

Entrance realignment and berm profiling of a small coastal lagoon to control dune erosion

D Wiecek¹ and P Gangaiya²

¹ NSW Office of Environment and Heritage, Wollongong, NSW

² Wollongong City Council, NSW

ABSTRACT

Bellambi Lagoon, a small coastal lagoon, 7 km to the north of Wollongong (Figure 1), has a long history of entrance channel migration causing erosion of dunes immediately to the north. The Estuary Management Committee (EMC) for Bellambi Lagoon identified this erosion as the highest ranking issue in their Estuary Management Plan (EMP), completed through the NSW Government Estuary Management Program. The channel migration north to the base of the dunes was causing significant undercutting of the dunes, resulting in the gradual loss of dune vegetation and the potential to impact on regionally significant Aboriginal heritage items. Over the last 20 years, the dunes have receded about 10m where erosion has been most active (DECC, 2008), leaving a steep and unstable erosion scarp several metres in height over a distance of around 250m.

The Office of Environment and Heritage assisted by preparing a preliminary technical study to enable Council and the EMC to understand the processes contributing to dune erosion, and help in identification of potential management options. The study was used to consult with the community and canvass various options on dune erosion and entrance management. The option chosen was to undertake a trial to realign the entrance channel to a southerly position and berm maintenance as required to maintain a southerly entrance position. The trial began in mid June 2010, with council re-profiling the entrance area and cutting a pilot channel to the south. A data collection and monitoring program was then instigated to monitor change in entrance channel position and beach profile over the next 12 months, in order to evaluate whether entrance realignment and berm maintenance is a viable ongoing management approach. This paper discusses results of the trial, the lessons learnt, and how the community has been involved in determining future management of the Bellambi Lagoon entrance.

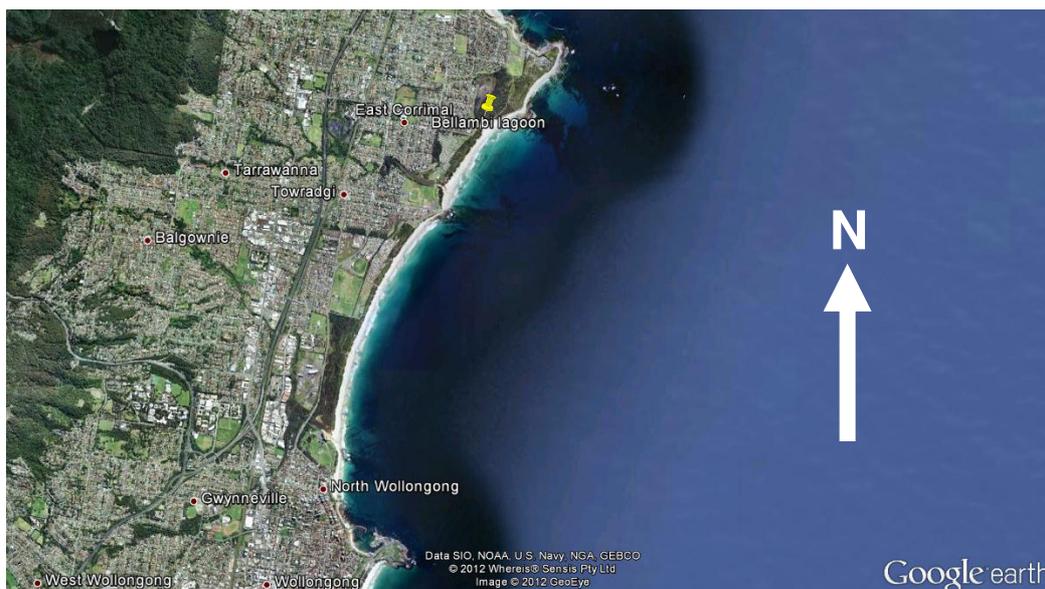


Figure 1: Aerial photo showing the location of Bellambi Lagoon in respect to the Wollongong Coastline (courtesy of Google Earth).

ENTRANCE CHANNEL MIGRATION

Understanding Entrance Channel Migration

Entrance channels of intermittently closed or open lakes and lagoons (ICOLLs) have a natural tendency to migrate up and down the beach in response to discharge of floodwaters and coastal processes. As a result, the location where breakout occurs across the beach berm can differ markedly over time, in the order of hundreds of metres in some instances. This migrating behaviour of the entrance channel maintains an unvegetated sand area landward of the beachface, which is typically low lying and wide in comparison to the rest of the subaerial beach (Figure 2).

The predominant longshore drift direction can determine the direction towards which the entrance channel has a natural tendency to migrate. For example, a natural tendency to migrate towards the north has been documented at places like Dee Why Lagoon on Sydney's Northern Beaches (PWD, 1984) and Lake Currimundi on Queensland's Sunshine Coast (GSCM, 2010), likely as a response to a predominant northerly longshore drift. However, other factors such as location on the beach (e.g. northern or southern end), beach exposure and orientation to offshore wave climate, and sheltering effects from headlands and islands will be equally important. Analysis of historical aerial photography usually provides a good indication of any dominant entrance channel position, as well as highlighting the range of entrance channel locations possible (depending on the temporal coverage).

There will be circumstances, however, where although an entrance channel may have a natural long term tendency to migrate in a specific direction, it will migrate in the opposite direction. This may be due to a large storm or flood discharge event. For example, during major flood events, discharge from the entrance can cause significant erosion to the beach berm and the nearshore area. This in turn can allow larger waves to attack further up the beach face and can cause migration of the entrance channel (NSW Government, 1990).



Figure 2: Oblique aerial photo of Bellambi Lagoon showing the area of unvegetated low lying sand area maintained by the migrating entrance channel (shaded) (taken 21/4/2000, OEH).

Entrance Migration Hazard

As with other coastal hazards, entrance channel migration is usually only an issue where the migration impacts on infrastructure, either directly or indirectly. Direct impacts can occur as a

result of the entrance migrating to a position where discharge of floodwaters scours the adjacent dunes causing erosion that threatens infrastructure. Indirect impacts occur as a result of the entrance channel migration maintaining a low lying sand area that can be more frequently overtopped by storm waves, enabling wave action to erode dunes with greater frequency and intensity, or inundating back beach assets.

Managing Entrance Channel Migration

Where migrating entrance channels have led to impacts on adjacent infrastructure, management intervention has often been necessary. The management response has been to either use hard engineering structures such as seawalls or training walls, or softer techniques involving ongoing beach scraping and channel realignment. Training walls were used with success at the entrances of both Dee Why Lagoon (1980's) and Racecourse Creek at Old Bar (1990's) to limit the northern and southern extents respectively of entrance channel migration. In both cases the migration of the channel created a threat to assets from both flood discharge scour and erosion from storm waves. At Dee Why Lagoon, the northern channel migration had lowered the sand area in front of the surf club, which enabled the 1974 storm waves to directly attack the surf club foundations (PWD, 1984). At Racecourse Creek, both flood discharge scour and storm wave action were a threat to private properties (AWACS, 1991). The training walls used at both these locations are not considered conventional training walls, in that they were designed to be partially buried and project no further seaward than the current berm (Figures 3 and 4).

Softer techniques involving infilling the existing channel and reprofiling the beach and berm to force the entrance channel to a desired location have also been used as a method of managing entrance migration. At Lake Currimundi on Queensland's Sunshine Coast, this technique was used to return the entrance channel to its dominant northerly alignment after the entrance migrated to the south, believed to be caused by a substantial storm (GSCM, 2010). The migration to the south resulted in erosion around council infrastructure, which prompted council to rebuild the southern berm and relocate the channel to the north. As this technique proved successful, a recommendation for limiting the migration of the entrance channel to the northern half of the lake mouth through a berm management program was made in a study into ongoing management of the Lake (GSCM, 2010).



