Waituna Lagoon Management Study

Stage One

Urgent Measures Report

July 2011

Final Report

OPUS

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1 Summary

Coastal lagoons in good ecological health are becoming rarer around the World, and are of high conservation and ecological importance, as evidenced by the international Ramsar designation for Waituna Wetland.

Seagrass (Ruppia) is regarded as a 'keystone' species to indicate the ecological health of the lagoon. Over recent years the extent of healthy seagrass beds has reduced considerably at the same time as the clarity and quality of the lagoon water has decreased. This is thought to be associated with a rapid rise in nutrient load in the lagoon as a result of run-off from the increasing agricultural intensification of the catchment.

There is concern that the lagoon could 'flip' to a phytoplankton/algal dominated state which would have a significant negative impact on the quality of the lagoon. Previous experience is that once a lagoon has flipped, it very rarely reverts to its original condition (see Hamill 2010), instead assuming an altered steady state. For example Lake Ellesmere in Canterbury is a coastal lagoon of a similar type, this flipped in 1968, and still remains in a super-eutrophic state of very low ecological value, even though it continues to be mechanically opened to the sea when water levels triggers are met (Schallenberg et al 2010), and despite intensive monitoring and management.

Figure 1.1 below shows the location of Waituna lagoon.

Figure 1.1: Location of Waituna Lagoon

The most sustainable solution for Waituna Lagoon would be to manage land-use in the catchment to reduce the nutrient and sediment load entering the lagoon. This is recognised by many parties, but is likely to take some time (upward of two years) before it can achieve a tangible improvement. Consequently, at the same time as pursuing this more long-term solution, there needs to be immediate action taken to stop the lagoon from 'flipping' within the next two years.

This report assesses what urgent actions can be taken and recommends that a breach be formed in the beach at Charlies Bay at an appropriate time around the end of July 2011.

2 Waituna Lagoon

The Waituna Lagoon is a classic barrier bar estuary where longshore drift provides constant renewal of material to the beach (see Schallenberg *et al*. 2010). Waituna Lagoon barrier breaches would have occurred naturally but much less frequently than now and at higher lagoon levels. Under natural conditions, the timing of breaches and the longevity of the openings would have depended on the interaction between the lagoon water levels, weather conditons and sea state. Anecdotal evidence suggests that natural breaches occurred to the western end of the barrier; where the current breaches are artificially created (Waghorn pers comms, 2011).

The opening of the coastal barrier to the lagoon and the interaction of flow dynamics between the ocean and the lagoon requires an understanding of the coastal processes involved in building up of the barrier beach between them. The material that makes up the barrier, the geometry and height of the barrier together with the sea state provide vital clues to the coastal processes involved.

2.1 Barrier material

The barrier beach is composed of well-sorted and well-rounded fine grained gravel of median diameter of 6 to 8 mm: locally described as pea gravel (Figure 2.1). The material is non-cohesive, highly mobile and maintains only very low angles of repose. Very brief inspection indicated the occurrence of interstitial coarse sands within 100 mm of the surface (Figure 2.2). The surface material at the lagoon side of the barrier is of similar size as that of the ocean side but less well sorted. The surface material is overwashed by wave overtopping events during heavy storms at high tides.

Figure 2.1: Typical beach surface material – 6 to 8 mm median diameter gravel of variable depth.

Figure 2.2: Typical sub-surface sediment sample at lagoon side of the barrier adjacent to Charlies Bay showing gravel in sand matrix.

2.2 Geometry of the barrier and coastal environment

Eleven cross-sections of the barrier along the lagoon coast are shown in Figure 2.3a & b. The general absence of berm/dune features indicates that the barrier is occasionally overwashed by wave runup. The foreshore slope varies from 1 in 8 to 1 in 16. The slope varies according to incoming sea state. It is noticeable from Figure 2.3b that the beach is quite unifrom along its 9.3km length, with the crest height only varying by about 1.5m, and the width (measured at the 2.0m elevation) varying from about 50m to 75m.

