Clutha Catchment Sediment Management Plan

Prepared for Contact Energy Limited

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Contact Energy Limited
Clutha Catchment Sediment Management Plan

CONTENTS

APPENDICES

LIST OF FIGURES

1 Introduction

Resource consents were granted to Contact Energy Limited (Contact) to dam, divert, take use and discharge water to generated electricity from the Clutha River in 2007.

Condition 20 of the Clyde Water Permit (No 2001.585), Condition 14 of the Clyde Discharge Permit to Discharge Water (No 2001.393), Condition 20 of the Roxburgh Water Permit to Dam (No 2001.386) and Condition 19 of the Roxburgh Discharge Permit to Discharge Water (No2001.394) require the preparation of an options plan for the long term management of sediment in the Clutha Catchment that is either stored within or moving through the Crown easement area or is discharged through the Clyde or Roxburgh Dams. The detailed requirements of these conditions are set out in Section 2.1 below.

MWH New Zealand Limited (MWH) has developed this Sediment Management Plan on behalf of Contact Energy Ltd to address the requirements of these consent conditions.

Sediment management practices from around world have been reviewed in order to put the situations at Clyde and Roxburgh into context. As well as presenting an overall sediment management strategy this sediment management plan has reviewed the effectiveness of a number of related consent conditions and their requirements in relation to the management of sediment. The related consent conditions referred to in this report are set out in the Appendix B.

In 2007 Contact Energy engaged NIWA and MWH to provide advice on preparing the sediment management plan and a programme of investigations and studies has been undertaken since then. This sediment management plan brings together the results of these studies and other information required for the preparation of this plan. Throughout this report reference is made to various studies and key technical documents. This report summarises the key conclusions and recommendations of these reports. These reports are referenced at the end of this report.

NIWA and Opus International Consultants (Opus) have provided a number of technical inputs and studies to assist in the preparation of this sediment management plan. The on-going work by Contact has also contributed to this sediment management plan.

The initial version of this plan was submitted to the Otago Regional Council in October 2011. In accordance with the conditions of consent Contact arranged peer review of the plan. This revised sediment management plan has addressed the findings of the peer review.

1.1 Objectives of the Sediment Management Plan

The purpose of this sediment management plan is to provide for the long term management of sediment in the Clutha Catchment that is either stored within or moving through the Crown easement area or is discharged through the Clyde or Roxburgh Dams.

This sediment management plan will:

- Address the requirements of the relevant resource consent conditions;
- Outline management options for sediment;
- Recommend a management approach;
- Outline on-going actions to implement this approach;
- Outline any changes required to existing resource consent conditions to provide for the long term management of sediment accumulation; and
- Review the effectiveness of related consent conditions.

2 Background

The Clutha River catchment has the largest catchment area of any river in New Zealand and also has the largest mean flow of any river in New Zealand. The Clutha catchment includes Lakes Wakatipu, Wanaka and Hawea, all of which are fed by waters from the main divide. Downstream of those lakes the waters of the Clutha are added to by the Hawea River and the Kawarau River as well as the Shotover, Arrow, Nevis, Cardrona, Lindis, Fraser and Manuherikia Rivers.

NIWA 2000 (Clutha River Sediment Budget) provides a comprehensive analysis of sediment movements in the Clutha catchment. NIWA estimated that pre-dams the total sediment load passing Balclutha would have been 2.6 Mt/yr and the main source of this sediment would be the Shotover River, supplying 60% of the total.

The Roxburgh Dam was completed in 1956 and NIWA calculated that an average of 1.96Mt/yr of sediment was trapped in Lake Roxburgh from 1961 to 1989 with an overall trap efficiency of 74%. The accumulated sediment exacerbated flood levels at Alexandra and floods in 1994, 1995 and 1999 caused significant flood damage to the town. A number of mitigation actions have been implemented, as outlined in this sediment management plan, to reduce or mitigate flood effects.

The Clyde Dam was completed in 1992 and NIWA calculated that Lake Dunstan has an overall trap efficiency for suspended sediment of 93%. The Clyde Power Project understood the sedimentation issue and undertook backwater studies to predict sediment patterns 30 and 100 years after lakefilling. Land was acquired to account for raised flood levels. With the Shotover River being the dominant sediment source sediment accumulation in the Kawarau Arm has been measured at 1.32 million m^3/yr and is forming a prograding wedge progressing towards the confluence with the Clutha Arm at Cromwell. This dominant and highly visible sediment accumulation is the focus of a number of Contact's consent conditions.

As expected the sediment accumulation in the Clutha Arm of Lake Dunstan is much less at around 0.38 million m^3/yr and is forming a shallow delta at the head of the arm.

Around the perimeter of Lake Dunstan there are a number of areas of special interest identified in the consent conditions. They include:

- Bendigo Wildlife area at the head of the Clutha Arm of Lake Dunstan
- Bannockburn Inlet
- Lowburn Inlet
- Surface and groundwater abstraction around the Kawarau Arm

Figures 2.1 and 2.2 show the extent of the areas described above and referred to in this sediment management plan.

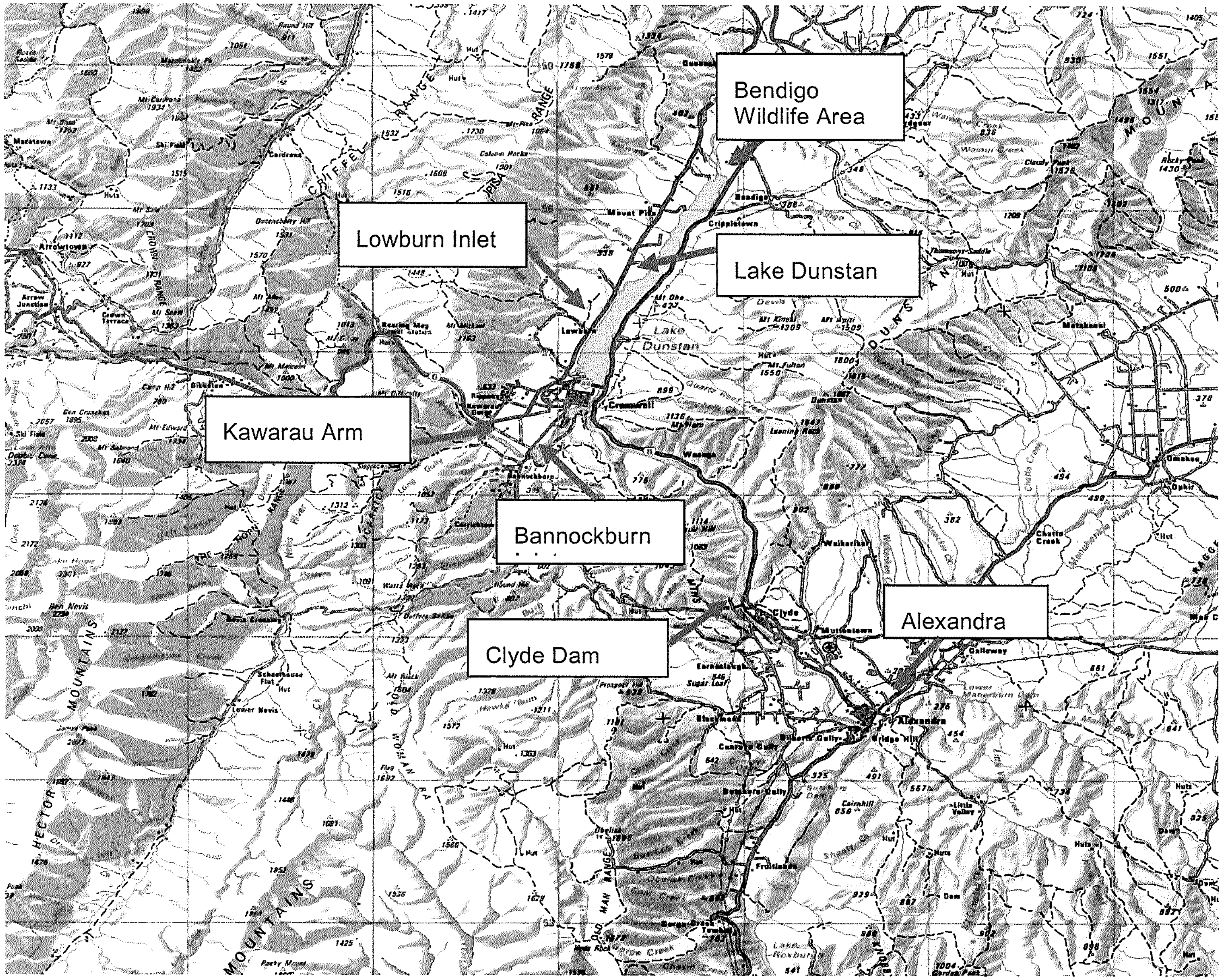


Figure 2-1 : Lake Dunstan key sites

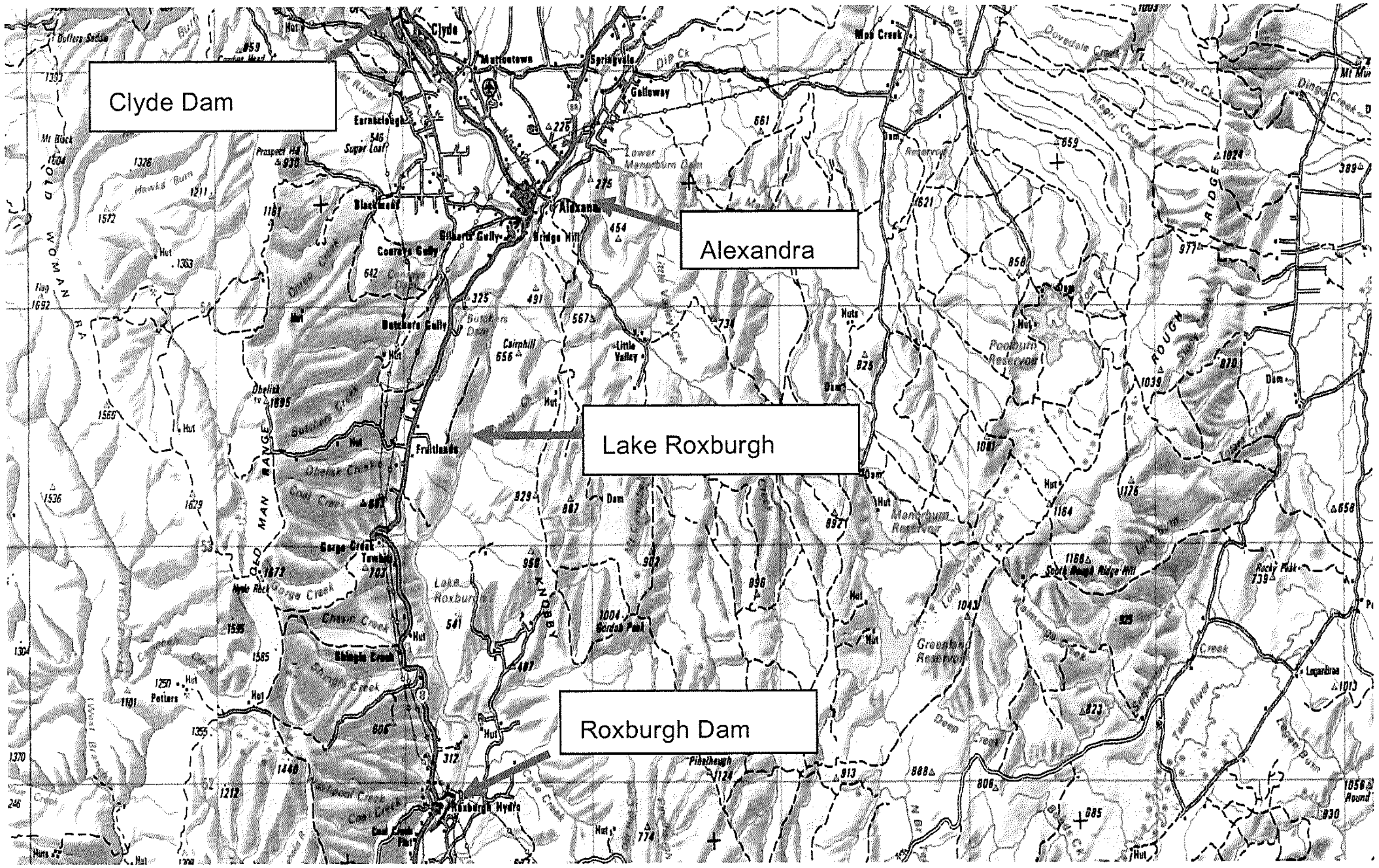


Figure 2-2 : Lake Roxburgh key sites

2.1 Relevant Consent condition

The key consent condition of relevance to this sediment management plan is:

a) *The consent holder shall within six months of the commencement of this consent commission the preparation of an option plan for the long term management of sediment in the Clutha Catchment that is either stored within or moving through the Crown easement area or is discharged through the Clyde or Roxburgh Dams.*

In assessing the options, consideration shall be given to:

(i) Sediment deposition in the head of the Clutha Arm of Lake Dunstan and the implications for the Bendigo Wildlife Area;

(ii) Maintaining access to water for the existing surface water abstractors and the provision of access to water for future users;

(iii) The implications for groundwater abstractors adjacent to the Kawarau Arm of Lake Dunstan specifically those with bores within 100 metres of the existing lake edge;

(iv) Effects on flooding levels in Lake Dunstan and at Alexandra and along the lower Manuherikia River;

(v) Implications of revising the Flood Management Plan if it is not possible to obtain easements over land affected by raised flood levels;

(vi) Implications of changes in sediment trap efficiency of Lake Dunstan if the tipping face is allowed to advance down the Cromwell to Clyde Reach, including in particular the effect on flood levels at Alexandra;

(vii) The causes and mechanisms of the deposition of fine sediment in and on the margins of the lower Clutha River from Roxburgh Dam to the sea;

viii) The extent to which sediment starvation contributes to coastal erosion problems.

b) The plan shall also include an assessment of the adverse and positive effects of each option, and the technical feasibility of each option together with a draft management plan for the imposition of the recommended options.

c) The plan shall be concluded within four years of the commencement of this consent and forwarded to the Otago Regional Council.

d) The consent holder shall commission a peer review of the plan by suitably qualified experts independent of the consent holder.

e) Within five years of commencement of consent the consent holder shall submit the plan and peer review prepared under this condition to Otago Regional Council.

f) Within six months of receiving the plan and peer review, Otago Regional Council may serve notice pursuant to section 128 of the Resource Management Act 1991 of its intention to review the conditions of this consent and the other consents listed in condition 2 to consider the adequacy of conditions governing the long term management of sediment in the Clutha catchment.

3 Sediment Management Practices

3.1 Worldwide practice

A review of international sediment management practice has been undertaken in order to put the Clyde and Roxburgh situations and approach to sediment management into context. This section also outlines the current trends to manage sediment and outlines the various mitigation options for controlling sedimentation.

3.1.1 Background

Many dams have been built in the period from 1930 to 1980, with their reservoirs having been in service for the range of 30 to 80 years. The International Committee on Large Dams indicates that worldwide sedimentation occurs at a rate of about 0.3 percent per year but in many regions is much higher at between 0.5 to 1 per cent per year. Therefore many reservoirs are beginning to find serious problems with sedimentation and many more will over the next 50 to 300 years as their storage capacity is reduced.

MWH reviewed international sediment management practices for Contact in 2008 (MWH, 2008). The review found that while much research had been carried out and mitigating measures were undertaken at many dams comprehensive sediment management plans had not been implemented as yet. There is a growing body of case history information becoming available that provides lessons from the experience of others as to how to mitigate the effects of sedimentation. There are also a number of publications available that focus on sedimentation issues and their management.

The International Committee on Large Dams (ICOLD) published Bulletin 115 (1999) *Dealing with Reservoir Sedimentation.* The bulletin provides detailed accounts of reservoir sedimentation and a number of international case studies. In March 2009 the ICOLD Sedimentation Committee provided MWH with a draft of a new Bulletin *Sedimentation and Sustainable use of reservoirs and River Systems.* The bulletin covers upstream and downstream effects on sedimentation, ecosystem impacts, remedial measures and economic analysis. The 2009 ICOLD Congress in Brasilia addressed under Q 89 the Management of Siltation in Existing and New Reservoirs. A number of papers presented at the Congress have been reviewed in the preparation of this plan.

While it may be possible to assign an economic life to a hydro generation facility and its components, and replace generation components at the end of their economic life, there are not a lot of sites available to provide new sediment free reservoirs at the end of a design life assigned to reservoir storage. A design life approach has the potential to render a project useless once there is complete loss of storage without any provision to deal with it. In the case of Clyde and Roxburgh dams and the storage provided at Hawea, a substantial loss of Roxburgh and Clyde storage may not adversely affect hydro generation, although other effects such as flooding will be important considerations.

The current trend is to acknowledge that impoundments cannot be continuously constructed to offset the storage losses from sedimentation. The focus is on sediment management techniques, that may vary in the life cycle of the dam and reservoir to enable perpetual use of the reservoir in a sustainable manner. The Annadale and Palmieri ICOLD Brazil Conference Q89-R17 paper *"Reservoir Sustainability – identification, assessment and successful implementation of reservoir sedimentation management strategies"* provides a comparison of the Design Life and Life Cycle Management approaches to dam design. The design life approach sets a finite life on a dam prior to its decommissioning and sedimentation issues are considered to be an external environmental factor and do not provide for the management of sedimentation. The lifecycle management approach is a more sustainable approach allowing for reservoir sedimentation management in the design, construction, operation and maintenance of dams and their reservoirs.

The paper outlines that the objective of reservoir sedimentation management is to minimize the adverse effect that sediment deposition in a reservoir has on its usability and concludes that it is more economical to design, operate and maintain large dams and reservoirs in a sustainable manner in contrast to decommissioning of dams and ancillary features at the end of their design life.

Also in recent years the ability to model sedimentation processes has advanced so that now management options can be assessed to develop options that can be optimised and implemented.

3.1.2 Mitigation Options

Methods for controlling sedimentation can be divided into a number of general categories. The first category consists of methods that reduce sediment inflow into the reservoir by controlling sediment generation through watershed management. In addition debris dams can be built upstream to store sediment and bypass tunnels can be constructed around a reservoir to prevent transport of high sediment loads into the reservoir.

Upstream sediment control measures have been studied in the past. In particular, the Shotover River Catchment – Report on Sediment Sources and Feasibility of Control by National Water and Soil Conservation Organisation in 1975 outlined an extensive array of potential remediation measures for the control of bank and slope erosion that they considered could reduce the sediment yield from the Shotover catchment by 30-35%. However the study rated the feasibility of most of the suggested bank remedial measures as having severe or extreme implementation limitations.

It is not considered practicable for Contact to control sedimentation in the Shotover or other catchments that supply sediment to the Clutha River. In a broader sense, land use, gravel extraction and associated effects are controlled by regional and district plans.

The second general category consists of methods that use the flows to reduce the accumulation of sediment in the reservoir. This can include operational modes that allow suspended sediment to be sluiced through the reservoir. Sediment can also be flushed from a reservoir with drawdown of the reservoir so that the flows over the sediment delta approach original river conditions.. If sediment concentrations are such that density currents can form in the reservoir then sediment can be vented from the reservoir using low level outlets at the dam.