Figure 3: Design of the training wall that was constructed at Racecourse Creek to control entrance migration south (left) (from Worley Parsons, 2010a). Note how the training wall

does not extend beyond the beach berm like a conventional training wall would. Photo of the training wall (right) taken June 2008 (from Worley Parsons, 2010b).



Figure 4: The partial training wall under construction at Dee Why Lagoon entrance (from PWD, 1984). The main photo shows the intent for the training wall to be largely buried.

Advantages and Disadvantages of Management Techniques

There are pros and cons to both hard and soft engineering techniques for controlling entrance channel migration. Hard engineering techniques such as partial training walls, as used at Dee Why Lagoon and Racecourse Creek, would provide a permanent barrier controlling entrance migration beyond the training wall, requiring minimal ongoing maintenance. However, depending on the amount of burial of the training wall, the character of the beach and entrance area would be changed as well as potentially being unsightly. They also have a relatively high cost (in the hundreds of thousands of dollars).

Soft techniques such as entrance channel realignment and berm maintenance have the advantage that no major permanent engineering changes need to be made. They simply require moving the location of the channel and sand over the berm area, which can be done with a backhoe or excavator. It is therefore fairly cheap (\$10,000 to \$20,000) and can be considered a no regrets option. The main disadvantage is that entrance channel and beach berm maintenance would need to be done as an ongoing activity to maintain the desired entrance channel position.

UNDERSTANDING THE DUNE EROSION ALONG BELLAMBI LAGOON ENTRANCE CHANNEL

History of Erosion

The issue of dune erosion along Bellambi Lagoon entrance has been recognised for at least 20 years. In 1990 works to stabilise and revegetate the dune along Bellambi Lagoon entrance channel were undertaken. This involved planting the eroding bank with dune grass

species, fencing the dune, and creating a formalised access path down the dune face to the entrance channel. These measures stabilised the dune erosion scarp initially, but as little as two years later undercutting of the dune had occurred to the point where a new erosion scarp was created and access control fencing was undermined (Figure 5). Since this time, erosion of the dune face has continued. This suggests that the processes causing the erosion were not addressed by the dune stabilisation works and that other management actions would need to be considered in conjunction with these works to significantly reduce dune erosion along the entrance channel.



Figure 5: Photo of the completed dune stabilisation works as they looked two years after completion in October 1992. Dune erosion has already occurred and part of the fencing has been undermined.

Significant exacerbation of the dune erosion occurred after several natural entrance openings along the base of the dunes over the period 2007 to 2008 (Figure 6). This led to local residents and members of the Estuary Management Committee that covers Bellambi Lagoon to increase their lobbying for council to manage the erosion. Concerns ranged from the 3m+ erosion scarp being a public safety risk, to loss of dune vegetation and potential impacts on significant Aboriginal heritage items located in the dunes.



Figure 6: Dune erosion scarp after several natural entrance openings at the base of the dunes causing scour and undercutting of the dunes (photo taken 29/2/2008).

Preliminary Technical Study

To assist Wollongong Council and the Estuary Management Committee understand the processes contributing to dune erosion at Bellambi Lagoon, as well as help in identification of potential management options, a preliminary technical study was completed in 2008 (DECC, 2008). The study involved a number of aspects, specifically:

- Analysis of available historical aerial photography from 1941 to 2007 to determine any variation in the position of the entrance channel and identify any dominant alignment.
- Document the history of dune instability and attempts to stabilise the dune in the past.
- Develop a preliminary understanding of the coastal processes controlling the entrance channel position.
- Quantify rates of erosion for past, current and future behaviour based on photogrammetric analysis.
- Outline the likely causes of the dune erosion based on analysis of coastal and estuarine processes.
- Outline several technically feasible management options that will control the erosion based on managing the likely causes.
- Assess the advantages and disadvantages of the feasible management options.

Entrance Channel Alignment and Cause of the Erosion

The analysis of historical aerial photography showed that the dominant alignment of the entrance channel since the 1940's is at the base of the northern dunes (Attachment 1). There is only one period of time in the mid 1970's where the entrance channel was clearly located to the south. This is first indicated in the 1974 aerial photo and is more clearly depicted in the 1976 aerial photo. By 1979, the channel has migrated back to a northerly position alongside the dune, indicating that coastal processes caused the entrance channel to migrate to its northernmost position in about five years.

The northerly alignment of Bellambi Lagoon entrance channel is due to a combination of currents, waves and wind pushing sand in a predominant south to north fashion, resulting in the channel infilling from the southern side and causing the channel to migrate to the north. The predominant south to north transport of sand is a result of the dominant wave energy coming from the south, which is typical along the NSW coastline. A similar pattern of ICOLL entrance channel migration to the north causing dune erosion occurred at Dee Why Lagoon on Sydney's northern beaches.

As a result of the entrance channel being aligned at the base of the dunes, when the entrance is opened and in particular after heavy rainfall, channel flow scours the base of the dunes leading to undercutting and then dune collapse (Figure 7). This was likely to have been a large factor in exacerbating the erosion immediately prior to the DECC study, with 10 openings documented over the previous 8 months (DECC, 2008). Ocean wave attack during significant storms would also be contributing to further erosion of the dunes, which has been observed on a couple of occasions where storm waves have coincided with spring tides. Unrestricted access along the dunes and trails that lead up and down the current scarp have led to further destabilisation of the dunes, with windborne transport of sand resulting in dune blowouts at several points (Figure 7).



Figure 7: Entrance channel at the base of the northern dunes where channel flow scour has led to bank undercutting and collapse (left), and several access points along the middle of the northern dune scarp where dune blowouts have resulted (right).

Feasible Management Options

Five technically feasible options were outlined in the DECC study and the advantages and disadvantages of these were presented to the community at a consultation workshop organised by Council. The five options were:

1. Do nothing,
2. Regular realignment of the entrance channel to a southerly position and berm maintenance as required,
3. Periodic dredging to maintain an enlarged entrance channel to lower velocity of outgoing flow when the entrance opens and limit channel migration north,
4. Construction of a rock revetment along the currently eroding dune scarp, and
5. Construction of a short northern training wall to force channel flow eastwards.

The option that the community agreed on at the workshop was for the regular realignment of the entrance channel to a southerly position and berm maintenance as required (Figure 8). By manipulating the height of the entrance berm and periodically moving sand from the berm in front of the pilot channel to the north, the entrance was thought to be more likely to continue to breach in the southerly position, as this would be the lowest point in the entrance berm. Doing nothing was not acceptable to the community, but neither did they want a hard engineering solution that would transform the character of the area. It was agreed that the realignment option would initially be done as a trial to see if the channel could be maintained in a southerly position, and/or how long it would last in that position before it migrated back to the north with the potential to cause further erosion.

