Lake Elterwater

-

A basis for discussion

- Ecology
- Management
- Policy
- Future

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Executive Summary

Marlborough District Council (MDC) commissioned this report to provide information about the ecological values of Lake Elterwater, the current management practices and their impact, the policy framework applicable to the lake and catchment, and the fit between current management and this framework. Key findings of the report are:

- Climatic factors such as low rainfall, high sunshine hours, wind and temperature result in a water short catchment where average annual evaporation exceeds rainfall by almost 800mm
- The lake is dependent on runoff events to fill it, and there are only a few (ca. 5 - 6) such events per year
- While the lake is relatively full, it acts as a lake, while when relatively empty it functions more as ephemeral wetland
- Lake full volume is calculated to be 568,000m^3 (much less than previously estimated)
- Daily, seasonal, and annual water level fluctuations coupled with warm temperatures create a hydrological regime unique to the site, favouring the development of specific plant (and animal) communities
- Modifications to natural lake hydrology include reduced vegetation cover in the catchment, loss of wetland from the head of the lake, beds of willows, a lowered lake outlet, multiple dams (91) and irrigation takes within the catchment
- These modifications are likely to be having a significant effect on the natural hydrology of the lake
- Hydrology is the prime determinant of wetland structure and function
- The lake has been dry at least 10 times in the last 100 years
- Hydrological investigations revealed a lack of data for the catchment and point to the need for on site data collection
- A wide range of plant communities are present, of particular note are some high shore and ephemeral
- A wide range of bird species are present, as well as freshwater mussels, bullies and eels
- Current land status is Crown Land administered by LINZ, with overlying Wildlife Refuge designation
- It is listed as a significant wetland in the Marlborough Environment Plan (MEP), Open Space 3 zoning
- Assessment of conservation values clearly shows Lake Elterwater to have high conservation values
- Historical and current management has not reflected those values, with recent management during dry times being for agricultural purposes
- Planting of crops and grazing within the lake bed has resulted in significant impacts through displacement of natural communities, weediness, trampling, and almost complete destruction of regenerating trees and shrubs
- These impacts result in a low wetland condition assessment, comparable to Lakes Ellesmere & Forsyth
- A range of policy and planning instruments guiding wetland management are discussed, including those acting at international, national, and local levels
- Analysis of these instruments shows that current management for agricultural purposes is in conflict with many of them, including the MEP
- Some factors to be considered for future management are discussed, including weed management, fencing, predator control, habitat enhancement, reintroductions and a conservation status in keeping with the high conservation values of the site

Background

Recently there has been some discussion regarding management of Lake Elterwater, particularly with regard to some farming practices taking place within the bed of the lake. At a community meeting (held on 23/8/2016) it was agreed that outside advice would be sought to provide an assessment of the lake ecosystem, and to consider what actions could be taken to enhance the lake. Marlborough District Council requested WetlandsNZ to provide this advice. This report provides a site description of the ecological and legal aspects of the lake, and an assessment of the ecological values. These values are discussed within a wider ecological context. A brief description of the current and proposed management for the site is followed by an assessment of how this management fits within the legislative framework. Some possibilities for enhancing the ecological values and functioning of the lake are also outlined.

Site Description

The site is described in terms of its location, hydrology, plant and animal communities, wetland classification and boundaries.

Location

Lake Elterwater is situated about 35km south east of Blenheim, 3km north of Ward adjacent to State Highway 1 (Figure 1). It is 17m above sea level. Low hills to the east (typically 300m high) separate it from the sea to the east, 5km away. To the north lies Lake Grassmere (less than 6km away), with an area of low relief between them. It has access off the highway, including a picnic area, toilets and viewing platform.

It is located in the south east corner of the Flaxbourne Ecological District (E.D.). This E.D. (especially on its eastern margin) is characterised by low rainfall, dry springs and summers, strong winds and moderate winter temperatures.

It is the second largest freshwater lake in the Marlborough District by surface area (third largest by volume), and the fourth largest wetland. There are no other similar lakes in Marlborough, but in Canterbury, St Anne's Lagoon shares some characteristics. They are both located in low rainfall catchments, are of substantial size but very shallow, lack permanent inflow and outflow, are important areas for wildlife, have ephemeral edge communities, and were both dry in early 2017. St Anne's Lagoon differs in being smaller and less linear in shape.

The predominant land use of the catchment is pastoral farming, with some small areas of grapes.

The lake is part of the catchment of the Flaxbourne River.

Hydrology

It is the hydrology of a wetland which is the single biggest factor in determining its structure and function. This is especially true of Elterwater, where a special set of characteristics result in hydrology which, if not unique for the District, is very uncommon. A number of factors influence the hydrology of the lake. These include catchment size, run off, groundwater, lake morphology, climate, soil type, and catchment modification. The ideal situation is to have field measurements of lake inflow, outflow, precipitation, soil moisture capacity, open water evaporation and changes in lake level so that a more detailed understanding of the hydrology of the catchment is possible. In the absence of such a study, figures obtained from other sites may be used to provide a best estimate of the hydrology. The approach taken in describing the hydrology of the lake is to discuss the elements which go to make up the natural hydrology, then consider modifications which have been made to the catchment over time. Consideration is then given to using data from a range of sources to generate a water balance estimate for the lake.

Catchment description

Figure 2 shows the catchment of the lake. Total catchment of the lake is about 1600ha, of which the lake bed occupies 73.5ha, or 4.4%. About 13 streams make up the whole catchment, most of which flow into the lake via Elterwater Stream. The lake flows out only at times of high water, when it connects with Flaxbourne River via a meandering channel, then out to sea, about 6km away. The streams are ephemeral in nature, as is the lake.

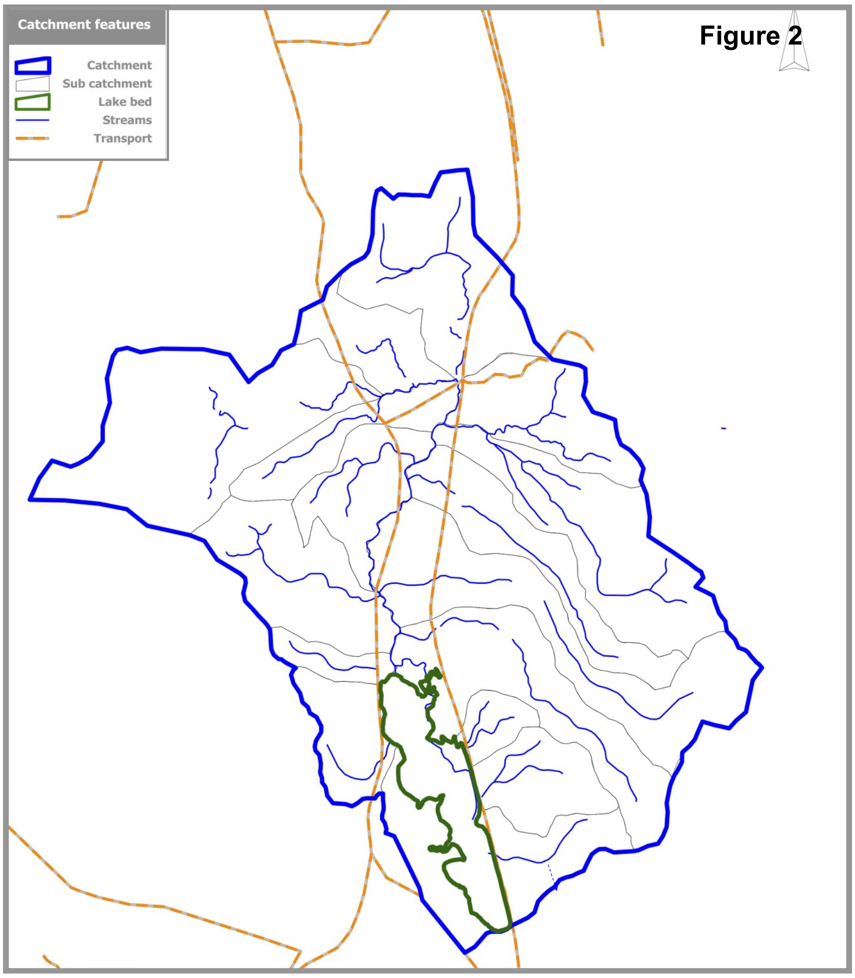


Figure 2

Climate

The key components of climate are rainfall, temperature, wind, solar radiation, and evaporation.

Rainfall

There are a number of potential sites which could be used to establish rainfall. To the north two sites at or near Lake Grassmere have average rainfalls (determined by downloading data from NIWA CliFlo records, and averaging all full year records) of 594mm and 574mm, while on the coast Cape Campbell has 522mm. To the south Chancet has 755mm, while recent records for Flaxbourne River to the east average 571mm. It would appear that there is a rainfall gradient from north to south, and a figure of about 605mm is estimated for the site (see page 6). This may be an overestimate, based on observations recorded on the Taimate website, which list rainfall as 500mm with an average of about 400mm over the last decade (including a June 2002 - June 2003 very low figure of 165mm).

Figures used for temperature, solar radiation, wind, soil moisture deficit, and evapotranspiration are derived from the maps in Chappell (2016), while runoff days and depths are those downloaded from the NIWA CliFlo site (CliFlo 2017).

Temperature

Temperature is slightly moderated by the strong winds, so the main valleys of lowland Marlborough have warmer average summer daily maximums than Elterwater, which are around 20° C - but still high regionally.. During winter this average is about 4 - 5° C., one of the mildest areas outside of the Marlborough Sounds. Daily temperature fluctuations are relatively small, typically about 8°C for Grassmere Salt Works, and 11°C for Blenheim, so probably about 9°C for Elterwater.

Sunshine

Sunshine hours for Marlborough generally are amongst the highest in the country, with Elterwater averaging approximately 2,275 hours per year, perhaps 125 hours less than Blenheim. Global solar radiation is higher at Grassmere than Blenheim.

Wind

In a regional context, Elterwater is a windy site, with average wind speeds being exceeded only in the Cook Strait influenced Marlborough Sounds, and in the mountains. Elterwater is very exposed to the predominant north-westerly wind, as well as southerly blasts, with low relief at both ends of the lake. A change in water level of as little as 20mm from wind piling water up at one end of the lake may add more than 50 metres to the wetted area of the lake, creating a daily cycle of lake levels which are an important driver of plant and animal communities in this ecosystem.

Summary of primary climatological factors

In both a regional and national context, Elterwater has low rainfall, high wind, moderate-high temperatures, and high sunshine hours and solar radiation.

Derived climatological factors

These primary factors combine to produce some derived parameters which are key to the understanding of the hydrology of the Elterwater catchment. Of particular interest are evapotranspiration and soil water balance, which in turn produces estimates of the number of days and amount of runoff. These factors are discussed in more detail in the section on hydrology but are briefly discussed below.

Soil moisture deficit

If available soil moisture is all lost to evapotranspiration, then a soil moisture deficit occurs, and plants cease growth. For the Elterwater catchment this occurs on more than 110 days per year.

Evapotranspiration

Evapotranspiration rates for Lake Grassmere are the highest recorded in the country, with Penman Open Water Evaporation being 1401mm.

Runoff days and depths

Key measurements for site hydrology are the number of days with rainfall which result in runoff, and how much runoff results. For Grassmere, assuming available water capacity of 150mm (McConchie 2009), only 5.3 days per year result in runoff. Over 85% of these days are in the months of June, July, and August, illustrating how important winter is in the replenishment of water lost from the system throughout the rest of the year. Total runoff for the year is calculated to be 57.1mm, with over 80% of this occurring in winter.

Summary of derived climatological factors

These theoretical figures illustrate a typical season, which results in an average of less than 6 days with runoff per year, with under 60mm runoff flowing on these days. In a catchment with climatic factors weighted towards drought, it is what happens on these few days which replenish soil and open water resources.