The third category consists of removal of sediment by mechanical means such as dredging.

ICOLD Bulletin 115 makes the comment that a range of options can be used and notes. "*The methods of operation need not be inflexible for a reservoir, but can change with different stages of storage loss. Storage operation may be continued in reservoirs with large capacities relative to sediment loads, while sluicing/flushing operation can be introduced once the loss of storage capacity reaches a certain stage. The method of operation may also be changed from year to year according to the inflow patterns.*

3.1.3 Case Histories and Recent Experiences

Cheng Xuemin (1992) reports that the high silt content of Chinese rivers has caused major sedimentation problems at the reservoirs of some of the country's largest hydro schemes. From a study of a number of reservoirs the lessons learned included:

1. Controlling the operating level is a proven approach in controlling the sedimentation process. Lowering the level during the flood season, which is usually the silt concentration season, definitely reduces sedimentation in the reservoir, but of course also results in a loss of power generation.

2. Short term forecasts (24 to 48 hours) of incoming flood peaks, as well as silt peaks, are valuable for the operating personnel of hydropower stations on a silt-laden river, to facilitate prompt operations of spillways and silt flushing systems to minimize reservoir sedimentation.

3. In the case of a small capacity reservoir, sedimentation will take place quickly during the initial years of operation. A state of equilibrium will be reached after 70-90 percent of the reservoir capacity has been lost. At this stage a small percentage of the reservoir volume might be able to be maintained by lowering the operating level during the flood season, or making use of the flood waters from the previous flood season to flush out a small amount of silt and to use some of the reservoir capacity which can be used as daily pondage.

4. Low level outlets are effective for lowering the reservoir operation level if they are properly dimensioned for this. They are also effective at flushing sediment from the reservoir.

5. Low level sluices below the power intake can be used to protect the power intakes so that silt cannot enter the turbines causing abrasion.

6. An upstream reservoir is helpful in alleviating reservoir sedimentation in the downstream projects.

ICOLD Draft Bulletin (2006) reports that at the Sanmenxia Dam in China sediment sluicing has been able to maintain long term reservoir capacity. This was only after reconstruction of outlets at the dam, and much reduced operating water levels. In the period 1960 to 1962 the operating range of the lake was 324.04 m to 332.58 m. During this period the reservoir trapped 93% of the sediment inflow and 7% was passed downstream. In the period of 1973 to 1978 the operating range was lowered to 317.18 m to 305.06 m, with 2 tunnels, 4 penstocks and 8 diversion outlets available for flushing. Sediment outflow was 100% of sediment inflow over this period.

Chen Lie (2008) reports on sediment management in the Three Gorges Project (TGP) reservoir. This mainly covers experience gained during the construction phase of the dam before the reservoir is filled to its full storage and operating phase. "Water and sediment inflows to the TGP reservoir are characterized by very large runoff with relatively small sediment concentrations and both runoff and sediment transport mainly occur during the flood season. The reservoir created by the Three Gorges dam has a narrow-channel shape, with a total length of 680km and an average width of 1000m. Taking advantage of these conditions an operating system known as "impounding the clear water and releasing muddy water" is to be applied to slow down the sedimentation process and ensure long term functioning of the reservoir. The reservoir is drawn down from RL175m to RL 145m over a 6 month period and held at the flood control level of 145m for 3 months before refilling to RL175m."

Reasons for commencing this process early in the reservoir life are associated with maintaining navigation channels near the head of the reservoir and also to reduce flood level rises at Chongqing City in the backwater zone. The author concludes that the data gained during the construction phase gives too short a period to draw general conclusions and should not be extrapolated for evaluation of future events. Longer term observations are considered necessary to obtain statistically significant results and along with gradual rise in the pool level sediment research should be undertaken for a long time. Observations should be integrated with field work, laboratory tests and numerical and theoretical analysis.

Water Power (2011) published two articles on sedimentation, one on China's challenge and the second by Annandale on going full circle with sustainable management practices – in a similar vein to his 2009 Brazil ICOLD Conference paper.

The articles note that the four main sedimentation control strategies utilized in China are:

1. Drawdown and flushing
2. Storing the clear water and releasing (sluicing) the turbid water
3. Releasing turbidity currents
4. Dredging

If turbidity currents are present or can be created in a cascade development from an upper reservoir such that sediment travels through downstream reservoirs with release through bottom outlets, then it presents an enticing sediment management technique since it does not require reservoir drawdown. Such strategies require further investigation and may only be available in special circumstances.

Annandale (2011) makes the observation that by regularly removing deposited sediment from the reservoir it is possible to retain the water supply benefits in perpetuity. His specific comments on sluicing, flushing and dredging follow.

3.1.3.1 Sluicing

This is an operational technique in which sediment laden flows are released through a dam before the sediment particles can settle. In essence, the sluicing concept consists of maintaining sediment transport capacities in the water flowing through a reservoir that will prevent or minimize the amount of sediment depositing in a reservoir. Ideally sluicing should be executed in a manner that will result in the amount of sediment entering a reservoir equalling the amount exiting.

3.1.3.2 Dredging

Dredging generally consists of using hydraulic pumps on barges with intakes down to the reservoir bed, which can create enough suction to remove sediment from the reservoir bottom. Sometimes cutter heads are required as well to loosen materials. Dredging is generally expensive and is rarely used to remove large amounts of sediment. More often than not it is used to perform "tactical dredging" which means it is only used to remove sediment from specific areas.

3.1.3.3 Drawdown flushing

This is a technique requiring drawdown of a reservoir to re-suspend deposited sediment in the reservoir and flush it downstream. Therefore an important requisite for drawdown flushing is that deep gated spillways or low level gates of adequate size should be present in the dam. The gates should be large enough to freely pass the flushing discharge through the dam without upstream damming.

Successful flushing of sediment is best accomplished if river-like flow conditions can be established in the reservoir upstream of the dam. In order to accomplish this it is necessary for:

- The reservoir to have a narrow valley with steep sides
- The river bed to have a fairly steep longitudinal slope
- To maintain river discharge beyond a minimum quantity so that it can mobilize and transport sediment,
- Deep gated spillways or low level gates to be installed in the dam.

The draft ICOLD Bulletin "*Sedimentation and Sustainable use of Reservoirs and River Systems*" is reasonably consistent in the recommended methods to reduce sedimentation rates such as sluicing and flood flushing. For sluicing only partial water drawdown is required as long as sediment transport capacity through the reservoir is high during a flood.

This bulletin includes the figures below (Figure 2.1-3 and 2.1-4) which shows the reservoir capacity/mean annual runoff (MAR) ratio and reservoir capacity /mean sediment yield for reservoirs worldwide and likely boundary lines between operating in storage mode and flushing modes.

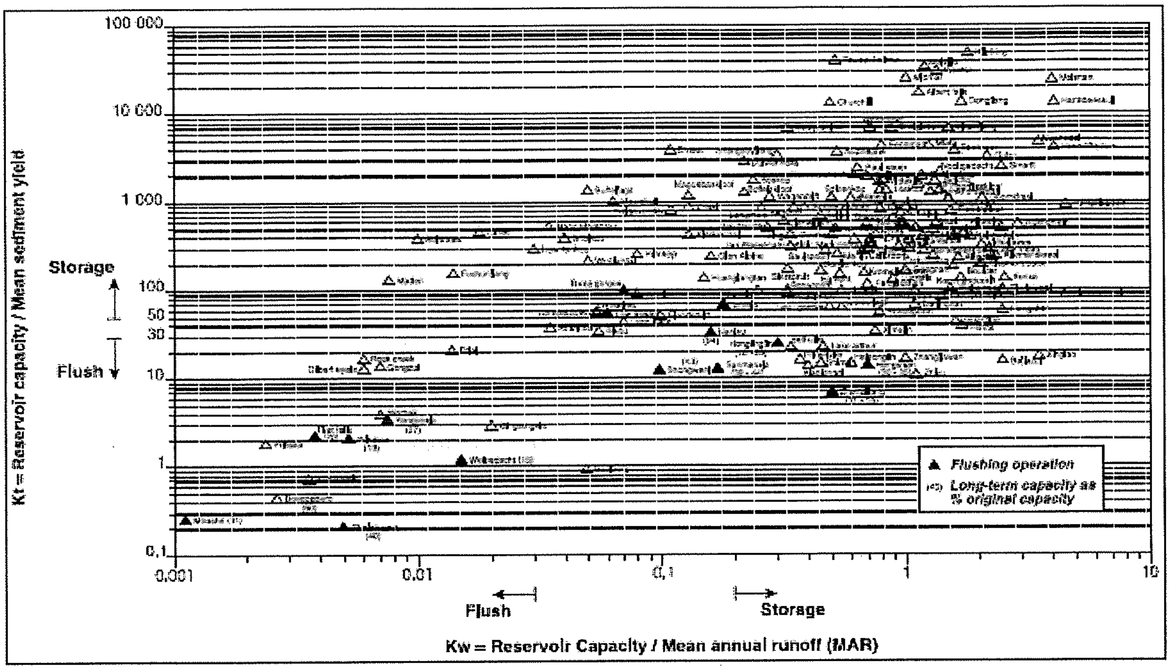


Figure 2.1-3 Dams with different modes of operation

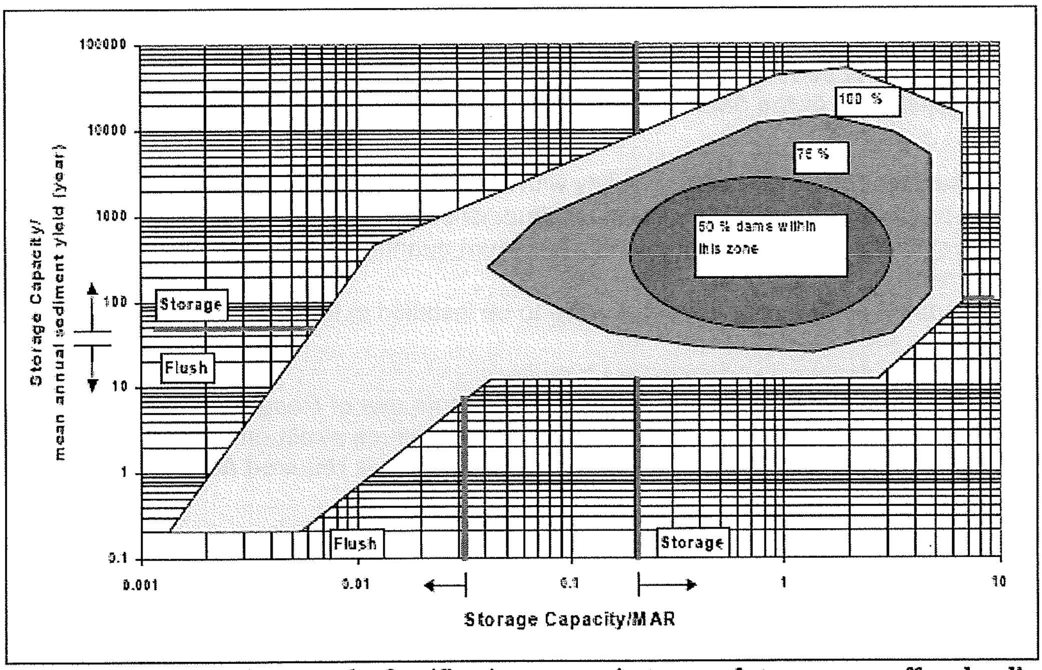


Figure 2.1-4 Empirical reservoir classification system in terms of storage, runoff and sediment yield

The above figure indicates a reservoir could well start its life in storage mode and move to a flushing or sluicing mode as the storage capacity reduced.

The red lines indicate the zones where sediment storage operation is likely to be continued when either storage capacity/annual sediment yield is large or where storage capacity/MAR exceeds 0.2. Flushing can be introduced once the loss of storage reaches a certain stage. The transition zones can be found between the storage and flushing zones in Figure 2.1-4.

At Lakes Roxburgh and Dunstan, hydro generation is run of river and there is no significant reservoir storage requirement. The reservoirs have a narrow operating range that is able to handle daily variations in power generation. It is practical in this situation to allow storage operation in the early life of the reservoir as happened at Lake Roxburgh. Undertaking partial drawdown operations in the early life will serve to redistribute sediment within the reservoir but will not be effective in flushing sediment downstream of Clyde Dam.

Hussain (2009) discusses numerical modelling to assess a sediment management programme for the proposed Daimer Basher Reservoir in Pakistan. This is a very large reservoir, with large inflows and very high sediment volumes – it will fill on a faster time scale compared to Roxburgh dam (up to 1993) and Lake Dunstan.

The storage capacity of the Daimer Basher reservoir is about 10 billion m^3, and the mean annual runoff is 62.3 billion m^3 (1970 m^3/s).

Other key data is:

a)	Full reservoir supply level	RL 1160 m
b)	Minimum reservoir operation level	RL 1060 m
c)	Mean annual sediment load	195 million tons/year
d)	Power intake invert level	RL1030m

A standard case simulation with no sediment management programme indicates that after 50 years the reservoir will be largely filled with sediment and the power intake works would be possibly blocked by sediment deposition. The remaining active storage would be reduced to some 3.1 billion m^3 after 50 years of operation.

Sediment flushing options were considered with the reservoir drawn down to RL 1010 and it was found that flushing need not commence until some 40 to 45 years after impoundment. The reservoir trapping efficiency dropped from 75% in the 45th year to about 10% in the 60th year. The flushing would require a time period of three months with an enormous financial penalty to the project. Further numerical studies indicate that if the minimum operating level was raised 2.0 m/yr after 30 years then flushing could be delayed by several years. Power intake flushing tunnels are incorporated into the design below the intakes.

The study concludes that the reservoir life can be significantly increased from 50 years to about 80 to 85 years if careful management of sediment is undertaken. The plan is also recommending the development of a dam in the Upper Indus basin which would significantly benefit the remaining active storage capacity of the Daimer Basher reservoir and retard the progress of a sedimentation delta towards the dam.

The above review of worldwide practice and case histories has a number of common themes that can be applicable to Lake Roxburgh and Lake Dunstan. This includes:

1. A trend towards long term sustainability
2. Long narrow reservoirs are ideal to limit overall sediment storage by sluicing or drawdown flushing
3. Deep gated spillways or low level gates give flexibility in operating modes available to the dam owner
4. Operating procedures can change during the life cycle of the reservoir with sluicing and flushing being introduced once the loss of storage capacity reaches a certain stage or other effects such as upstream backwater effects need to be managed.
5. The method of operation can change throughout the year depending on flood and sediment inflow patterns.
6. Monitoring information and data gathering used in conjunction with sediment transport analysis programs are tools available to model future options.

Strategies such as releasing turbidity currents and the Chinese practice of storing clear water and releasing turbid water may be relevant to rivers carrying predominantly fine sediment, but would have little benefit in rivers with coarse sediment feed, such as the Clutha. However, there would be benefit in establishing data for the Kawarau River on monthly sediment loads and their variances for operating purposes in the future.

3.2 Lake Roxburgh and Lake Dunstan

Lakes Roxburgh and Dunstan when first filled had a storage/MAR at below 0.01 and storage/mean annual sediment yield at 54 (Roxburgh) and 82 (Dunstan). By 1993 at Lake Roxburgh the available storage/mean sediment yield ratio had dropped to 28 after 37 years of operation. Sedimentation rates into the reservoirs were close to 1% when they were receiving the full sediment inflow. By 1994, when Lake Dunstan had filled and commenced trapping sediment, the available storage/mean sediment yield ratio at Lake Roxburgh then increases. Lake Roxburgh could have operated in storage mode if it were not for the effect of sediment increasing flood hazard at Alexandra that initiated the flood draw down operating procedure.

The Roxburgh and Clyde storage and runoff parameters fall into the ICOLD range of operating the reservoirs in a storage mode for a significant period of time and then switching to sluicing or flushing during floods (or seasonal) to extend the reservoir life to a more long term sustainable position. In Lake Dunstan the storage mode could well operate out to 50 or 70 plus years before sluicing or flushing considerations need to be made.

Roxburgh and Clyde dam do not require a large active storage zone and are essentially run of river stations with a daily pond storage. The inter-seasonal storage is provided at Lake Hawea to transfer spring/summer flows for hydrogeneration at Clyde and Roxburgh in the winter months.

Flood drawdown sediment sluicing has been in operation at Roxburgh since 1994 and with the larger floods has resulted in a redistribution of sediment within the reservoir and some sluicing downstream via the penstocks and spillway. Previous NIWA studies indicated that flood draw down would be more efficient in moving sediment as opposed to seasonal drawdown, as the reservoir would be drawn down for fewer days to move the same amount of sediment.

The low level diversion sluices at Roxburgh dam are now operational sluices and open up the opportunity of more aggressive drawdown in the future (when consents allow) and sluicing or flushing in tandem with Lake Dunstan when sediment trapping in Lake Dunstan is reduced and management options are implemented to encourage a balance between sediment inflow and outflow. Lake Roxburgh is long and narrow and is conducive to sluicing and flushing.

Lake Dunstan has been trapping sediment since 1993 and regular surveys to 2009 have confirmed (Shotover River sourced) a sediment build-up averaging 1.15 million m^3/year in the Kawarau arm of the reservoir. These arms of the reservoir are long and narrow (not as narrow as Lake Roxburgh) and are conducive to sluicing and flushing.

Clyde dam has intakes set low and was able to generate power from RL 177 m to RL 194.5 m during the lake filling process. It also has a large capacity low level sluice adjacent to the power intakes. Specific comment on options for Lake Dunstan and Roxburgh are given in the following sections based on worldwide experiences and consideration of information available since the reservoirs first filled.

3.2.1 Lake Dunstan

Based on the ICOLD Bulletin and worldwide practice outlined above it appears appropriate to operate in a sediment storage mode for at least 50 years until the storage/mean sediment ratio falls to below 30 or 25 based on Cromwell to Clyde dam storage., Sluicing or flushing are then valid alternatives to consider. Prior to considering future alternatives it will be necessary to run sluicing trials, in addition to gathering data and undertaking modelling, before finalizing the long term solution for Lake Dunstan.

In the meantime data gathering would commence and continue involving:

1. Bed sampling to establish sediment particle distributions
2. Bed surveys and flood level predictions as per recent Opus Reports
3. Turbidity monitoring for the Kawarau arm
4. Monitoring associated with Bendigo Wildlife Area
5. Surface extraction and groundwater in the Kawarau arm.

Morphological modelling of the build-up of the sediment delta and flood level projections needs to be completed within the next 10 years in order to more accurately assess future lake level effects. If the lake is to operate in storage mode for the full duration of current consents detailed modelling of the various sluicing and flushing options is premature until more data is gathered. The sediment management strategy timeline (Appendix A) shows the sediment management approach for Lake Dunstan and Roxburgh in context of the life of the consents.

Within the current consents there are still opportunities to trial amended flood operating rules to pass floods near the minimum operating lake levels at the dam, rather than allowing the lake to rise to its flood storage levels. Furthermore as the bottom set materials approach the dam then use of the sluice for flood passage may be advantageous to sluice sediment and assessing options to continue its sluicing through Lake Roxburgh.