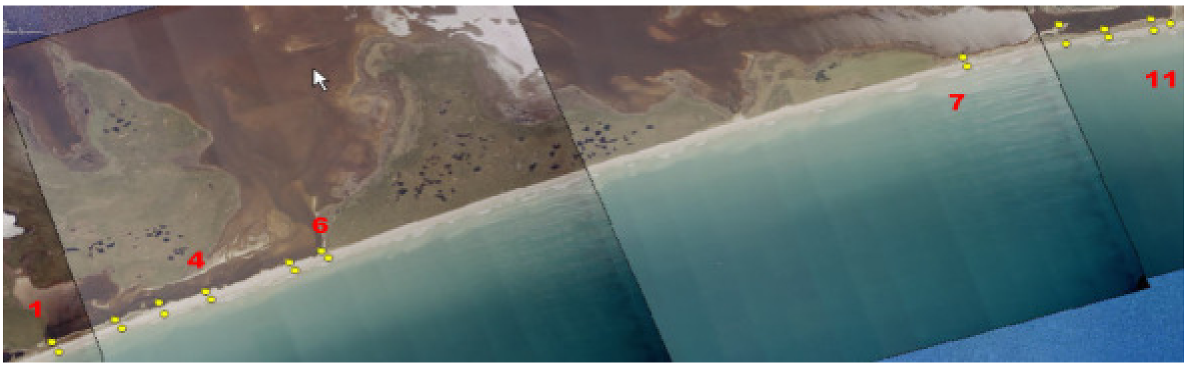

Figure 2.3a: Location of East and West Cross Sections (Environment Southland and Department of Conservation Data 2009)

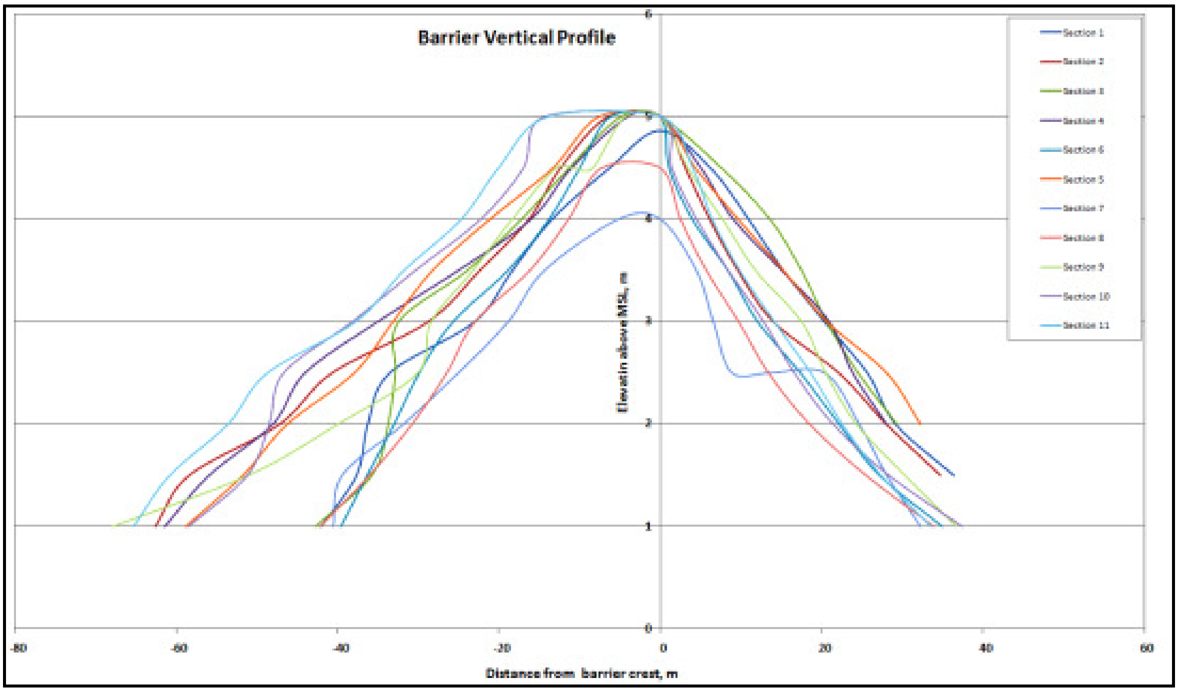

Figure 2.3b: Cross sectional profiles East and West end of Lagoon – lagoon on the left and ocean on the right (data from Environment Southland).

Further beach profile data was extracted from LiDAR data at the locations indicated in Figure 2.4a, covering the Charlies Bay area. The beach profiles are shown in Figure 2.4b.