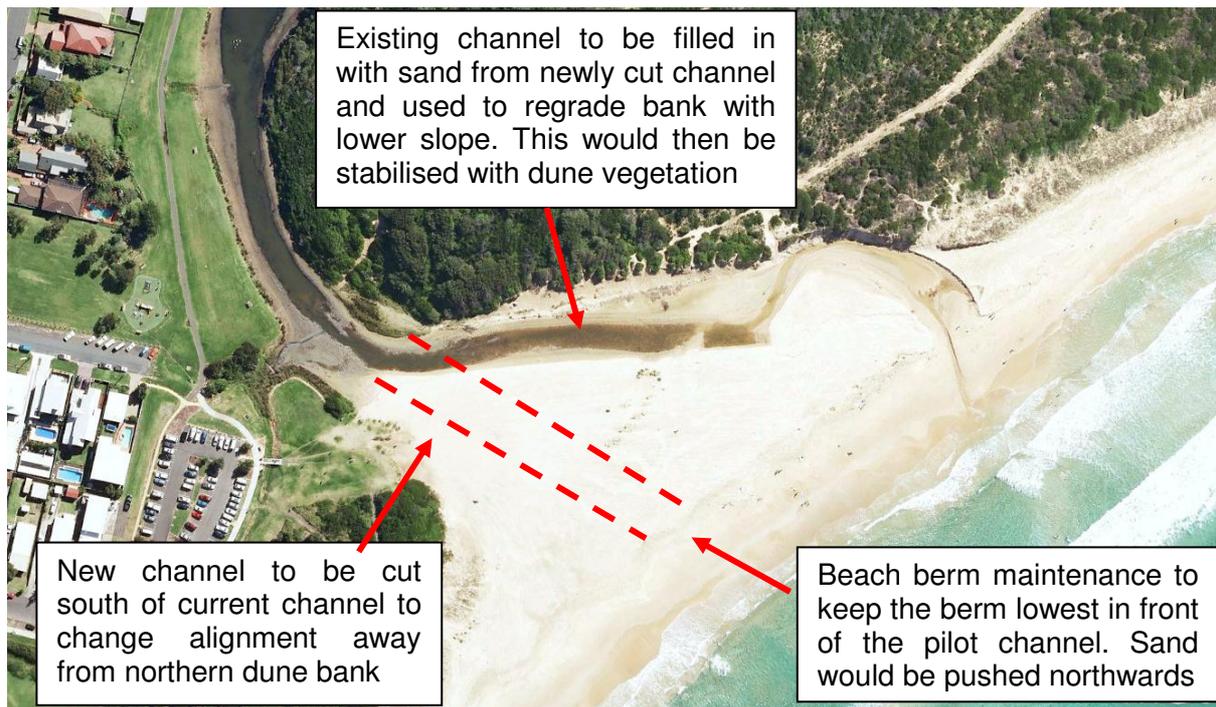


Figure 8: Concept diagram of the management approach taken, involving realignment of the entrance channel to a southerly position and berm maintenance as required.

THE TRIAL

The trial began in mid June 2010, with Council re-profiling the entrance area using a bulldozer by filling in the existing channel and pushing sand up against the eroding dune, then cutting a pilot channel to the south (Figure 9). Estuary Management Program grant funding totalling \$38,000 (matched by Council) was provided to assist with the trial of the entrance realignment works and inform the preparation of an entrance management policy, which is currently being prepared.

A data collection and monitoring program was also instigated to monitor change in entrance channel position and beach profile in response to coastal and estuarine processes. This was to allow an informed evaluation, involving community consultation, to be made of whether entrance realignment and berm maintenance is a viable ongoing management approach and if any modifications need to be made. Data collected included:

- Water levels from a temporary water level recorder in the lagoon maintained by Manly Hydraulics Laboratory,
- Offshore wave height from the OEH Port Kembla waverider buoy operated by Manly Hydraulics Laboratory,
- Beach profiles via regular topographical surveys undertaken by council,
- Photo points via weekly photos taken by council, and
- Rainfall from Bureau of Meteorology for the Bellambi Monitoring Station.



Figure 9: Initial entrance realignment works involving using a bulldozer to infill the northern channel (pictured) and create a pilot channel to the south (taken 10/6/2010).

RESULTS FROM MONITORING THE TRIAL

To determine how effective the trial has been and whether it is likely to be a viable ongoing management strategy, an understanding of how coastal processes have influenced entrance conditions and position over the trial period is required. Key questions that need to be considered include whether the trial occurred over a particularly unseasonal stormy or wet period and how the entrance channel responded to large wave and rainfall events and their combined impacts with elevated ocean conditions (spring tides and storm surge).

Rainfall and Lagoon Water Levels

The amount and intensity of rainfall that falls in the catchment and drains into an ICOLL has a large influence on how often an entrance opens and for how long it stays open (Wiecek and Floyd, 2007; Haines, 2008). In wet years, there will be more entrance openings as the ICOLL (particularly for small ICOLLs) is more quickly filled to the point where it overtops the berm. However, frequent entrance openings (e.g. monthly) can restrict the height that the berm can build to (Hanslow *et al.*, 2000), which can influence the amount of scour that results from the opening and therefore the duration of the opening (Spurway *et al.*, 2000).

In the case of Bellambi Lagoon, more frequent entrance openings could potentially result in less opportunity for the entrance to migrate northwards. This is a result of a decreased length of time for longshore sediment processes to fill in the channel from the south between entrance openings. Conversely, extended periods of low rainfall would likely enable greater infilling of the channel from a predominantly southern direction causing the entrance to open in a more northerly direction. As total yearly rainfall over the trial period was approximately

20% greater than the average yearly total (Figure 10), this could have aided in maintaining the entrance channel in a desired southerly position.

Very intense large rainfall events over short periods can also influence how long an ICOLL entrance stays open, particularly for small ICOLLs where the catchment has a rapid rainfall response time (e.g. large catchments with a small waterbody) (Wiecek and Floyd, 2007). Large intense rainfall events that lead to an entrance opening and large discharges continuing after the opening, will generate maximum entrance scour and result in maximum channel dimensions (width and depth). Maximum scour events will generally result in an entrance staying open longer, but this will also depend greatly on associated wave conditions (e.g. large wave events can quickly lead to entrance closure) (Spurway *et al.*, 2000). Scour events can also result in channel migration north or south as the channel width increases (NSW Government, 1990). This occurred during the trial period after 200mm of rainfall fell over a period of 4 days (19-22 March, 2011). The channel widened to the south as a result of the discharge scour, which enabled storm waves to erode the beach dunes to the south of the entrance (Figure 11). A second intense rainfall event of over 100mm in around 12 hours on the 15th October resulted in significant bed scouring, creating low lagoon water levels and leaving seagrasses exposed. However, minimal entrance migration was noted after this event.

Water level data downloaded from the temporary water level recorder installed in Bellambi Lagoon in October 2010 indicates that Bellambi Lagoon opens frequently in response to rainfall, averaging around once per month (Attachment 2). More than 15 openings occurred from October 2010 to November 2011, ranging in height at opening from approximately 1.3m to 2.1m AHD. Once opened, closure usually occurs quickly ranging from days to around two weeks. All openings over this period were natural unassisted openings. When comparing this to previous water level records from June 2007 to January 2009, a similar range of opening heights and length of time until entrance closure existed (Attachment 2). Openings averaged around once per month over this period as well.