3.2.2 Lake Roxburgh

When first filled, Lake Roxburgh had a storage/MAR at below 0.01 and storage/mean annual sediment yield of 54. Based on Figure 2.1-4 the reservoir falls into the storage zone area of the empirical relationship. By 1993 the storage to mean annual sediment yield ratio had dropped to 28 after 37 years of operation, suggesting from the empirical relationship that flushing would be an option. However as the sediment yield dropped to near zero with the filling of Lake Dunstan a continuing storage mode would have been appropriate, if it were not for flood effects at Alexandra.

The sediment accumulation has exacerbated flood levels at Alexandra and cause amenity issues in the Manuherikia River, but, has not affected hydro generation and there are no effects related to irrigation takes, groundwater or amenity in the main reservoir,

The flushing strategy, operated since 1994, has enables sediment redistribution to occur with a percentage of the remobilized volume being sluiced out of the reservoir through the penstocks or over the spillway, In 2010, NIWA built a morphological model of Lake Roxburgh and updated it in 2011 to reflect recent bed survey, surface grain size and core sampling data. This is outlined in more detail in section 4.1.1 of this report.

On-going monitoring and assessment should continue to enable the sediment management strategy to be reviewed at regular intervals. Future operating scenarios may need to consider lower drawdown levels, and use of the sluice gates to promote greater sediment volumes sluiced from the reservoir, and again seasonal versus flood thresholds as a basis of partial lake lowering. The sediment management strategy should be aimed at maintaining or increasing the gains already achieved. Modelling to consider operation of Lake Roxburgh when sluicing or flushing is part of Lake Dunstan operations is not required at present but will be required in the future.

It would be useful to gather sediment inflow data in the Kawarau River to establish whether a seasonal sluicing regime is possible.

Between now and the end of the current consent period, it is anticipated that lake Dunstan will continue to trap most of the sediment, and that sediment load into lake Roxburgh will not change significantly.

The long term alternative operating strategy has not been modelled at present. It could potentially involve operating both Clyde and Roxburgh dam reservoirs for a significant portion of the year to limit bed aggradation within the reservoirs and to promote sediment transport through the reservoirs. Operating at current reservoir levels may still be acceptable in winter months when inflows are statistically lower and flow is supplemented by clear water from Lake Hawea.

3.2.3 Climate Change Effects

The predicted impact of climate change on Clutha River flows for each of the 12 Global Circulation Models (GCM) and the average of the 12 GCMs for the A1B emissions scenario for the periods centred around 2040 and 2090 is presented by Poyck et al (2011).

The model was calibrated to stream flow at Balcultha, at Lindis and at Matukituki and showed the annual stream flow and seasonality of stream flow was well predicted over a 20 year calibration period.

"The consistent trend shown by both the 12 individual model runs, and the 12-model average, is that total annual precipitation will increase under the A1B scenario. As a result, yearly stream flow volumes also increase (mean predicted changes of ~6% for 2040 and ~10% for 2090 scenario), but the percentage contribution of snow melt decreases significantly. The main predicted increase in stream flow occurs in winter and spring (this is true for all GCM simulations and for both future time periods). Despite the predicted reduction in snowmelt contribution, we found no substantial reduction in spring or summer flows for the 12 model average, as the reduced snowmelt was offset by (slightly) higher future rainfall totals. However the individual predictions vary from a circa 10% decrease to a 10% increase in January – April for 2040, and a circa 50% decrease to 25% increase of total streamflow in January – April 2090." Poyck et al (2011).

It is difficult to predict trends in sediment volume transport with the above range of uncertainties and no conclusive predictions on extreme rainfall events that are associated with floods and larger volumes of sediment transport. If mean flow increases by about 6% then sediment supply could increase by a similar amount. On-going monitoring of sediment capture in Lake Dunstan will provide additional data to enable trends to be seen in the future. Trends may affect the implementation time for future operational changes, but not necessarily the options that will be evaluated and implemented. It is considered that the ongoing regular sediment monitoring and the 10-year reviews of the sediment management plan will be adequate to identify and respond to an increasing sediment trend.

3.2.4 Seismic effects

Rupture of the Alpine fault or any other active fault in the vicinity of the Clutha catchment has the potential to result in an increase in landslides and rockfalls creating a surge in sediment transport in post-earthquake heavy rainfall and flood events, particularly in the Shotover catchment. When the sediment is eventually transported to the Shotover delta and fed into the Kawarau River there will be an increase in sedimentation rates into lake Dunstan.. Such changes in sedimentation rates post-earthquake may last for decades or longer and would manifest themselves in increased deposition rates in Lake Dunstan. What response was appropriate would depend on whereon the existing time line the event occurred.

It is considered that the ongoing regular sediment monitoring and the 10-year reviews of the sediment management plan will be adequate to identify and respond to an increasing sediment trend.

4 Lake Roxburgh

4.1 Sedimentation

Lake Roxburgh commenced filling in 1956. The lake progressively filled with sediment until 1992 when Lake Dunstan began filling and from this date the sediment supply was significantly reduced. In 1994 there was a significant flood event. This demonstrated that the flood risk at Alexandra had markedly changed since the reservoir filled. Following this flood a sediment flushing procedure was implemented associated with the partial draw down of Lake Roxburgh levels during flood flows. This was a trial partial drawdown for 8 days then a full bed survey of the lake was completed in February 1994. The partial bed survey in January 1994 and a full bed survey in February 1994 provided data to assess whether sediment was being moved with the partial drawdown of the lake.

When flood drawdown commenced it was not because sedimentation was an impediment for hydro generation, but because of the backwater effect at the upstream end of the reservoir increasing flood risk at Alexandra.

Since 1994 the lake has been drawn down during floods on numerous occasions. Monitoring of water levels at Alexandra have indicated an improvement since 1994. Figure 4-1 on page 17 (Alexandra Bridge Rating Curve) shows the 1994 flood level event and subsequent water levels.

The bed of Lake Roxburgh has been surveyed at regular intervals by Opus including in 2000, 2005, 2008 and 2009. The Opus report in 2000 *(Clutha Hydro Lakes Cross-Sections: Survey and Analysis)* provides a tabulated list of survey dates and sediment volumes. In summary the report shows that 44 million m3 of sediment accumulated in Lake Roxburgh between the first survey in July 1961 and a survey in February 1994. Based on the sedimentation rate Opus estimated that 7 million m^3 was possibly deposited between 1956 and 1961 giving a total of 51 million m^3 since lakefilling commenced.

The Clyde Dam was filled in 1992-3 resulting in the sediment supply to Lake Roxburgh being significantly reduced and instigation of the flushing procedure since 1994 has resulted in redistribution and loss of sediment from the reservoir. Many surveys and reports have been completed since 1994 and Opus 2009 (Lake Roxburgh Sedimentation and Backwater Analysis for July 2009 Bed.) provides the latest sedimentation analysis. The report shows a cumulative bed volume reduction, between 5 and 35km upstream of the dam, of just over 9 million m^3 from 1994 to 2009. Of this amount 5.5 million m^3 (61%) is estimated to have redistributed into the 5 km reach immediately upstream of the dam and the remaining 3.5 million m^3 (39%) has been flushed downstream of the dam.

Most of the sediment in Lake Roxburgh is deposited within the dead storage zone of the reservoir and only a few million m^3 causes the increased backwater effect in the upper reaches of the reservoir. This is why NIWA 2011 (*Lake Roxburgh Sediment Modelling Study – Stage 2 Future Projections*) focuses on sediment movement in the 11 km 'critical' reach downstream of Alexandra.

4.1.1 Lake Roxburgh Sedimentation Modelling

Previous sediment modelling of Lake Roxburgh (Works, NIWA, 1995, Works/NIWA 1996, MacKay et all 2000) used a sediment equilibrium transport model, which has some limitations as described in NIWA Lake Roxburgh Modelling Study – Stage 1 Model Setup and Validation.

In October 2009, Contact commissioned NIWA to undertake a Stage 1 study to build and validate a new morphological model of Lake Roxburgh which was completed in May 2010.

Sediment sampling was undertaken by Contact in 2010 to provide sediment particle size information for the model. NIWA developed and validated the model in an initial study *Lake Roxburgh Sediment Modelling Study – Stage 1 Model Setup and Validation.* A report was prepared on the study and details the model setup and validation process using cross section data from 1961-2009. In this model a scaling factor of 1.5 was applied to the sediment transport formula used within the sand/silt reach between Roxburgh dam and the narrows (at 17 km upstream of Roxburgh Dam). Without scaling the model was found to under-predict erosion in the 5 to 17 km reach. NIWA consider that the scaling factor of 1.5 falls within acceptable limits, and it is standard practice in morphological modelling to calibrate the model to field data by adjusting the sediment transport function.

The new model is an improvement on previous models in that it uses a non-uniform sediment no equilibrium transport model. The main benefit of this is its capability of simulating bed textural adjustments, including surface armouring effects, that may reduce erosion rates under flood draw down operation.

A Stage 2 study was commissioned in August 2010 which updates the morphological model of Lake Roxburgh accounting for recent bed survey, surface grain size and core sampling data. The modelling was to include long term projections to provide a sound basis for arriving at a sediment management strategy and was to build off previous sediment model studies in 1995-1996. The model was then used to compare projections of current and alternative sediment management strategies and for long term simulations to develop near equilibrium bed profiles. In this modelling a sensitivity check was done for the period February 1994 to July 2009 with a zero sediment feed boundary condition and a fine sediment feed of 0.26 Mt/yr, which represents sediment outflow of Lake Dunstan and from the Manuherkia and Fraser Rivers, all combined. The zero sediment feed sensitivity trial gives a slightly better match to surveyed cumulative volume change at the Narrows, and a much better match to surveyed data curve in the 5 -17 km reach.

The good overall agreement in cumulative volume change between the zero sediment feed sensitivity run and surveyed volumes suggests that little of the incoming sediment feed should be depositing. This is consistent with our existing knowledge, from turbidity monitoring, that fine sediment sourced from Lake Dunstan largely passes through Lake Roxburgh as wash load.

This NIWA work has been undertaken to support the long term management of sediment as recommended in this sediment management plan.

The Stage 2 study report *Lake Roxburgh Sediment Modelling Study – Stage 2 Future Projections* used the validated model from Stage 1 to estimate sediment movements over the next 20, 50 and 100 years using different sediment management strategies.

The different management strategies analysed were:

- No Draw down
- Cur Flood Draw Down – current flood drawdown strategy to RL 125.75m
- Cur Flood Draw Down + Agg DD – Current flood drawdown strategy plus more aggressive drawdown to RL120m over a 3 day period each year during normal flow.
- Cur Flood Draw Down +Oct DD – Current flood drawdown strategy plus drawdown to RL125.75m for 3 weeks each year during October.

The mix of strategies modelled by NIWA does not imply that a sediment management strategy is limited to these four options or cannot change over time as the situation demands. They are intended to provide a range of results in order to compare different strategies.

If an aggressive drawdown strategy is considered in the future, the effects on landslides around the reservoir will need to be considered.Piezometric data may need to be gathered from selected landslides to confirm how fast the groundwater systems within and beneath the slide react under current drawdown situations. This will then allow projections to be made to assess slide stability with a more aggressive drawdown.

The NIWA modelling has confirmed that the current flood draw down strategy remains an effective strategy for managing sediment in Lake Roxburgh for the next 50 years. Over this timeframe sediment that passes through Lake Dunstan should be sufficiently fine to mostly pass through Lake Roxburgh as wash load, as was found for the period 1994 to 2000 calibration of the model.

For the sediment supply to Lake Roxburgh NIWA modelled two scenarios. The first assumes that all sediment sourced from Lake Dunstan is sufficiently fine to pass through Lake Roxburgh as wash load i.e. the current situation. The second assumes that Lake Dunstan is fully silted up and is no longer acting as a sediment trap, which is the eventual long term (>150 years) situation.

NIWA also concluded that:

On the basis of the 50 year projection, assuming continuation of the current flood draw down strategy and typical inflows, the average erosion rate in the critical reach from Old Alexandra Bridge to the Narrows is estimated to be 45,000 m^3/yr for the initial 20 years falling to 20,000 m^3/yr for the following 30 years.

The NIWA modelling suggests that an alternative strategy combining the current flood draw down with a more aggressive drawdown could be considered. These alternative strategies are not provided for by the existing consents and the aggressive Draw Down may not be currently feasible from a power grid security of supply viewpoint. The necessary consents and infrastructure upgrades would need to be secured in the future if a more aggressive drawdown was to be implemented.

In the long term (approximately > 150 years), the NIWA modelling indicates that with full bypassing of sediment through Lake Dunstan, a general bed level rise in Lake Roxburgh of approximately 5 m over 50 years, and 7.5m over 100 years is to be expected unless an alternative operational strategy is to be adopted. An alternative operating strategy has yet to be modelled, but it could involve prolonged operation at a lower operating range with a shorter extension to current operating levels in the winter when sediment concentrations are typically low and clean water is discharging from Lake Hawea. The Sediment Management Strategy Time presented in Appendix A shows the indicative dates for the transitional phase from flood draw down to flood draw down and aggressive draw down if required however, an alternative operational strategy may be identified at that time.

The timing of the changes of the operating strategy for lake Roxburgh will depend on many factors including economic imperatives, how Clyde is operated to pass sediment, and possible constraints on sediment and flow releases to minimise downstream impacts. Ultimately it is anticipated that the low sediment flow in the river downstream of Roxburgh dam that has existed since 1956, is not sustainable when Clyde and Roxburgh dams are operated to pass sediment.

As outlined above, the current flood drawdown (FDD) strategy remains the most appropriate strategy at present. However it is considered that modelling of Lake Dunstan and reassessment of progress at Lake Roxburgh should be undertaken over the next 10 years and the flood drawdown strategy then be reviewed when sediment modelling of Lake Dunstan is completed. If at that time flood drawdown has not made further progress other strategies such as aggressive drawdown or seasonal drawdown may need to be implemented once appropriate consents and infrastructure are in place.

In the longer term when operational procedures at Lake Dunstan cause sediment outflow to be close to 100% of sediment inflow, the operational strategy at Lake Roxburgh may need to be further adjusted to prevent a further rise in bed level within Lake Roxburgh. At this time, it remains speculation that one possible alternative strategy may be to operate Lake Roxburgh at lower lake levels at the dam for a significant period of the year and return to current lake levels during the late autumn and winter periods of the year.

4.1.2 Sedimentation Monitoring

4.1.2.1 Cross Sections

The volume of sedimentation in Lake Roxburgh has been monitored by surveying a series of 85 cross sections since 1961 as described in the report by Opus in 2000 *(Clutha Hydro Lakes Cross-Sections: Survey and Analysis)*. While newer technologies are now available to monitor sediment volumes such as digital terrain models it is considered that the cross section method remains a reliable and effective method for a long narrow reservoir such as Lake Roxburgh.

The sedimentation analysis undertaken by Opus after each cross section survey is an informative report on sediment volume changes over the different reaches. The cross section surveys and sedimentation analysis are a requirement of the consent (Refer to Appendix B - Lake Bed Monitoring conditions).

The 2009 Opus report (*Lake Roxburgh Sedimentation and Backwater Analysis for July 2009 Bed*) recommended that:

"In our opinion, the resource consent condition requiring Lake Roxburgh to be resurveyed and results of the survey to be re-analysed more frequently that every 2 years is of little value when the flood activity has been minimal over the inter-survey period and the changes in the lakebed profile are accordingly likely to have been fairly minimal.

The resource consent condition also requires a cross-section survey to be undertaken with 3 months of lake inflows exceeding 1,750 m^3/s. The last 2 surveys have shown that the expected sediment movement over short time periods is likely to be within the survey accuracy, and with the relatively low threshold of 1,750m^3/s to undertake an additional survey, the routine interval could be extended out to 5 yearly and would be adequate to measure the sediment changes which are expected over a longer time period than 5 years".

The 2011 NIWA sediment modelling analyses are consistent with Opus' view that over the next 20-50 years the sediment changes are expected to be slow gradual changes. As part of this sediment management plan it is recommended that the Lake Bed Monitoring conditions be amended to provide for the Lake Roxburgh routine surveys to be undertaken every 5 years.

The suite of Lake Bed Monitoring conditions also requires survey monitoring of a series of cross sections in the Lower Manuherikia River at no more than 2 yearly intervals. It is also recommended that the consent conditions be changed to provide for the Lower Manuherikia surveys also to be undertaken every 5 years.

4.1.2.2 Turbidity

NIWA undertake turbidity monitoring for Contact at the following sites:

- Kawarau River at Ripponvale.
- Clutha at Alexandra
- Manuherikia at Galloway.
- Clutha at Millers Flat.
- Clutha at Balclutha.

The sensors and monitoring procedures are described in the NIWA report *Clutha Turbidity Monitoring Data Report 1995-2010.* The turbidity monitoring provides useful information during flood events, especially when flushing, and enables the effects of the reservoirs on suspended sediment to be assessed. The data can also be used to calculate sediment budgets over flood events as described in Section 8 of the NIWA report.

4.1.3 Dam Gates and Operating Consents

The Roxburgh Dam can pass water via the machine intakes, spillway and sluice gates. The intakes and spillway have sufficient discharge capacity at the onset of floods to lower the lake level for flushing. The spillway capacity reduces as the lake level is drawn down to the flushing level of 125.75m and at the peak of large floods the level of the lake will rise until the discharge matches the inflows. However two of the three original low level diversion gates were upgraded in the 1990's and are fully operational sluice gates. Contact has procedures in place to open the sluice gates during and after floods in order to hold the flushing level and to ensure the sluices are kept clear of sediment.

The spillway, with a crest level of 119.19m, would not have sufficient capacity to lower the reservoir to 120m for the aggressive drawdown scenario. However the low level sluice gates have sufficient capacity to discharge all flows up to 2,500 cumecs at the 120m level and higher flows could be discharged using both the spillway and sluice gates.

The current consents for Roxburgh Dam provide for lowering the reservoir below the 'normal' minimum operating level of 130.15m to 125.75m for flushing when inflows into Lake Roxburgh are anticipated to rise such that within 48 hours they are likely to exceed 850 cumecs the lake level may be reduced to a minimum of 125.75m above datum, as measured at the lake Roxburgh Dam site (Appendix B). In previous drawdown events the sluice gates have not been operated in tandem with the spillway gates. If they were the rise in lake levels above the drawdown level for peak flows in the

1995 and 1999 floods would have reduced with an outcome of increased flushing effectiveness. An action for Contact is to review gate operating procedures at Roxburgh to encourage the use of sluice gates during flushing events.

The Flood Management Plan and Flood Rules (Clutha Flood Rules Version 1) provide operational procedures around this. Contact can confirm that the consents and procedures have operated satisfactorily. The Flood Management Plan includes a condition requiring reassessment of the plan at 5 yearly intervals. This will ensure all these plans and procedures are kept up to date.

It is considered that the dam gates and consents are adequate to implement the current flood drawdown strategy. The gates at Roxburgh can provide for more aggressive drawdown, but as outlined above, Contact would need to resolve any security of supply issues for the lower South Island with Transpower and arrange a secure power supply for the power station itself as auxiliary machines, which currently supply the station, cannot operate with the lake level drawn down below the current flushing level of 125.75 m.