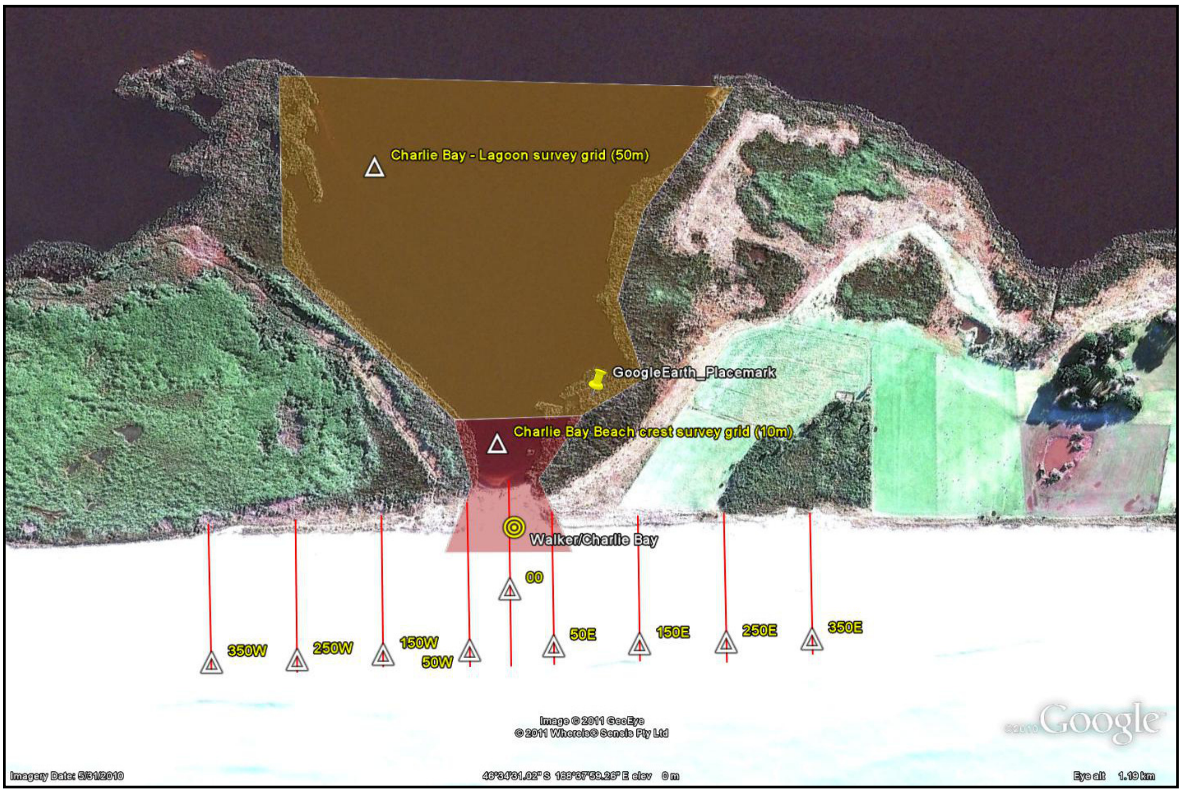

Figure 2.4a: Location of beach sections and required survey data at Charlies Bay

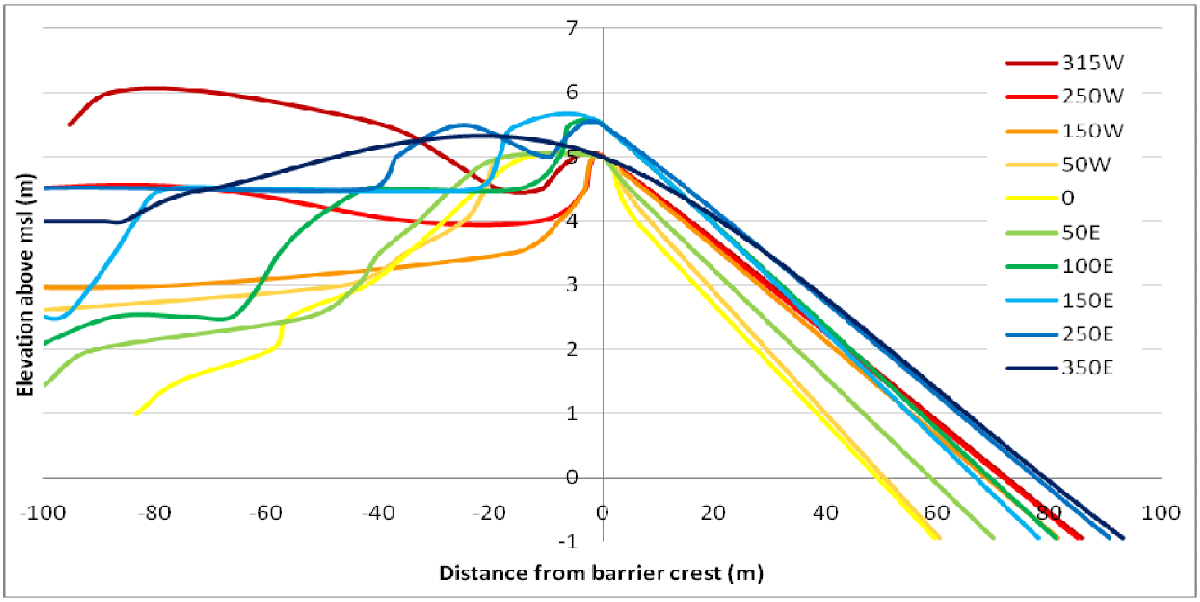

Figure 2.4b: Beach profiles at Charlies Bay - lagoon on the left and ocean on the right (data from Environment Southland).