Lake contours and volume

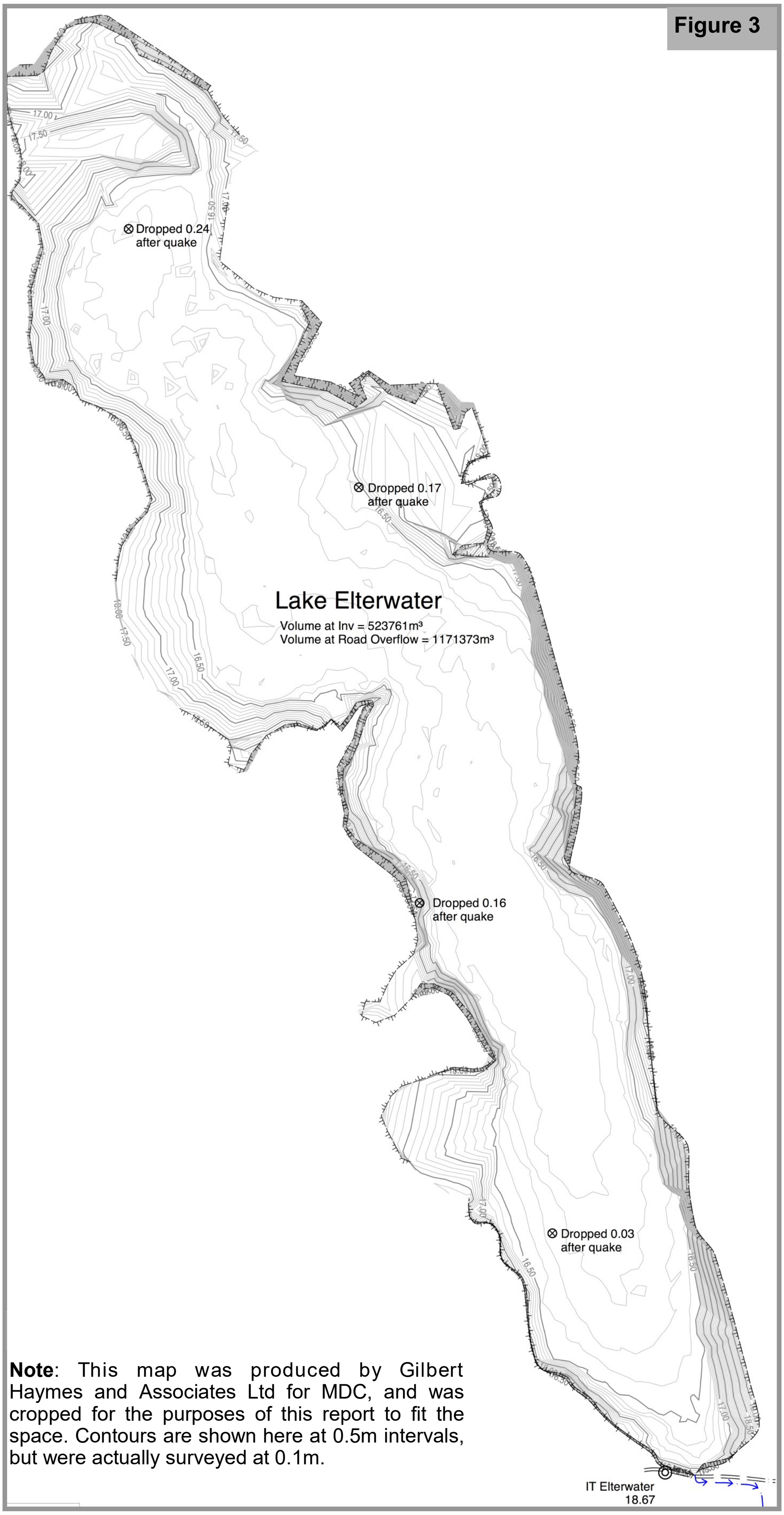
The Marlborough District Council commissioned a survey of the lake during the summer of 2016-17. The initial part of this survey comprised a survey of the lake edges which was carried in September 2016 out while there was still some water in the middle of the lake, and then the centre of the lake was surveyed using a vehicle mounted GPS device in February 2017.

The East Coast earthquakes occurred between these two surveys, with significant changes noted. The whole of the Flaxbourne/Ward area, including Lake Elterwater, rose by 1.5 to 1.8 metres. The survey showed that the southern end of the lake rose 0.24m more than the northern end, which will have the effect of slightly deepening the northern end, as well as adding a small amount to the lake volume.

Figure 3 shows a contour map of the lake bed. The key observations are that lake full volume is 568,000m^3, lower than the previous estimate of volume of 600,000 - 1,000,000m^3 by MDC hydrologist Val Wadsworth.

When full, maximum lake depth is 1.8m. While the edges are comparatively steep, the central part of the lake bed has a very low gradient with only about 40cm difference over about 80% of the width of the lake.

Figure 3



Note: This map was produced by Gilbert Haymes and Associates Ltd for MDC, and was cropped for the purposes of this report to fit the space. Contours are shown here at 0.5m intervals, but were actually surveyed at 0.1m.

Lake chemistry

There has been very little information recorded regarding the chemistry of the lake water. During the course of this study some measurements were made, and these provide a starting point for future work. Basic measurements were taken of lake temperature and salinity in the 10 weeks prior to the lake drying up in early December.

Salinity

The vegetation of the lake has some elements (e.g. Bachelor's button and three square) which indicate a saline influence. Measurements of salinity started while water depths were approximately 25cm, at which time salinity was under the threshold for measurement of 2ppt (seawater is about 36ppt). However, by the time the lake had almost dried up salinity had increased to about 4.6ppt. Clearly, evaporation had increased the salinity of the water, creating conditions suitable for some species which tolerate low to moderate salinity.

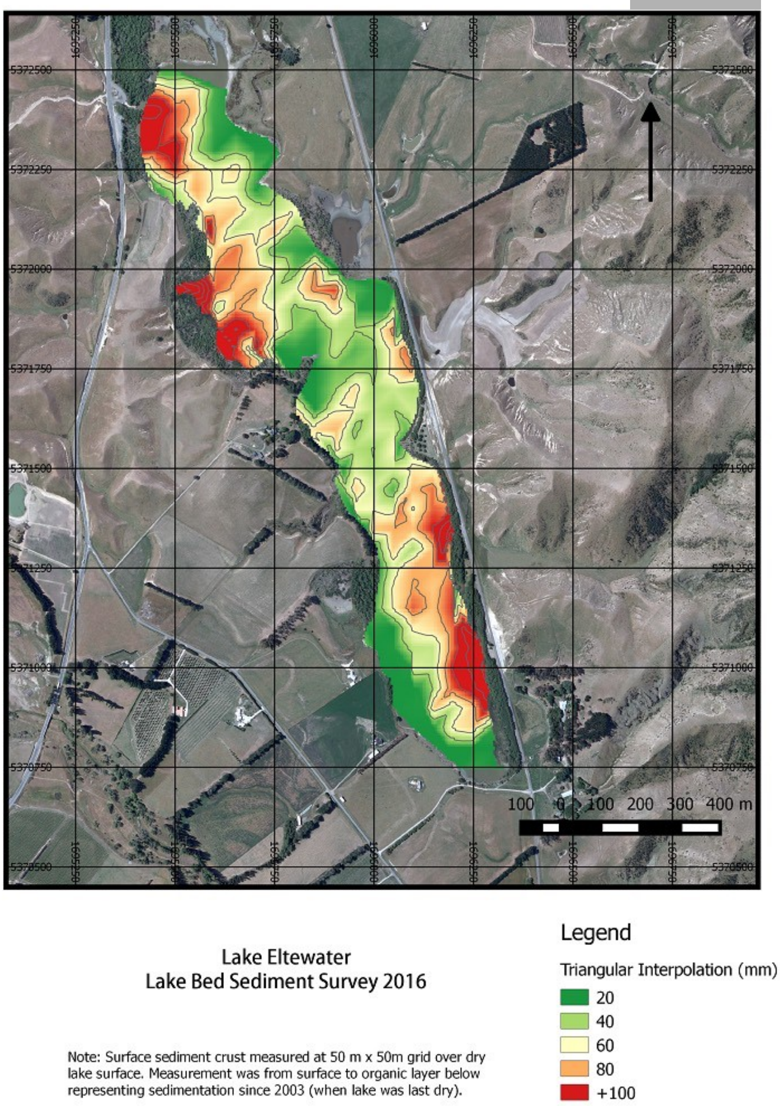
Temperature

The average water temperature for September 2016 was 12.7, October 14.3, and November 15.8. These warm water temperatures are facilitated by shallow water, and create favoured early season habitat for waterfowl.

Sedimentation

Some initial analysis of sedimentation rates was carried out by Adamson (pers. comm., Figure 4) who documented rates of between 1.7 and 8.3mm/year, with an estimate of an average sedimentation rate (by this author) of over 4mm/year. These are relatively high rates compared with Wainono Lagoon (South Canterbury) where a sedimentation rate of 3mm/year has been measured (Schallenberg & Saulnier-Talbot, 2014). Lake Tutira (Hawkes Bay) showed sedimentation rates under pasture as 13.0mm/year, under natural forest 1.47mm/year, and under fern/scrub of Polynesian times 2.43mm/year. Lake Waikaremoana has rates less than 1mm/year (Harding et al, 2004). Twelve Rotorua lakes were analysed and shown to have net sedimentation rates of between 0.6 - 3.0mm/year (Trolle et al, 2008). Lake Horowhenua has deposition rates of about 3.3mm/year. While this was not intended to be a full scale study, it serves to identify a potential issue of concern needing further investigation and management. For example, inflow areas to the lake could be actively managed by plantings and sediment traps to reduce the amount of sediment reaching the lake.

Figure 4

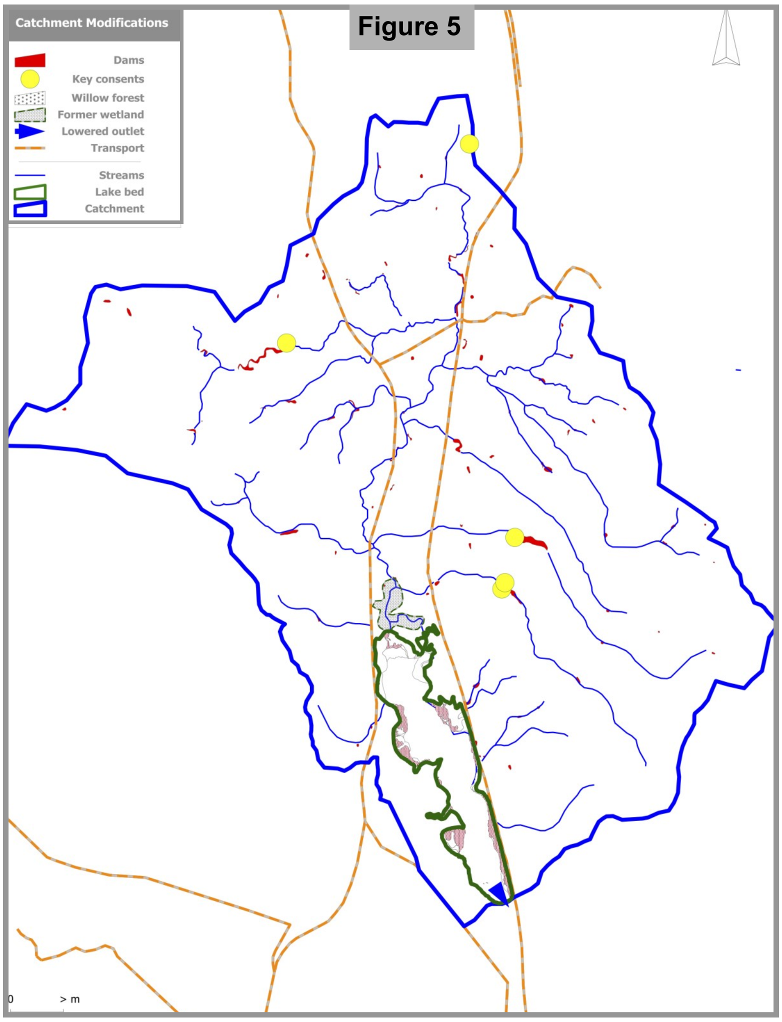


Hydrological modifications

While the natural hydrology of a wetland is the primary determinant of natural character, modifications to this hydrology can have a significant impact on structure and function. The natural setting of the lake is one of a water short catchment, shallow lake morphology, high evaporation and significant fluctuations in water level on a daily, seasonal, and annual basis. Significant changes to the natural state include the presence of transport infrastructure, reduced vegetation cover, willows, sedimentation, damming of tributaries, extraction of water from the system, and loss of former wetland area. Most of these changes are shown in Figure 5 below.

Transport infrastructure

SH1 and the Christchurch-Picton Railway line run more or less parallel to the shores of the lake. While a detailed survey has not been carried out, it is clear from examining aerial photos that the railway in particular has isolated areas of the lake bed, legally and hydrologically. SH1 may have had some effect on natural patterns of drainage, and also isolated a small area of lake bed.



Reduced vegetation cover

Historically it is likely that there was a denser cover of native plants within the catchment, which would have served to slow runoff.

Willows

One of the hydrological modifications to the catchment is the presence of willows. Crack willow (*Salix fragilis*) is recognised as having very high evapotranspiration rates. A cold climate example in Sweden (Iritz et al) documents evaporation rates of about 4 - 5mm/day in summer, and 0 - 4mm/day in spring and autumn. Of total evaporation, transpiration made up 66%, soil evaporation 23%, and interception evaporation 11%. In Australia peak transpiration rates have been recorded up to 15mm/day (Doody & Benyon). The most comparable study was carried out in the Moutere District of Nelson (Amaravathi), where the "average daily transpiration (September to April) of crack willows in the wetland (6.4mm/day) was close to twice the PET for grassland (3.9mm/day)... The highest willow transpiration rate was 12.4mm/day and the lowest was 0.8mm/day. The ratio of annual transpiration of willows to PET was 1.7, but for the summer period it was more than 2." If this ratio is applied to PET values for Grassmere (1155mm), transpiration rates for willows at Elterwater are estimated as being 1963mm/year. When this is applied to the total area of willows around the lake (9.76ha, excluding those already dead) the total volume of water transpired per year by willows is approximately 191,640m^3, compared to 112,729m^3 if the area was in pasture, so an additional 78,910m^3 is used by willows. While some of the assumptions made in this calculation may need refining, it is clear that a significant amount of water is used by the willows.