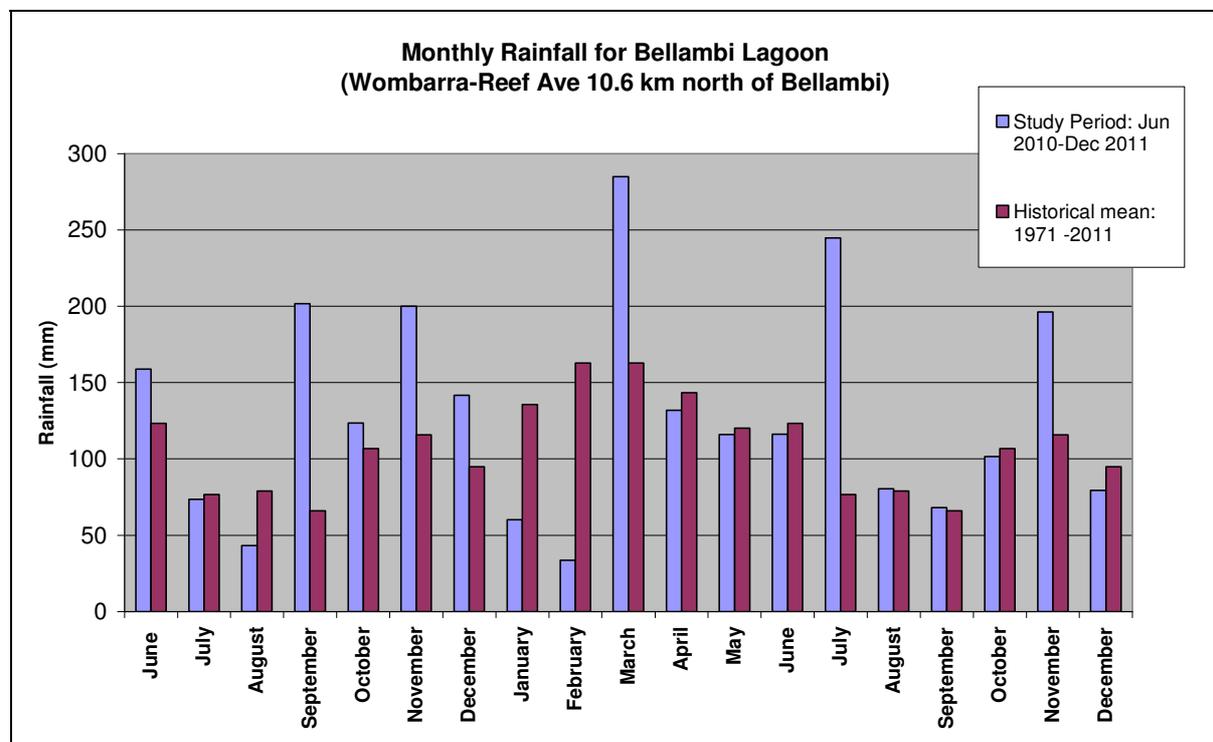


Figure 10: Monthly totals of rainfall of the study period from June 2010 to December 2011 in comparison to the monthly historical mean (BOM, 2011) (*Wombarra was used instead of

the rain gauge at Bellambi because there were a few months during the study period where the Bellambi gauge was off line and did not record rainfall).



Figure 11: Bellambi entrance channel abutted against the southern dunes causing some minor erosion after a large flood discharge event (taken 22/3/2011). The top right photo shows the southern dune erosion that occurred after storm waves in combination with spring tides (taken 3/6/2011).

Wave Climate and Elevated Water Levels

Together with rainfall, wave climate (and resultant longshore drift) and tides determine the entrance dynamics of ICOLLs (Haines, 2008). Large storm waves can lead to berm overtopping and infilling of ICOLL entrance channels with marine sand (Hanslow *et al.*, 2000). For small ICOLLs like Bellambi Lagoon, significant storm waves can result in considerable erosion of and redistribution of sand over the unvegetated berm and entrance channel areas, particularly when coinciding with elevated ocean conditions associated with spring tides and storm surge. Elevated ocean conditions allow storm waves to penetrate further inland, resulting in a greater ability to cause erosion and redistribute sand (NSW Government, 1990).

This ability to infill entrance channels and redistribute sand was evidenced at Bellambi Lagoon on the 13th August 2010, two months after the initial channel realignment and berm profiling. Large seas with H_{sig} over 6m and H_{max} over 11m (Port Kembla Wave Rider Buoy) peaked during the top of a spring tide measuring at 1.87m AHD (from Fort Denison – the predicted tide was 1.6m AHD). This resulted in considerable berm overtopping and erosion, which completely filled in the pilot channel that was cut to the south (Figure 12). While no recognisable pilot channel leading to the back of the berm was evident, a deeper section was still maintained in the southerly direction at the point where the entrance channel bends to the east. This enabled council to make a relatively easy artificial entrance opening in a southerly position a couple of weeks later on the 2nd September to alleviate minor nuisance flooding.



Figure 12: Bellambi Lagoon entrance channel and adjacent area after a substantial storm event (taken 13/8/2011), with overtopping still occurring at the time of photo taken.

The large waves in combination with the elevated ocean conditions also resulted in some very minor erosion on the northern dunes (most eastern section). However, without the works to infill the northern dune channel and beach scraping to move sand in front of the dunes and build up the berm in this area, it is likely that there would have been considerable erosion along this section of the dunes.

Overall, the study period was above average in terms of storminess, with a greater frequency and duration of minor to moderate storms (MHL, 2012). In total, three significant wave events (H_{sig} of 6m+ and H_{max} of 10m+) occurred between June 2010 and November 2011 (Figure 13). While all events led to overtopping of the berm, only the event on the 13/8/10 led to major redistribution of sand over the berm and channel areas. Analysis of wave statistics from the Port Kembla wave rider buoy (incorporating wave direction from the Sydney directional wave rider buoy) for all three events shows that the peak of the storm event on the 13/8/10 had a slightly larger wave period and had a more easterly direction compared to the two other storm events (Figure 14). However, the event on 20/7/11 had a much longer duration. While wave height, wave period, direction and duration can all have an influence on the impact of a storm on the coast, it is believed that the elevated ocean conditions in combination with large waves was the main reason why the storm event on the 13/8/10 had a greater impact on the entrance channel and surrounding unvegetated area. However, as this event was less than two weeks after the first major storm event, the beach and berm were likely still recovering and may have made overtopping easier.