From a comparison between the beach profiles in figure 2.3b and 2.4b it can be seen that the depth (taken at the 2.0m MSL level) of beach to be breached at Charlies Bay is about 50% wider (90m rather than about 60m) than at the SW Corner/Walker Bay site where it is usually breached. Note that the breach would be formed at section '0', the yellow profile shown on Figure 2.4b. The significance of this is discussed later in the report, but essentially it means it will probably close quicker.

The typical tidal range for this coast is about 2.4 m (data from Environment Southland) and according to the wave data for the period between 1/11/98 to 30/12/09 for this site (from MetOcean Ltd as supplied by Environment Southland), the significant wave height and peak period are 1.1 m and 11.7 s, respectively. The wave environment is dominated by long period swells from the Southern Ocean. Long period swells tend to reduce the foreshore slope and short period local storm waves tend to increase it.

2.3 Littoral drift

Figure 2.5 shows the plan form of the coast at Toetoes Bay. This area lies in the shadow of the Stewart Island from the predominant Southern Ocean swells. It suggests the net littoral drift is from the east to the west. The main source of sediment is likely to be gravel beds in the eastern Foveaux Strait and Toetoes Bay and the nearby cliff to the east. From time to time, the direction of the drift may reverse in accordance with the direction of local incoming waves, but the source of sediment from the west is limited. This means that outlets in the east are likely to close more quickly.

Figure 2.5: Map of coastal form around Waituna Lagoon showing direction of littoral drift

2.4 Water mixing, circulation and barrier openings

The Waituna Lagoon monitoring data shows the lagoon is predominately well mixed in terms of temperature and salinity. Weak temperature-salinity stratification occurs in periods of calm weather conditions. The principal driver for mixing is wind induced surface waves and currents. An increase of current velocity in the sheltered and deeper regions of the eastern lagoon will help to improve water quality.

Currently, the opening at the western side of the lagoon mainly benefits the flushing and removal of sediment from the shallow main body of the lagoon. Water circulation in the deeper eastern side of the lagoon appears to be relatively poor. This and the relatively weak current movement make this eastern area more prone to siltation. A high proportion of soft mud is found in the central basin toward the eastern end (Stevens and Robertson 2007). Mud particles tend to adhere together to form flocs and settle more quickly especially in the presence of sea water. A significant proportion of nutrients are adhered to mud flocs creating a negative impact on the local ecology.

3 The Problem

Waituna Lagoon is a natural feature evolved over thousands of years as a result of the interaction between the freshwater streams draining the catchment, and the coastal processes driving the formation of the beach. The beach forms a natural barrier against which the freshwater impounds to form the typical brackish lagoon of this type of coastal lagoon. Under natural conditions (which do not pertain currently), once the retained water level gets high enough, it will push through the beach to form a breach. This allows the retained water to drain to the sea, and sea water to enter at high tides. During storm events or under a period of prolonged wave action, the beach closes up again, and the cycle begins again.

Over this time *Ruppia* has become established, and the lagoon has become a feature of significant ecological interest, as recognised by its international RAMSAR status. As the value and extent of agricultural production has increased in the catchment, the lagoon has been breached by mechanical intervention to improve land drainage in the catchment.

The four photos in figure 3.1 overleaf show the typical opening process at Waituna Lagoon (SW Corner/Walker Bay site) taken from the openings in 2002 and 2010. The top left image shows the initial cut being dug by an excavator, and then top right and bottom left show the development of the breach channel within 6 hours of opening. The bottom right photo shows the full extent of the breach channel.

In more recent years there has been an intensification of agricultural production in the catchment, and in particular the rapid conversion of sheep farms to dairy. The change in land use intensitifcation has resulted in increased loadings of phosphorous, nitrogen and sediment in the lagoon tributaries. The resulting eutrophication has impacted on a range of biotic interactions, particularly the health and extent of the *Ruppia* sea grass beds within the lagoon.

The current management dilemma is to breach the barrier to release the nutrient rich waters but to maintain the breach for only a short a period to minimise risks to the remaining *Ruppia* beds. These risks include increased salinity during the critical *Ruppia* germination period over summer, drying out of beds and increased temperatures in summer due to shallower water. A rapid barrier breach closure is also favoured to maintain higher water levels for *Ruppia* growth.