If both lake Dunstan and lake Roxburgh are to operate in a flood drawdown mode as part of future operations, it will be necessary to develop operating rules for drawdown that are based on rainfall and flood forecasting models so that the drawdown can occur in a timely manner ahead of floods, without causing unusually high flows in the Clutha below Roxburgh Dam. The 48 hour period to commence drawdown ahead of an anticipated flood may need to be extended if both lakes are to be drawn down in tandem or sequentially.

As outline above, the current consents do not provide for lowering the lake to 120 m for the aggressive drawdown scenario. If this option is required in the future, Contact would need to secure the necessary consents to provide for this.

The consent application would need to consider effects of increased sediment discharge downstream as well as the effects on recreational users of Lake Roxburgh.

4.2 Lake Roxburgh Flood Effects

When the Roxburgh Dam was constructed in the 1950's, the backwater effect of forming the lake was understood and land was acquired around Alexandra generally up to an elevation of at least 140.28m. However, the rate of sediment inflow was not accurately predicted or provided for at the time.

The effect of sedimentation on flood levels is clearly shown on the Alexandra Rating Curve in Figure 4.1 below. This shows that the 1957 flood (soon after the Roxburgh dam was commissioned in 1956) reached an elevation of RL136.68m and by 1994 the effect of sedimentation had increased flood levels by approximately 4.2m. Implementation of the flushing procedure since 1994 has reduced the effect to around 2.6m.

Floods in 1995 and 1999 exceeded the 140.28m level (141.91m in 1995 and 142.29m in 1999) and caused extensive flood damage around Alexandra. Following the 1999 flood the Crown and Contact Energy developed a flood mitigation package which included:

- Property purchase
- Purchase of flooding easements over private property
- Construction of flood banks (true left bank only) around Alexandra.

Where property owners were agreeable, flooding easements were purchased over entire properties or over parts of properties up to elevations of around 142.7m. Agreements were not reached with all property owners.

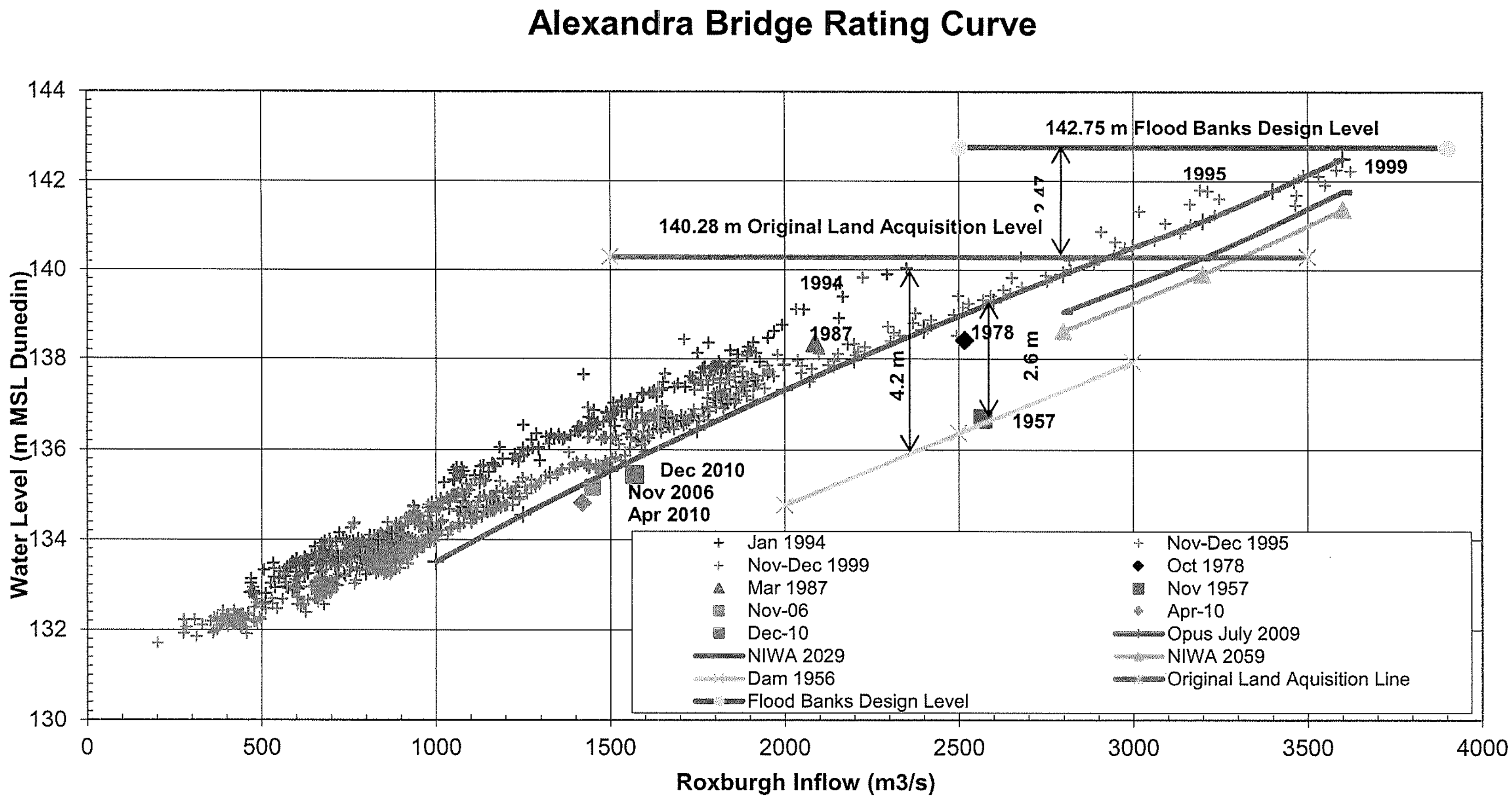
The flood banks were designed to a water level of 142.75m with 0.5m freeboard to the crest level of 143.25m.

The flood banks design level and property easements at 142.7m are 2.42m higher than the original land acquisition level of 140.28m. This is almost equal to the current sedimentation effect of 2.6m.

Further reduction of flood levels is predicted by NIWA if the flushing procedure is continued and these are also shown on Figure 4-1 below.

In 2009 Contact applied for, and was granted, a variation to the consents to increase the normal operating level at Roxburgh Dam from 132.0m up to 132.6m. Flood issues were carefully considered and the Flood Rules were amended to require the lake level to be lowered below 132.0m in advance of flood flows so that flooding is not exacerbated by the increased operating level.

Figure 4-1 : Alexandra Bridge Rating Curve



4.2.1 Manuherikia Flooding Effects

The large floods in 1995 and 1999 demonstrated that the flood levels in the Lower Manuherikia reach are principally a backwater effect determined by the total inflow into Lake Roxburgh and has been impacted by sediment build up in lake Roxburgh in a similar manner to water levels at Alexandra. Equally the benefits of continued flushing that can occur at Alexandra will also be reflected in the Lower Manuherikia reaches as well.

4.2.2 Flood Monitoring

The lake level is monitored at the following locations:

- Roxburgh Dam
- Clutha at Alexandra.
- Clutha at Clyde.
- Clyde Dam tailwater level.
- Manuherikia at Campground (ORC site).

Flow monitoring is undertaken at:

- Clyde Dam
- Clutha at Clyde
- Manuherikia at Ophir
- Manuherikia at Campground.
- Roxburgh Dam.

It is considered that this monitoring provides more than adequate coverage for monitoring water levels and flows during floods and providing suitable data for backwater analyses.

4.3 Feasibility of Dredging Lake Roxburgh

The feasibility of dredging sediment from Lake Roxburgh to reduce the flood effect at Alexandra was considered in a study by URS commissioned for Contact's resource consent hearings in 2003. The report *Lake Roxburgh Sediment Removal Options Comparative Study* concluded that *"On the basis of cost, practicability and potential environmental effects, Best International Practice dictates that flushing is a better option than dredging for sediment removal at Lake Roxburgh"*.

In preparing the sediment management plan a review of the URS study has been undertaken. It is considered that dredging technology and costs have not significantly altered in the intervening eight years and the difficulties of mitigating environmental effects of dredging and spoil disposal would be similar today as they were in 2003.

On the true right bank, immediately downstream of the Alexandra Bridge, there is a prominent gravel bar. Lake Roxburgh cross section 1D crosses the downstream end of the bar and shows that the bar built up by approximately 3 metres from the original 1960 survey. Consideration was given as to whether excavation of this bar, (which could potentially be achieved using excavators and trucks rather than the dredge operations suggested in the URS study), would be beneficial. However, in discussion with NIWA it was concluded that the bar was stable and does not contribute much to the flood backwater effect such that its removal would not reduce flood risk at Alexandra.

The maintenance of the Manuherikia River bed is required by the Lakebed Monitoring and Maintenance of the Manuherikia Riverbed consent conditions (Appendix B). These conditions require excavation of gravel build-up in two reaches of the Lower Manuherikia River on a two year cycle. The first excavation in 2009-10 removed 100,000 m^3. Surveying in 2011 has confirmed that 48,000 m^3 will need to be removed in 2012. While the condition was aimed more at flood levels, landscape, and amenity it is also significantly reducing the sediment supply from the Manuherikia River into Lake Roxburgh.

Since the URS study in 2003:

- Flushing has slightly reduced the flood risk.
- New sediment modelling has provided enhanced confidence that flushing can make further reductions albeit with diminishing returns.
- Contact's consents granted in 2007 are managing various related flooding effects.
- Sediment supply has been further reduced with maintenance required of the Manuherikia River bed.

Given all the above factors it is considered that there is even less reason now for dredging of Lake Roxburgh than when previously considered in 2003.

4.4 Mitigation of Effects by Related Consent Conditions

In addition to the flushing procedure and the flood mitigation package outlined above there are a number of related consent conditions for the Roxburgh Dam that mitigate the effects of flooding around Alexandra. They are:

- Flood Management Plan
- Lakebed Monitoring
- Flood Hazard Maps for Alexandra
- Alexandra Flood Compensation
- Land Purchase
- Roading Issues
- Safety Signage

These conditions amongst others are listed in Appendix B (Related Consent Conditions) and contribute towards mitigating the flood effects.

The Flood Management Plan outlines procedures for flood preparedness, monitoring, control, notifications and operation of the dams. The plan brought together mostly existing procedures into a coordinated plan and was prepared in consultation with the district councils (QLDC, CODC and CDC) and was approved by the ORC.

The Lake Bed Monitoring condition requires regular surveying of cross sections and assessment of flood levels. To address this requirement Opus undertakes a Sedimentation and Backwater Analysis after each survey. Figure 4-1 is a simple and informative diagram which can be used to track changes in the Alexandra rating curve. It is recommended that this is included and updated in future Opus Sedimentation and Backwater Analysis reports.

The Flood Hazard Maps have been prepared and approved by ORC and provide a useful indication of the potential extent of flooding for hypothetical events including 1 in 100 AEP floods, 1 in 500 AEP floods and the PMF.

The Alexandra Flood Compensation condition provides for Contact to compensate property owners for flood damage caused by the exercise of the consent. In effect, provide flood insurance for Alexandra.

The Land Purchase condition required a number of easement negotiations that were outstanding at the time of the consent hearings in 2003 to be completed. The condition also required Contact to commission an investigation into the effects of flooding and risks to safety on the true right bank between Clyde and Alexandra. The investigation was completed in 2010 and the report supplied to the Otago Regional Council.

The report concluded that:

- The risk of flooding to private properties beyond easement lines is low and the Alexandra Flood Compensation condition provides assurance of compensation for any flood damage. Therefore no further flood mitigation actions for private properties are considered necessary.

- No improvements to Earnscleugh Road were considered necessary to reduce the flood risk but the Roading Management Plan requires Contact to reimburse CODC for any clean up and repair costs.

- Two minor improvements to the Alexandra to Clyde Walkway were recommended to improve escape routes under flood conditions and a procedure to close the Alexandra to Fraser section of the track.

Since the report was prepared by Contact in August 2010, the improvements to the Alexandra to Clyde Walkway have been implemented and procedures put it place with CODC to close the Alexandra – Fraser section of the track when the water level reaches 134.4m. This corresponds to a flow of approximately 1,275cumecs. Posts have also been installed at appropriate places along the track to provide for a chain and signage to be attached to notify that the track is closed due to flooding.

The Roading Management Plan required by the Roading Issues condition, assessed the effects of flooding on public roads and was prepared in consultation with the CODC. The risk based approach used in the Plan determined that *'minor clean up and repairs may be required, but no improvements will be undertaken'*. While no improvements were considered necessary to reduce the flood risk to roads the Plan does require Contact to reimburse CODC for any clean up and repair costs.

From our review of these conditions, and in discussion with Contact, we consider that the related consent conditions are adequately addressing their respective aspects.

5 Lake Dunstan

5.1 Sedimentation

The Opus report prepared in 2001 (*Lake Dunstan Sedimentation Report*) outlined the expected sedimentation rates in Lake Dunstan and provided a good description of the expected fluvial landscape for each arm of the lake.

Opus estimated that the sediment deposition rate in the Kawarau Arm would be 1.19 million m^3 per year based on measured deposition rates at Lake Roxburgh and predicted trap efficiencies at Lake Dunstan. In 2001 sandy-gravel point bars and medial bars had already appeared upstream of the Bannockburn Bridge and Opus predicted that the Kawarau Arm would ultimately "*stabilise with an alternate-bar, possibly semi-braided habit*". The photograph in Figure 5.1 below was taken in 2005 and shows a fluvial appearance consistent with Opus' prediction.

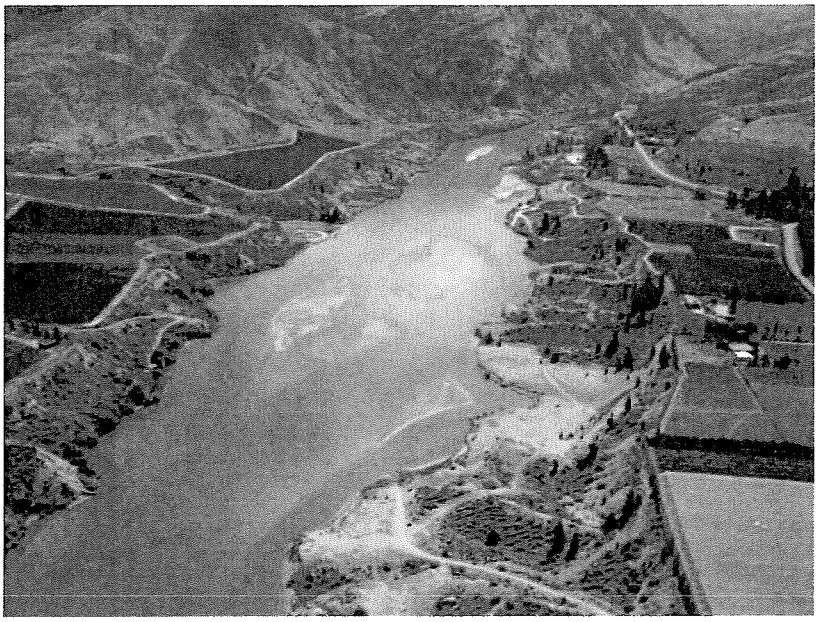


Figure 5-1 : Aerial View of Kawarau Arm upstream of Bannockburn Bridge 2005

A series of cross sections in the Kawarau Arm are surveyed at regular intervals to determine the sediment deposition rate. The Opus 2009 survey report (*Lake Dunstan Sedimentation and Backwater Analysis for July 2009 Bed*) provides the latest sedimentation analysis. Opus calculated the average sedimentation rate over the 15 year period between the initial bed survey in April 1994 and the July 2009 survey to be 1.15 million m^3 per year. This is marginally less than the original estimate of 1.19 million m^3 per year.

The Opus report (*Lake Dunstan Sedimentation and Backwater Analysis for July 2007 Bed*) calculated that 3.7M m3 of sediment deposited in the Main Arm downstream of the confluence from 1994 to 2007. If this volume is included with the Kawarau Arm deposition an overall deposition rate of 1.50M m3 per year is calculated which is higher than original estimates.

The 2009 survey showed the tipping face of the advancing sediment delta was located approximately 3.5km upstream of the confluence of the Kawarau and Clutha Rivers and as shown in Figure 5-2 below medial bars are now appearing well downstream of the Bannockburn Bridge.

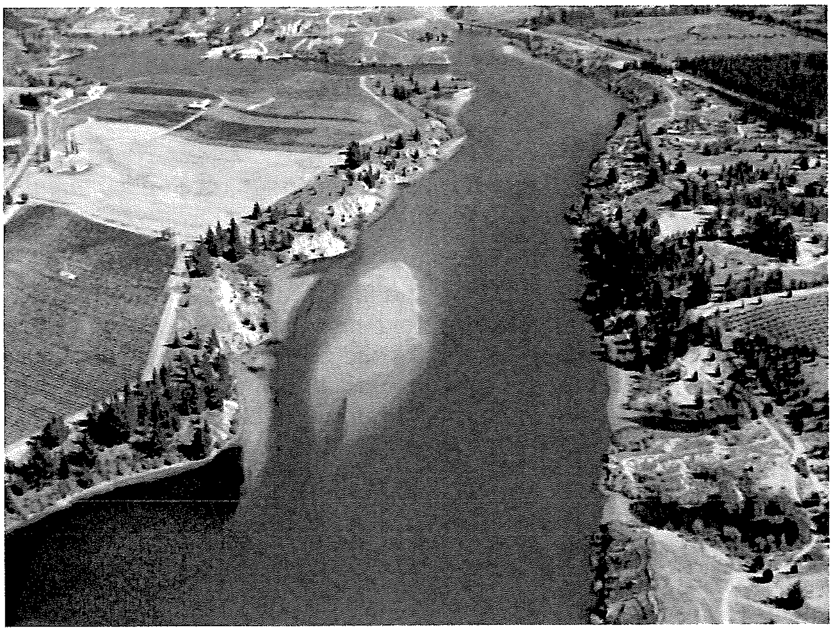


Figure 5-2 : Aerial View of Kawarau Arm downstream of Bannockburn Bridge 2010

The Opus 2001 report suggested that the morphology at the confluence of the Kawarau and Clutha Rivers should resemble the situation where the Shotover River joins the Kawarau River i.e. the Clutha flow will be pushed into a narrow channel against the left bank. This may cause a transient blocking effect as occurs at the Shotover/Kawarau confluence with implications for flood levels in the Clutha Arm.

Based on the 2009 survey and measured deposition rates, Opus has estimated the tipping face will reach the confluence around 2014. NIWA recommended that detailed 2D sediment modelling of the Clutha/Kawarau confluence is undertaken to better understand and predict the potential blocking effect. This should be completed in the next 5 years so that the findings can be used in subsequent backwater studies and flood hazard maps as discussed further in Section 5.3 below.

In the Upper Clutha Arm the expected sedimentation rate is much smaller at 0.17 million m^3 per year. The Opus 2001 report expected that an anastomosing channel pattern, with several channels passing between stable vegetated islands, would slowly develop and resemble the pre-dam reach of the river just downstream at Lowburn. The actual measured sedimentation rate from 1994 to 2007 was 0.38 million m^3 per year. This included the 1995 and 1999 floods which were two very large events. NIWA consider the long term rate may fall between the originally expected rate and the current rate. The regular ongoing monitoring of cross sections in this reach will be adequate to identify and respond to any change in the sedimentation rate.

