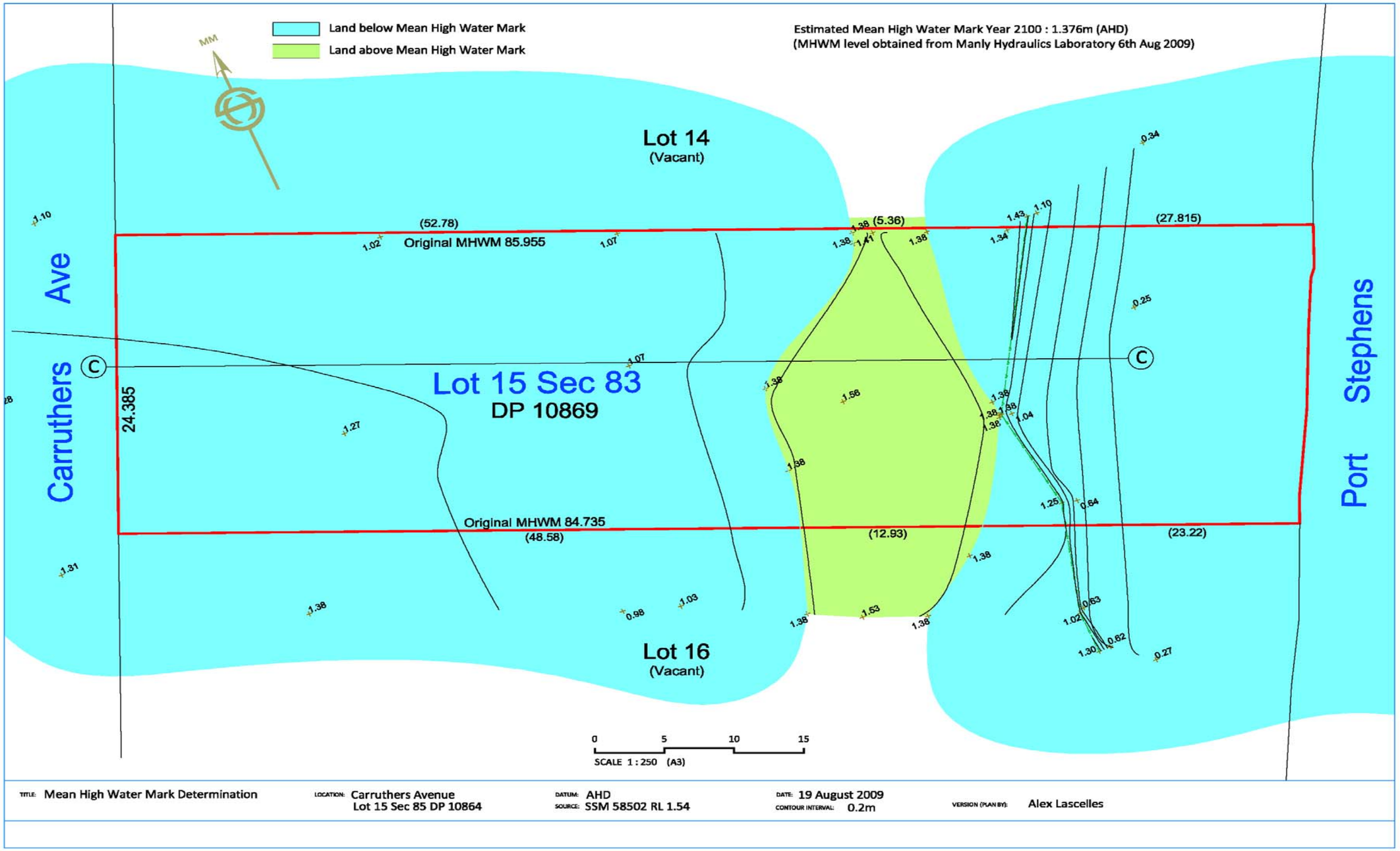
Appendix N


Land below Mean High Water Mark
Land above Mean High Water Mark
MM
Current Mean High Water Mark : 0.476m (AHD)
(MHWM level obtained from Manly Hydraulics Laboratory 6th Aug 2009)
Lot 14
(Vacant)
Original MHWM 85.955
MHWM by Survey 71.59 (2009)
Carruthers Ave
Lot 15 Sec 83
DP 10869
24.385
MHWM by Survey 70.98 (2009)
Original MHWM 84.735
Port Stephens
Lot 16
(Vacant)
0 5 10 15
SCALE 1 : 250 (A3)
TITLE: Mean High Water Mark Determination
LOCATION: Carruthers Avenue
Lot 15 Sec 85 DP 10864
DATUM: AHD
SOURCE: SSM 58502 RL 1.54
DATE: 19 August 2009
CONTOUR INTERVAL: 0.2m
VERSION (PLAN BY): Alex Lascelles

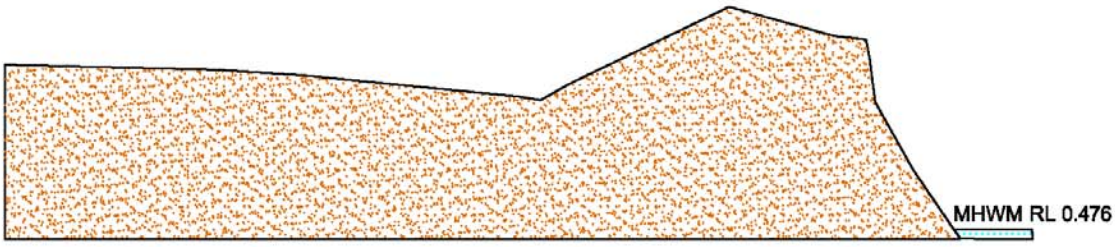
Appendix O


Land below Mean High Water Mark
Land above Mean High Water Mark
Estimated Mean High Water Mark Year 2050 : 0.876m (AHD)
(MHWM level obtained from Manly Hydraulics Laboratory 6th Aug 2009)
MM
Lot 14
(Vacant)
Original MHWM 85.955
MHWM estimate 68.02 (2050)
Lot 15 Sec 83
DP 10869
24.385