The most sustainable solution would be to manage land-use in the catchment to reduce the nutrient load entering the lagoon. This is recognised by many parties, but is likely to take some time before it can achieve a tangible improvement. Consequently, at the same time as persuing this more long-term solution, there needs to be immediate action taken to minimise the risk of the lagoon 'flipping' to a eutrophic state, which would significantly reduce its ecological value. 'Flipping' has occurred before – in 1968 when Lake Ellesmere in central Canterbury (a very similar coastal lagoon, but much larger) flipped in the Wahine storm, the lagoon has never recovered, despite continuing to open on an occasional basis. Figure 3.2 shows the Lake Ellesmere lagoon during the recent mechanical opening in November 2006 (Hamill 2010; Schallenberg et al. 2010).

Consideration of lagoon management and other longer-term issues is being undertaken by the Lagoon Technical Group (LTG) and Catchment Technical Group (CTG). This Stage 1 Report is focussed solely on where and when to open the breach, as it has already been established by the LTG that beach opening is the most appropriate achievable action in the short-term (2yrs).

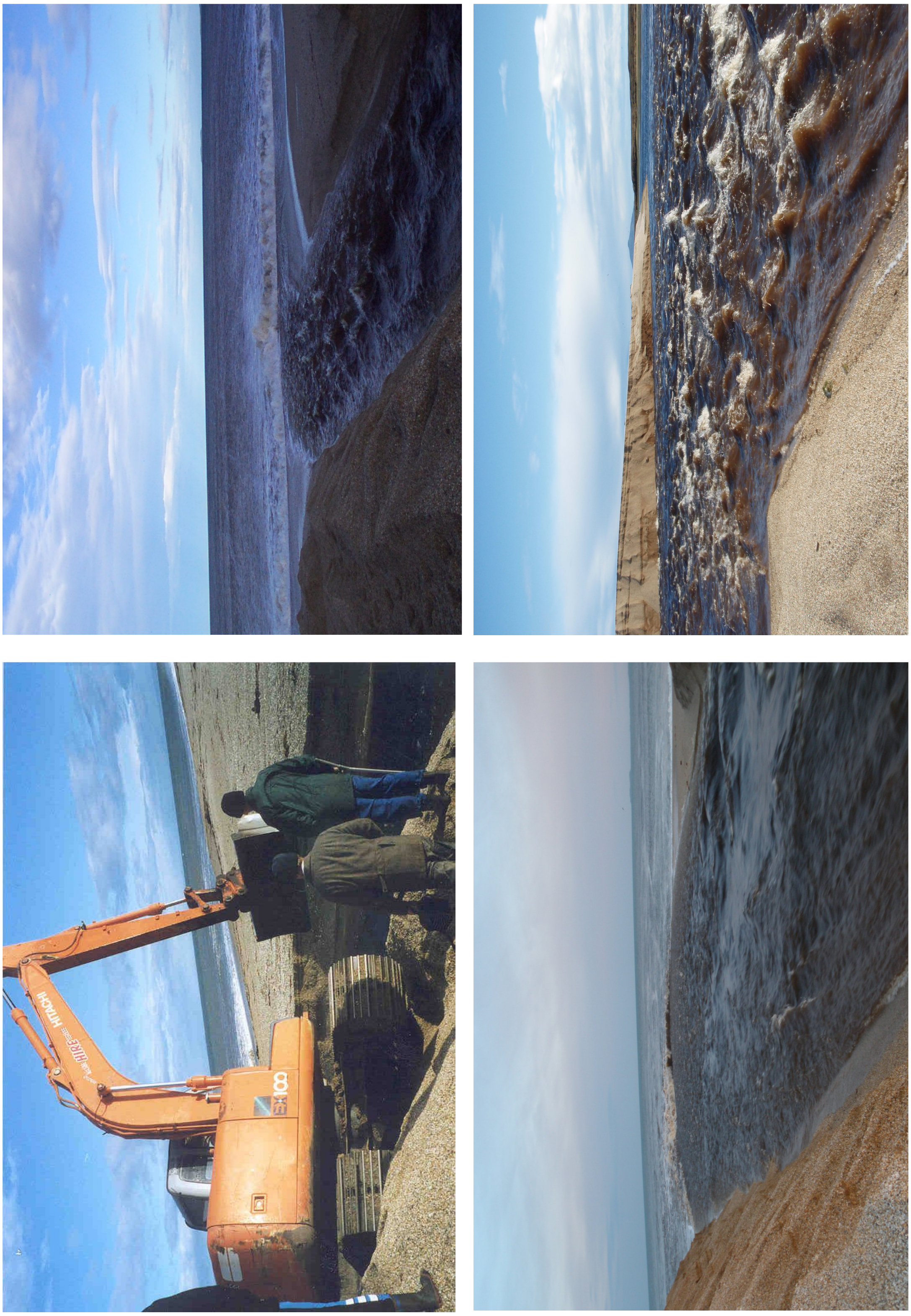

Figure 3.1: typical opening of Waituna Lagoon (photos from 2002 and 2010). The top left and bottom right photos show the breach channel development within 6 hours of opening. The bottom right photo shows the established breach channel.