Dams

A series of dams are found throughout almost every part of the lake catchment. Mostly these are for stock water, but three of the 91 are irrigation dams. Total area of the dams is 7.7ha. Two consents for water take are allocated from within the catchment, and an additional two consents to take water from outside the catchment. Within the catchment one consent allows 400m^3/day to be taken from a dam (35,000m^3) to irrigate 16.19ha, while the other allows 242m^3/day to be taken from two dams (50,000m^3) to irrigate 11ha. From outside the catchment, one consent allows 1552.2m^3/day to be taken from the Flaxbourne River up to 50,000m^3/year, and another permits 3975m^3/day to be taken from the Awatere River, though neither of these consents have been actioned. So current consents allow irrigation of 27.19ha with 642m^3/day from within the catchment, and allow takes of 5527.2m^3/day from outside the catchment.

In considering what impact dams and irrigation have on the hydrology of the lake, the storage of all the dams needs to be considered, as well as the daily takes for irrigation. The storage capacity of the three consented dams is 85,000m^3, but this is not known for the remaining 88 small dams. However, their collective surface area is 4.8ha. If the assumption is made that their average depth is 1m (a very conservative figure), then their collective storage volume is 48,085m^3, giving a total dam storage volume of 133,085m^3. In effect, this means that water equivalent to over 25% of lake full volume is retained in the dam system of the catchment.

Lowered lake outlet

Historically in the 1950's the lake level was lowered about 0.5 metres through digging out the outlet by a local who was concerned with erosion caused by high lake levels and wind. This would have reduced the lake volume by approximately 324,000m^3, about 36% of current lake volume. Another, much smaller lake near Ward, was completely drained in earlier years.

Altered lake inlet

The low gradient, proximity to the lake, presence of drains and poorer draining soils indicate the former presence of wetland at the head of the lake. This would have had the effect of slowing down flows, and filtering sediment and nutrients. In addition, the inlet was formerly via the stream bed to the east, with the new inlet cutting directly to the head of the lake. Clear evidence of sediment deposition is visible on recent aerial photos.

Dry years historic record

At least 8 years (Table 1) with a completely dry lake have been documented (mainly from McConchie, 2009). Some additional records indicate that the lake has gone dry 10 times since 1900, 5 prior to dams being completed by 1978 (so 1 in 15.6 years) and 5 post dam completion (1 in 7.6 years). Part of this is attributable to the drop in lake level in 1955 due to the outlet and drain created by a local to alleviate bank erosion caused by high lake levels. Figures 6 & 7 shows the lake bed at the southern end, in December 2016.

Table 1

Year	Event
1916	Elterwater dry
1933	Elterwater dry
1953	Outlet lowered
1958	Elterwater dry
1974	Moonraker dam built
1978	Taimate dams built
1984	Elterwater dry
2001	Elterwater almost dry
2004	Elterwater dry
2005	Elterwater dry
2016	Elterwater dry
2017	Elterwater dry

Figure 6

Figure 7

Water Balance Estimate for Lake Elterwater

The most critical aspect of the ecology of Lake Elterwater is its hydrology. As the section on climate has shown, it is located within in an area which is windy, very exposed to wind, has high sunshine hours, low rainfall, few days of runoff, and very high evapotranspiration. Collectively these factors result in a water short ecosystem, and when combined with the shallow, long and narrow lake morphology they produces complex interactions involving relatively rapidly changing water levels (compared to more typical lakes), which in turn create characteristic assemblages of plants and animals. Therefore it is important to develop a basic understanding of the hydrology of the lake. Part of this is to estimate the water balance. The approach taken is to develop water balances for the unmodified catchment, then compare this with the current situation.

Unmodified catchment water balance

If the lake is considered in isolation, effectively as a raised swimming pool with no inflow or outflow, then the change in storage over time is the difference between evaporation and precipitation. Evaporation from open water can be estimated from various measures of evapotranspiration, including raised pan evaporation, Priestley-Taylor evapotranspiration, Penman open water transpiration, and raised pan evaporation x a constant. Similarly rain can be measured from a number of sites, and estimates made of what is appropriate for this site. However, some measurement of lake level took place in the three months before it went dry in early December, and this enables some testing of methodology to match actual observations. Over a period of 91 days, (from September 4th to December 3rd 2016) water level dropped by 285mm, as measured at the deepest point of the lake. Table 2 below sets out the two variables being considered, rainfall and evapotranspiration. During this time 80.2mm of rain fell at Lake Grassmere while at Ward 190.9mm of rain fell. Because Grassmere rainfall was just over 40% of Ward during this period, an estimate for Elterwater rainfall was made by calculating 40% of the difference between the two sites, about 127mm. The results in the table give the results for the equation: ΔDepth (mm) = Rainfall (mm) - Evaporation (mm) for each of the rainfall and evaporation scenarios presented. From observation the actual change in level was -285mm, and results which fall within 10% of this are highlighted in the table. While it is fully appreciated that such an approach cannot take the place of field measurements, it is at least based on a measured observation and it serves to indicate which are the best estimates of rainfall and evapotranspiration. With regard to evapotranspiration, clearly Penman Open Water Evaporation is the best measure for open water. With regard to rainfall, an estimate of 100mm rainfall gives almost exactly the observed difference in lake level.

Table 2

Rainfall mm (Sep-Dec)	Grassmere (80.2)	100	110	120	Estimate (127)	Ward (190.9)
E Priestley-Taylor	-154	-134	-124	-114	-107	-37
E Penman	-307	-287	-277	-267	-260	-190
E Raised pan	-426	-406	-396	-386	-379	-309
E Raised pan x 0.7	-274	-254	-244	-234	-227	-157

The relationship ΔDepth = Rainfall - Evaporation holds true in this situation because there were no surface flows, and groundwater flows were ignored. The table illustrates the inherent dangers in choosing location and methodological variants of two parameters (rainfall and evaporation).

To estimate the change in water level over a year requires an estimate of rainfall and evaporation for Elterwater. For the purposes of this exercise a figure of 605mm rainfall and 1400mm evaporation are chosen, giving a water level change for open water of about -795mm. Assuming these assumptions of rainfall and evaporation are correct, and no surface or groundwater flow, then every body of open water will lose about 795mm of depth in an average year.

The previous discussion referred to the lake in isolation, but clearly it is necessary to consider the lake in a catchment context, for which water balance can be calculated using the basic water balance equation: Input - output = change in storage, or the expanded equation: $(P + Q_{in} + G_{in}) - (E + Q_{out} + G_{out}) = \Delta S$. These parameters are shown in Figure 8 (adapted from Greater Wellington, 2005). The limited scope of this investigation excludes field measurement of all of these factors, but approximations of some parameters have been made using published climatic data.

Figure 8

Water inflows	**Water outflows**
Rainfall P • rain that falls directly onto the wetland	**Evapo-transpiration E** • evaporation from standing water or saturated soils • transpiration from plants
Surface water Q_{in} • water run-off from surrounding land • streams and rivers that flow into the wetland • occasional flood waters from nearby streams and rivers	**Surface water Q_{out}** • water run-off from the wetland • streams and rivers that flow from the wetland
Groundwater G_{in} • groundwater inflow	**Groundwater G_{out}** • groundwater outflow
ΔS Change in storage	

However, an examination of Table 3 below reveals the paucity of actual measurements from within the catchment, and the potential variation in calculations arising from incorrect assumptions. It is very difficult to see how any determination of water balance, or impact of catchment modifications on Elterwater hydrology has any credibility without reference to actual measurements taken within the catchment.

Table 3

Parameter	Comment
Lake, catchment, sub catchment areas	Accurately mapped
Lake depth	No historical record
Dam area and volume	Dam areas mapped, no accurate volume estimate
Rainfall	No site measurements documented, significant differences between two nearest stations, Grassmere is 76% of Ward
Evaporation (open water)	No measurements from catchment. Priestley-Taylor estimates are 40% of raised pan estimates
Groundwater flows	No measurements or estimates available, but evidence of groundwater flows at lake edge.
Inflow and outflow	No measurements from catchment, Grassmere RO is 43% that of Ward.
Available water capacity	For rainfall and evaporation similar to Elterwater, AWC of 80mm is 240% that of AWC 160mm. AWC assumed at 150mm, but no mapping of soils undertaken to establish site specific measurements

Modified Catchment Water Balance

Some of the catchment modifications which can be quantified include an adjustment for increased evapotranspiration from willow forest, dam volume, water take, and the lowered lake outlet.

Lowered lake outlet

The lake outlet was lowered by digging an outlet, reducing lake full volume from 892,000m^3 to 568,000m^3, a reduction of storage capacity of about 322,000m^3. This means that lake full volume was about 36% greater than the current total volume of the lake, a substantial change. While it would not have been full for a high percentage of the time, the greater volume would have provided a buffer against the lake drying out. This modification took place perhaps 60 years ago, but should not be forgotten in any consideration of the original nature of the lake.

Willow transpiration

The substantial area of willow forest transpires at a much higher rate than reference evapotranspiration rates which are based on pasture. Calculations indicate that willows use an extra (willow evapotranspiration - pasture evapotranspiration) 78,910m^3/year in an average year, and this is water which would have been otherwise part of the lake.

Dam volume

Dam volume and water take are both able to be quantified. In most situations, it is only runoff from significant winter rain events which will fill the large dams, so they will fill (at best) once a year and be drawn down by evaporation and irrigation. It is the volume intercepted by the dams which affects the hydrology of the lake. Previous calculations have shown that the three large dams hold approximately 85,000m^3, while the smaller stock water dams hold approximately 48,000m^3, so the dams can potentially store 133,000m^3, or about 23% of lake full volume. This scenario assumes that all dams are fully drawn down, which is not the only possibility, but it serves to illustrate the scale of dam storage.

Summary

The combined influence of a winter rainfall event resulting in sufficient runoff to just fill up the dams from empty, coupled with the extra transpiration of willows over a year result in about 212,000m^3 not being available to the lake. This is about 37% of lake full volume. While it is acknowledged that these figures need refining, and illustrate only one scenario, it is clear that hydrological modifications to the catchment could be having a significant effect on the hydrology of Lake Elterwater.

Hydrology conclusion

While this study set out to make an attempt at establishing a hydrological balance for the lake, the lack of actual measured data from within the catchment is a significant limiting factor in the ability to be able to produce any meaningful analysis. Rainfall, evaporation, evapotranspiration, soil moisture capacity, runoff, dam volumes, lake levels and volume, and groundwater flows are all factors for which different assumptions or datasets can be used, producing wildly varying results. This study shows that this is a water short catchment, with a set of factors producing a very unusual hydrology, possibly unique within Marlborough. Daily, annual, and seasonal water level fluctuations in a shallow, warm, windy environment create suitable conditions for a range of communities. This is, however, a finely balanced water supply and significant catchment modifications mean that there is some concern over their impact on the hydrology of the lake. The need for a proper hydrological study involving field measurements is very apparent.

Wetland classification.

It is useful to consider how best to describe the area: lake or wetland? A 'lake' is defined in the RMA as 'a body of fresh water which is entirely or nearly surrounded by land'. Wetlands are defined in the RMA as including 'permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions'. Clearly, both definitions are met. Under the New Zealand Wetland Classification (Johnson & Gerbeaux) system all wetlands are classified initially into hydrosystems which include lacustrine (lakes) and palustrine (most wetlands). Lacustrine wetlands are those associated with lakes large enough to display characteristic lake processes such as fluctuating water levels, wave action, often with some deep water. Arbitrarily they are considered to have a major dimension larger than 0.5km (2km for Elterwater). Palustrine wetlands are normally those not associated with lakes. Technically, the most appropriate classification for Elterwater is that of lake, and this certainly applies when the lake is relatively full. The size, wave action, and fluctuating water levels all fit, the exception being a lack of deep water. It is important to note that classifications do not always accurately describe some of the more unusual situations found in real life, and Elterwater certainly displays some characteristics better described under the palustrine classification. Wetland types which could be used to describe Elterwater include shallow water and ephemeral wetland. In practice, Elterwater functions more like a lake during high levels (Figure 9), and more like an ephemeral wetland at low levels (Figure 10).