In the Dunstan Arm downstream of Cromwell the Opus report suggests the likely morphology is an alternate bar pattern much the same as in the upper reaches of Lake Roxburgh upstream of Alexandra.

NIWA recommended that a sediment model of Lake Dunstan is developed and sediment modelling is undertaken to better predict the future development of the sediment delta, changes in sediment outflow quantity and composition over time, and to reassess flood profiles. Sediment sampling will need to be planned and undertaken to provide sediment input information on particle size grading of the surface layer and bulk deposit.

5.1.1 Sediment Monitoring

Sediment accumulation in Lake Dunstan has been monitored by surveying a series of 101 cross sections established soon after lake filling (Refer to Opus 2000 report *Clutha Hydro Lakes Cross-Sections: Survey and Analysis*).

The Lakebed Monitoring condition (Appendix B) requires the cross sections to be surveyed at intervals of not more than 24 months in the Kawarau Arm and not more than 5 years in the Clutha and Dunstan

Arms. A survey is also required in the Kawarau Arm within 3 months of a flow exceeding 800 cumecs. The condition also requires a backwater analysis after each survey.

It is considered that the monitoring is appropriate but it is recommended that the Kawarau Arm survey intervals could be extended out to 30 months (i.e. 2 1/2 years) so that it aligns with the 5 yearly survey interval for the remainder of the lake.

Sediment monitoring requirements should remain flexible to ensure the most appropriate data is obtained. For example, it will be more appropriate to survey the cross sections in the Main Arm more regularly once the tipping face is past the confluence and reduce the survey frequency in the Kawarau Arm.

5.2 Kawarau Arm Groundwater Effects

The Sediment Management Plan conditions states that consideration should be given to:

The implications for groundwater abstractors adjacent to the Kawarau Arm of Lake Dunstan specifically those with bores within 100 metres of the existing lake edge.

It is possible that this requirement was developed from the 2002 URS report (*Identification of Issues and Options for Irrigation Improvements, Kawarau Arm, Lake Dunstan*) which outlined groundwater and lake siltation issues and suggested that siltation issues will probably not affect wells that are more than ~100m from the lake margins.

The report outlined two potential concerns:

1. Will silt clog up the pore spaces in the gravels and
2. Will the silt seal off the gravels to water percolating from the lake.

Contact is not aware of any groundwater issues at present but has discussed the issue with Jens Rekker, groundwater hydrologist, Otago Regional Council.

The following points were noted from the discussion:

- The forming of Lake Dunstan greatly enhanced the groundwater resource.
- Jens Rekker is not aware of any current difficulties with groundwater bores but notes there is only a limited number at present.
- Even if the sediment had an effect (Jens Rekker didn't expect it would) it would have to be significant to offset the enhancement due to the lake. In addition percolation from the Clutha Arm side could still happen.
- A recent CODC bore in Cromwell for irrigating the sports grounds had proved very good.
- ORC is undertaking a 2 year groundwater study of the Cromwell Flats with the objective of working towards a Groundwater Allocation Plan.
- Ryan Nichol, a University of Canterbury masters student, is doing a thesis on the Cromwell groundwater aquifer.

The 2002 URS report provides a good background study for this potential issue and the ORC groundwater study should provide an increased understanding of the groundwater resource.

While there appears to be no sedimentation effect on groundwater at present this could change as sediment deposits further down the Kawarau Arm. It is recommended that Contact discusses the findings of the groundwater study with ORC when it is finalised.

5.3 Flood Effects

As sediment accumulates in Lake Dunstan the backwater effect will increase with time and raise flood levels. The Clyde Power Project understood this and acquired land to provide for raised flood levels. In 1991 a backwater study was completed which predicted the effect 30 and 100 years after lake filling.

In 2006 Opus completed a backwater analysis (*Backwater Profile Predictions for the Kawarau Arm of Lake Dunstan*) using the 2004 bed survey and projected sediment deposition out to 2023 to update the 30 years after lake filling estimate. The results showed a higher level at the confluence but a slightly lower level at the Ripponvale recorder than the 1991 estimates.

Contact's consent conditions require a sediment and backwater analysis to be completed after each lake bed survey. The latest study was completed by Opus in 2009 (*Lake Dunstan Sedimentation and Backwater Analysis for July 2009 Bed*). These regular surveys and analyses do not include future projections of sediment deposition. It is considered appropriate to review the future projections undertaken in 2006 using actual sediment and water level measurements to update and calibrate the predictions. The results of this review could then be used to confirm that the predicted flood levels are within the acquired land.

Land was purchased in the Kawarau Arm generally up to elevation 220m, which is well above the predicted flood levels, except for a small area of one property near the Bannockburn Bridge and a small section of road reserve at the Bannockburn Inlet. In the Clutha Arm, land was acquired generally to at least elevation 196m. As discussed above, the Opus 2006 study indicated higher flood levels at the confluence than originally predicted and this will reflect in flood levels in the Clutha Arm. There is significant development around the Clutha Arm and it is considered that the flood level projections should be updated and shown on appropriate flood hazard maps in context with legal property boundaries.

The updated future projections are not required immediately but should be completed within the next 10 years to allow for improved estimates of the sediment deposition downstream of the confluence which is the key parameter influencing the results.

At the head of the Clutha Arm there is a need to extend the backwater model further upstream. Figure 5-6 below shows the head of the Clutha Arm looking upstream. This area was studied by Opus in 2009 (*Bendigo Wildlife Reserve: Assessment of cross-sections and sediment management).* Opus made three recommendations as a result of the study relating to surveying the 5 Bendigo cross sections and extending the model upstream to assess the flood risk to adjoining properties. Contact agrees with these recommendations.

Figure 5-3 : Head of the Clutha Arm of Lake Dunstan looking upstream

The updated flood projection information for lake Dunstan should be provided to the Otago Regional Council to allow them to advise the Central Otago District Council.

5.3.1 Flood Rules

The Flood Rules for Clyde Dam include a table discharge procedure that increases the discharge in 200 cumec steps for every 50mm rise in lake level. A level of 195.1m is reached at the dam for a discharge of 3,200 cumecs. These are generous steps and future backwater projections could investigate if some slight modification to the rules is all that is required to maintain flood levels within land purchase boundaries.

5.3.2 Flood Monitoring

Water levels are monitored at four locations around Lake Dunstan:

- Clyde Dam
- Lake Dunstan at Ripponvale
- Lake Dunstan at Cromwell
- Lake Dunstan at Crippletown

Flows are measured at the Clyde Dam and at the following upstream locations:

- Clutha at Cardrona
- Lindis at Lindis Peak
- Kawarau at Chards Road
- Nevis at Wentworth Station

It is considered that this is satisfactory for measuring flood levels and flows and for providing good quality data for ongoing assessments.

5.3.3 Dam Gates and Operating Consents

No sediment management actions, such as flushing, are proposed at Clyde Dam at the moment or indeed for some considerable time into the future.

The Clyde Dam can pass water via the machine intakes, spillway gates and sluice gate. The spillway gates and sluice gate would have sufficient discharge capacity to lower the lake for flushing when that is required in the future. Experience was gained during lake filling with operating the machines with lake levels in the range of RL177 - RL194.5m.

The consent conditions for Clyde Dam do not currently provide for lowering the lake for flushing and variations to the consents would be required.

5.4 Mitigation of Effects by Related Consent Condition

5.4.1 Access for Irrigation Takes

At the resource consent hearings in 2002-03 a number of submitters expressed concerns that the sedimentation in the Kawarau Arm would affect existing and future irrigation takes. Contact consulted with a group of existing irrigators known as KASAG (Kawarau Arm Siltation Action Group) and agreed a side agreement which provided for Contact to pay for the clearance of sediment or relocation of intakes if sediment deposition impeded the taking of water at eight existing intakes. The agreement also provided for Contact to assess the intakes for increasing flood levels and make alterations where necessary.

To date Contact has arranged to relocate one intake and has completed flood protection improvements at two other sites. Figure 5-3 below shows the upper storey of the Ripponvale Irrigation Company intake constructed to house the electrical control and flood proofing of the original lower storey.

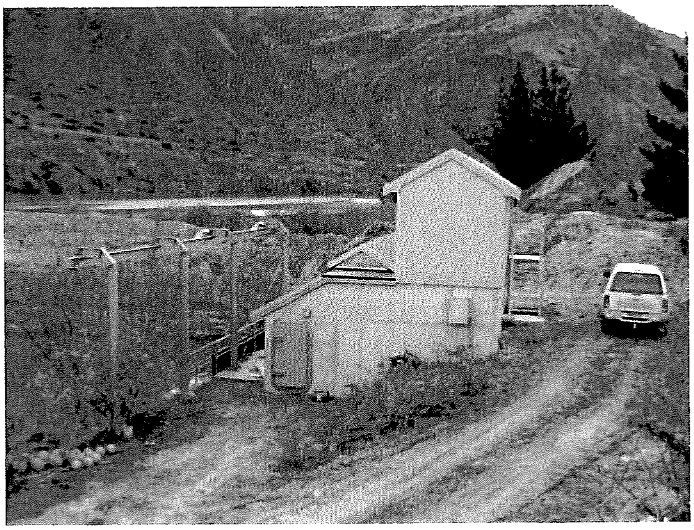


Figure 5-4 : The Ripponvale Irrigation Company Intake.

The Access for Water Takes Kawarau Arm consent condition (Appendix B) mitigates potential sedimentation effects to future irrigation takes. Condition (b) requires Contact to identify the optimum sites on which to locate three new intake facilities. Condition (d) then requires Contact to undertake periodic channel maintenance work to secure the provision of access to water. Contact commissioned Opus to determine the optimum locations for these intakes and the Opus 2010 report *Kawarau Arm Lake Dunstan Access for Future Water Users* describes the investigation.

The investigation determined that there was no demand for the intakes at present. Therefore Contact has applied for a variation to the consent to delay construction of the intakes by three years to 2014.

The KASAG agreement is working well for both parties and the CODC has provided written approval for the consent variation which has yet to be processed. This indicates that sedimentation effects on irrigation takes are currently managed and there are processes in place to mitigate future effects if they develop.

5.5 Amenity Effects

When the lake was originally filled it was sediment free. Deposition of sediment has since led to sediment bars which have changed the recreational and visual amenity of the Kawarau Arm. This was always predicted and a number of related consent conditions are in place to manage effects.

5.5.1 Recreational Amenity

Recreational boating on the Kawarau Arm is becoming increasingly limited and hazardous with medial bars sometimes just submerged by the lake. Warning signs to comply with the Safety Warnings and Safety Signage consent conditions (Appendix B) have been erected by Contact at boat ramps as shown in Figure 5-4 below.

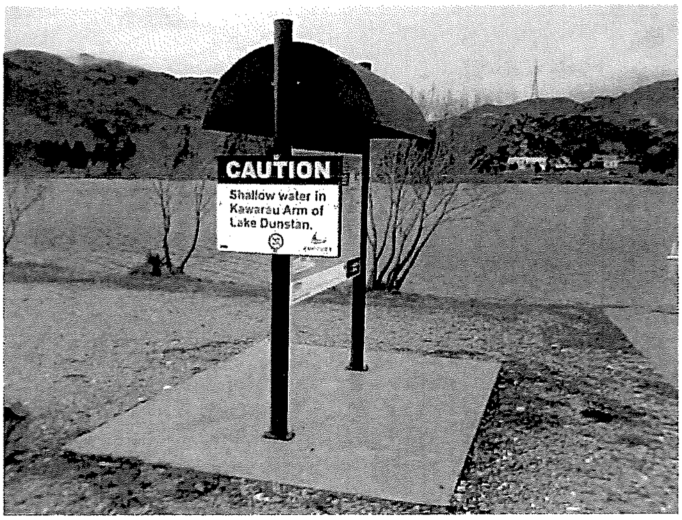


Figure 5-5 : Warning Sign at Cromwell Boat Ramp

In addition the Safety Signage conditions require a signage plan to be prepared and approved by the Otago Regional Council and reassessed every three years.

As the sediment front advances further down the Kawarau Arm recreational effects may develop around the boat ramps and jetty at Cromwell. Effects are difficult to predict so it is suggested that Contact instigate an observational approach to assess effects in consultation with central Otago District Council (CODC), who administer recreational activity in the lake, and determine any appropriate mitigation actions. Contact has an established line of communication with CODC on such matters as Contact sends a representative to attend the CODC Clutha Management Committee meetings.

5.5.2 Bannockburn Inlet

The Bannockburn Inlet is a high recreation amenity area. The Bannockburn Inlet condition (Appendix B) requires Contact to undertake an initial bathymetric survey of the inlet and every 5 years thereafter remove deposited sediment so that the lakebed conforms to the initial survey. The first five year survey is due in 2012.

While the first dredging is yet to be undertaken the condition should ensure that the inlet is kept free of sediment and maintains its amenity value.

5.5.3 Lowburn Inlet

The Lowburn Inlet is also a high recreation amenity area. The Lowburn Inlet condition (Appendix B) requires Contact to survey and remove deposited sediment back to the original landscape profiles. A significant amount of sediment deposited where the Lowburn Stream enters the inlet during the 1999 flood. In 2009, Contact completed excavation of the inlet in accordance with the requirements of this condition. Figure 5-5 below shows the Lowburn inlet in 2010 following the completion of the inlet excavation.

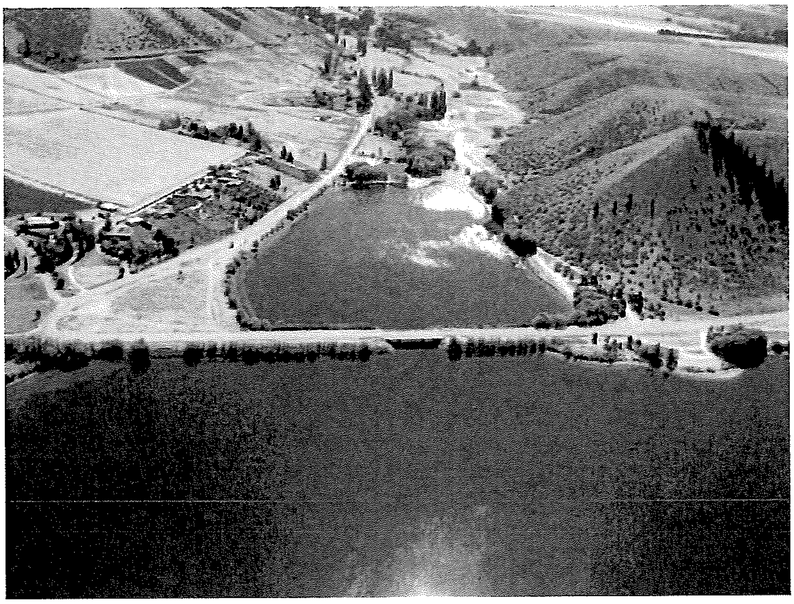


Figure 5-6 : Lowburn Inlet 2010

5.5.4 Visual Amenity

The visual amenity in the Kawarau Arm is mitigated by a Landscape and Visual Amenity Management Plan condition (Appendix B). Contact has prepared this plan in consultation with the Central Otago District Council (CODC) and it was approved by the Otago Regional Council. The condition requires that the plan is reassessed every 5 years. Contact is implementing the Landscape and Visual Amenity Management plan and the reassessment process should ensure any developing visual effects are addressed.

6 Lower Clutha

6.1 Bed Degradation

In 2008 ORC published the report *Channel morphology and sedimentation in the Lower Clutha River*. The report assessed cross section and historical observations from as far back as 1875.

The report noted a general trend of aggradation from Roxburgh to Balclutha starting in 1875 and suggested that this may have been related to increased input of coarse sediment from gold mining operations. However, the report noted that starting in the 1920's bed levels started to degrade at Roxburgh Bridge followed by similar lowering at the Millers Flat and Beaumont bridges downstream. The report states that *"Between 1948 and 1982, bed degradation of approximately 5m was recorded at Commissioners Flat, just downstream of the Roxburgh Dam. This is undoubtedly due to course material being trapped behind the dam, resulting in erosion of the bed downstream. A similar fall in bed levels occurred between 1948 and 2007 at Roxburgh, while a trend of bed level decline occurred at Millers Flat from 1940 to 1982 and at Beaumont between 1948 and 1982"*.

The report also notes that *"The signal of reduced coarse sediment supply from upstream is likely to take decades to work through the Clutha River/Mata-Au system downstream of Roxburgh Dam"*. It concludes that *"Between Roxburgh dam and Roxburgh, the impact of the damming of the river at Coal Creek is being felt with significant levels of bed degradation. The impacts of this degradation appear to include high levels of bank erosion. The future impacts of a generally lowering river bed will probably include further bank erosion in these reaches"*.

A 2001 study by Ryder Consulting *(Lower Clutha River Sediment and Erosion Issues)* includes a review of erosion and geomorphological aspects by Opus. The Opus review provides a good summary of many previous studies and noted that *"currently the problem area for river channel instability in the Lower Clutha River, as evidenced by ongoing bank erosion and gravel accumulation, is the reach between Clydevale and Balclutha"*.

The discharge consent for Roxburgh Dam includes a Riverbank and Berm Stability condition (Appendix B). This condition requires Contact to contribute 50% of the costs of an ORC investigation into river changes and instability and 50% of the costs of remedial actions in respect of riverbank and berm instability. The consent has been operative since 2007 and there have been no costs to date.

A second condition, Rivermouth Maintenance and Opening (Appendix B), requires Contact to pay 90% of the cost of maintaining the two Clutha River mouths open and 90% of the cost of maintaining the training works. This condition relates more to the effects from fluctuating flows discharged from Roxburgh Dam than the reduction in sediment supply.

It is clear that the construction of the Roxburgh Dam has reduced the coarse sediment supply and this is resulting in bed degradation downstream. It is apparent that the changes are slow and may take decades to progress downstream. Contact's consents include conditions to contribute to investigations and maintenance works. It is therefore considered that the issue is well managed at present.

6.2 Deposition of Fine Sediment

When the flushing procedure was first instigated in 1994 the amount of fine sediment discharged downstream was increased compared to the previous situation of no flushing. Sand particles were washed downstream whereas prior to flushing little sand passed Roxburgh Dam. However, it must be noted that the amount of sediment passing Roxburgh Dam even when flushing, is still only a small percentage of the total sediment load that existed pre 1956 as approximately 90% is trapped in Lake Dunstan.

The NIWA *Clutha turbidity monitoring data report 1995 – 2010* provides discussion on the effects of flushing on downstream turbidity and shows that the turbidity at Millers Flat is only marginally higher than at Alexandra during flushing events. With the expected reduction in the effectiveness of flushing over time the effect on turbidity downstream is likely to be even less.

Two studies by Ryder Consulting have assessed this issue with respect to ecology effects. These are their 1996 report *An Investigation into the Causes and Effects of Suspended Sediment in the Lower Clutha River* by Ryder Consulting in 1996 and *Fine Sediment Deposition and Benthic Ecology in the Lower Clutha River* in 2000.

It is concluded that the deposition of fine sediment in the Lower Clutha was a temporary issue during the more effective early years of flushing operations. The turbidity monitoring undertaken by NIWA for Contact will provide on-going data to assess effects on downstream suspended sediment.