Figure 3.2: Opening of Lake Ellesmere November 2006. The top photo shows the high nutrient-load water flowing out, with the lower photo showing sea water inflow.

4 Options

4.1 General

This report is focussed on engineering options that can be undertaken to reduce the risk of the Lagoon 'flipping'. In particular focus has centred on various options around creating an opening in the beach, to help flush dirty water; and subsequently closing the opening to increase water levels and minimise the potential impact of saline water on Ruppia germination.

There are clearly a number of other measures that could be considered to reduce the risk of 'flipping', but these would all require further assessment and discussion, and would not be implementable with the urgency required at this stage. These options include other potential measures and facilities for managing flushing and retained water level of the lagoon such as: pumping over the beach, a siphon system, and the construction of fixed drainage control structures. These and other potential measures such as: management of nutrient sources in the catchment; provision of vegetated buffer strips to intercept direct run-off; construction of treatment wetlands at the main watercourse inlets to provide some primary treatment; and the diversion of additional freshwater flows to the catchment; will all be considered in detail during the next part of this project (Stage 2).

Figure 4.1: The four potential sites for beach opening

Figure 4.1 shows the location of the four potential opening sites considered. Most recently the lagoon has been opened at the SW Corner/Walker Bay site, but on previous occasions it is believed to have been opened or opened naturally at the Eastern Corner site. Two further sites were also suggested for consideration, those at Charlies Bay (also known as Hansens Bay), and two sites in the eastern lagoon (Opposite Carrans Creek and the Eastern/Bottom of the lake).

Following an inspection of the lagoon and the barrier beach and after discussion with a member of the Lake Waituna Control Assocation (LWCA), the project team and ES convened a workshop to discuss management options to address the current water quality of the lagoon and its potential effect on the lagoon's ecology. It was concluded that urgent intervention was required to breach the barrier, to release and flush the impounded water and allow limited mixing with sea water. However, a constraint on opening was the concern that the heightened salinity of the lagoon had the potential to adversely affect the Ruppia, particularly during the Summer growing season. There is also a concern that increased sea water intrusion would increase the likelihood of algal blooms when the water warms in the summer. Hence, a shorter-lived opening was desirable.

5 Assessment of options

5.1 Methodology

A site visit, workshop and discussion with a Lake Waituna Control Association (LWCA) member were carried out on the 2/5/11 and 3/5/11, provided a general background, appreciation of the issues involved with the lagoon and its management. Further discussions have been held with Keith Hamill of the LTG, and key Environment Southland staff, including Greg Larkin, Jane Kitson, Kirsten Meijer, and Chris Jenkins.

The following information provided by Environment Southland was used for the assessment of the options considered:

- Cross sectional barrier profiles
- Tidal and wave data
- Wind rose
- Lagoon bathymetry
- Lagoon inflow and outflow data
- Past record of barrier opening and closing
- Site inspection notes and observation
- Past investigation reports
- Maps

5.2 Criteria

A number of criteria were considered when assessing the most appropriate option to implement. These were:

- Health & Safety of the breaching operation
- Lagoon water levels in relation to catchment flooding
- Water quality issues within the lagoon
- Flush of the winter nutrient load
- Speed of implementation (including the obtaining of consents and approvals)
- Speed of closure
- Lagoon flushing efficiency

- Potential for saline intrusion
- Damage to plant roots, especially *Ruppia*
- Potential timing of closure

5.3 Assessment Summary

The most critical area that requires immediate attention is at the eastern end of the lagoon adjacent to Carran Creek which has adequate cover of *Ruppia* (50-80%) in 30-150 cm deep very soft mud.. The eastern opening locations offer good flushing but the risk to *Ruppia* from physical scouring during breaching is likely to be high. Unconsolidated mud is easily eroded and re-suspended by even a small increase of current velocity 0.01 m/s. The flushing may be affected by winds. Winds from and to the west can cause wind setup and set-down of more than 300 mm, respectively at the eastern end. In addition, a spit in the eastern lagoon opposite the Carran Creek indicates that a significant littoral transport eastwards. This is the result of wind induced wave action.