Figure 9

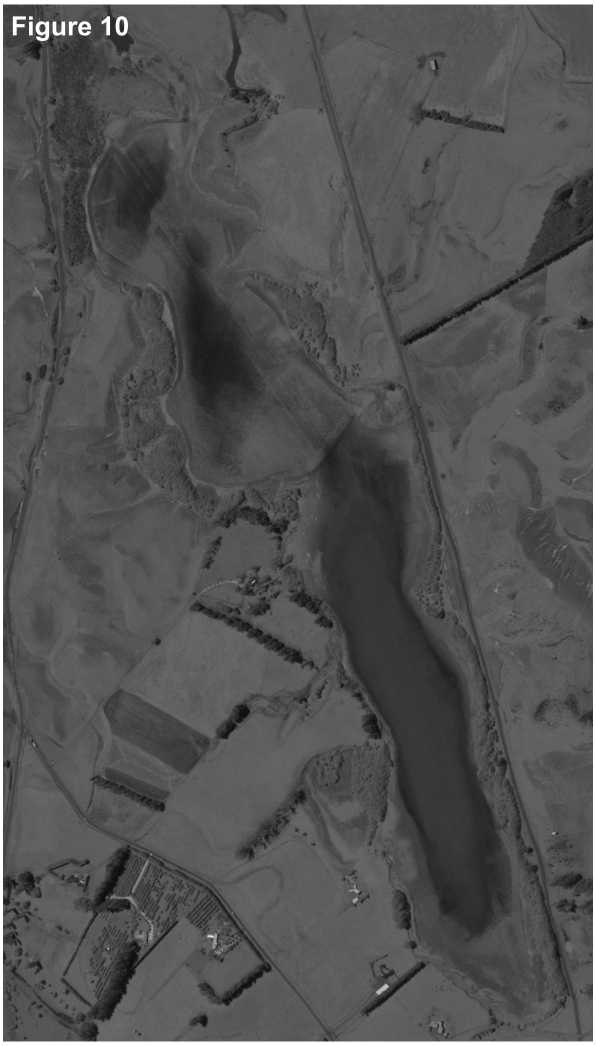


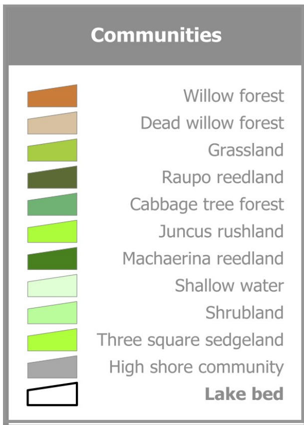
Figure 10

Vegetation

The main vegetation communities of the lake are mapped in Figure 11, with the associated table showing the area covered by each community. Mapping exercises for this lake are difficult and can only provide a snapshot in time, especially for the ephemeral communities. A map showing communities present while the lake is full will be quite different if the lake has been dry for a few years. For the purposes of this exercise the lake has been mapped as if it is full to the edge of the willows. The smaller and more ephemeral communities are discussed separately.

Shallow water

Shallow water is by far the largest community when the lake has water. The shallow depth of water and gently sloping lake bed produce large areas of shallow edge much favoured as feeding areas for bird species such as the pied stilt, shown in Figure 12. The rapid transition from shallow water to vegetated lake bed is illustrated in Figure 13.



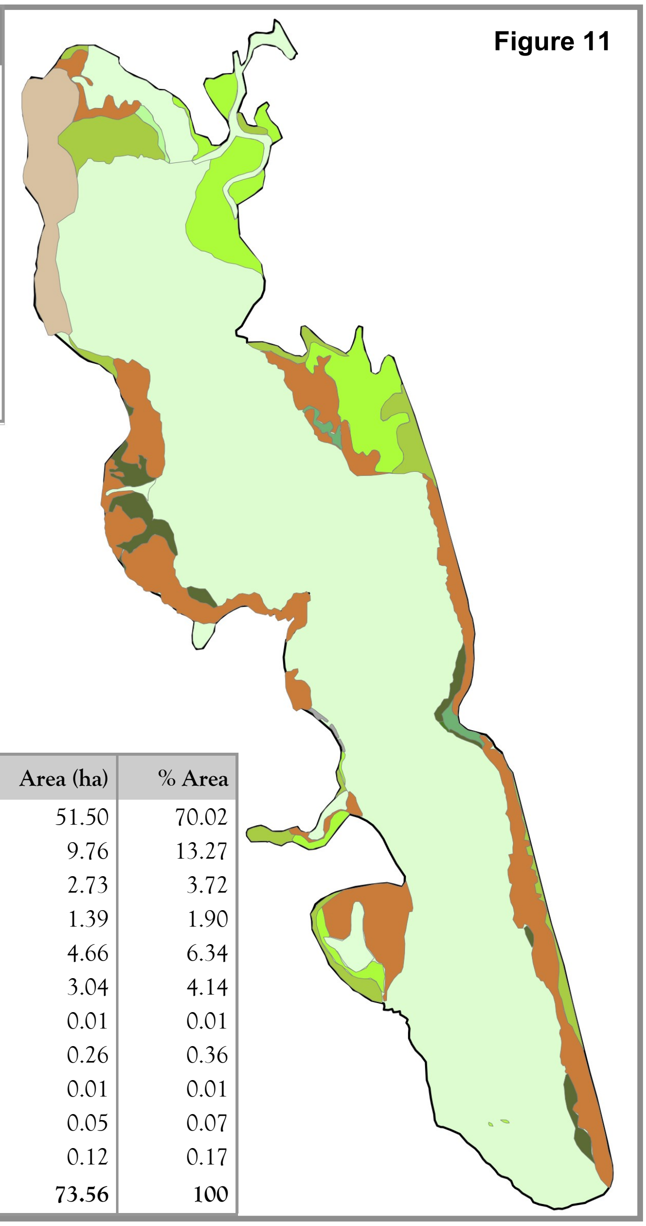


Figure 11

Community	Area (ha)	% Area
Shallow water	51.50	70.02
Willow forest	9.76	13.27
Dead willow forest	2.73	3.72
Raupo reedland	1.39	1.90
Juncus rushland	4.66	6.34
Grassland	3.04	4.14
Machaerina reedland	0.01	0.01
Cabbage tree forest	0.26	0.36
Three square sedgeland	0.01	0.01
High shore community	0.05	0.07
Shrubland	0.12	0.17
Total	**73.56**	**100**

Figure 12

Figure 13

Willow forest

Willows are the largest vegetation community by area and biomass. They are all crack willow (*Salix fragilis*), and mostly mature trees. There does not seem to have been significant spread in recent years. Most areas have a closed canopy, with little regeneration of native species beneath. Figure 14 shows a willow community (with raupo in front) on the eastern side of the lake in winter, while Figure 15 shows part of the same communities in summer. Swamp nettle (*Urtica lineariifolia*) has been reported (D. Barker, pers. comm.) from the understory. *Carex virgata* and cabbage tree (*Cordyline australis*) are occasionally present.


Figure 14


Figure 15

Raupo reedland

Raupo (*Typha orientalis*) forms a series of dense, almost monospecific stands on the lake edge. Usually these are narrow stands, typically with no other permanent vegetation between raupo and the lake. Raupo is adapted to permanently wet conditions, and is able to live in the deepest water of any emergent vegetation. Normally raupo will occupy the deepest water, and less moisture tolerant species will occupy positions higher on the shore. In Elterwater this situation is reversed, which suggests that these stands are indicators of groundwater discharge.

Juncus rushland

These communities are dominated by *Juncus edgariae*, with *J. sarophorus* also present. They often have a range of other species present. Typically they occupy the high shore area of the lake bed, as shown in Figure 16 below showing a narrow strip of rushland on the western side of the lake. Some larger areas occur at the head of the lake on the eastern side, and within the 'lagoon' area on the eastern side of the lake.


Figure 16

Grassland

These are areas of introduced species of grasses at the highest lake levels. The largest of these areas is at the head if the lake, shown in Figure 17.

Figure 17

Cabbage tree forest

Cabbage trees (Cordyline australis) are found around most of the edge of the lake, but only in one small area are there sufficient to map as forest. Almost all are mature trees, with all young plants having been very heavily grazed. Figure 18 shows the area in winter.

Figure 18

Machaerina reedland

Machaerina rubiginosa (formerly *Baumea rubiginosa*) is present in only one small stand, sandwiched between three square and raupo. It was heavily trampled by stock over winter, but has recovered well in summer, as shown in Figure 19.

Figure 19

Shrubland

A small area of shrubland is mapped at the head of the lake. The area concerned should have been mapped as grassland, but it was mapped as shrubland to record the presence of shrubs in several locations around the lake. Not to record this understory component would result in not considering the range of species which go to making up the shrublands of the lake. Species observed include Porcupine shrub (*Melicytus alpinus*), Coastal tree daisy (*Olearia solandri*), shown in Figures 20 and 21 respectively, and *Coprosma robusta.* Porcupine shrub is probably the most common, but there are never more than a few individuals.

High shore communities

Figure 20

Figure 21

Several different high shore communities are present, usually occupying small areas of slightly different elevation or sediment size.

The most common of these communities is dominated by two sedges; the small, clump forming slender clubrush (*Isolepis cernua)*, and the larger *Carex buchananii*. Slender clubrush forms cushions and is the dominant species within the community, while *C. buchananii* occurs as individuals scattered throughout. This community occurs in substrates with a high proportion of gravel, sorted by wave action. Figure 22 shows the nature of this community, with cushions of *Isolepis* interspersed with individuals of C. buchananii, shown in Figure 23.

Figure 22

Figure 23

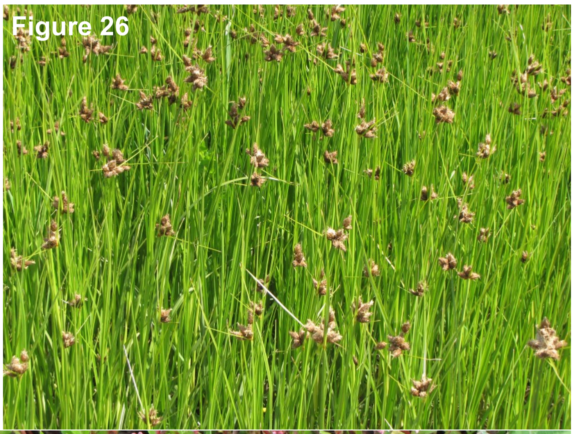
Another high shore community is dominated by *Lilaeopsis novae-zealandiae* with Coastal goosefoot (*Oxybasis glauca ssp. ambigua*) a significant component. This occurs in softer sediments, below the sedge dominated community described previously. The curved leaves of Lilaeopsis are shown in Figure 25, with the distinctive spathulate leaves of Coastal goosefoot shown in Figure 24.

Ephemeral communities

The previously described set of communities are those which are visible when the lake is at a high level. However, when lake level recedes a whole new range of communities develop. To do justice to a description of these communities, and an understanding of how they develop and are influenced by water levels, would require repeated fieldwork over the seasons. However, comparison between late winter and early summer has revealed development of some of these communities. Extended dry periods result in larger areas of these communities, characterised by their extremely dynamic nature.

Three square sedgeland

Three square (*Schoenoplectus pungens*) is not visible during winter, but when early summer comes colonies pop up very quickly. By December 2016 none were observed as large areas, but the number of colonies was increasing. A typical colony was shown in Figure 19, while Figure 26 shows a close up view. Of interest is that three square is typically a plant of saline areas, often found towards the freshwater end of estuaries. This may indicate a saline influence on the vegetation, reinforced by the presence of Bachelor's button.



Willow weed herbfield

In some areas willow weed (*Polygonum persicaria*) has developed very quickly into large communities. One such area is shown in Figure 27. This is another soft sediment community.

Ranunculus herbfield

Celery buttercup (*Ranunculus scleratus*) occupies large areas, especially toward the southern end of the lake. This community occurs on soft sediments, and is illustrated in Figure 28.

Bachelor's button herbfield

By far the most dramatic of these ephemeral communities in early summer was that dominated by Bachelor's button (*Cotula coronopifolia*). This is a community occurring quire high up the shore, sometimes being adjacent to raupo on the western side of the lake. Figure 29 shows it in full flower, a spectacular sight en masse.

Cropland

Much of the lake bed had been planted in ryegrass and oats, with the fertility of the lake being reflected in the crop. Figure 30 shows the edge of the planted crop in mid-December. The height of the crop is approximately 1.5 metres.

Wildlife

Lake Elterwater has been well known for its' wildlife, evidenced by the conservation status of "Wildlife Refuge" dating back to December 1956. A species list is contained in Appendix 1. These records were supplied largely through Jack Taylor's observations as supplied to OSNZ, with a few additions from Dave Barker. The lake is well known to birdwatchers who make regular trips to see whatever species are present at the time.

Waterfowl

It is perhaps best known for waterfowl, with good numbers on the lake any time water is present. Waterfowl particularly like water bodies which warm up quickly in spring and early summer. The mild winter temperatures, high nutrient status, and shallow water assist with creating a highly productive early season environment for waterfowl. Most visible are Canada geese, Black swan, and mallards. At times it is very much favoured by Grey teal, with numbers up to 3,500 being recorded. Paradise shelduck have been counted by Fish & Game Nelson/Marlborough over 32 of the years since 1976, with numbers ranging from none in dry years (all counts take place in January) up to 3500, with an average of just over 1,000. Good numbers of New Zealand shoveler are often seen.