It is recommended to continue with on-going flushing at Lake Roxburgh for the next 20 – 50 years and sediment storage at Lake Dunstan for some considerable time. Issues in the Lower Clutha are therefore not expected to change from current trends until such time as operational regimes are in place to encourage sediment movement through both Lake Dunstan and Roxburgh to sustain long term hydro operations.

6.3 Coastal Effects

The extent to which Contact's operation of the Roxburgh Dam contributes to coastal erosion at Molyneux Bay is difficult to quantify. The expert evidence presented at the resource consent hearing in 2001 was in disagreement as to what the primary cause of coastal erosion is. Despite this, it was generally accepted by the hearing commissioners that the operation of the Roxburgh Dam at least partly contributes to coastal erosion due to trapping of sediment behind the dam. This has been recognised in the Coastal Erosion consent condition (Appendix B) requiring Contact to contribute 50% towards the cost of an ORC coastal erosion management programme.

To address this condition Contact commissioned NIWA to prepare a Coastal Erosion Management Programme Specification in 2008. This was forwarded to ORC but was not agreed to.

In 2009, ORC had New Zealand Aerial Mapping capture LIDAR data for Molyneux Bay and compared this to the 2004 data. In May 2010, ORC prepared a scoping paper of potential monitoring options. This recommended a 5 yearly survey of shoreline positions using GPS and hydrographic surveying of 10 transect lines in Molyneux Bay. Contact has agreed to this recommendation.

As at August 2011, it is understood that the ORC has not internally approved the project and no further progress has been made.

It is likely that any coastal effects from the reduction of sediment supply to the coast will lag some considerable time after the sediment reduction. The Roxburgh Dam was filled in 1956 (55 years ago) and the Clyde Dam was filled in 1993 (18 years ago). As described above, the Lower Clutha is still adjusting to the change and erosion of the river bed may in part be making up for the reduction in sediment supply to the coast.

Overall it is considered that coastal erosion effects are a complex and difficult issue to assess. However, commencement of the monitoring programme may, over time, help to quantify sediment movement and coastal erosion.

7 Conclusions

This sediment management plan has been developed to address the requirements of consent conditions. In the preparation of the sediment management plan, international sediment management practices have been reviewed and it has been determined that there are a number of common themes applicable to Lake Roxburgh and Lake Dunstan and the approach to sediment management is consistent with international practice.

The sediment management plan has considered the NIWA sediment modelling work and the various sediment surveys and backwater analysis undertaken by Opus.

The following specific conclusions are made:

Lake Roxburgh

Sedimentation in Lake Roxburgh has exacerbated flood effects around Alexandra. However the implementation of the FDD procedures since 1994 has reduced the sedimentation effect on flood levels from a maximum of 4.2 metres in 1994 down to 2.6 metres currently.

The current flood drawdown strategy remains the most appropriate management strategy at present. However Contact should review their procedures for operating the low level sluices during flood drawdown events.

A number of related resource consent conditions are mitigating specific flood effects and Contact and the Crown have purchased properties and flooding easements approximately 2.4m higher than the original land acquisition level when the Roxburgh Dam was constructed.

The monitoring of water levels and flows in considered adequate.

Existing consent conditions for monitoring sedimentation are adequate and it is recommended that the consent conditions be changed to allow the cross section surveys to be undertaken on a 5 year basis.

There is even less reason now for dredging of Lake Roxburgh than when previously considered in 2003.

NIWA predict from sediment modelling that the current flood drawdown strategy can further reduce the sedimentation effect on flood levels.

The flood drawdown strategy for Lake Roxburgh should be reviewed in 10 years time when sediment modelling of Lake Dunstan is completed and progress of the flood drawdown strategy is assessed.

The Alexandra rating curve (Figure 4-1) should also be included in future reports by Opus on the sedimentation and backwater analysis after each lakebed survey.

Lake Dunstan

No changes to the current operational consents are considered necessary. This should be reviewed in 10 years time when sediment modelling of Lake Dunstan is completed.

Contact has applied for a change of consent conditions to delay construction of three new intakes to 2014. CODC has provided its written approval to the change of consent condition although the application has yet to be processed by ORC.

The KASAG agreement is working well. Contact has relocated one water intake and completed flood protection improvements on two other water intakes. Processes are in place to mitigate further effects on intakes should they arise.

Lake Dunstan can continue to operate in sediment storage mode. This is acceptable for Lake Dunstan and fits with the strategy to continue flushing at Lake Roxburgh.

Sediment monitoring and backwater assessments required by the consent conditions are appropriate. An amendment to the Lake Bed Monitoring consent condition could be sought to provide for the survey of the Kawarau Arm at intervals of not more than 2.5 years.

Sediment modelling of the Upper Clutha/Kawarau confluence should be undertaken within the next 5 years to better understand and predict potential blocking effects. The findings will then be used in subsequent backwater studies and flood hazard maps. Future projections of flood levels around Lake Dunstan should be submitted to the Otago Regional Council.

Groundwater Effects Kawarau Arm

There are no known groundwater issues at present. ORC are undertaking a ground water study of Cromwell Flats to enhance understanding of the groundwater resource. This study will inform a Groundwater Allocation Plan. Contact should undertake further discussions with ORC on the findings of the groundwater study once it is completed.

Lower Clutha and Coastal Effects

The construction of the Roxburgh Dam has reduced the coarse sediment supply and this is resulting in bed degradation downstream. These changes are slow and may take decades to progress downstream.

Consent conditions require contributions towards investigations and river maintenance works.

Turbidity monitoring will provide on-going data to assess effects on downstream suspended sediment.

With on-going flushing at Lake Roxburgh and sediment storage at Lake Dunstan, issues in the Lower Clutha are unlikely to change from current trends.

Coastal Effects

The cause of coastal erosion is complex and difficult to assess. The commencement of the coastal monitoring programme by ORC may assist in quantifying sediment movement and coastal erosion over time.

7.1 Sediment Management Strategy

7.1.1 Current Strategy

This sediment management strategy has been derived after considering the requirements for each lake and as a combined set. A sediment management timeline is graphically presented in Appendix A. It assists in appreciating the long term nature of this issue and the need to consider both lakes together.

For Lake Roxburgh the timeline indicates continuing with the flood drawdown strategy, out to at least 2030 (20 years from present) and then an operational change to a more aggressive strategy in anticipation of an increasing amount of sediment passing Clyde Dam. The actual date for the required change in strategy will become apparent with time.

For Lake Dunstan, sediment storage is provisionally indicated out to at least 2043 (50 years after lakefilling) before an operational change is required. When this occurs it is noted that this would have to be operated in tandem with Lake Roxburgh to prevent bed aggradation in Lake Roxburgh.

In the longer term (100 to 150 years from present) a change to alternate operating strategies will be required at both lakes.

As sediment management will be an on-going and changing issue, we consider that this Sediment Management Plan is reviewed 10 years from the date it is submitted to ORC with any changes considered necessary for the management of sediment. Subsequent reviews are then recommended at periods of 10 years.

At first glance the suggested 10 year review interval may seem too long when compared to other consent review requirements. However sediment management is an on-going and long term requirement. The first significant operational change is anticipated at Lake Roxburgh in perhaps 20 years time. With such long time periods a 10 year review interval is considered adequate to undertake monitoring requirements, update progress and , review strategies.

The following actions are recommended for the on going management of sediment in Lake Roxbugh and Lake Dunstan over the next ten years.

7.1.2 Future Strategy Options

A feasible solution for managing bedloads into Lake Dunstan and lake Roxburgh sustainably will need to be determined before about 2090. Dredging for land disposal is costly, assuming disposal sites are available. This is probably not sustainable given the total sediment influx into the reservoirs each year.

A high level option is to consider operating at lower lake levels for significant portions of the year and returning to current levels in winter periods when sediment transport is low. This provides future generations with power generation benefits from the hydropower stations, albeit reduced from current annual output. If required, dredging could operate close to the dam to ensure intakes are kept clear of sediment, with the sediment disposed into the river downstream of the dam to allow the river to transport it further downstream, eventually to the coast.

Recommended Actions for sediment management

Lake Roxburgh	1a. Continue with the flood draw down (flushing) procedure.
	1b. Review the flood drawdown strategy for Lake Roxburgh in 10 years (2021) when sediment modelling of Lake Dunstan is completed.
	1c. Continue lake bed monitoring and backwater assessments as required by the consent conditions
	1d. Include the Alexandra rating curve (Figure 4-1) into future sedimentation and backwater analysis reports.
	1e. Seek an amendment to the Lake Bed Monitoring conditions to provide for the survey of Lake Roxburgh and the lower Manukerikia River at 5 yearly intervals.
	1f. Review gate operating procedures to encourage the use of low level sluices during flood drawdown operations
	1g. Continue compliance with related consent conditions.
Lake Dunstan	2a. Continue to operate in sediment storage mode.
	2b. Plan and undertake sediment sampling to provide sediment input information on particle size grading of the surface layer and bulk deposit.
	2c. Develop a sediment model of Lake Dunstan and undertake sediment modelling to better predict the future development of the sediment delta, the change in sediment outflow, quantity and composition over time and to reassess flood profiles.
	2d. Develop a 2D sediment model of the Clutha/Kawarau confluence area of Lake Dunstan to assess the potential blocking effect of the sediment delta.
	2e. Update the future flood level projections for the Clutha Arm and prepare flood hazard maps with property boundaries shown. Include investigation of modification of the Flood Rules in the flood level projections. Provide the flood level projections to the Otago Regional Council.
	2f. Continue lake bed monitoring and backwater assessments as required by the consent conditions.
	2g. Undertake regular 5 yearly surveys of Bendigo cross sections and extend the Lake Dunstan backwater model upstream to cover this reach.
	2h. Seek an amendment to the Lake Bed Monitoring condition to provide for the survey of the Kawarau Arm at intervals of not more than 2.5 years.
	2i. Instigate an observational approach to assess potential recreation effects in the Kawarau Arm in consultation with the Central Otago District Council
	2j. Continue compliance with related consent conditions
General	3a. Review the Sediment Management Plan in 10 years and resubmit to Otago Regional Council With any changes considered necessary for the management of sediment. Undertake further reviews at periods of 10 year intervals.

8 References

Cheng Xuemin, 1992 Water Power and Dam Construction: *Reservoir sedimentation at Chinese hydro schemes*.

Contact Energy Limited, August 2010: Effects of Flooding Clutha Right Bank. Prepared by P Silvester (Contact Energy)

Contact Energy Limited, January 2010: Lake Roxburgh Bed Surface Sediment Sampling 2010. Prepared by P Silvester (Contact Energy)

Contact Energy Limited, November 2010: Lake Roxburgh Sediment Core Sampling 2010. Prepared by P Silvester (Contact Energy)

ICOLD Bulletin 115, 1999: *Dealing with Reservoir Sedimentation*

ICOLD Draft Bulletin, 2006*: Sedimentation and Sustainable use of reservoirs and River Systems.*

ICOLD Brasil, paper Q89-R17, May 2009: Reservoir Sustainability – identification, assessment and successful implementation of reservoir sedimentation management strategies. Prepared by GW Annandale and A Palmieri

ICOLD Brasil, paper Q89-R29, May 2009:. Development of sediment management programme for Diamer Basha reservoir based on one dimensional numerical modeling. Prepared by F Hussain.

Ministry of the Environment Climate Change Effects and Impacts Assessment, 2nd edition May 2008.

MWH, March 2008 Roxburgh and Clyde Dam Sediment Management Plan. International Sediment Management Practices Review

NIWA, May 2010: Lake Roxburgh Sediment Modelling Study – Stage 1 (Model Setup and Validation). Prepared by NIWA for Contact Energy.

NIWA, May 2011: Draft Lake Roxburgh Sediment Modelling Study – Stage 2 (future projections). Prepared by NIWA for Contact Energy Ltd

NIWA March 2011: *Clutha Turbidity Monitoring Data Report 1995-2010.*

NIWA, 2000: Clutha River Sediment Budget. Prepared by NIWA for Contact Energy Ltd

Opus International Consultants Ltd, 2006: Backwater Profile Predictions for the Kawarau Arm of Lake Dunstan. Prepared by M G Webby and W B Veale.

Opus International Consultants Ltd, June 2001: Lake Dunstan Sedimentation Report. Prepared by P F Foster (Opus) and M Hicks (NIWA)

Opus International Consultants Ltd, 2010: *Kawarau Arm Lake Dunstan Access for Future Water Users*

Opus International Consultants Ltd, 2009: Lake Dunstan Sedimentation and Backwater Analysis for July 2007 Bed. Prepared by M G Webby, C Apirumanekul, G Labaznova and R Belleville.

Opus International Consultants Ltd, December 2009: Bendigo Wildlife Reserve: Assessment of Cross Sections and Sediment Management. Prepared by S Paine and Dr J McConchie (Opus).

Opus International Consultants Ltd, February 2010: Lake Roxburgh Sedimentation and Backwater Analysis for July 2009 Bed. Prepared by FJ Maas and C Apirumanekul (Opus).

Opus International Consultants Ltd, 2000: *Clutha Hydro Lakes Cross-Sections: Survey and Analysis*.

Otago Regional Council, July 2008: Channel Morphology and Sedimentation in the Lower Clutha River.

Poyck Suzanne, Hendrikx Jordy, Mc Millan Hilary, Orn Hreinsson Einar, Woods Ross (2011) Combined snow and streamflow modelling to estimate impacts of climate change on water resources in the Clutha river , New Zealand. Journal of Hydrology (NZ)

Robertson Ryder Ltd, July 1996: An Investigation into the Causes and Effects of Suspended Sediment in the Lower Clutha River.

Ryder Consulting Ltd, November 2000: Fine Sediment Deposition and Benthic Ecology in the Lower Clutha River.

Ryder Consulting Ltd, February 2001. Lower Clutha Sediment and Erosion Issues

Statement of Evidence of Peter Foster, October 2002: In the matter of the Resource Management Act 1991 and in the matter of an application by Contact Energy Limited to Otago Regional Council for its resource consents to permit operation of its hydro-electricity facilities in the Clutha River/Mata-au catchment.

URS, July 2002: Identification of Issues and Options for Irrigation Improvements, Kawarau Arm, Lake Dunstan. Prepared by URS for Contact Energy Ltd and Kawarau Arm Siltation Action Group.

URS, 2003: *Lake Roxburgh Sediment Removal Options Comparative Study*

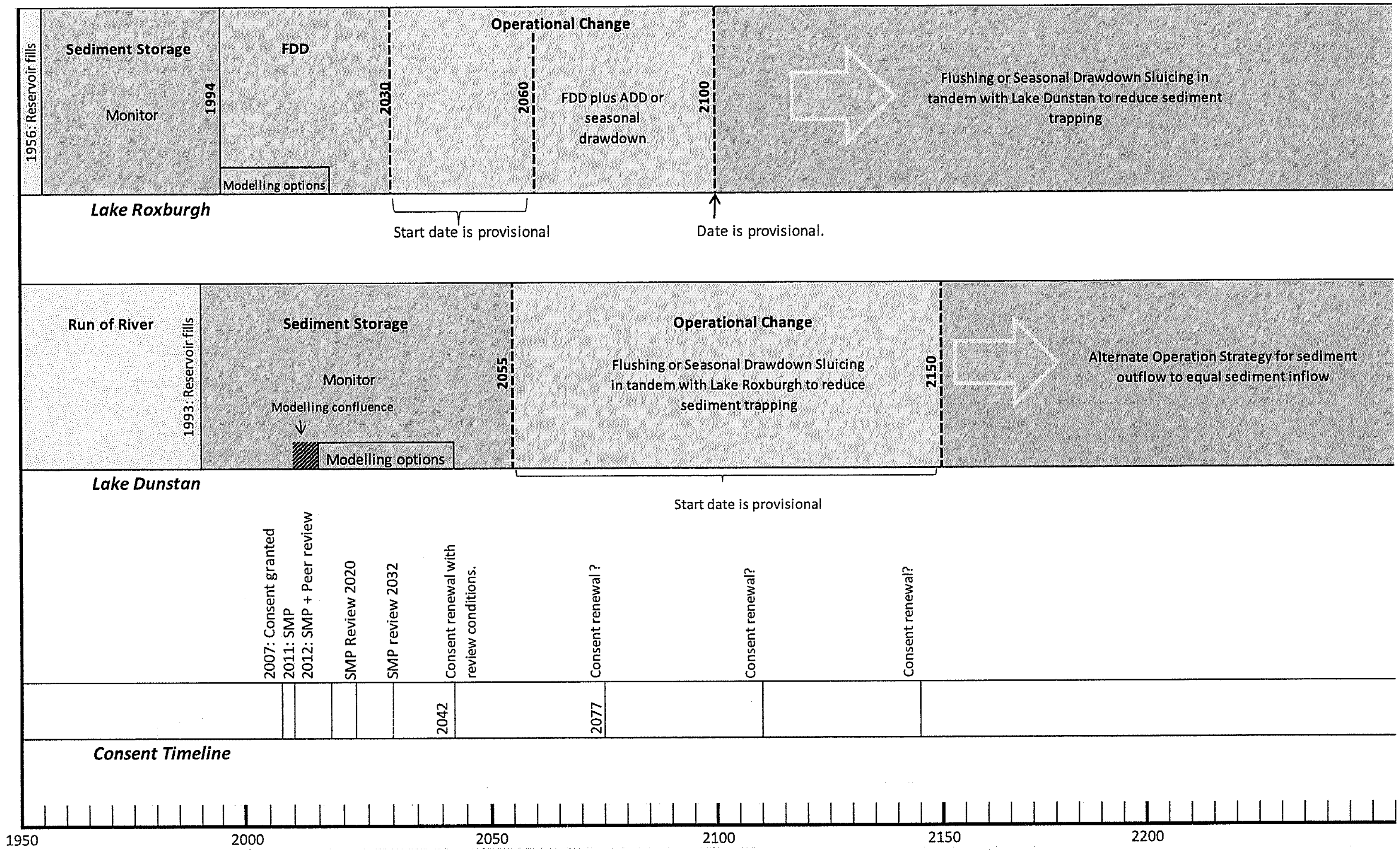
Water Power Magazine, April 2011: *China's Challenge*. Prepared by K DiFracesco.

Water Power Magazine, April 2011: *Going Full Circle*. Prepared by GW Annandale.

Works Consultancy Services Ltd, February 1993: Draft Lake Roxburgh Sedimentation Pre-Feasibility Study. Prepared by Works Consultancy Services Ltd for ECNZ

Appendix A Lake Roxburgh and Lake Dunstan Sediment Management Strategy Timeline

Lake Roxburgh and Lake Dunstan Sediment Management Strategy Timeline



Appendix B Related Consent Conditions

Clyde Water Permit to Dam No. 2001.385

Lakebed Monitoring

a) The consent holder shall survey the Lake Dunstan cross sections identified in the Opus (July 2000) report on Drawing No. 8/1291/01/7834/1X and 2X and attached as part of this consent, at the following frequency:

- at intervals of not more than 5 years in the Dunstan and Clutha Arms; and
- at intervals of not more than 24 months in the Kawarau Arm; except that
- in the Kawarau Arm a survey shall occur within 3 months of a flow exceeding 800 cumecs, as measured in the Kawarau River at the Chards Road site (Site No. 75262).

