North Bank Tunnel

Flow and In-stream Habitats Management Plan

DRAFT

Prepared for

Client Name

by

Boffa Miskell Limited

And

NIWA

June 2007

Boffa Miskell

CONTENTS

1.0 INTRODUCTION

This Management Plan has been prepared as part of Meridian's resource consent applications for the North Bank Tunnel Hydro Electricity Scheme (NBT) in the Lower Waitaki River.

The focus of this Plan is the management activities that Meridian will carry out, or will assist others to carry out, as mitigation of potential effects of the NBT proposal, to meet the Objectives of the Waitaki Catchment Water Allocation Regional Plan with NBT in operation. It contains Meridian's objectives, actions, methods, and monitoring programme associated with maintaining the existing characteristics of the Lower Waitaki river bed in the reach of the river affected by NBT.

Meridian has developed a series of management plans to address various issues identified during the project development and consultation. The aim is to develop a series of inter-related River Management Plans that address the following:

- *River Geomorphology and Riverbed Vegetation Management*
- *Flow and In-stream Habitat Management*
- *Braided River Bird Management*
- *Abstractive Users' Infrastructure Management*
- *Wetlands Management*

The NBT resource consent application *Assessment of Effects on the Environment (AEE)* (section 6.1.3) sets out the matters proposed to be covered by each Plan; section 6.18 of the AEE outlines the specifics to be addressed in each plan.

NBT will not be operative until approximately 2016. In the interim, design, consenting, resource investigations, and river monitoring will continue (assuming that resource consent applications are approved). During this time, the management plans will be revised in response to ongoing findings and developments. The timeframe will allow for additional refinement of the Plans, as necessary.

The Plan does not address in any detail, the management activities that other groups, organisations, or individuals will carry out in the Lower Waitaki. These were considered in drawing up Meridian's proposals for management and the Plan provides documentation of the relationship between the current and ongoing river management

activities carried out by Environment Canterbury (ECan) and those proposed by Meridian as part of NBT.

Liaison and consultation with other river managers and stakeholders will continue to be a key part of developing and adapting the management plans. An implementation plan, outlining timeframes, funding, roles and responsibilities, will be completed once the resource consent applications have been approved and the NBT is closer to being operative.

1.1 Context

Since September 2005, water allocation in the Lower Waitaki River has been managed through an integrated suite of objectives and policies in the Waitaki Catchment Water Allocation Regional Plan (WRP). These recognize the environmental, social, cultural and economic factors operating within the catchment.

In 2004 the Lower Waitaki River Management Group was formed by the community and ECan. The group (now the Lower Waitaki River Management Society) prepared a *Lower Waitaki River Management Strategy* in May 2006. The Mission Statement and goals of this Strategy fit alongside the Objectives of the WRP. The contents of these more strategic documents anticipate the preparation of more detailed management plans, action plans and/or monitoring programmes as part of resource consent applications or other specific water uses.

The flow regime and management plans proposed for NBT in the applications made in October 2006 take into account this set of mission statement, goals, objectives, and policies that form the context for river management in the Lower Waitaki today.

1.2 Purpose of plan

The purpose of the *Flow and Instream Habitat Plan* is:

To ensure the flow regime provides aquatic habitat between Waitaki Dam and the discharge outfall of sufficient quantity and quality to maintain fish stocks, fisheries, and other instream values at the levels prior to the exercise of these take and discharge consents in the Lower Waitaki River.

1.3 Content and layout of plan

This Plan focuses on the mitigation actions to be carried out by Meridian to achieve adaptive management objectives for the resource. It does not repeat the strategic direction or background material already available in the NBT AEE, Technical Reports, or other strategic documents. A list of these documents is attached at Appendix A.

The NBT AEE and consultation have guided the contents of each Plan as follows:

1. *Objectives for management* – the outcomes sought for river management. These focus on water management only at this stage. The River Management Plans may be able to be extended or additional management plans prepared to address issues raised in the Stage Two consent application to construct and operate a tunnel.