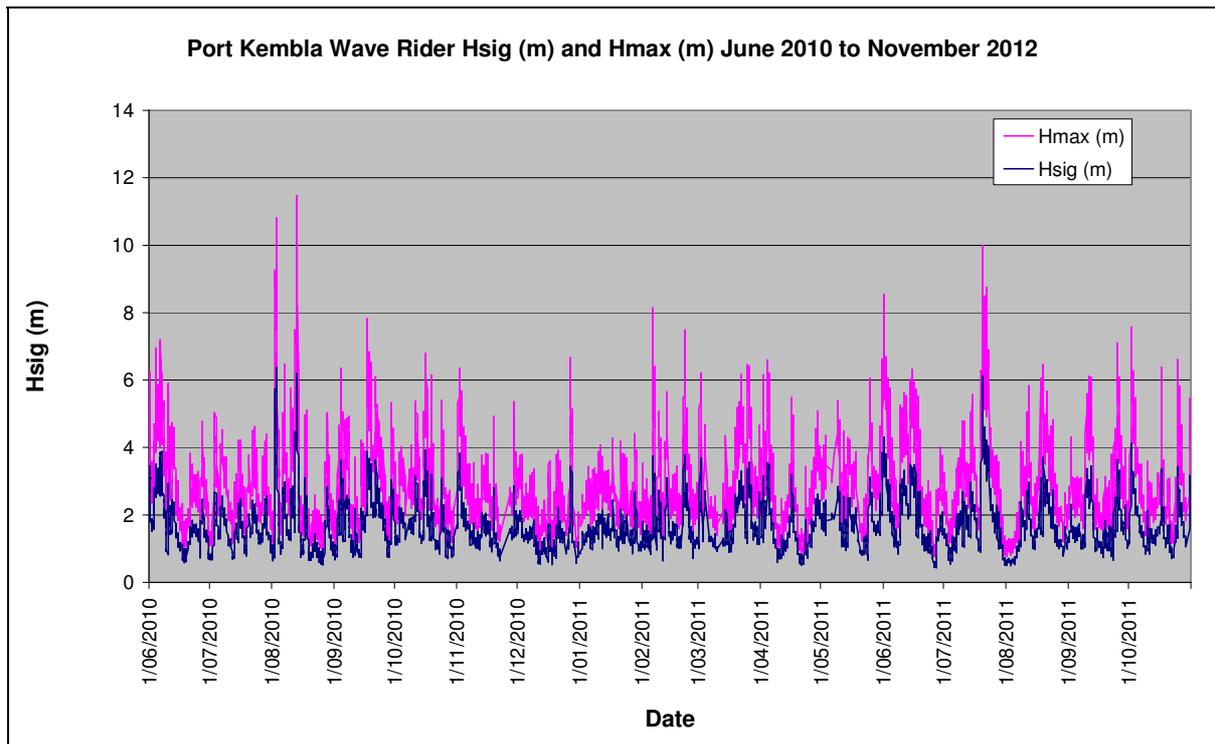


Figure 13: Significant wave height and maximum wave height recorded from the Port Kembla wave rider buoy over the study period. (Note: two periods of roughly 3 months data in total was supplemented from the Sydney wave rider buoy due to the Port Kembla buoy being offline). The NSW Office of Environment and Heritage is acknowledged as owner of the above data and MHL is acknowledged for the collection and provision of the data.

Storm Event 1 2nd to 3d August 2010		Storm Event 2 12th to 14th August 2010		Storm Event 3 19th to 24th July 2011	
Hsig Duration (hours)		Hsig Duration (hours)		Hsig Duration (hours)	
Duration Hsig >3m	25	Duration Hsig >3m	32	Duration Hsig >3m	76
Duration Hsig >4m	17	Duration Hsig >4m	25	Duration Hsig >4m	32
Duration Hsig >5m	12	Duration Hsig >5m	8	Duration Hsig >5m	5
Duration Hsig >6m	3	Duration Hsig >6m	1	Duration Hsig >6m	1
Average Wave Direction (from Sydney directional wave rider)		Average Wave Direction (from Sydney directional wave rider)		Average Wave Direction (from Sydney directional wave rider)	
Wave Direction At Storm Peak (when Hsig > 5m)	S	Wave Direction At Storm Peak (when Hsig > 5m)	SSE	Wave Direction At Storm Peak (when Hsig > 5m)	S
Average Wave Direction Over Event (when Hsig > 3m)	S	Average Wave Direction Over Event (when Hsig > 3m)	SSE	Average Wave Direction Over Event (when Hsig > 3m)	S - SE
Average Wave Period (s)		Average Wave Period (s)		Average Wave Period (s)	
Wave Period Range Over Storm Peak (when Hsig > 4m)	8.8 to 10.7	Wave Period Range Over Storm Peak (when Hsig > 4m)	9.9 to 12.2	Wave Period Range Over Storm Peak (when Hsig > 4m)	8.8 to 12.4
Ocean Water Levels (mAHD)		Ocean Water Levels (mAHD)		Ocean Water Levels (mAHD)	
Predicted Tide at Storm Peak (when Hsig > 6m)	1.1m	Predicted Tide at Storm Peak (when Hsig > 6m)	1.6m	Predicted Tide at Storm Peak (when Hsig > 6m)	0.6m
Actual water level at peak (from Fort Denison)	1.36	Actual water level at peak (from Fort Denison)	1.8	Actual water level at peak (from Fort Denison)	0.74
Predicted Highest Tide Over entire Storm Event	1.41m	Predicted Highest Tide Over entire Storm Event	1.82m	Predicted Highest Tide Over entire Storm Event	1.62m

Figure 14: Summary wave statistics from the Port Kembla wave rider buoy for the three storm events that occurred over the trial period, as well as summary ocean level conditions from NSW tide charts (predicted tides) and Fort Denison (actual water level). Wave direction data is taken from the Sydney directional wave rider buoy.

EVALUATING THE SUCCESS OF THE TRIAL

From the point of view of council and OEH, the trial has been largely successful. The southerly alignment of the entrance channel has been maintained over and beyond the 12 month trial period with minimum intervention required. Hence, from a purely technical point of view, entrance realignment and beach / berm scraping has been shown to be an effective solution to controlling dune erosion as a result of entrance migration to the north. However, other factors also need to be considered in evaluating the trial, including costs and any environmental or social impacts.

Costs

The initial channel realignment and berm profiling in June 2010 cost \$10,000. This covered the costs for two days use of a bulldozer to move the sand around, and three staff (one driver, two staff for crowd control - OH&S requirement). One artificial manual entrance opening was undertaken in September 2010 at a cost of \$2000, which covered use of an excavator for a couple of hours and three staff. Follow up beach profiling / beach scraping works were required once in March 2011 at a cost of \$7000 for use of a bulldozer for two days and three staff. Hence, the costs of the trial equate to an upfront cost of \$10,000, then a further \$9000 for maintenance works over the trial period until present (December 2011).

The monitoring phase of the trial also had costs. These consisted of in-house council costs for staff time to take weekly photos and undertake monthly topographical surveys of the berm and channel area. In kind support was also provided from OEH for installation and maintenance of a temporary water level recorder in Bellambi Lagoon, and provision of water level and wave height data. These costs also need to be taken into account and will need to be incorporated into any ongoing management approach.

Social Impacts

While unanimous support was initially provided for the trial of the entrance realignment works at a community workshop, there have been some issues raised informally by the community over the trial. These include:

- Minor erosion of the southern dunes and temporary loss of beach access along the south of the entrance channel (note: a formal chain and board access over the dunes exists approximately 20m to the south).
- Interfering with natural processes and a preference to let nature take its own course.
- Loss of access to the northern dunes from the beach for recreation (e.g. sliding down the sand).

The southern dune erosion was likely assisted by the beach scraping event that council undertook over the 14-15th March. Council's bulldozer started scraping sand from the incipient dunes immediately south of the unvegetated berm area to build up the berm to the north. This would have resulted in the berm being lowered too far to the south making it easier for the entrance channel to migrate in this direction. Lowering of the berm area in this southern position would then have increased the southern dunes exposure to storm waves, causing further dune erosion.

This situation of the entrance channel migrating to abut the southern dunes could be minimised by adjusting the beach scraping locations to manipulate the berm height to keep

the entrance channel well clear of the northern dunes, but sufficiently north of the southern dunes as well.

Environmental Impacts and Other Considerations

Any environmental impacts as a result of realigning the entrance channel are hard to quantify, as the realigned entrance position is within the natural range of its migration. One observed impact since the realignment was a significant scour event that lowered the bed level leaving seagrasses exposed, leading to die off (likely to be only temporary). The scour was a result of over 100mm rainfall falling over a 12 hour period on the 15th October 2011. However, it is not known whether the entrance has or could scour to the same level if located in the northern position. Unfortunately, bed levels cannot be compared to previous water levels as the temporary water level recorder is installed at too high an elevation to capture full low water level.