Shags

Black, Pied, and Little shags are all present, with the latter two having had breeding colonies present.

Gulls

Three species of gull have been observed, Black backed, Black billed, and Red billed.

Waders

South Island pied oystercatchers, Pied stilts, Banded dotterel and Black fronted dotterel have all been observed, perhaps a smaller list than expected given the proximity to the Wairau Lagoons and L. Grassmere.

Wetland edge species

Bittern and Spotless crake have been recorded, but these are older records. It is likely that the Bittern record was a bird which was passing through rather than a resident. A 2017 sighting of a Marsh crake is an exciting new record.

Grebes etc

Of particular interest is the presence of Crested grebe, which have bred here on several occasions. In 2014 11 chicks were fledged. Also recorded are the Australian little grebe, and the Hoary headed grebe, which attracted considerable interest amongst bird watchers. The record of a New Zealand dabchick in 1987 was the last known dabchick sighting in the South Island.

Freshwater mussel

There are many shells of the freshwater mussel (*Echyridella menziesii*) visible in lake sediment, so clearly they once had a reasonable presence in the lake. It is likely that they played an important ecological role. As filter feeders they could reduce suspended sediment and organic matter, and improve water quality. They rely on the presence of fish species like the common bully to complete their life cycle. They are classified as an At risk species.

Fish

The two documented fish species are the Common bully (*Gobiomorhus cotidianus*) and the Short finned eel (*Anguilla australis*). These are very important parts of the lake ecosystem if for no other reason than as food for the various bird species which depend on them. For the lake to be restocked after it has dried out requires not only water to refill the lake, but also sufficient to create an overflow to connect the lake both with the Flaxbourne River and the Pacific Ocean.

Boundaries

In discussing the boundaries of the lake it is important to be clear as to exactly which boundary is being referred to. There are a number of boundaries relevant to the lake including property, planning, Wildlife Refuge, AMF considerations, and the ecological boundary. These boundaries are shown in Figure 31 as best as the author can draw them for the purposes of illustration rather than precision.

Property

These are the individual private property boundaries. Note that the lake is Crown Land, without a title.

Planning

In the Marlborough Environment Plan planning maps show the extent of private land and the zones applicable to all land. For the area concerned, the lake bed is zoned Open Space 3, while the adjacent farm land is Rural Environment. The lake itself is also designated as significant wetland.

AMF

There may be *ad medium filum aquae* rights attached to part of the lake. However, the provisions of the RMA and MDC Resource Management plans apply regardless of land tenure.

Ecological lake bed

This is the natural extent of the lake depression as best as can be established by the author, intended to be maximum water holding capacity.

Wildlife refuge

The boundary of the Wildlife Refuge (5 chains from the lake bed) is shown approximately below. The only real effect of this boundary is to control hunting of gamebirds within this area.

Recent events

Several significant events occurred during recent months; the Kaikoura Earthquake hit in November 2016, the lake dried up in early December, and a significant rainfall event in February partially filled the lake. Rainfall throughout 2017 has filled the lake and maintained it in a lake full state.

Earthquake

The earthquake caused the whole area to rise by 1.5 to 1.8 metres. This lifting was not uniform in effect, with the southern end of Lake Elterwater rising 0.24m more than the northern end. Effectively it tilted the lake to the north, shifting the deepest point further north and increasing the total lake full volume.

February rainfall

Typically higher rainfall events occur in winter, but in mid February 2017 132mm fell in a day. This event resulted in considerable runoff, and the lake began to fill, but only partially.

Ongoing rainfall

The lake began to fill with the February rainfall, and filled to capacity in April and has remained in this state up to the end of September 2017.

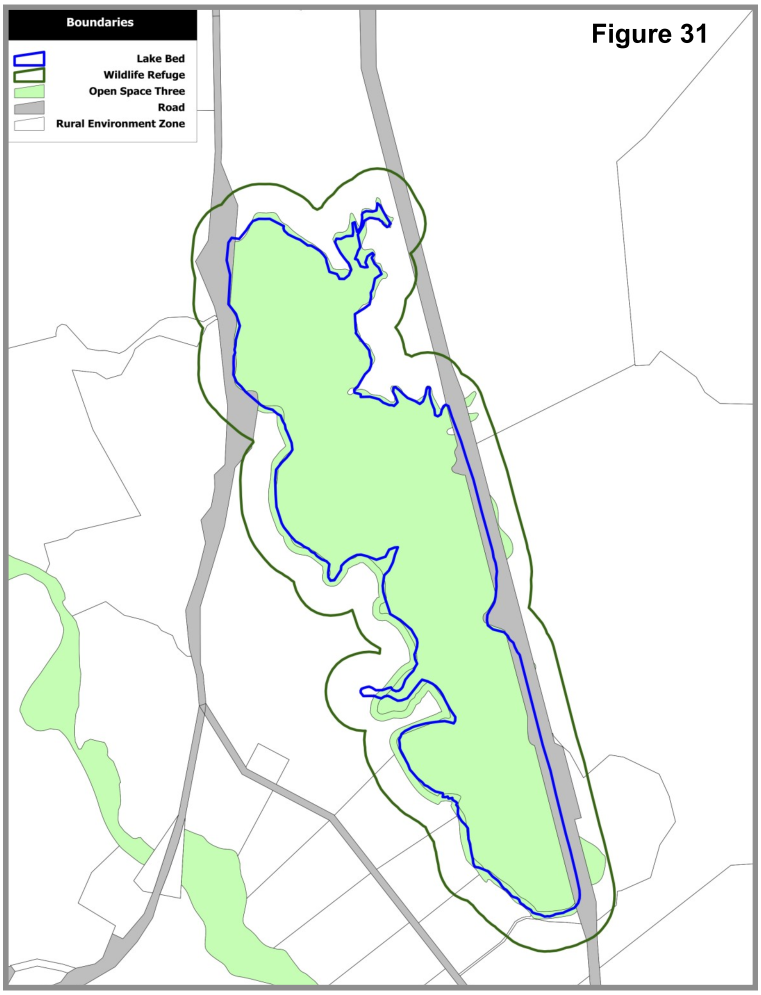


Figure 31

Assessment of conservation values

Conservation values are assessed against two sets of criteria, first those used by MDC to assess significance, and second those used in the Statement of National Biodiversity Priorities (MfE, 2007).

MDC Ecological Significance Assessment

Representativeness

1. Indigenous vegetation or habitat of indigenous fauna that is representative, typical or characteristic of the natural diversity of the relevant ecological district
2. Indigenous vegetation or habitat of indigenous fauna that is a relatively large example of its type within the relevant ecological district.

Elterwater is the only lowland freshwater lake with an ephemeral character in Marlborough. It is the largest freshwater lake in Marlborough. For both criteria it scores High.

Rarity

4. Indigenous vegetation or habitat of indigenous fauna that has been reduced to less than 20% of its former extent in Marlborough, or relevant land environment, ecological district, or freshwater environment

Wetlands have been reduced to less than 10% of their former extent in Marlborough (Preece, 2001).

5. Indigenous vegetation or habitat of indigenous fauna that supports an indigenous species that is threatened, at risk, or uncommon, nationally or within the relevant ecological district

There are at least 9 species with this level of threat status. Again for both criteria the score is High.

Diversity and pattern

7. Indigenous vegetation or habitat of indigenous fauna that contains a high diversity of indigenous ecosystem or habitat types, indigenous taxa, or has changes in species composition reflecting the existence of diverse natural features or ecological gradients.

The site has a high degree of diversity especially with birds, and also vegetation communities, and has zonations and patterning of vegetation reflecting complex environmental gradients. High ranking.

Distinctiveness

8. Indigenous vegetation or an association of indigenous species that is distinctive, of restricted occurrence, occurs within an originally rare ecosystem, or has developed as a result of an unusual environmental factor or combinations of factors.

The combination of low gradient, shallow water, high evaporation, and high winds within a water short catchment have created a complex of environmental factors resulting in the development of an unusual set of communities. Lake margins are classed as vulnerable, and ephemeral wetlands as critically endangered, and both of these ecosystems are present giving a High ranking.

Size and shape

9. The site is significant if it is moderate to large in size and is physically compact or cohesive.

The site is linear, but at over 73ha large enough to display a reasonable degree of resilience. This shape, with its orientation lining up with the predominant nor westerly wind, is one of the factors shaping the character of the lake. The wind exposure coupled with relatively long fetch create surges resulting in daily cycles of wetting and drying. Ranking Medium.

Connectivity/ecological context

12. Indigenous vegetation or habitat of indigenous fauna that provides important habitat (including refuges from predation, or key habitat for feeding, breeding, or resting) for indigenous species, either seasonally or permanently.

This is an early season hotspot for waterfowl breeding, also shags and Crested grebe seasonally. In bird terms the site is relatively close to Lake Grassmere and the Wairau Lagoons. Medium-High ranking.

Sustainability

13. The site is significant if it is ecologically resilient, i.e. its natural ecological integrity and processes (functioning) are largely self-sustaining.

It has survived with little assistance to this point, but ongoing survival and thriving of this ecosystem will depend on management which recognises the values and issues associated with this ecosystem. Medium ranking.

Statement of National Priorities for Biodiversity

In 2007 the Ministers of Conservation and Environment jointly released a Statement of National Priorities for protecting rare and threatened native biodiversity on private land. While it is acknowledged that this is not private land, neither does it have any strong conservation status, and it serves to illustrate some values which perhaps have not been fully considered before

Land Environment with less than 20% indigenous cover left

This refers to classifications made under LENZ (Leathwick et. al., 2002) mapping which maps environments by how much of their natural vegetation cover remains. The highest priority for protection efforts are those which have been most modified. All of the area adjoining falls into the highest priority category for protection.

Indigenous vegetation or habitat for indigenous fauna associated with sand dunes or wetlands

In terms of wetlands, this statement recognises the extreme losses and modifications incurred by these ecosystems, and elevates wetlands to a high priority for protection. Lake Elterwater is clearly a wetland and therefore also meets this criteria.

Indigenous vegetation or habitat for indigenous fauna associated with originally rare ecosystem types

Rare ecosystem types are documented in a review of New Zealand's historically rare terrestrial ecosystems (Williams et. al., 2007) which includes lake margins and ephemeral wetlands. The margins of Lake Elterwater contain some of the communities such as turfland and herbfield which are uncommon. Lake margins are described as Vulnerable (Holdaway et. al., 2012). Ephemeral wetland communities are also present in Elterwater, and these are a characteristic feature. They are considered to be Critically endangered (Holdaway et. al, 2012).

Habitat of acutely and chronically threatened indigenous species

At least six recently recorded species of birds have this level of threat status (see Appendix 1), with another six At Risk, while swamp nettle is considered to be At Risk (Declining).

Summary of conservation values

The two tables below summarise the assessment of ecological values. Table 5 shows results for the criteria used by MDC, while Table 4 shows how the site relates to National Biodiversity Priorities on private land. Despite the modifications which have been made to the lake, these tables summarise a consistent and compelling documentation of high conservation values. .

Table 4

Priority	Yes/No
1. Land environment with less than 20% indigenous vegetation cover left (LENZ Level IV)	**Yes**
2. Indigenous vegetation or habitat for indigenous fauna associated with sand dunes or wetlands	**Yes**
3. Indigenous vegetation or habitat for indigenous fauna associated with originally rare ecosystem types	**Yes**
4. Habitat of acutely and chronically threatened indigenous species	**Yes**

Table 5

Criterion	Ranking
Representativeness	High
Rarity	High
Diversity & pattern	High
Distinctiveness	High
Size and shape	Medium
Connectivity/ecological context	Med-High
Sustainability	Medium
Overall significance	**High**

Current management

Currently the lake is being used for farming, conservation, and recreation. In considering the lake ecosystem it is also necessary to consider activities within the catchment which impact on the lake. A preliminary investigation of hydrology showed that evaporation is greater than rainfall for the lake, and therefore it is completely dependent on catchment runoff to maintain water in the lake.

Conservation and Recreation

Designation as Wildlife Refuge in effect protects the lake from gamebird shooting. It does not confer any protection or ability to manage the land or water, and there is little evidence of management under this status. In recent years some poisoning of willows has been undertaken, to good effect, while there have also been some plantings of native species around the northern end. Some limited predator trapping has taken place, on at least one property (D. Barker, pers. comm.), with cats and ferrets the main target.

Lake Elterwater has always been a popular location for bird watching with its range of species and occasional visits by interesting species. The development of picnic area, toilet, and lookout have facilitated casual recreation by way of picnics and observation of the lake and its wildlife.

Overall the impact of conservation and recreation has been relatively minor on the lake as a whole.