2. *Implementation, actions, and methods* - to achieve the objectives for river management. 'Actions' outline 'what' will be done to achieve the objectives while 'methods' explain 'how' actions will be achieved.

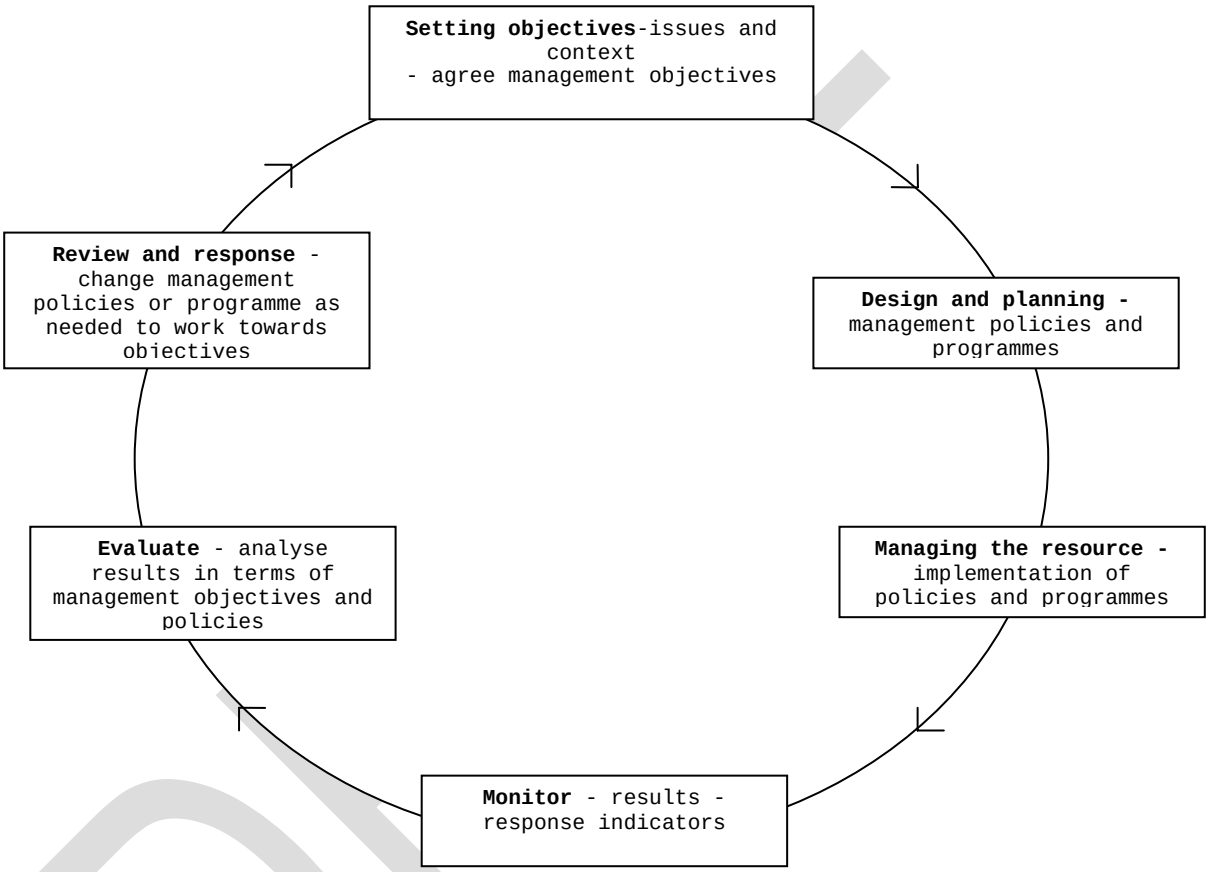
3. *Indicators* - to be used to determine (through monitoring) whether the objectives for management are being achieved.

4. *A specific programme for carrying out the methods* in the short - medium term, including timeframes and interaction with other river management organisations.

5. *A monitoring programme*, including methods for feeding the results of monitoring into the adaptive management cycle and, if warranted, the adaptation of specific implementation methods and the review of the River Management Plans where required.