MHWM estimate 68.42 (2050)
Original MHWM 84.735
Lot 16
(Vacant)
Carruthers Ave
Port Stephens
B
B
0 5 10 15
SCALE 1 : 250 (A3)
TITLE: Mean High Water Mark Determination
LOCATION: Carruthers Avenue
Lot 15 Sec 85 DP 10864
DATUM: AHD
SOURCE: SSM 58502 RL 1.54
DATE: 19 August 2009
CONTOUR INTERVAL: 0.2m
VERSION (PLAN BY): Alex Lascelles

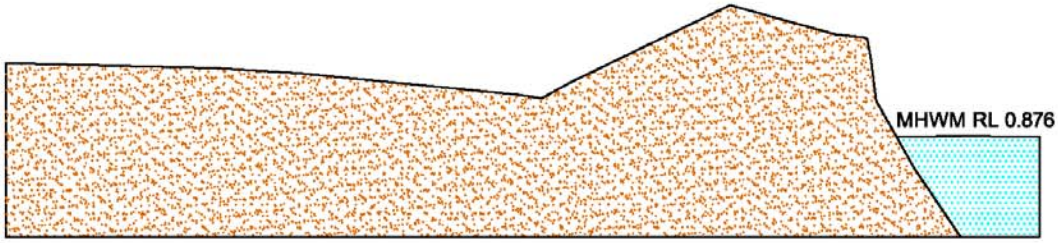
Appendix P


Land below Mean High Water Mark
Land above Mean High Water Mark
Estimated Mean High Water Mark Year 2100 : 1.376m (AHD)
(MHWM level obtained from Manly Hydraulics Laboratory 6th Aug 2009)
MM
Lot 14
(Vacant)
(52.78)
Original MHWM 85.955
(5.36)
(27.815)
Carruthers Ave
Lot 15 Sec 83
DP 10869
24.385
Port Stephens
Original MHWM 84.735
(48.58)
(12.93)
(23.22)
Lot 16
(Vacant)
0 5 10 15
SCALE 1:250 (A3)
TITLE: Mean High Water Mark Determination
LOCATION: Carruthers Avenue
Lot 15 Sec 85 DP 10864
DATUM: AHD
SOURCE: SSM 58502 RL 1.54
DATE: 19 August 2009
CONTOUR INTERVAL: 0.2m
VERSION (PLAN BY): Alex Lascelles