Farming

The lake was dry in parts of 2004, 2015, 2016 and 2017. During this time the lake bed has twice been planted with fodder crops and grazed, with some herbicide spraying undertaken as preparation for planting. It would also appear that stock have had access to the eastern edge of the lake for a longer period of time.

Figure 32 below shows an overview of the lake looking towards the south (photo supplied by MDC, 3/8/2016). Clearly visible are the fodder crops sown over most of the lake bad, cattle grazing, an unplanted area, and the contrast between unplanted lake bed and sown fodder crops.

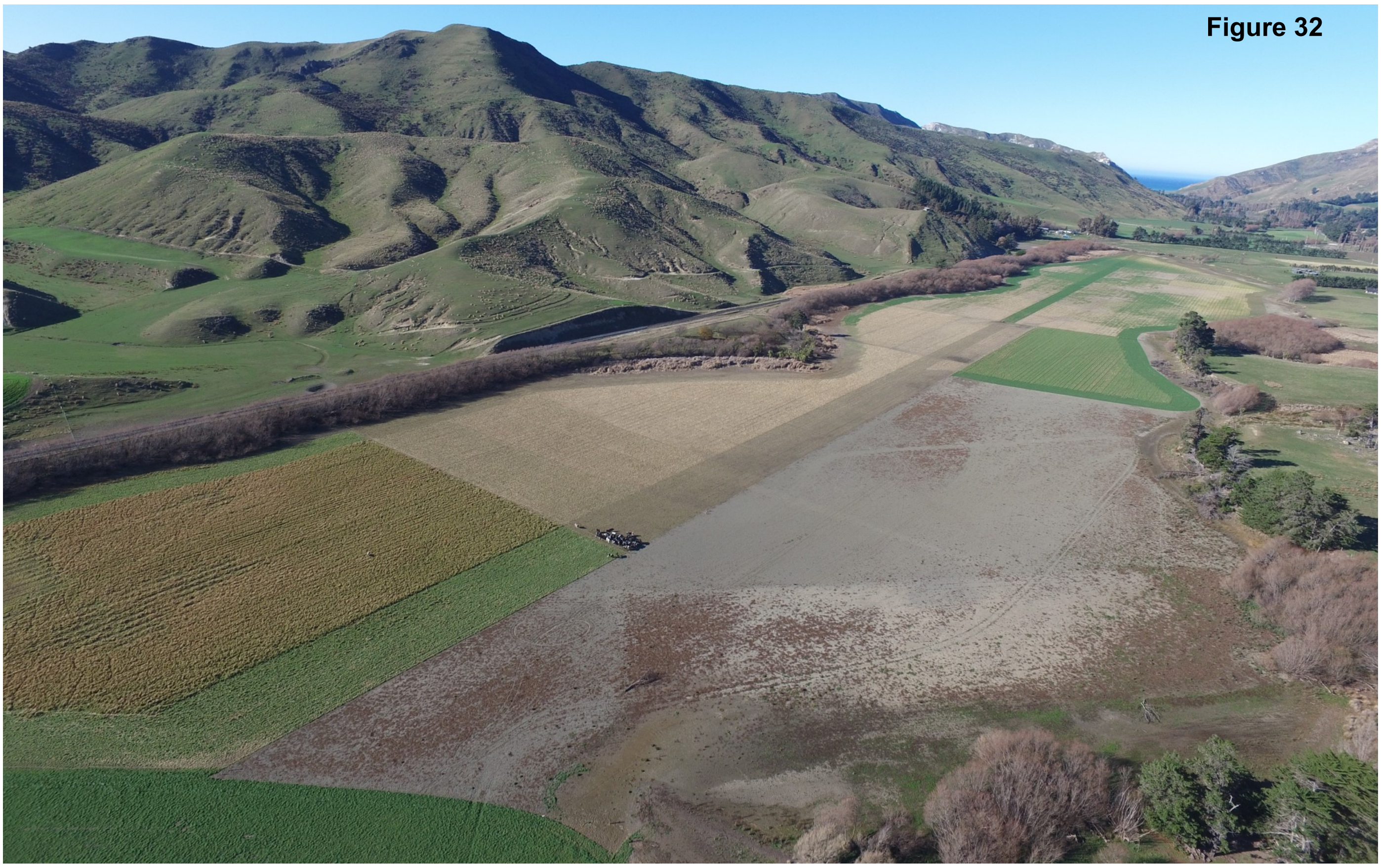


Figure 32

Impacts of current management

In considering the impacts of current and historical management wetland extent and condition is first assessed in a wider context. Then the direct impacts on vegetation, hydrology, and the lake bed are discussed, and a brief assessment of the condition and pressures operating on the lake is given.

Wetlands Context

When considering wetland issues at a local level, it is useful to consider a wider context. Internationally, about 50% of the world's wetlands have been lost. USA has lost 53%, Canada 70%, Europe 50% and very few countries have a higher rate of wetland loss than New Zealand's 90% (Moser et al 1996). Of the published loss rates, the author can find only Italy (93.6% loss) with a higher rate of loss. Loss rates from lowland Marlborough have not been calculated with accuracy, but almost certainly exceed the average rate for New Zealand (Preece, 2001). Focus on this loss rate tends to obscure consideration of the condition of remaining wetlands, which is often very poor, and this is largely unquantified in New Zealand. While overseas the trend is towards extensive restoration and creation of wetlands (with USA now having a net gain of wetlands), New Zealand is still experiencing losses mainly from conversions to more intensive land use such as vineyards and dairying. Although sometimes these losses are obvious (with drains and earthmoving), in many cases the loss in condition is insidious and best described as "death by a thousand cuts". Activities such as drainage, diverting water away from wetlands through damming, grazing, weed invasion etc are cumulative in their effect, and individual effects need to be considered in this context.

Vegetation impacts

Natural communities have been impacted in various ways, particularly through grazing of the lake edge and bed, and through displacement of natural communities by the sowing of fodder crops.

Forage crops have been planted over approximately 75% of the mapped lake bed. Evidence of cattle grazing was observed over much of the lake bed with cattle feeding in both dry areas and grazing in the water. Some of the grazing on lake margins appeared to be more long term than a one off seasonal event. Figure 33 shows a small cabbage tree grazed almost to the ground, protected only by driftwood, while Figure 34 shows heavy grazing pressure on an edge community. The effect of the edge grazing has been to almost eliminate recruitment of native shrub and tree species to edge communities. Continuation of this edge grazing regime will result in reduction in area and viability of these already small communities.

Figure 33

Figure 34

Photo: D. Barker

Planting of crops has caused displacement of natural communities, as shown on Figure 35. In this case it is a sparsely vegetated area, but some of these communities developed much more vegetation later in the season. Crop planting and grazing has introduced a wide range of weeds, which, combined with the crops, has had a major influence on the natural character of the communities of the lake bed.

Figure 36 shows the potential erosive effects when full lake and high winds coincide. The long fetch of waves down the lake can generate substantial waves with considerable potential to cause erosion in unprotected areas. A number of areas at the southern end (but many other areas also) of the lake show signs of bank erosion and have some rudimentary "protection" in place. This situation is almost certainly exacerbated by grazing of the lake edge, which has not allowed development of the natural edge vegetation which would some provide degree of protection against erosion. In walking around part of the lake almost no natural regeneration is apparent, with heavy grazing pressure from cattle destroying almost all young plants.

Herbicide application to lake bed communities is shown in Figure 37, and while it may be that the majority of species sprayed are introduced, it is inevitable that some native species will have been sprayed.

Figure 35

Figure 36

Figure 37

Photo: D. Barker

Lake bed impacts

Agricultural activities have had a number of impacts on the lake. These range from direct input of faeces and urine to both the waters and bed of the lake, cattle trampling and vehicle compaction, and herbicide application. Figure 38 illustrates cattle amongst flooded fodder crops. Although the green areas appear to be dry, the lake in fact extends a considerable distance (ca. 80 metres) into the fodder crop.

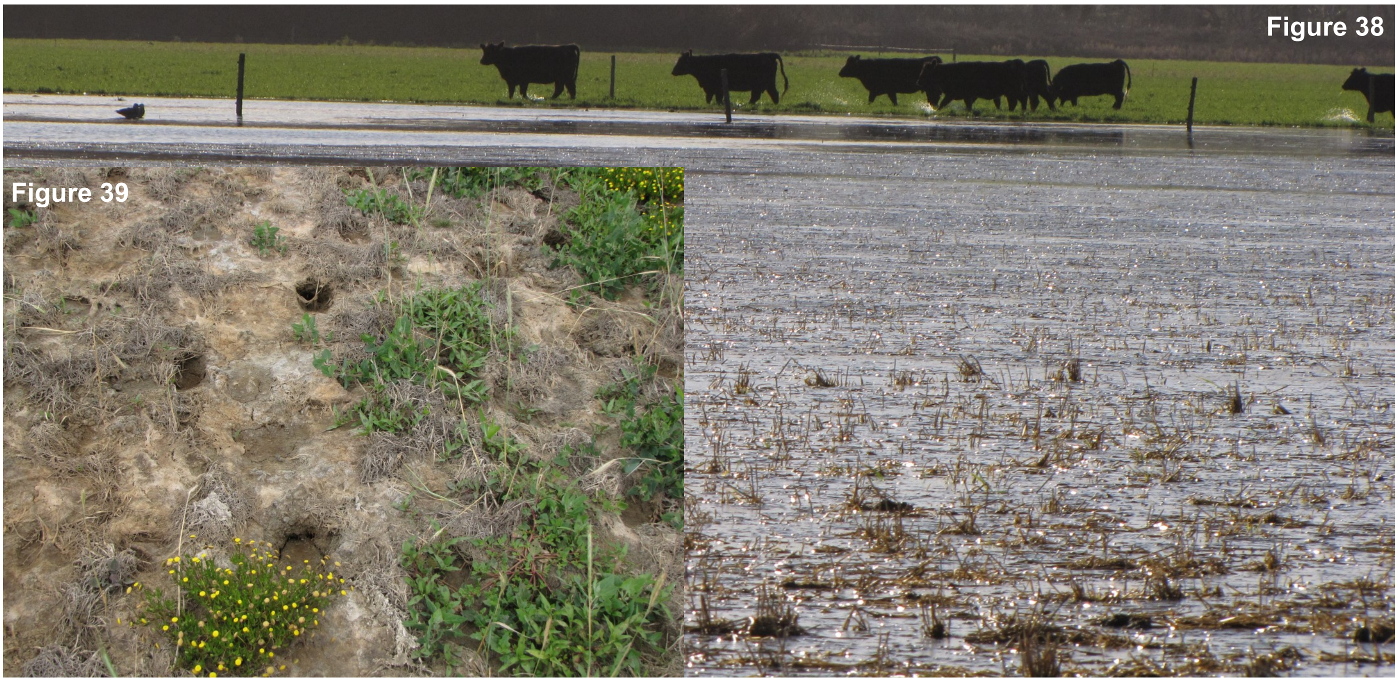


Figure 38

Figure 39

Figure 39 shows hoof prints from cattle in the lake bed. Cattle walking on damp ground create hoof prints which break up the soil structure, cause compaction, and create ideal sites for germination of weeds.


Figure 40

The effect of compaction from tyre tracks is not documented, but Figure 40 clearly shows tyre tracks in December 2016 some considerable time after the original event. It also shows the fence posts which have been dotted throughout many parts of the lake.

Hydrological impacts

There are a range of impacts arising from hydrological changes to the lake and catchment. These are detailed in the section on hydrology, but include lowering of the lake outlet, willows around the lake edge, dams and irrigation in the catchment, and loss of wetland at the head of the lake. Potentially the lowering of the outlet reduced the lake full volume by 20 - 25%, willows transpire a similar amount, and dams within the catchment can retain up to about 40% of lake full volume. Collectively this is a very significant amount, leaving the lake reliant on major rainfall events to fill up. Not only does the lake need to fill up to complete the natural hydrological cycle, but also there needs to be reasonable flow for some time to allow restocking of fish from the Flaxbourne River and the sea. The effect of these modifications is to change the duration and frequency of the natural wet and dry cycles of the lake. Hydrology is the primary determinant of the structure and function of wetland ecosystems, so hydrological changes have significant ecological impacts. A recently proposed alteration to the hydrology of the lake is to use it as water storage for irrigation, using water from outside the catchment. This would destroy the natural hydrological cycles with major changes to the natural character of the lake.

Summary of management impacts

Table 6 summarises the impacts of current and historic management within the Elterwater catchment.

Ideally some of these impacts should have been quantified by before and after sampling, but this has not happened. While it could be argued that some of these impacts are lessened by the relatively low frequency of the lake bed drying out and being used for grazing, the impacts of this management carries on far beyond the time of the actual grazing. This is illustrated by the wetland condition assessment overleaf.