Wave overtopping of the berm and backflow into the lagoon was observed on several occasions throughout the trial. The backflow into the lagoon led to a small channel being cut at the base of the northern dune, causing some minor erosion (Figure 15). Water was also perched in some low points on the unvegetated berm area for days after overtopping occurred. This was likely the result of the beach scraping works leaving some low points and some settlement following the scraping works. This situation could likely be resolved by building up these low points in future beach scaping events.



Figure 15: Ponding of water in low areas in front of northern dunes after berm overtopping from storm waves (main photo), with the backflow channel that formed as a result of the overtopping and water flowing back towards the lagoon (bottom photo).

Formal Evaluation of the Trial via a Consultancy

Wollongong Council has appointed a private consultancy (BMT WBM Pty Ltd) to undertake an evaluation of the trialled realignment of the entrance channel, and to formalise ongoing entrance management as an entrance management plan. A major component of the evaluation will be seeking the community's views and preference for future management of Bellambi Lagoon entrance. Based on the outcomes from the formal evaluation, an entrance management plan will be prepared for Bellambi Lagoon that will guide the ongoing management of the entrance. Options being considered will be to continue with periodic entrance channel realignment and berm maintenance, do nothing, or utilise other potential soft techniques. The entrance management plan would also need to identify suitable indicators or triggers that can alert council on the need for intervention strategies such as beach scraping.

CONCLUSIONS

Since the entrance channel realignment to the south over a year ago, the southerly alignment has been maintained, with council only needing to undertake berm maintenance and beach profiling once. This has led to the dune erosion of the northern dunes to be controlled, with natural dune building and assisted revegetation stabilising the previous unstable erosion scarp. While there has been some minor erosion to the southern dunes as a result of entrance migration too far to the south, it is believed this can be overcome by manipulation of the berm height over a more defined location. While the trial is considered a success, whether or not council continues with this management regime and formalises it within an entrance management plan will depend on the results from formal community consultation, programmed for early 2012.

REFERENCES

AWACS (1991). *Racecourse Creek Entrance at Old Bar: A Management Strategy*. Report 91/11, Australian Water and Coastal Studies, August 1991.

BOM (2011). Daily Weather Observations. Bureau of Meteorology website - <http://www.bom.gov.au/climate/dwo/IDCJDW2014.latest.shtml>

DECC (2008). *Bellambi Lagoon Entrance Channel Northern dune erosion – preliminary technical study*. Prepared for Wollongong City Council by the Estuaries Unit, Coastal and Floodplain Programs Section, Department of Environment and Climate Change, April 2008.

GHD (2007). *Estuary Management Plan for Several Wollongong Creeks and Lagoons, Estuary Management Study and Plan*. Prepared for Wollongong Council, December 2007.

GCCM (2010). *Lake Currimundi Dynamics Study, Volume 1: Final Report*. Griffith Centre for Coastal Management, Research Report No.75, January 2010.

Haines, P.E. (2008). *ICOLL Management: Strategies for a sustainable future*. BMT WBM Pty Ltd, Broadmeadow, NSW.

Hanslow, D.J., Davis, G.A., You, B.Z. and Zastawny, J. (2000). *Berm heights at coastal lagoon entrances in NSW*. Proceedings 10th NSW Coastal Conference, 20-24 November 2000, Yamba, NSW.

Manly Hydraulics Lab (2012). Unpublished data.

NSW Government (1990). *Coastline Management Manual*, NSW Government, September 1990.

PWD (1984). *Coastal Project Sheet: Long Reef Beach*, Beach and Coastal Management Field Day: Warringah Shire, Palm Beach to Freshwater, Sunday 25th November 1984, Public Works Department.

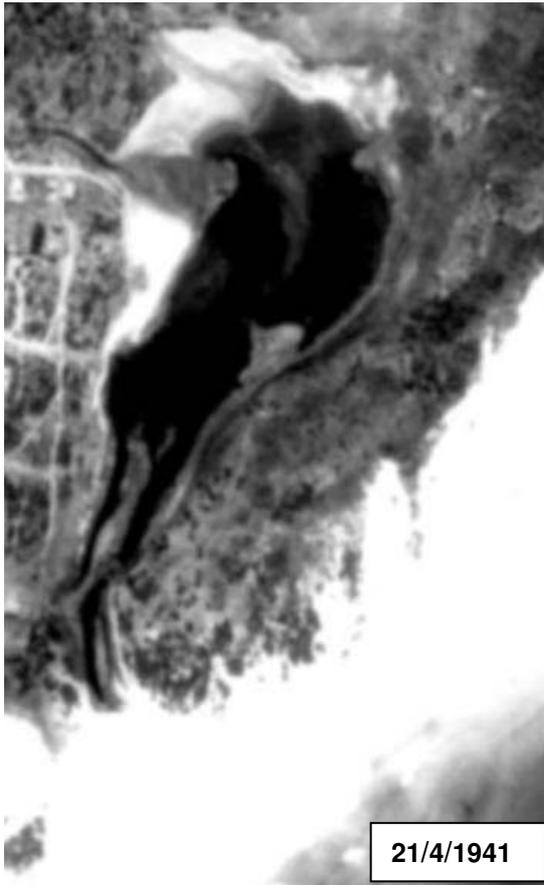
Spurway, Roper & Stephens 2000. *Community consultation, conservation, crustaceans, calculations and consents - Entrance Management Policies for ICOLLs*. Proceedings 10th NSW Coastal Conference, 20-24 November 2000, Yamba, NSW

Wiecek, D. and Floyd, J. (2007). *Does dredging in ICOLL entrances improve tidal flushing?* Proceedings 16th NSW Coastal Conference, 7-9 November 2007, Yamba, NSW.

Worley Parsons (2010a). *Black Head to Crowdy Head Coastline Hazard Definition Study*, Volume 2: Figures. Prepared for Greater Taree City Council, September 2010.

Worley Parsons (2010b). *Greater Taree Coastline Management Study*, Black Head to Crowdy Head, Prepared for Greater Taree City Council, October 2010