Lagoon flushing is likely to be more efficient at the eastern end, however this is also the area of greatest *Ruppia* concentration. The initial outflow velocity from the breach is likely to be relatively high, which could scour away or significantly damage the roots of the *Ruppia*. For this reason breaching at the Eastern Corner sites is not the favoured option due the likely adverse affects to *Ruppia*.

It is thought that the opening site at the SW Corner does not achieve a very effective flushing of the lagoon, particularly at the eastern end, which is now the only site in the lagoon to continue to have good cover of *Ruppia*.

At Charlies Bay the beach is significantly wider which will greatly reduce the energy gradient of the escaping lagoon water, which will result in a narrower and potentially shallower breach channel. There is also a shallow mudstone sill in Charlies Bay at 1 msl which will likely stop channel incision to the spring low tide level of 0.5- 0.6 msl (Envrionment Southland Monitoring Data 2011). This is likely to lead to a quicker lagoon closure as less material will be needed to fill the breach, and it will need to move less far. The outflow and flushing from the central and eastern area of the lagoon is expected to be significantly higher than for an opening at the SW Corner site.

Members of the LWCA were of the opinion that openings to the western end of the lagoon were traditionally easier to create and, once open, remain open for longer periods than breaches in the east. Our investigations tend to support this view, particularly the direction of the local littoral drift, and indicate more stable breach conditions (i.e.open for longer) at the western end of the barrier.

In terms of timing, it has been assessed that opening the breach at the end of July/August is the best compromise between flushing out a nutrient laden water and sufficient time for for winter storms and littoral drift to close the beach before the *Ruppia* growing season. This also gives sufficient time for winter rain events to fill the lagoon to an optimal level to allow good plant growth in the spring and summer. However, it must be noted that if the lagoon fills quickly (1-2 months) it may require breaching again, which will leave the lagoon with low water levels going in to summer. This ‘risk’ is significant and needs to be accepted as it may have deleterious effects to lagoon water quality at the end of the 2011-12 Summer.

6 Preferred Option

6.1 Summary

The preferred option is to create a breach in the beach at Charlies Bay (Figure 6.1). This should be undertaken at the end of July or soon after. This offers the best option to balance the need for good flushing and the risk of disturbing *Ruppia* beds. It is centrally located in the elongated eastern region and should produce a good flush to the lagoon as a whole, with a significantly more active flushing of the critical eastern end.

The beach is deeper (wider) here and there will be a longer breach channel, about twice the length of the existing opening site in the west. This will reduce the tendency of large lateral spreading during breakout by reducing the energy gradient of the flow. Charlies Bay was last opened prior to 1995 and it has been said that the channel was confined to a width of about 60 m. The risk of uncontrolled enlargement greater than this is likely to be low.

Table 6.1 below, is a summary matrix of the site selection assessment against the four criteria of minimising harm to *Ruppia* beds, promoting good flushing of the lagoon in the vicinity of the *Ruppia* beds, the probability of quick closure of the breach and minimising the impact of saline intrusion on the *Ruppia* during the period of opening.

Site (from west to east)	**Minimise direct harm to *Ruppia***	**Promote good flushing of *Ruppia* areas**	**Probability of quick closure**	**Minimise impact of saline intrusion on *Ruppia***	**Overall assessment**
SW Corner (Walker Bay)	High (furthest from main area of *Ruppia* growth)	Low (furthest from main area of *Ruppia* growth)	Low (narrow section of beach, less local material)	High (furthest from main area of *Ruppia* growth)	**Medium**
Charlies Bay (Hansens Bay)	High (not adjacent to *Ruppia* beds and mudstone sill and beach breadth limits outflow velocities)	High (Close to *Ruppia* beds and central to barrier)	High (wide section of beach, mudstone sill limits breach channel depth, lots of local beach material)	Medium (Close to *Ruppia* beds)	**High**
Opposite Carran's Creek	Low (closest to *Ruppia* beds)	High (close to *Ruppia* beds)	Low (narrow section of beach, less local material)	Low (closest to *Ruppia* beds)	**Low**
Eastern Corner	Low (close to *Ruppia* beds and narrow beach)	Medium (not close to *Ruppia* beds)	Low (narrow section of beach, less local material)	Medium (Close to *Ruppia* beds)	**Medium/ low**

Table 6.1: Breach location assessment summary table

6.2 Location

Charlies Bay has been chosen as it is reasonably central and should produce good lagoon flushing, but far enough from the main Ruppia beds to avoid direct root damage. It also has an increased probability of a short opening period due to the increased beach width and the action of littoral drift.

Figure 6.1: Charlies Bay. Last opened in 1995. Barrier fully reclaimed and partially covered with vegetation in May 2011.