Table 6

Management	Impact
Herbicide application	• Killed some lake bed vegetation communities
Growing fodder crop on lake bed	• Massive change to natural structure of lake bed vegetation • Loss of native vegetation communities as a result of changed nutrient and shade regime • Total change to function of lake bed, now dominated by aerobic photosynthetic grasses rather than mainly bare lake bed • May cause significant drop in water quality as water level rises, grass dies, and oxygen gets used up in decomposition • Vehicles cause some compaction of lake bed
Grazing dry lake bed	• Contributing to higher sediment mobilisation risk • An almost total loss of recruitment of native woody plants • Deposition of large amounts of nutrients from dung and urine contributing to significant changes in nutrient profile of the lake • Trampling opening up soil to weed invasion
Grazing within water	• Deposition of large amounts of nutrients from dung and urine contributing to an immediate significant change in nutrient profile of the lake • Trampling opening up soil to weed invasion • Spread of pathogenic organisms
Grazing lake bed edges	• Dramatically reduced recruitment of native tree and shrub species • Causes significant damage to wetland vegetation communities • Disturbance contributes to increased weediness • Reduces resistance to erosion of lake edge
Hydrological	• Willows reducing lake water supply • Loss of wetland at head of lake increases ‘flashiness’ of flows • Water storage and use in catchment reduces water available to lake • Historic lowering of outlet reduced lake full capacity

Wetland condition assessment

The results of management can be quantified for a given wetland by assessing its condition using a standard methodology (Clarkson et. al., 2004). This methodology looks at a range of parameters to assess condition, with the results shown in Table 7. The score for Lake Elterwater is 13.2, similar to sites such as Lakes Ellesmere & Forsyth in Canterbury, and Lake Rotorua in Kaikoura. Low scores indicate an unmodified site, while high scores reflect greater modification. This score for Elterwater shows that the various impacts previously discussed have had significant adverse effects. However, despite these impacts, just as for Lake Ellesmere, high conservation values remain. The pressures operating on the site are quantified using the same methodology in Table 8, showing a high level of pressures acting on the ecosystem.

Table 7

Indicator	Indicator components	Comment	Score 0-5	Mean score
Change in hydrological integrity	Impact of manmade structures	Lowered lake outlet, drains at head of lake, dams	2	2.7
	Water table depth	Lowered lake outlet, irrigation, dams retain water	3	
	Dryland plant invasion	Willows occupying lake edge, 13% of lake bed	3	
Change in physico-chemical parameters	Fire damage	Not in recent times, probably significant historically	4	2.7
	Degree of sedimentation/ erosion	Not properly documented, anecdotally an issue	2	
	Nutrient levels	Not documented, assumed to be raised by catchment use	2	
Change in ecosystem intactness	Loss in area of original wetland	An area lost at head of lake	3	3.5
	Connectivity barriers	Reduced frequency of flow to Flaxbourne River and sea	4	
Change in browsing, predation, and harvesting regimes	Damage by domestic or feral animals	Cattle grazing edges, sometimes lake bed	2	2.3
	Introduced predator impacts on wildlife	Assumed to be high with narrow band of vegetation	2	
	Harvesting levels	Commercial eel harvest	3	
Change in dominance of native plants	Introduced plant canopy cover	Half of upper shore covered by willows, significant parts of vegetated lake bed	2	2.0
	Introduced plant understory cover	Grass species dominant	2	
Total wetland condition index /25				**13.2**

Table 8

Pressure	Rating	Comment
Modifications to catchment hydrology	3	Water takes for irrigation, stock water, lowered outlet
Water quality within the catchment	3	Growing pressure for intensification of land use
Animal access	3	Stock have had access to edges, occasionally to lake bed
Key undesirable species	3	Willows highly undesirable, documentation of other weeds needed
% catchment in introduced vegetation	5	All of catchment in introduced vegetation
Other pressures	?	Proposal to use lake for water storage
Total wetland pressure index	18	

Legislative and Policy Framework

Management of wetlands in New Zealand is informed and directed by a number of legislative and policy instruments, ranging from international conventions through acts of Parliament to local plans. These are summarised below. Note that italics and bold text are those of the author rather than the original text, and also these listings are not intended to be exhaustive, but provide only a brief summary.

International Instruments

The most relevant international conventions is the Ramsar Convention of 1976, which is the international convention on wetlands. New Zealand is a signatory to the Ramsar Convention, and therefore bound by its provisions. There are two main strands of policy associated with the Convention; designation of sites of international significance and implementation of "wise use of wetlands". Wise use of wetlands is now defined by Ramsar as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development". In turn, "ecological character" is "the combination of ecosystem components, processes and services that characterize the wetland at any given point of time". Although this aspect of the Convention is little known in New Zealand, the following quote from the Auditor General (2001) makes clear our commitment to wetland conservation: "*Both the international and national community have identified the protection and management of wetlands as critical. This is expressed through the Ramsar Convention, and within New Zealand through the RMA and CA. New Zealand is committed to including wetland conservation considerations within national land-use planning, and to promote as far as possible the wise use of wetlands. This commitment may be hindered by the absence of a national framework for planning and monitoring for wetland conservation and protection, but the commitment is not optional. All New Zealanders must be guided by it*".

Note that despite this imperative, and the wealth of guidelines provided, the Ramsar Convention is not mentioned in the Marlborough Environment Plan.

National Instruments

At a national level a range of legislation, policy, strategies, priorities and accords are in place. It could be argued that these do not form a cohesive, logical, or integrated framework, but collectively they provide a direction for management.

Conservation Act 1987

While this Act fundamentally changed conservation management in New Zealand, its main purpose was to facilitate the establishment and running of the Department of Conservation, and offered little by way of direction for wetlands management. Lake Elterwater is administered as a Wildlife Refuge under this act.

Resource Management Act 1991

The RMA was the first Act to define wetlands: "***wetland*** *includes permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions*". It also provides a definition for lake:

"***lake*** *means a body of fresh water which is entirely or nearly surrounded by land*" and **lake bed**: "*in relation to any lake, except a lake controlled by artificial means,– (ii) in all other cases, the space of land which the waters of the lake cover at its highest level without exceeding its margin;*"

In the case of Lake Elterwater, it is clear that it meets the legal definition for both lake and wetland.

Resource Management Act 1991

The RMA (along with the Ramsar Convention) is the foremost document in providing direction for management of wetlands in New Zealand. Some of the key provisions include:

"*In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall* ***recognise and provide for*** *the following matters of national importance:*

(a) ***the preservation of the natural character of*** the coastal environment (including the coastal marine area), ***wetlands, and lakes*** and rivers ***and their margins, and the protection of them from inappropriate subdivision, use, and development***:"

(c) *the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna*

There are a number of other relevant provisions, but these are the most applicable to this situation.

National Biodiversity Strategy 2000

The Biodiversity Strategy contains a number of objectives and actions (perhaps more so than any other similar strategy or policy statement) regarding freshwater ecosystems, the most relevant being:

2.1 (a) Ensure that management mechanisms, including mechanisms under the Resource Management Act and protected area statutes, adequately provide for the protection of freshwater biodiversity from adverse effects of activities on land and in water.

2.3 Restore areas of degraded or scarce natural freshwater habitat and ecosystems that are priorities for indigenous biodiversity.

National Priorities for Protecting Rare and Threatened Native Biodiversity on Private Land 2007

These priorities were fully documented in the section which assesses conservation values. In short, all the national priorities are met by this site.

National Policy Statement for Freshwater Management

The NPS for Freshwater Management was released in 2014 (NZ Govt., 2014). These policy statements are high level documents under the RMA. The wetlands related policies are:

Objective A2 (Water quality)

The overall quality of fresh water within a Freshwater Management Unit is maintained or improved while:

b) protecting the significant values of wetlands

Objective B4 (Water quantity)

To protect significant values of wetlands and of outstanding freshwater bodies.

Dairy Accord (DELG, 2015)

While it is acknowledged that the issues under discussion are not dairying related, these guidelines provide a clear indication of the way in which a major part of the agriculture industry sees the issue of grazing in wetlands.

- *Dairy farms will exclude dairy cattle from significant waterways and significant wetlands.*

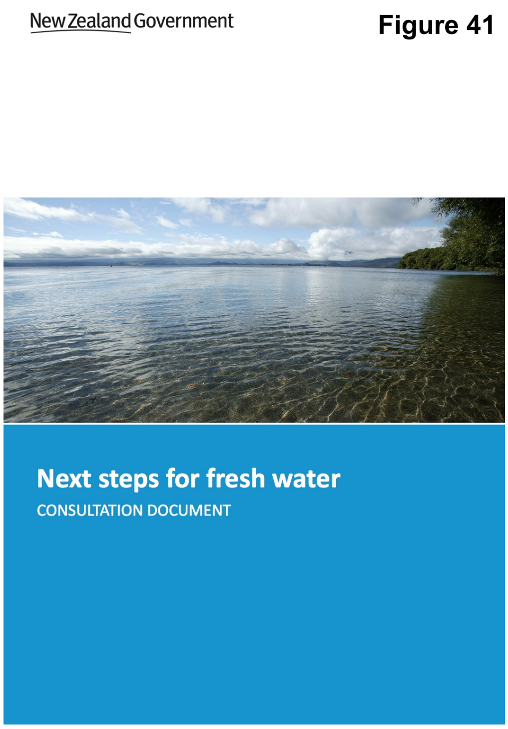
Next Steps for Freshwater Discussion Document (MfE, 2016a)

While this is not yet law, this statement (Figure 41) provides a clear indication of Government thinking (with a high level of support indicated by submissions) with regard to stock grazing of water bodies.

The proposal relating to stock exclusion is:

1.8 Create a national regulation that requires exclusion of dairy cattle (on milking platforms) from water bodies by 1 July 2017, and applies to all other cattle, deer and pigs on plains and rolling hills at later dates.

Figure 41



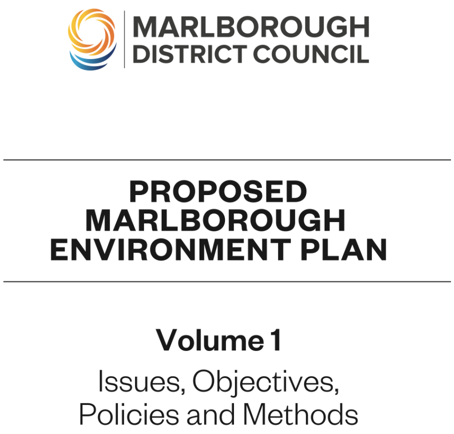
Regional and District

Up until recently the two major documents in operation at a regional and local level were the Marlborough Regional Policy Statement and the Wairau/Awatere Resource Management Plan.

Marlborough Environment Plan

However, with the notification of the Marlborough Environment Plan (MEP), this plan (Figure 42) became operational, and is effectively the major planning document for Marlborough. It combines the three documents of the former planning structure (Marlborough Regional Policy Statement, and Resource Management Plans for the Marlborough Sounds and Wairau/Awatere). The MEP sets out issues, objectives, policies, and methods, with reasons for their adoption. Rules are then set out to achieve the objectives, policies, and methods. The most relevant provisions to Lake Elterwater are documented below, and their fit with current management is analysed in the final section (note that this is not comprehensive and summarised in the interests of brevity):

Figure 42


MARLBOROUGH DISTRICT COUNCIL

PROPOSED MARLBOROUGH ENVIRONMENT PLAN

Volume 1

Issues, Objectives, Policies and Methods

Issue 6A – Resource use and changes in resource use can result in the degradation of the natural character of the coastal environment, and of lakes, rivers and their margins.

Objective 6.1 – Establish the degree of natural character in the coastal environment, and in lakes and rivers and their margins.

Policy 6.1.1 – Recognise that the following natural elements, patterns, processes and experiential qualities contribute to natural character:

(a) areas or water bodies in their natural state or close to their natural state;

(b) coastal or freshwater landforms and landscapes (including seascape);

(c) coastal or freshwater physical processes (including the natural movement of water and sediments);

(d) biodiversity (including individual indigenous species, their habitats and communities they form);

(e) biological processes and patterns;

(f) water flows and levels and water quality; and

(g) the experience of the above elements, patterns and processes, including unmodified, scenic and wilderness qualities.

Policy 6.1.5 – Determine the degree of natural character in and adjacent to lakes and rivers by assessing the degree of human-induced modification to the following: (then follows the criteria used in Policy 6.1.1 above)

Comment - the key point here is that a definition of natural character is provided, but no assessment of natural character for lakes or wetlands appears to have been undertaken yet.

Objective 6.2 – Preserve the natural character of the coastal environment, and lakes and rivers and their margins, and protect them from inappropriate subdivision, use and development.

Policy 6.2.1 – Avoid the adverse effects of subdivision, use or development on areas of the coastal environment with outstanding natural character values and on lakes and rivers and their margins with high and very high natural character values.

Policy 6.2.3 – Where natural character is classified as high or very high, avoid any reduction in the degree of natural character of the coastal environment or freshwater bodies.

Policy 6.2.7 – In assessing the cumulative effects of activities on the natural character of the coastal environment, or in or near lakes or rivers, consideration shall be given to:

(a) the effect of allowing more of the same or similar activity;

(b) the result of allowing more of a particular effect, whether from the same activity or from other activities causing the same or similar effect; and

(c) the combined effects from all activities in the coastal or freshwater environment in the locality.