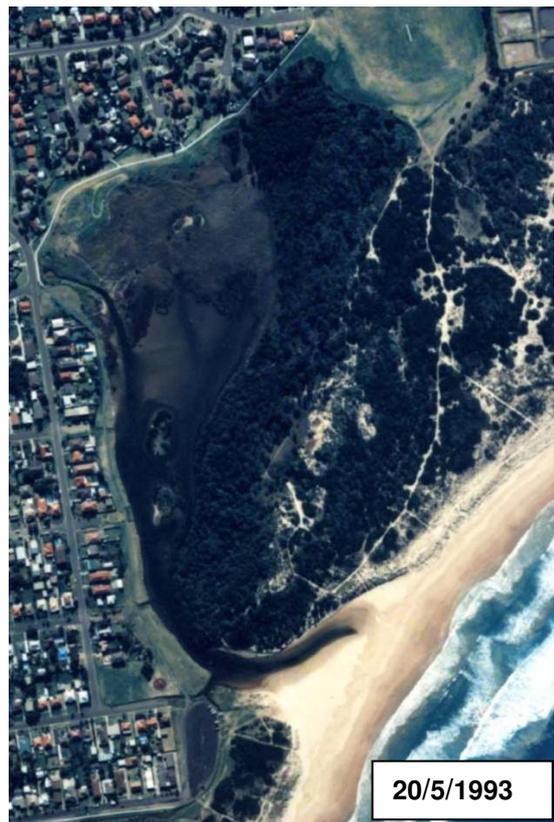
ATTACHMENT 1







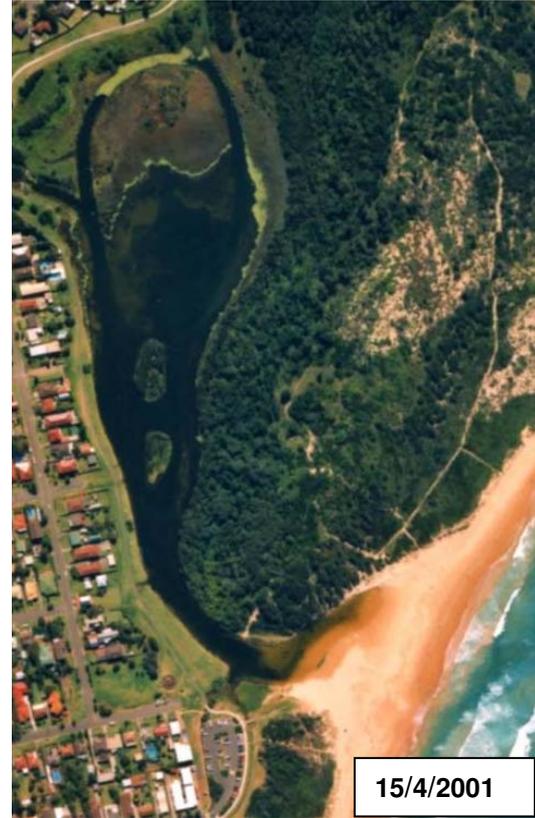
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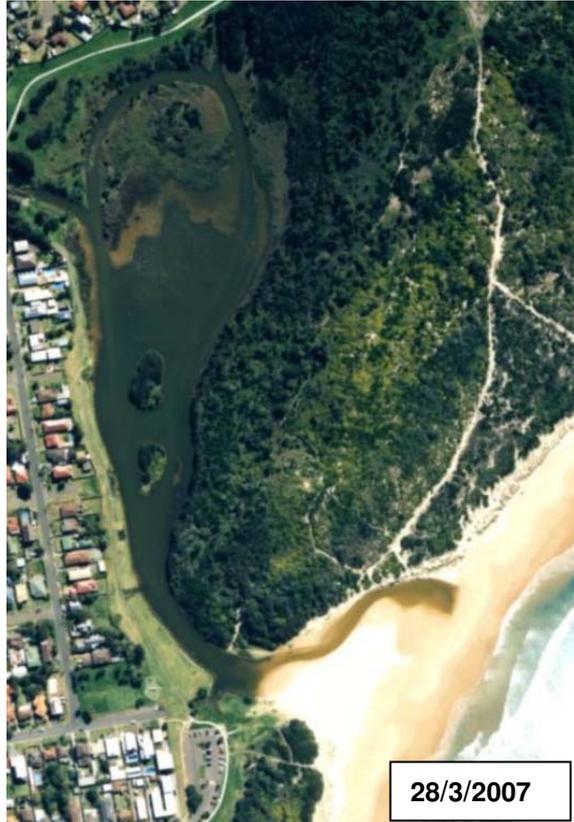
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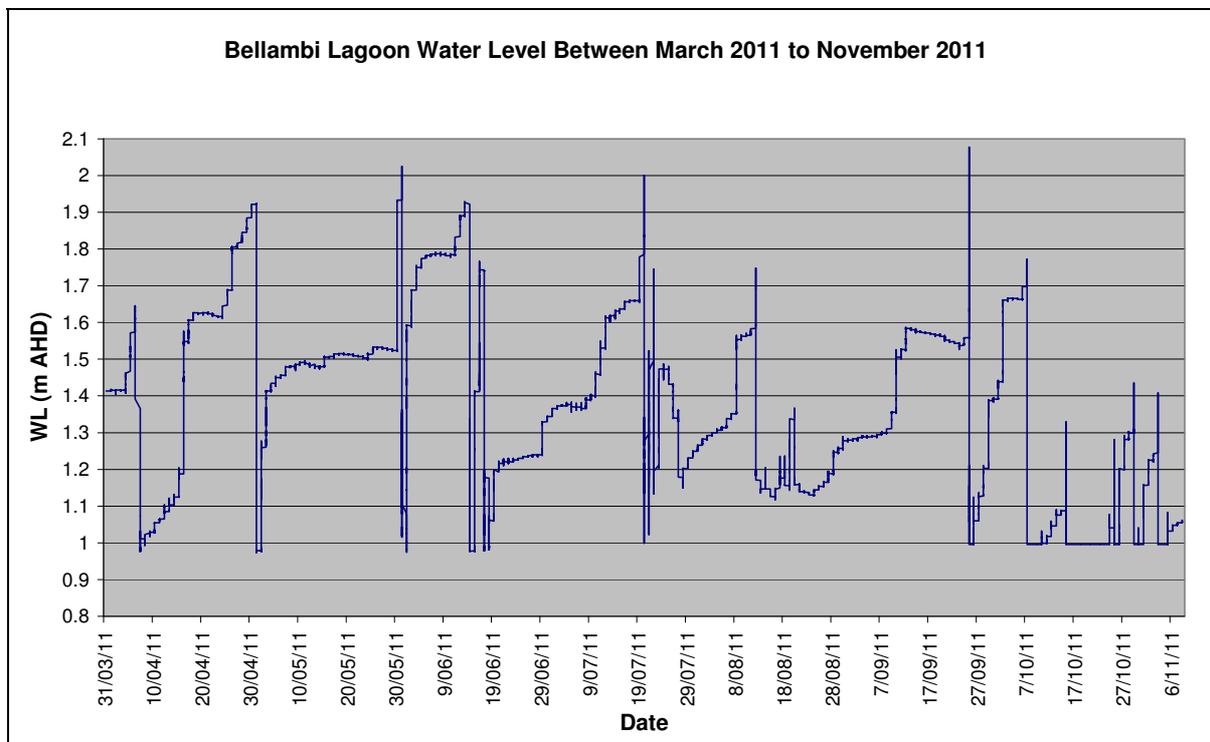
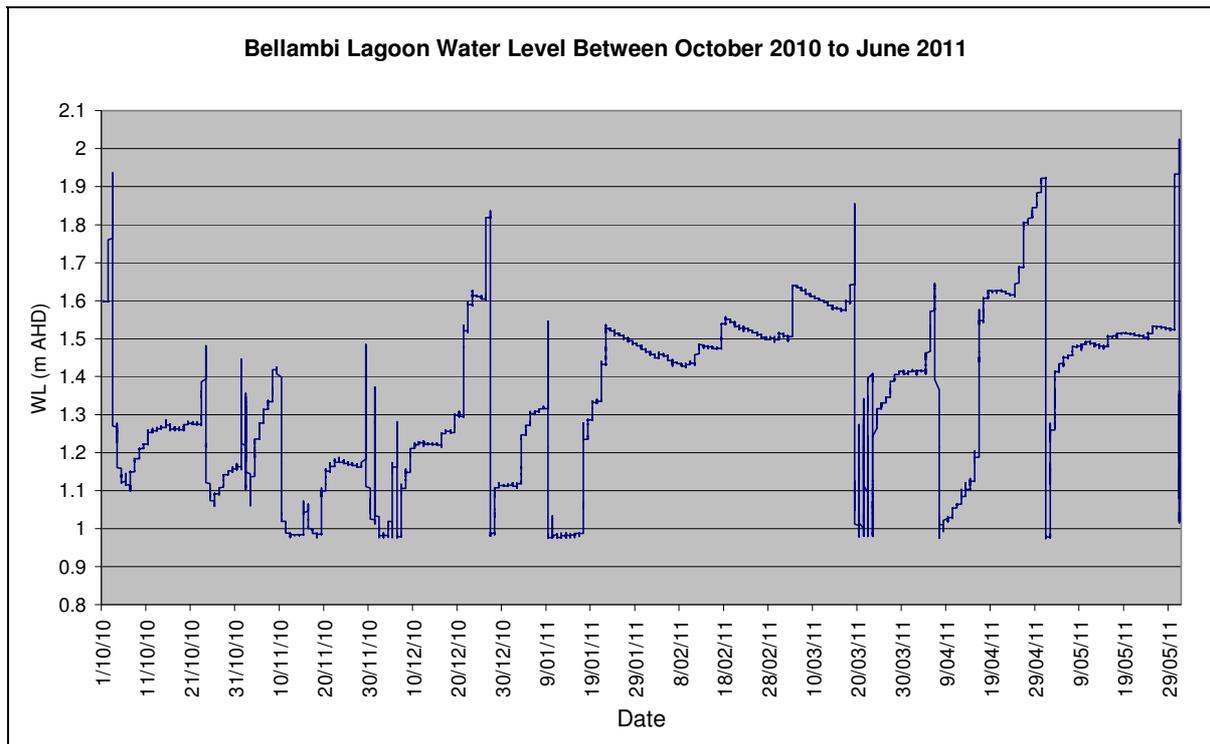
21/2/1999