6.3 Timescale

The end of July is seen as the optimal time as it should flush a large proportion of the winter nutrient 'soup' out, whilst still allowing a good chance of closure through winter storms. The issue of farmland flooding is important too, as currently the beach is opened chiefly to limit retained water levels to improve land drainage, and manage flood risk on the adjacent agricultural land. The lagoon water level is already high and has been over 2.0m MSL, the level at which the Opening Committee can create a breach.

It is reported that in 1973 and 1974, it took a day and 22 days for the opening at Charlies Bay to close, respectively. We recommend that the potential to flush sediments from the lagoon is maximised by allowing the lagoon to build up as high as possible before opening and opening on a spring low tide. This will also create a bigger breach channel. The peak water levels in the lagoon normally occur in July or August.

6.4 Implementation

Good information on opening measures was obtained from discussion with Ray Waghorn (member of LWCA) about previous openings. The LOC use an excavator to clear a narrow channel from low on the beach on an ebb tide. There needs to be minimal wave action, otherwise conditions become too difficult and dangerous to form the breach. Once the form of a narrow channel has been excavated towards the beach crest, a 'nick' is formed in crest using a wide reaching excavator, once flow has started flowing in the 'nick' it very quickly develops into wide 40m+ opening. This may be slower at Charlies Bay as longer channel needed (twice as long), reducing energy gradient.

The entire surface material over the barrier beach appears to comprise well sorted gravel. This requires a mobilisation velocity of about 1 m/s. If the velocity of the channel exceeds the critical velocity, erosion of the channel will occur. With the enlargement of the channel due to the erosion, the velocity will decrease until it drops below the mobilisation velocity at which point the channel erosion will cease.

6.5 Rationale

6.5.1 Rationale for selecting mechanical breaching of the beach as the most appropriate short-term measure:

- Breaching is a routine and acceptable practice
- Breaching can be undertaken very quickly (subject to approvals, consents and sea conditions)
- Lower water level to improve field drainage

6.5.2 Rationale for creating breach at Charlies Bay at end July/August:

- Location minimises harm to *Ruppia* beds
- Good chance of closure before *Ruppia* growing season (spring) – due to wider beach section
- Better flushing of eastern end of lake where key *Ruppia* areas are
- Flush significant part of the high winter nutrient load
- Decrease chance of requirement to re-open (by delaying to end July/August)

6.6 Risks

May not close – leading to high saline intrusion and impaired *Ruppia* growth. The risk to growth from saline intrusion increases with longer opening times

Poor water quality if high nutrient load after closure, low lagoon levels may reduce ability to open and flush

Harm to *Ruppia* bed – from route damage or scour caused by high initial outflow velocities

Gravel intrusion to lagoon – from wave action. This would become a higher risk for longer opening period, or severe storm driven wave action

Erosion to adjacent land – caused by formation of breach channel

Health & Safety – very rapid erosion of beach material once breach initiated, ensure operation is safe as possible, using long-reach excavator from stable position where possible. Use of PPE including lifejacket and provision of safety boat

Insufficient rainfall – may not be adequate to provide adequate water depth for optimal Ruppia growing conditions

Large storms – causing extreme wave action to close breach before thorough flushing complete

7 Next Steps

7.1 Winter 2011 Opening

Obtain resource consent on 'emergency' basis

Obtain agreement in principle from landowner (Ray Waghorn)

Consult with the Lake Waituna Control Assiocation for a amended consent for two locations, with different opening time and water level opening triggers

Determine suitable date/time in relation to tides, for example Spring tides

Closer to date, check weather forecast to assess potential sea state

7.2 Stage 2 – Consideration of Longer Term Management Options

Over the longer-term, the management issues of the lagoon will have to be tackled at their source. This will require intervention higher up the catchment to intercept agricultural runoff and prevent its direct ingress to the tributaries of the lagoon. There are a range of management techniques to treat nutrients from agricultural runoff and these could be implemented to good effect. Classically, the main issue is where to start. Catchment modelling tools can be used to very good effect to help prioritise the locations of catchment management works. Hydrodynamic modelling of the lagoon provides useful information on water quality management and operation.

Medium term options include appropriate management of barrier breaches for nutrient control rather than local flood mitigation. Perhaps local diversions of 'fresher' water (if such water exists) from neighbouring catchments. Although the environmental effects of this must be well understood before implementation.

It would be possible to build a permanent controllable breach in the barrier but the capital and maintenance costs are high. The non-cohesive barrier substrate combined with ever-changing sea and lagoon conditions would forever conspire to undermine, outflank and render such a structure useless.

The method of assessing the medium and long-term management options will be set out in the Brief for Stage 2 assessment, which is to be prepared and agreed as the next part of this study.

8 References

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