The first survey of all three arms shall be undertaken within six months of the commencement of the consent.

b) The results of each survey shall be provided to the Otago Regional Council within 3 months of completion of the survey. The reported survey results shall include an assessment of predicted flood levels for the lake as measured at each re-survey cross section based on a 3,200 cumecs per second flow at Clyde Dam.

Lowburn Inlet

a) Within one year of the commencement of this consent, the consent holder shall establish and survey a series of six cross sections at 20 metre intervals in the Lowburn Inlet. The cross sections shall run in a northeast direction and shall extend across the inlet from 195 metres above datum to 195 metres above datum. The first cross section shall be at the confluence of the Lowburn Stream and the Lowburn Inlet (as defined in the attached plan).

b) The results of the survey shall be provided to the Otago Regional Council within 3 months of completion of the survey.

c) Subject to it obtaining any necessary resource consents which are subject only to conditions substantially in the same form as conditions contained in condition 11 e) of this consent, the consent holder shall remove deposited sediment from the bed of the Lowburn Inlet to ensure that the lakebed specification set out in the attached plan which forms part of this consent, is met. The consent holder shall maintain the inlet free of deposited alluvial material as follows (except insofar as allowed by condition 11 d)):

(i) The area between the Lowburn Inlet boundary (as defined in the attached plan) and the 191.0 metre contour shall be maintained at an average grade of approximately 8:1;

(ii) The area inside the 191.0 metre contour shall be maintained with a bed level not exceeding 191.0 metres above datum.

d) The consent holder shall undertake repeat surveys of the two cross sections nearest to the Lowburn Stream outlet from time to time in consultation with the Otago Regional Council, but in any event at not greater than five yearly intervals. The results of the survey shall be provided to the Otago Regional Council within three months of the survey. Where more than 50% of the bed profile varies from any one or more of the cross-sections defined in condition 11 a) above by more than 0.5 metres vertically the consent holder shall ensure the inlet conforms to the specifications established in 11 c).

e) For any bed disturbance works required by this Condition the following conditions apply:

(i) Works shall not be undertaken during the months of November to April inclusive;

(ii) The consent holder shall take all reasonable measures to minimise any change in the colour or visual clarity of the water in the Clutha Arm of Lake Dunstan;

(iii) The consent holder shall take all reasonable measures to reduce dust emissions resulting from the disturbance of the bed material;

(iv) Any fuels or other hazardous materials stored near the site shall be kept at least 50 metres clear of any water body;

(v) Any refuelling of machinery shall occur at least 50 metres clear of the waterbody;

(vi) Once commenced, the works shall be completed without unreasonable delay and on completion the site shall be left tidy and all surplus material shall be removed from the site.

Bannockburn Inlet

a) The consent holder shall undertake a bathymetric survey, at not more than 1.0 metre elevation contour intervals, of the Bannockburn inlet below 194 m above datum and as defined in the attached plan, within three months of the commencement of this consent (the initial bathymetric survey) and every fifth year thereafter.

b) The results of each survey shall be provided to the Otago Regional Council within 3 months of completion of the survey.

c) Subject to it obtaining any necessary resource consents which are subject only to conditions substantially in the same form as the conditions contained in condition 12 e) of this consent, the consent holder shall remove deposited sediment from the bed of the Bannockburn Inlet to ensure that the lakebed between elevation 194.5 metres above datum and 191.0 metres above datum shall be graded to generally conform with the initial bathymetric survey data. Where the bathymetric survey data shows that the lakebed is lower than 191.0 metres above datum the consent holder shall maintain such lower levels at an elevation of not greater than 191.0 metres above datum.

d) The consent holder shall maintain a channel at least 50 metres wide with a bed elevation of not greater than 191.0 metres above datum between the flowing water in the Kawarau Arm and the Bannockburn Inlet.

e) For any bed disturbance works required by condition 12 (c) of this consent the following conditions apply:

(i) Works shall not be undertaken during the months of November to April inclusive;

(ii) The consent holder shall take all reasonable measures to minimise any change in the colour or visual clarity of the water in the Kawarau Arm of Lake Dunstan;

(iii) The consent holder shall take all reasonable measures to reduce dust emissions resulting from the disturbance of the bed material;

(iv) Any fuels or other hazardous materials stored near the site shall be kept at least 50 metres clear of any water body;

(v) Any refuelling of machinery shall occur at least 50 metres clear of the waterbody;

(vi) Once commenced, the works shall be completed without unreasonable delay and on completion the site shall be left tidy and all surplus material shall be removed from the site.

Access for Water Takes Kawarau Arm

a) Within two years of the commencement of the consent the consent holder after consultation with Otago Regional Council and the Central Otago District Council shall commission an investigation into how the needs of future irrigation users in the Kawarau Arm might appropriately be addressed.

b) The investigation shall involve identification of the optimum sites on which to locate three intake facilities that would give access to up to one million litres per hour of water each, and the design of which would have provision for future users to install (at their own cost and subject to their obtaining all necessary resource consents and land owner approvals) pumps, power supplies and landward reticulation systems.

c) The report on the investigations when completed shall be provided to the Otago Regional Council and the Central Otago District Council.

d) Subject to obtaining any necessary statutory consents or landowner approvals, the consent holder, within four years from the commencement of the consent, shall ensure that the three intake facilities are constructed and thereafter shall undertake periodic channel maintenance work as required to secure the provision of access via those intakes to run of river water sufficiently free of sediment as to be suitable for bulk irrigation supply purposes. For the avoidance of doubt, the consent holder shall not be obliged to ensure continuous access to water during temporary periods due to intake plant maintenance requirements and / or floods but shall use reasonable endeavours to limit supply disruptions during such times.

Safety Warnings

b) The consent holder shall provide and maintain adequate signage in good repair in the vicinity of the Clyde Dam where the public can gain access, to warn the public of safety and navigation risks associated with the accumulation of sediment within the Kawarau Arm and at other areas of hazardous sediment deposition around Lake Dunstan.

c) The consent holder shall maintain a boom on the lake surface, generally 600 metres upstream of the dam, to warn lake users of the hazards at the dam face (particularly with spillways). The boom shall be secured firmly to the shore or lakebed, shall not interfere with public use of the existing boat ramp in that vicinity, and shall be maintained in good repair, in safe condition and substantially clear of debris.

Safety Signage

a) The consent holder shall, in consultation with the Central Otago District Council, prepare and submit to the Otago Regional Council for approval a signage plan within 6 months of the commencement of this consent.

b) The signage plan is to provide for adequate signage to warn of the risk to public safety of operational changes in river flows along the Clutha River below the Clyde Dam.

c) The signage plan shall identify the sites and the form and content of the signs used by the consent holder.

d) The consent holder shall provide and maintain signage in good repair in accordance with the signage plan including any approved revisions of that plan.

e) The consent holder shall provide and maintain signage in good repair in the vicinity of the Clyde Dam to warn the public of any hazards associated with the operation of the structure and its appurtenant components.

f) The signage plan shall be reassessed by the consent holder and re-submitted to the Otago Regional Council for approval every three years after approval of the first signage plan prepared under condition 15 (a) of this consent.

Landscape and Visual Amenity Management Plan

a) Within two years of the commencement of this consent, the consent holder shall submit to Otago Regional Council for approval a Landscape and Visual Amenity Management

Plan that describes how it will manage the effects of its activities on landscape and visual amenity values in the bed of the Kawarau Arm of Lake Dunstan including a programme of actions, methods and timelines for required actions.

b) The Landscape and Visual Amenity Management Plan shall incorporate a monitoring component and a subsequent remediation component and shall be prepared in consultation with Otago Regional Council, and other potentially affected parties including Central Otago District Council.

c) The consent holder shall be responsible for ensuring implementation of the Landscape and Visual Amenity Management Plan, including approved revisions of that Plan.

d) The consent holder may reassess the Landscape and Visual Amenity Management Plan at any time in consultation with the Otago Regional Council, and any other potentially affected parties including Central Otago District Council. Any revisions to the Plan shall be submitted to Otago Regional Council for approval.

e) The consent holder in consultation with the Otago Regional Council and Central Otago District Council shall reassess the Landscape and Visual Amenity Management Plan every five years after approval of the first Landscape and Visual Amenity Management Plan and shall submit any revised plans to Otago Regional Council for approval within six months of the reassessment.

Land Purchase

The consent holder shall purchase an easement over that portion of land contained in CT11A/1285 (Otago Registry) affected by the operation of this consent subject to:

a) The purchase price being fixed by registered valuation (provided that valuation has been prepared in accordance with commonly accepted valuation principles); and

b) The owner of that land agreeing to sell that easement to the consent holder at the amount of the relevant valuation.

Roading Issues

a) Within two years of the commencement of this consent, the consent holder shall submit a Roading Management Plan to Otago Regional Council for approval addressing the matters below.

b) The Roading Management Plan shall be developed in consultation with Transit New Zealand and Central Otago District Council.

c) The objective of that Roading Management Plan shall be to avoid, remedy or mitigate adverse effects of erosion and flooding on public roads and properly maintained bridges within Central Otago District, where those effects are caused, or contributed to, by the exercise of this consent; and

d) That Roading Management Plan shall outline implementation methods, funding arrangements, and timing of any work which it requires. For the avoidance of doubt, the Roading Management Plan shall provide, amongst other things, for the use of Clyde Dam for access in an emergency, or at other times as requested by Central Otago District Council (when reasonable access across the Clutha River is restricted) provided in all cases that safety, security and operational conditions of the Clyde Dam are not compromised.

e) The consent holder shall be responsible for ensuring the implementation of the Roading Management Plan.

Clyde Water Permit to Take and Use No. 2001.390

Safety Warnings

a) The consent holder shall provide and maintain adequate signage in good repair in the vicinity of the Clyde Dam where the public can gain access, to warn the public of hazards associated with the operation of the structure and its appurtenant components.

b) The consent holder shall maintain a boom on the lake surface, generally 600 metres upstream of the dam, to warn lake users of the hazards at the dam face (particularly with spillways). The boom shall be secured firmly to the shore or lakebed, shall not interfere with public use of the boat ramp, and shall be maintained in good repair, in safe condition and substantially clear of debris.

Safety Signage

a) The consent holder shall, in consultation with the Central Otago District Council, prepare and submit to the Otago Regional Council for approval a signage plan within 6 months of the commencement of this consent.

b) The signage plan is to provide for adequate signage to warn of the risk to public safety of operational changes in river flows along the Clutha River below the Clyde Dam.

c) The signage plan shall identify the sites and the form and content of the signs used by the consent holder.

d) The consent holder shall provide and maintain signage in good repair in accordance with the signage plan including approved revisions of that plan.

e) The signage plan shall be reassessed by the consent holder and re-submitted to the Otago Regional Council for approval every three years after approval of the first signage plan prepared under condition 3(a) of this consent.

Clyde Discharge Permit to Discharge Water No. 2001.393

Safety Warnings

a) The consent holder shall provide and maintain adequate signage in good repair in the vicinity of the Clyde Dam where the public can gain access, to warn the public of safety and navigation risks associated with the accumulation of sediment within the Kawarau Arm and at other areas of hazardous sediment deposition around Lake Dunstan.

b) The consent holder shall maintain and operate warning sirens during daylight hours to give prior warning to the public in the vicinity of the Clyde Dam of the initial opening of any of the spillway or sluice gates.

c) The consent holder shall maintain a boom on the lake surface, generally 600 metres upstream of the dam, to warn lake users of the hazards at the dam face (particularly with spillways). The boom shall be secured firmly to the shore or lakebed, shall not interfere with public use of the existing boat ramp, and shall be maintained in good repair, in safe condition and substantially clear of debris.

Safety Signage

a) The consent holder shall, in consultation with the Central Otago District Council, prepare and submit to the Otago Regional Council for approval a signage plan within 6 months of the commencement of this consent.

b) The signage plan is to provide for adequate signage to warn of the risk to public safety of operational changes in river flows along the Clutha River below the Clyde Dam.

c) The signage plan shall identify the sites and the form and content of the signs used by the consent holder.

d) The consent holder shall provide and maintain signage in good repair in accordance with the signage plan including approved revisions of that plan.

e) The consent holder shall provide and maintain signage in good repair in the vicinity of the Clyde Dam to warn the public of any hazards associated with the operation of the structure and its appurtenant components.

f) The signage plan shall be reassessed by the consent holder and re-submitted to the Otago Regional Council for approval every three years after approval of the first signage plan prepared under Condition 11 a) of this consent.

Roxburgh Water Permit to Dam No. 2001.386

Flood Management Plan

The consent holder shall, within six months of the commencement of this consent, prepare for approval by Otago Regional Council, a Flood Management Plan in consultation with Queenstown Lakes District Council, Central Otago District Council and Clutha District Council, identifying:

(i) Procedures the consent holder will implement to ensure continual preparedness for flood events;

(ii) Monitoring and control actions the consent holder will implement during the rising, cresting and falling limbs of floods;

(iii) Procedures the consent holder will implement for notification to interested parties of such actions; and

(iv) The manner in which the consent holder will control the storage and flow of water in the Clutha River/Mata-au catchment to mitigate the adverse effects of flooding to the extent that this is practicable through the exercise of this consent and the other consents listed in condition 2.

Pending approval of the Flood Management Plan prepared under condition 6 a) of this consent, the consent holder shall exercise this consent in accordance with the Clutha Flood Rules Version 1.

Once the Flood Management Plan prepared under condition 6 a) of this consent is approved, the consent holder shall exercise this consent in accordance with that management plan including approved revisions of the plan.

The consent holder shall reassess the effectiveness and appropriateness of the Flood Management Plan prepared under condition 6 a) of this consent in consultation with Queenstown Lakes District Council, Central Otago District Council, Clutha District Council and Otago Regional Council no less frequently than every fifth anniversary of the commencement of this consent and also following any instantaneous flow in the Clutha River/Mata-au of greater than 2500 cubic metres per second as measured at Clyde (site 75213).

If the reassessment undertaken pursuant to condition 6 d) indicates to the consent holder that changes to the Flood Management Plan are necessary or desirable, the consent holder shall revise the Flood Management Plan accordingly, for approval by Otago Regional Council.

Lakebed Monitoring

a) The consent holder shall survey the Lake Roxburgh cross sections identified in the Opus (July 2000) report on Drawing No. 8/1247/86/8804/3 (copy attached) and the lower Manuherikia River bed at sections M1-M13 inclusive (as identified on the topographical map attached) at the following frequency:

- at intervals of not more than two years for Lake Roxburgh; and
- at intervals of not more than two years for the lower Manuherikia River; except that
- in the lower Manuherikia River, a survey shall occur within 3 months of a flow exceeding 350 cumecs as measured at the Ophir site (Site No. 75253); and except that
- in both Lake Roxburgh and the lower Manuherikia River, a survey must occur within 3 months of inflows into Lake Roxburgh exceeding 1750 cumecs (as measured at Clutha River at Clyde and Manuherikia at Ophir).

The first survey of all above areas shall be undertaken within 6 months of the commencement of this consent.

b) The results of each survey shall be provided to the Otago Regional Council within 3 months of completion of each survey. The reported survey results shall include an assessment of any predicted flood levels for Lake Roxburgh as measured at each re-survey cross-section based on a 3600 cumecs outflow at Roxburgh Dam.

Flood Hazard Maps for Alexandra

a) Within nine months of the commencement of this consent the consent holder shall lodge with Otago Regional Council for approval flood hazard maps covering Alexandra and its environs for the following real and hypothetical events:

(i) The peak level reached during the November 1999 flood;

(ii) An hypothetical instantaneous water flow of 3,850 cubic metres per second entering Lake Roxburgh (approximately 1:100 Annual Exceedance Probability);

(i) An hypothetical instantaneous water flow of 4,900 cubic metres per second entering Lake Roxburgh (approximately 1:500 Annual Exceedance Probability);

(ii) An hypothetical instantaneous water flow of 7,000 cubic metres per second entering Lake Roxburgh (approximately the Probable Maximum Flood);

b) The flood hazard maps shall contain a prominent note that changes in the Annual Exceedance Probability at various flood levels will occur over time.

c) The consent holder shall revise the flood hazard maps prepared pursuant to condition 11 a) of this consent, for approval by Otago Regional Council, as soon as practicable after any lake or riverbed survey undertaken in accordance with condition 10 of this consent.

Alexandra Flood Compensation

a) Subject to subcondition b), this condition shall apply to any damage caused by, or contributed to by, the exercise of this consent and attributed to inundation of land adjoining the Clutha River / Lake Roxburgh between Roxburgh Dam and Clyde Dam (including its tributaries to the extent they may be affected by water backing up behind the Roxburgh Dam). For the avoidance of doubt, this condition is intended to address flooding which is exacerbated by the existence of the lake and/or the presence of sediment on the bed of the Clutha River and/ or Lake Roxburgh between the Clyde Dam and the Roxburgh Dam.

b) This condition shall not apply in the case of:

(i) easements, deeds or agreements (in the case of residential dwellings the existence of which is noted on certificates of title) either specifically permitting the consent holder to inundate the property in question or specifically excluding the consent holder from liability to compensate for loss or damage arising from inundation of the property; or

(ii) any new structures that, on or after the date of approval of the Flood Hazard Map prepared pursuant to condition 11 a) (ii) of this consent, are constructed or placed on land identified on that map as subject to flooding in the event of a flood of 3850 cubic metres per second entering Lake Roxburgh. For the purpose of this sub-condition, the replacement or upgrading of an existing structure is not a new structure, provided the replacement or upgraded structure serves the same purpose as the existing structure.

Residential Dwellings

c) In the case of any residential dwelling entered by floodwaters the consent holder will offer to pay:

(i) the owner of the dwelling either the actual and reasonable costs of the cleanup of the dwelling and of repairing or replacing (if a suitably qualified assessor certifies that is necessary) all fixtures and fittings damaged by a flood (up to replacement cost); or reasonable replacement costs if the residential dwelling is destroyed;

(ii) the occupier of the dwelling the actual and reasonable costs of repairing or replacing (if a suitably qualified assessor certifies that is necessary) any chattels damaged by a flood (up to replacement cost);

(iii) the owner of the dwelling any rentals not received as a result of the flooding for as long as the premises are not fit for occupation, provided that the owner takes all reasonable steps to restore the premises to a condition fit for occupation as soon as practicable;

(iv) the occupier of the dwelling:

a. either the actual and reasonable costs of alternative accommodation while the flood waters recede, repairs are carried out and the house is made habitable; or

b. an allowance of $50 per person displaced per day as extra living costs if they stay with family, friends, or willing strangers;

d) (i) In circumstances where any residential dwelling – excluding any chattels, fixtures or fittings detached from the building or part of the building in which people live – is flooded, the consent holder will offer to pay $4,000 per residential dwelling solatium payment to the occupier or occupiers (as applicable) for distress and inconvenience.