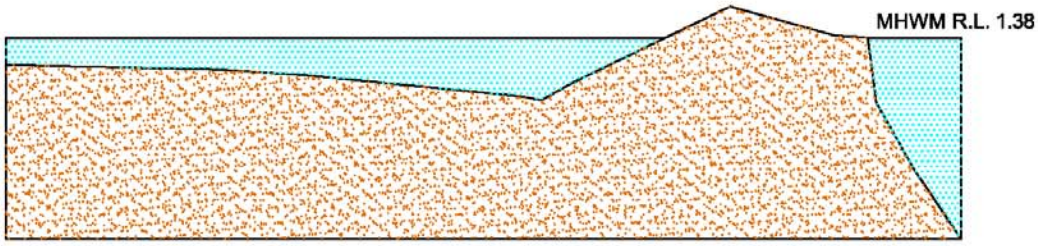
Appendix Q



Cross Section A-A
Scale Horizontal 1:500 Vertical 1:30
Current MHWM



Cross Section B-B
Scale Horizontal 1:500 Vertical 1:30
Estimated MHWM year 2050



Cross Section C-C
Scale Horizontal 1:500 Vertical 1:30
Estimated MHWM year 2100

Appendix R

Statement of Issue	Potential Effect from Project
Sustainability 1 Development today should not undermine the development and environmental needs of future generations.	Build awareness of planning issues into the future for land abutting coastal areas. Identifying at risk areas for level change.
Sustainability 2 Environmental protection shall constitute an integral part of the development process.	Draw attention to the need for a re-evaluation of land-use in proximity to at risk areas. Highlight the need for keeping abreast of sound scientific analysis of current and future changes in climate.
Sustainability 3 Surveying people should take into consideration global environmental impacts of local actions and policies.	Ensure that sound planning information is available with best scientific analysis of future trends used to make local decisions.
Sustainability 4 Scientific uncertainty should not be used to postpone measures to prevent environmental degradation.	Policy decisions between local government, states and territories coordinated to ensure self-interest for short-term gains does not outweigh best scientific opinion. Clearly establish areas of scientific uncertainty in this issue, ie, extent of sea level rise as opposed to factual information that sea levels are rising. Consider scientific evidence and take cautious approach.

Sustainability 5 Environmental issues should be handled with the participation of all concerned citizens.	The issue is one of concern to all citizens and the effects will be directly felt by some, and indirectly by others. Government bodies to take account of local concerns (such as rising sea levels) through to broader implications of climatic change.
Sustainability 6 The community has the right of access to and an understanding of environmental information.	Provision of easy access to climate change information by impartial bodies such as CSIRO. Monitor the reporting of climate change information by non-expert people (often with vested interest or political motivation) and provide up to date materials from reputable institutions for public consideration.
Sustainability 7 The eradication of poverty, the reduction of differences in living standards and the full participation of women, youth and indigenous people are essential to achieve sustainability.	With such a large percentage of the world's population living in close proximity to high water mark (many of whom are from poorer countries) a coordinated world effort will be required to re-locate potentially millions of people.
Sustainability 8 People in developed countries bear a special responsibility to assist in the achievement of sustainability.	See above.

Sustainability 9 Warfare is inherently destructive of sustainability, and, in contrast, peace, development and environmental protection are interdependent and indivisible.	One of the most alarming aspects of climate change in a world with a rapidly increasing population is the possibility of warfare as a result of diminishing resources. International organizations will have to play a key role in coordinating efforts to alleviate the consequences of climate change.