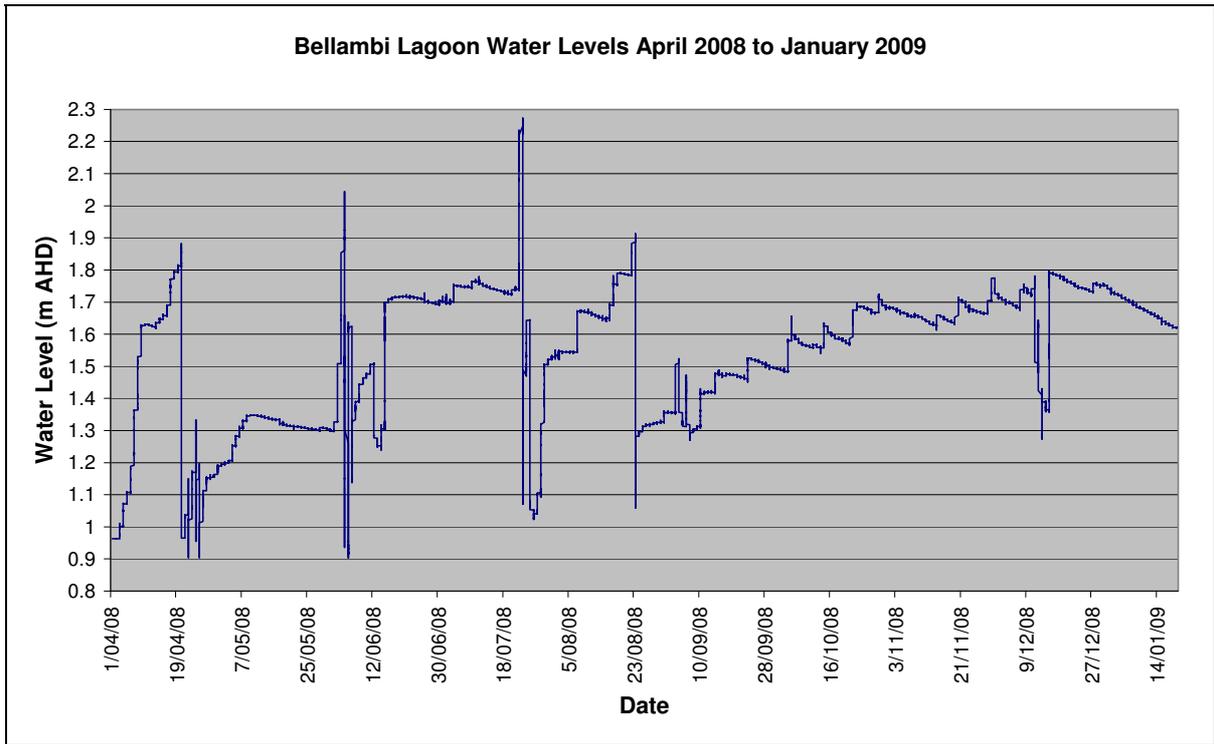
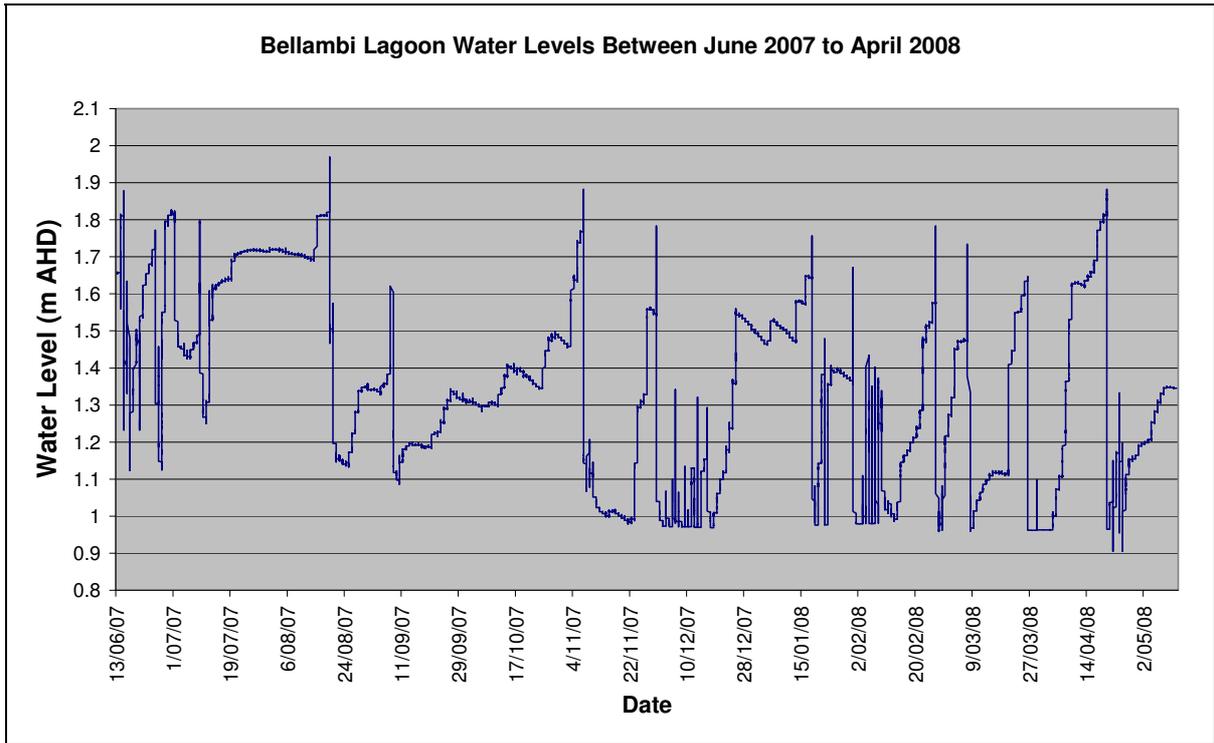


15/4/2001



Attachment 2





The NSW Office of Environment and Heritage is acknowledged as owner of the above data and MHL is acknowledged for the collection and provision of the data.