(ii) In circumstances where no monies are payable under condition 12 d) (i) but the occupants of any residential dwelling are directed to vacate the premises by Civil Defence authorities by reason of actual or potential flooding, the consent holder shall offer to pay to the occupier or occupiers (as applicable) either the actual and reasonable costs of alternative accommodation for so long as they are unable to return to their dwelling or an allowance of $50 per person displaced per day as extra living costs if they stay with family, friends, or willing strangers, and $500 per residential dwelling solatium payment for distress and inconvenience.

e) For the purposes of condition 12(c) and (d) 'residential dwelling' includes:

- a building or a part of a building in which people live;
- any external heat pump or air conditioning unit(s) used to heat or cool that building/part of building as applicable;
- domestic outbuildings, greenhouses and garages;
- permanent decks and built in furniture;
- aerials forming part of the building;
- letter boxes, exterior blinds and awnings, fixed clotheslines and built in barbecues;
- septic tanks, oil heating tanks, service tanks and water tanks including their fixed pumps;
- permanent spa or inground swimming pools, including their fixtures, pipes and fixed pumps;
- walls, fences, gates;
- gas pipes, fresh-water pipes, electricity and telephone cables;
- driveways, paths, footpaths and tennis courts;
- retaining walls;
- planted hedges, shrubs, lawns and plants.

Commercial Premises

f) The consent holder shall offer to pay to each occupier or owner (as appropriate) whose commercial premises are entered by floodwaters or who are directed to vacate the premises by Civil Defence authorities by reason of actual or potential flooding:

(i) In the case of an owner of commercial premises receiving rentals which are not paid by reason of flooding, all rentals that would otherwise have been paid for as long as the premises are not fit for occupation by the businesses that were carried on immediately prior to inundation or until the premises are replaced whichever is first;

(ii) In the case of an owner carrying on their own business within their premises, or whose commercial premises are untenanted at the time of the flood, 8% per annum of the capital value for the period commencing when the premises are entered by floodwaters or vacated at the direction of Civil Defence authorities (as applicable), until it is repaired, and made capable of being fully occupied. In this condition "capital value" means the value of the premises on the day before flooding commences or are vacated (as established by a suitably qualified valuer);

(iii) It is a condition of ongoing payment pursuant to conditions 12 f) (i) or (ii) that the owner must take all reasonable steps to restore the premises to a condition fit for the purpose for which it was being tenanted prior to flooding as soon as practicable;

(iv) Where an occupier is obliged to pay rent but is unable to occupy the premises for the purpose of carrying on the business by reason of flooding, any occupier for such rentals until such time as the premises are fit for occupation by the businesses that were carried on immediately prior to flooding provided that it is a condition of ongoing payment pursuant to this condition that the occupier must take all reasonable steps to restore the business to its previous status;

(v) In addition to the foregoing rental payments the consent holder shall also offer to pay:

a. the cost of replacement of all damaged or destroyed stock (provided that the consent holder has the right to the stock so replaced);
b. the actual and reasonable costs of repair or replacement of damaged plant and equipment (provided that the consent holder has the right to any plant or equipment replaced);
c. full replacement costs to the building owner if any building is destroyed;
d. all ordinary wages and other emoluments that have been paid while the business is not operating;
e. all other unavoidable costs that have been paid while the business is not operating;
f. $1,000 solatium payment for distress and inconvenience to the business owner; and
g. to the extent not falling within a category of loss or damage covered by any part of this condition 12 f), costs of business interruption, provided that any claims for such costs shall be reduced by any proceeds from

insurance claims for business interruption, and shall be supported by a reasonable assessment prepared in accordance with standard accounting practice by a Chartered Accountant;

Home business

g) Where a business operates from the owner's residential dwelling, the total of the claims made under conditions 12 c), 12 d), and 12 f) shall not exceed that person's actual losses.

Other Property

h) In the event that property not covered by conditions 12 c), 12 d), or 12 f) is damaged as a result of inundation, then:

   (i) the consent holder will offer to meet the actual and reasonable repair or replacement costs incurred by the property owner; and

   (ii) without affecting the generality of (i), damage to infrastructure like roads, telephones and power lines, stormwater and wastewater systems is included in the definition of 'prperty'.

Claims - General

i) Any claim shall be made in writing to the consent holder within 12 months of the flooding giving rise to it supported by evidence of costs incurred (if applicable).

j) Except for those claims (or parts thereof) in dispute, the consent holder shall make all payments prescribed in the above conditions, as soon as practically possible – and usually within three months maximum – after such undisputed claims are lodged.

k) Any person who submits a claim shall do so on the basis that that person agrees:

   (i) to provide access to affected properties;
   (ii) to submit to arbitration if arbitration is invoked pursuant to condition 12 n); and
   (iii) to provide such reasonable information that the consent holder, and or the Panel constituted under condition 12 m) may require.

Claims – Disputes Procedures

l) In the event of any dispute about the amount of compensation payable by the consent holder to any person entitled to make a claim pursuant to this condition, the following conditions shall apply:

   (i) The consent holder shall notify the claimant as to what part or parts of the claim are disputed;

(ii) If the part or parts of the claim in dispute are for a total sum less than $500,000, the dispute shall be settled on the basis set out in condition 12 m) (unless the claimant elects that the alternative procedure specified in Condition 12 n) shall be followed).

Short Form Resolution Process

m) The short form resolution procedure is as follows:

(i) One Chartered Accountant and one suitably qualified valuer (together “the Panel” who shall have the power to take expert advice as necessary) shall determine all disputed claims raised between any claimants and the consent holder not falling for determination under the Alternative Resolution Process in respect of each flood affecting property;

(ii) The Panel shall be appointed either:

a. by the Mayor of the Central Otago District Council and the consent holder by agreement; or

b. failing such agreement by the President for the time being of the New Zealand Institute of Chartered Accountants in the case of selecting a Chartered Accountant and the President of the New Zealand Institute of Property Valuers in the case of selecting a valuer, from a choice of six chartered accountants and six valuers – three nominated by the Mayor of the Central Otago District Council as representative of the community, and three by the consent holder;

(iii) The Panel’s costs shall be paid by the consent holder;

(iv) The Panel shall receive such evidence from the claimant and the consent holder as those Parties choose to provide, and make such other enquiries as it considers appropriate;

(v) The Panel shall not make any reduction in the value of any claim (or the amount of any approved claim) for alleged betterment in respect of replacement goods or chattels;

(vi) The Panel is not required to conduct a formal hearing, but access to private property will be given to the Panel if it wishes to inspect any house, building or its contents (provided adequate prior notice is given);

(vii) All other procedures are to be agreed by the claimant and the consent holder or failing agreement a fair procedure will be fixed by the Panel;

(viii) The Panel shall act as an expert (not an arbitrator);

(ix) By giving notice of dispute, the consent holder is deemed to enter into a contract with the claimant to participate in the short form resolution process (unless the claimant has elected to the alternative procedures specified in condition 12 n). The short form resolution process shall determine the amount (if any) and the consent holder's contractual obligation to the claimant. The consent holder shall make any payment owing to the claimant forthwith upon the decision of the Panel being communicated to it;

Alternative Resolution Process

n) Where the amount of any disputed claim for any one residential dwelling or commercial premises exceeds $500,000 or the claimant has elected to pursue this alternative procedure, the provisions of the Arbitration Act 1996 shall apply.

General Provisions– Claims

o) The consent holder shall make available to any person who believes on reasonable grounds that they have a claim for compensation under this condition 12 the services of a qualified Loss Adjuster to assist that person to formulate his or her claim. The Loss Adjuster's services shall be provided on the basis that he or she acts jointly for the potential claimant and for the consent holder, and reports to both.

p) Any person who makes a claim for compensation pursuant to this condition shall make such a claim on the basis that they agree they will be bound by the outcome of that process, that any payments they receive will be in full and final satisfaction for all claims which they might have made in respect of the inundation and that they will not issue any proceedings in any jurisdiction subsequently seeking to claim compensation for damage or loss caused by the inundation.

(Advice note – before making any claim pursuant to this condition it would be prudent for the potential claimant to take advice and in particular to consider their insurance position.)

q) In each case where a monetary figure is specified in dollars in this condition 12, for the purposes of implementation of the relevant part of condition 12, the figure shall be deemed to be adjusted by reference to increases in the Consumer Price Index from a base of the date of commencement of this consent to the date flooding of the property in question commences or the date the property is vacated in accordance with the directions of Civil Defence authorities (as applicable).

r) All payments made by the consent holder pursuant to this condition shall be gross payments including GST where applicable, provided that in the case where the claimant is GST registered, the claim must be supported by a GST invoice.

Safety Warnings

a) The consent holder shall provide and maintain adequate signage in good repair in the vicinity of the Roxburgh Dam where the public can gain access, to warn the public of hazards associated with the operation of the structure and its appurtenant components.

b) The consent holder shall maintain a boom on the lake surface, generally 50 metres upstream of the dam, to warn lake users of the hazards at the dam face (particularly with spillways). The boom shall be secured firmly to the shore or lakebed, shall not interfere with public use of the existing boat ramp in that vicinity, and shall be maintained in good repair, in safe condition and substantially clear of debris.

Safety Signage

a) The consent holder shall, in consultation with the Central Otago and Clutha District Councils, prepare and submit to the Otago Regional Council for approval a signage plan within 6 months of the commencement of this consent.

b) The signage plan is to provide for adequate signage to warn of the risk to public safety of operational changes in river flows along the Clutha River below the Roxburgh Dam.

c) The signage plan shall identify the sites and the form and content of the signs used by the consent holder.

d) The consent holder shall provide and maintain signage in good repair in accordance with the signage plan including approved revisions of that plan.

e) The signage plan shall be reassessed by the consent holder and re-submitted to the Otago Regional Council for approval every three years after approval of the first signage plan prepared under condition 14 a) of this consent.

Land Purchase

a) Within two years of the commencement of this consent, the consent holder shall commission an investigation of the effects of flooding on private property and risks to safety on the true right bank of the Clutha River between the Clyde Dam and the Alexandra Bridge caused by or contributed by the consent holder's activities. The investigation shall determine:

(i) The nature and extent of the problem if any;

(ii) The degree to which the consent holder is responsible;

(iii) The options available to mitigate the effects;

and report to the Otago Regional Council what action if any has been undertaken.

b) The consent holder shall purchase an easement over land affected by the operation of this consent namely;

(i) CT401/95 (Otago Registry);

(ii) Section 12 Block XXXIV town of Alexandra;

(iii) Sections 4 & 5 SO Plan 23675 situated in Blocks XIX and XXXIV town of Alexandra;

(iv) Section 1 SO Plan 23338 and Section 3 SO Plan 23675 Block XXXIV;

Subject to:

The purchase price being fixed by registered valuation (provided that valuation has been prepared in accordance with commonly accepted valuation principles) and the respective owners of that land agreeing to sell that easement to the consent holder; at the amount of the relevant valuation.

Roading Issues

a) Within two years of the commencement of this consent, the consent holder shall submit a Roading Management Plan to the Otago Regional Council addressing the matters below.

b) The Roading Management Plan shall be developed in consultation with Transit New Zealand and Central Otago District Council.

c) The objective of that Roading Management Plan will be to avoid, remedy or mitigate adverse effects of the erosion and flooding on public roads and properly maintained bridges within Central Otago District, where those effects are caused, or contributed to, by the exercise of this consent; and

d) That Roading Management Plan will outline implementation methods, funding arrangements, and timing of any work which it requires. For the avoidance of doubt, the Roading Management Plan shall provide, amongst other things, for the use of Clyde Dam for access in an emergency, or at other times as requested by Central Otago District Council (when reasonable access across the Clutha River is restricted) provided in all cases that safety, security and operational conditions of the Clyde Dam are not compromised.

e) The consent holder shall be responsible for ensuring implementation of the Roading Management Plan.

Landscape and Visual Amenity Management Plan

a) Within two years of the commencement of this consent, the consent holder shall submit to Otago Regional Council for approval a Landscape and Visual Amenity Management Plan that describes how it will manage the effects of its activities on landscape and visual amenity values in the bed of the Manuherikia River and adjacent Crown Land from the confluence with the Clutha River to cross-section M10 (located 3.97 kilometres upstream from Lake Roxburgh), including a programme of actions, methods and timelines for required actions.

b) The Landscape and Visual Amenity Management Plan shall incorporate a monitoring component and a subsequent remediation component and shall be prepared in consultation with Otago Regional Council, and other potentially affected parties including Central Otago District Council.

c) The consent holder shall be responsible for ensuring implementation of the Landscape and Visual Amenity Management Plan, including approved revisions of that Plan.

d) The consent holder may reassess the Landscape and Visual Amenity Management Plan at any time in consultation with Otago Regional Council, and other potentially affected parties including Central Otago District Council. Any revisions to the Plan shall be submitted to Otago Regional Council for approval.

e) The consent holder shall, in consultation with the Otago Regional Council and Central Otago District Council, reassess the Landscape and Visual Amenity Management Plan every five years following approval of the first Landscape and Visual Amenity Management Plan and shall submit any revised plans to Otago Regional Council for approval within six months of the reassessment.

Roxburgh Water Permit to take and use 2001.391

Safety Warnings

a) The consent holder shall provide and maintain adequate signage in good repair in the vicinity of the Roxburgh Dam where the public can gain access, to warn the public of hazards associated with the operation of the structure and its appurtenant components.

b) The consent holder shall maintain a boom on the lake surface, generally 50 metres upstream of the dam, to warn lake users of the hazards at the dam face (particularly with spillways). The boom shall be secured firmly to the shore or lakebed, shall not interfere with public use of the existing boat ramp, and shall be maintained in good repair, in safe condition and substantially clear of debris.

Safety Signage

a) The consent holder shall, in consultation with the Central Otago and Clutha District Councils, prepare and submit to the Otago Regional Council for approval a signage plan within 6 months of the commencement of this consent.

b) The signage plan is to provide for adequate signage to warn of the risk to public safety of operational changes in river flows along the Clutha River below the Roxburgh Dam.

c) The signage plan shall identify the sites and the form and content of the signs used by the consent holder.

d) The consent holder shall provide and maintain signage in good repair in accordance with the signage plan including approved revisions of that plan.

e) The signage plan shall be reassessed by the consent holder and re-submitted to the Otago Regional Council for approval every three years after preparation of the first signage plan under condition 3 a) of this consent.

Roxburgh Discharge Permit to Discharge Water No. 2001.394

Riverbank and Berm Stability

The consent holder shall provide 50% of the actual and reasonable costs of an Otago Regional Council investigation into river changes, instability and erosion in the Clutha River downstream from Roxburgh Dam, which shall be undertaken by 30 June of every second year, from the date of commencement of the consent. The consent holder shall provide 50% of the actual and reasonable costs of subsequent remedial actions in respect of riverbank and berm instability and erosion provided that such expenditure is for maintenance only, or, where new works are to be undertaken they shall be attributable to the consent holder's operations under this consent and the other consents listed in condition 2.

Rivermouth Maintenance and Opening

a) The consent holder shall contribute 90% of the actual and reasonable costs of maintaining the coastal mouth of the Matau and Koau branches of the Clutha River open at all times, to ensure efficient egress of flows to the sea without exacerbation of flood levels, and without interference with both groundwater levels and effective land drainage.

b) The consent holder shall contribute 90% of the actual and reasonable costs of maintaining, in good repair, the river mouth training works at the Matau and Koau branches of the Clutha River.

Safety Warnings

a) The consent holder shall provide and maintain adequate signage in good repair in the vicinity of the Roxburgh Dam where the public can gain access, to warn the public of hazards associated with the operation of the structure and its appurtenant components.

b) The consent holder shall maintain and operate warning sirens during daylight hours to give prior warning to the public in the vicinity of the Roxburgh Dam of the initial opening of any spillway and / or sluice gates.

c) The consent holder shall maintain a boom on the lake surface, generally 50 metres upstream of the dam, to warn lake users of the hazards at the dam face (particularly with spillways). The boom shall be secured firmly to the shore or lakebed, shall not interfere with public use of the boat ramp, and shall be maintained in good repair, in safe condition and substantially clear of debris.

Safety Signage

a) The consent holder shall, in consultation with the Central Otago and Clutha District Councils, prepare and submit to the Otago Regional Council for approval a signage plan within 6 months of the commencement of this consent.

b) The signage plan is to provide for adequate signage to warn of the risk to public safety of operational changes in river flows along the Clutha River below the Roxburgh Dam.

c) The signage plan shall identify the sites and the form and content of the signs used by the consent holder.

d) The consent holder shall provide and maintain signage in good repair in accordance with the signage plan including approved revisions of that plan.

e) The signage plan shall be reassessed by the consent holder and re-submitted to the Otago Regional Council for approval every three years after approval of the first signage plan prepared under condition 12 a) of this consent.

Coastal Erosion

a) The consent holder shall contribute 50% of the costs of an Otago Regional Council coastal erosion management programme specifically addressing:

(i) An analysis of historic shoreline positions using appropriate techniques at specific representative coastal sites that may be dependent on Clutha-derived sediment; and

(ii) A comprehensive physical coastal monitoring programme at the representative sites, covering the nearshore transport zone between the limits of the beach foredune system and seaward limit of the nearshore sand wedge between Nugget Point and Taieri Mouth.

Roxburgh Land Use Consent to Alter the Lake Roxburgh Lakebed and Lower Manuherikia Riverbed No. 2001.398

Lakebed Monitoring

a) The consent holder shall survey the Lake Roxburgh bed at the cross sections identified in the Opus (July 2000) report on Drawing No. 8/1247/86/8804/3 (copy attached) and the lower Manuherikia River bed at sections M1- M13 inclusive (as identified on the topographical map attached) at the following frequency:

- at intervals of not more than two years for Lake Roxburgh; and
- at intervals of not more than two years for the lower Manuherikia River; except that
- in the lower Manuherikia River, a survey shall occur within 3 months of a flow exceeding 350 cumecs as measured at the Ophir site (Site No. 75253); and except that
- in both Lake Roxburgh and the lower Manuherikia River, a survey shall occur within 3 months of inflows into Lake Roxburgh exceeding 1750 cumecs (as measured at Clutha River at Clyde and Manuherikia at Ophir).

The first survey of all above areas shall be undertaken within six months of the commencement of the consent.

b) The results of each survey shall be provided to the Otago Regional Council within 3 months of completion of each survey. The reported survey results shall include an assessment of any predicted flood levels for Lake Roxburgh as measured at each re-survey cross-section based on a 3600 cumecs outflow at Roxburgh Dam.

Landscape and Visual Amenity Management Plan

a) Within two years of the commencement of this consent, the consent holder shall submit to Otago Regional Council for approval a Landscape and Visual Amenity Management Plan that describes how it will manage the effects of its activities on landscape and visual amenity values in the bed of the Manuherikia River and adjacent Crown Land from the confluence with the Clutha River to cross-section M10 (located 3.97 kilometres upstream from Lake Roxburgh), including a programme of actions, methods and timelines for required actions.

b) The Landscape and Visual Amenity Management Plan shall incorporate a monitoring component and a subsequent remediation component and shall be prepared in consultation with Otago Regional Council, and other potentially affected parties including Central Otago District Council.

c) The consent holder shall be responsible for ensuring implementation of the Landscape and Visual Amenity Management Plan, including approved revisions of that Plan.

d) The consent holder may reassess the Landscape and Visual Amenity Management Plan at any time in consultation with Otago Regional Council, and other potentially affected parties including Central Otago District Council. Any revisions to the Plan shall be submitted to Otago Regional Council for approval.

e) The consent holder shall, in consultation with other potentially affected parties including Central Otago District Council, reassess the Landscape and Visual Amenity Management Plan at the expiration of every five years following approval of the first Landscape and Visual Amenity Management Plan and shall submit any revised Plans to Otago Regional Council for approval within six months of the reassessment.