Policy 6.2.8 – Require land use activities to be set back from rivers, lakes and the coastal marine area in order to preserve natural character.

Comment - These policies require consideration of cumulative effects.

Issue 8A – A reduction in the extent and condition of indigenous biodiversity in Marlborough.

Objective 8.1 – Marlborough's remaining indigenous biodiversity in terrestrial, freshwater and coastal environments is protected.

Objective 8.2 – An increase in area/extent of Marlborough's indigenous biodiversity and restoration or improvement in the condition of areas that have been degraded.

Policy 8.2.2 – Use a voluntary partnership approach with landowners as the primary means for achieving the protection of areas of significant indigenous biodiversity on private land, **except for areas that are wetlands.**

Policy 8.3.2 – Where subdivision, use or development requires resource consent, the adverse effects on areas, habitats or ecosystems with indigenous biodiversity value shall be:

(a) avoided where it is a significant site in the context of Policy 8.1.1...

Comment: Note that wetlands are subject to a regulatory regime rather than a voluntary partnership approach. Effectively, any activity which requires resource consent for a significant wetland (which Lake Elterwater is classified as), shall have any adverse effects avoided. This raises the questions: do the current activities require resource consent, and are there adverse effects? See policy 2.10.2 for further discussion.

2.6 Prohibited Activities

2.6.4 provides a list of water bodies from which take, use, damming or diversion of water is prohibited.

Comment: Given that a similar list in the Wairau-Awatere Plan included Lake Elterwater, it is somewhat surprising to see it omitted from this list.

2.10. Discretionary Activities

Application must be made for a Discretionary Activity for the following:

2.10.2. Any activity in, on, under or over the bed of a lake or river not provided for as a Permitted Activity or limited as a Prohibited Activity.

Comment: While livestock are allowed to enter onto or pass across the bed of a river, no such provision is listed for lakes in 2.7.9, therefore it is not a permitted activity and requires consent as a Discretionary Activity.

Rule 19.3.15.3 The application must not result in the agrichemical being deposited in or on a river, lake, Significant Wetland, drainage channel or Drainage Channel Network that contains water.

Comment: Applies to Open Space 3 Zone, which is the lake zoning.

Current Management fit with Legislative Framework

To this point the legislative framework has been outlined at International, National, Regional and District level. Some wetlands context has been provided, as well as a description of the current management regime and the impacts on wetland values. The purpose of this section is to bring everything together to determine how current management sits within the legislative framework. Table 9 summarises the key directives of the major legislative instruments and compares them against current management.

Table 9

Instrument	Key directive	Fit with current management
Ramsar Convention	"Wise use" of wetlands	Does not meet Ramsar definition of wise use because it does not maintain the ecological character of the wetland
Wildlife Act	Protection of wildlife	Current management not beneficial to wildlife
RMA	Preservation of natural character of wetlands Protection of significant areas of vegetation	Destroying natural character Destroying significant areas of vegetation
National Priorities 2007	Four criteria, as discussed in Summary of Conservation Values, page 20.	In conflict with all criteria
NPS Freshwater	Protect significant values of wetlands both in terms of water quality and quantity	Values are being degraded, not protected
Dairy Accord	Exclude cattle from wetlands	While this does not directly apply, the direction is clear
Next Steps	Exclude cattle from water bodies	Again a later timeline applies, but direction is clear
MEP		
6.2.1	Avoid adverse effects on natural character	Currently adversely affecting natural character
6.2.8	Require land use activities to be set back from lakes	No set back of activities
8.1	Protect as per National Priorities	In conflict with all 4 priorities
8.2	Improvement in condition of degraded areas	Significantly adding to ongoing degradation
8.3.2	Avoid adverse effects on significant wetland	Adverse effects occurring
15.1a	Protect mauri of wai	Current management conflicts with objective
15.1.31	Disturbing lake bed potentially results in adverse effects on water quality	Current management disturbs wet lake bed
2.10.2	Non permitted activities on lake bed require consent	No consent obtained
3.3.13.4	No cultivation of lake bed - applies to Rural Environment Zone, but intent is clear	Lake bed has been direct drilled
19.3.15.3	No deposition of agrichemical on lake bed	Agrichemical has been applied to lake bed

The spirit of the various directives is reinforced repeatedly, with the key issues being the maintenance of natural or ecological character, and protection of significant values of wetlands, especially vegetation. As the framework is worked through from International to District level, the objectives, policies, and rules become more specific, but this particular area is afforded surprisingly little protection at the most specific level of rules. While a number of policies offer clear intent, few rules apply directly. However, there is an overwhelming weight of broader level objectives and policies which have directives at odds with current management, as well as some key specific policies and rules. In particular, the effect of Policy 8.3.2 (Vol. 1) is that where use requires resource consent, adverse effects in a Significant Wetland shall be avoided. This raises the question of whether grazing a lake bed requires consent.

Section 2.7 (Vol. 2) sheds light on this by listing (2.7.9) Livestock entering onto, or passing across, the bed of a river as a permitted activity in the section governing use in, on, over, or under the bed of a Lake or River. This is further explained by 2.10.1, which lists as Discretionary Activities, any activity on, in, over or under the bed of a lake or river not provided for as a Permitted Activity. While stock entry to a riverbed is a Permitted Activity, there is no mention of stock entering a lake bed, therefore this is a Discretionary Activity, and requires consent. This then triggers Policy 8.3.2, i.e. adverse effects in a Significant Wetland shall be avoided, and the only way to avoid adverse effects is to cease the current activities involving stock in the lake bed. Rule 19.3.15.3 dictates against agrichemicals being applied into a lake or Significant Wetland in Open Space 3 Zone. There is some room for confusion with the last part of the rule "that contains water" which can be interpreted as meaning the lake or wetland contains water, but more likely it means the part is attached to i.e. a Drainage Channel Network. Even if interpretation could be stretched to say that "contains water" refers to the wetland or lake, it is not particularly relevant because the lake still contains water, it is just below the surface.

In summary, the spirit of the legislative framework is overwhelmingly at odds with current management, and plan specifics also dictate that stock access to lakes and wetlands is not a Permitted Activity, therefore it is a Discretionary Activity which requires consent, which triggers the requirement that adverse effects shall be avoided. Even a limited inspection shows evidence of adverse effects, indicating that management is in conflict with the legislative framework, both at a broader policy and objective level, and at the level of rules applying to the Open Space Zone 3 and Significant Wetland Designation of Lake Elterwater.

Future management

Although this document is not a Management Plan, it is useful to identify issues and opportunities for the future management of the lake and its catchment.

Hydrology

The critical factor for the structure and function of Lake Elterwater is hydrology, which is best considered at a catchment level. Preliminary studies indicate that this is a water short, finely balanced system about which very little is known in terms of hydrology. Clearly a very high priority is to carry out a thorough hydrological study which will provide a water balance for the lake, from which an understanding of how the lake and it's systems function, and management proposals can be based on fact. This will establish the impacts of stock and irrigation dams, and irrigation takes, as well as the change brought about by a lowered lake outlet.

Willow control will have a positive impact on the hydrology of the lake, allowing more water to remain in the lake. However, there are definite caveats with large scale short term removal, especially with regard to the role played by willows in limiting bank erosion. Also, rapid removal tends to favour weed expansion, so considerable thought needs to be given to the extent, rate, and timing of willow control.

Wetland restoration at the head of lake would reduce the rapidity of flood flows into the lake, and could be designed to remove nutrients and reduce sedimentation, so this would provide benefits to lake hydrology.

Grazing

The current gazing regime is limiting regeneration, damaging plant communities, and creating conditions suitable for weed invasion. Fencing of the lake margin is needed to control stock movement.

Weed management

Weeds are a significant issue for the lake margins and bed, and a long term strategy is needed to reduce their impact on native vegetation.

Erosion control

The long fetch of the lake combined with strong winds create significant waves, especially at times of high water levels. There is considerable potential for erosion which needs to be addressed through stock management and revegetation.

Revegetation

The edge of the lake is dominated by weed species, especially willow, with only small areas of native communities. In the long term this can be reversed, but planning must allow for the possibility of new plantings being underwater in their first season and in a full scale drought for the next two! The key is to view this as a long term project, with goals to match resources and conditions.

Bird habitat enhancement

The lake provides an important habitat for a range of species, and their needs have to be met. For example, shags breed on the lake margins and require roosting trees, so planting and willow control need to be timed to allow for this. Some species particularly like dead trees to roost on in the water, and these could be provided. Floating rafts could be considered as breeding habitat for species such as Crested grebe, to improve breeding success. Such structures also enhance bird watching opportunities, if carefully sited.

Predator control

Given the importance of the area to breeding birds, predator management will improve breeding success.

Reintroductions

Consideration could be given to reintroduction of some species which formerly lived here, once restoration has restored suitable conditions. Freshwater mussels and marsh crake are two species which spring to mind.

Reserve status

The current status of Wildlife Refuge does not do justice to its conservation values, which would be better recognised by classification under the Reserves Act as Scenic Reserve, for example. The lake is adjacent to SH1 so is highly visible, providing an ideal opportunity to showcase its values and restoration efforts.

Discussion

This study set out to:

- provide a basic description of the ecology of the lake
- assess ecological values and place these in context
- describe current management
- summarise the legislative framework
- assess how management fits within the legislative framework
- identify some future management possibilities

Key findings are that the lake has high diversity in both animal and plant communities, as well as a set of hydrological and morphological conditions which create an unusually complex hydrological regime with water level fluctuations on a daily, seasonal, and annual basis. This drives the nature of the communities present at any given time. This is a water short catchment, with evaporation exceeding rainfall, so if only these two factors are considered there is a net loss in water depth each year. Recharge of lake levels is therefore dependent on runoff events, which are uncommon in the catchment. There are a number of hydrological modifications within the catchment which reduce the amount of water available for runoff to the lake. The water short nature of the catchment, the delicately poised water balance of the lake, the potential impact of modifications to catchment hydrology, and the lack of field measurements of hydrological parameters all point to the need for a field based hydrological exercise to establish the hydrology of the lake. Current management is farming based, with clear adverse effects on conservation values. Assessment of wetland condition documents significant impacts. A plethora of planning and policy instruments apply, and current management is shown to be at odds with many of these instruments. While the values of the lake have been impacted by various modifications, a range of possibilities for future management suggest that significant improvements can be made over time. These include weed management, fencing, predator control, habitat enhancement, reintroductions and a conservation status befitting the values of the site.

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Appendix 1 - Bird species recorded from Lake Elterwater

Common name	Scientific name	Conservation status	Comment
Mallard duck	*Anas platyrhychos*		
Grey duck	*Anas superciliosa*	Nationally critical	
Paradise shelduck	*Tadorna variegata*		Important moulting site
NZ shoveler	*Anas rhychotis*		
NZ scaup	*Aythya australis*		
Grey teal	*Anas gracilis*		Important site
Australian mountain duck	*Tadorna tadornoides*		
Australian coot	*Fulica atra*		
Canada goose	*Branta canadensis*		
Black swan	*Cygnus atratus*		
Australasian bittern	*Botaurus poiciloptilus*	Nationally critical	Historical record
Australasian crested grebe	*Podiceps cristatus*	Nationally vulnerable	Important site
Spotless crake	*Porzana tabuensis tabuensis*	At Risk - Declining	Historical record
Marsh crake	*Porzana pusilla affinus*	At Risk - Declining	2017 record
Hoary headed grebe	*Poliocephalus poliocephalus*		
Australian little grebe	*Tachybaptus novaehollandiae*		
Pied stilt	*Himantopus himantopus*		
White faced heron	*Egretta novaehollandiae*		
Royal spoonbill	*Platalea regia*	Naturally uncommon	
Welcome swallow	*Hirundo neoxena*		
Spur winged plover	*Vanellus miles*		
NZ dabchick	*Poliocaphalus rufopectus*	Nationally vulnerable	Last South Island record 1987
Black shag	*Phalacrocorax carbo*	Naturally uncommon	
Pied shag	*Phalacrocorax varius*	At Risk - Recovering	Breeding
Little shag	*Phalacrocorax melanoleucos*		Breeding
Pukeko	*Porphyrio melanotus*		
Southern black backed gull	*Larus dominicanus*		
Black billed gull	*Larus bulleri*	Nationally critical	
Red billed gull	*Larus novaehollandiae*	At Risk - Declining	
Caspian tern	*Hydroprogne caspia*	Nationally vulnerable	
Banded dotterel	*Charadrius bicinctus*	Nationally vulnerable	
Black fronted dotterel	*Elseyornis melanops*		
Swamp harrier	*Circus approximans*		
NZ falcon	*Falco novaeseelandiae*	Nationally vulnerable	
South Island pied oystercatcher	*Haemotopus finschi*	At Risk - Declining	

Appendix 2 - List of Figures

Appendix 3 - Tables