1.4 Adaptive Management

Adaptive management is a structured approach to managing complex systems (such as rivers). It involves a process for setting management objectives based on anticipated outcomes. The results of management efforts are monitored and management approaches are adjusted in order to achieve the objectives. Adaptive management is an ongoing and cyclic process, with feedback loops so that management can improve over time, as follows:



The key stages in the cycle are:

Setting Objectives – the issue is identified and defined, and the resource information is reviewed. Hypotheses can then be developed about how the resource will respond to management. Once the objectives are set specific indicators of management success (or failure) can be identified.

Design and planning – the preparation of management plans and programmes for managing the resource

Managing the resource – implementing management actions and methods

Monitoring – monitoring the effects of management on indicators

Evaluation – analysis of monitoring results in relation to objectives and management programme i.e. are the objectives being achieved.

Review and response – reviewing and refining the hypothesis, management plan and programme to better meet the objectives. There may also need to be adjustment of policies, programmes and budgets of other organisations involved with the resource or issue. After this stage the process starts again with *design and planning.*

The process has to be flexible, to respond to changes in the existing management regime, the resource, and the environment, and to changing issues and political circumstances.

The adaptive management approach to managing the Lower Waitaki is also described in NBT AEE, Appendix 26 (Adaptive Management and the Use of River Management Plans).

1.5 Management Plan Principles

The management of flow and instream habitat set out in this plan is based on some underlying principles. Some of these principles apply to all the proposed management plans; others are more specific to the resource being addressed through each plan and the issues affecting it.

The relevant principles for this Plan are:

i. The preference is for management to happen within the affected reach

Flow and instream habitat management will focus on the area potentially affected by NBT (between Waitaki Dam and the NBT outfall). Where necessary, management may occur below the outfall. The location of management actions will be decided on their merit or, where it is likely to be most effective and efficient, for example vegetation control measures.

ii. Focus of the plans

The focus of these Plans is to establish a process for addressing identified effect of NBT. It is important to recognise that the river is also affected by factors other than hydro-electric power generation (such as the recent didymo

invasion, extreme weather events, or other river users). While some of these other factors will be managed as part of an effective adaptive management approach, the River Management Plans do not set out to mitigate all effects caused by factors other than NBT.

iii. 2001 baseline

The Actions, methods, and monitoring must be measured against the baseline. Given the uncertainty about the date on which NBT might be operational, and the date on which management prescribed in this plan might commence, the year 2001 will be considered as the "baseline" against which changes will be assessed.

2001 was the year used as the baseline for Project Aqua investigations, and modelling on which the WRP was based and is the year in which significant river data was collected. Documented changes since that time (e.g. arrival of Didymo) are considered as far as possible.

iv. Limits to knowledge

In spite of the large amount of intensive research carried out on behalf of Meridian and independently, there is a limit to the knowledge and understanding of some of the processes involved in flow and instream habitat dynamics. This means that there may never be certainty about which changes in instream habitat can be attributed to NBT and which changes are a part of on-going, existing, natural and human-influenced processes.

v. Working with Environment Canterbury

ECan has a primary role in management of the Lower Waitaki riverbed and riverbed vegetation for a range of values and uses. The management proposed in this Plan is being developed by Meridian in consultation with ECan river engineering staff.

vi. Working with other key stakeholders

Other key parties with an interest in, and responsibility for, aspects of river management include Land Information New Zealand (LINZ), the Department of Conservation (DoC), Tangata Whenua and the owners of land adjacent to the Waitaki River. The roles and responsibilities of these other parties have not been incorporated into this Plan at this stage. The relationship of this Plan to responsibilities such as kaitiakitanga by Tangata Whenua and issues of land ownership administered by LINZ and DoC will be explored during ongoing consultation. Consultation will

also be undertaken with the adjoining landowners and other abstractors companies to ensure ongoing access to water and compatibility of in-stream works.

1.6 Existing Environment

The existing environment in the Lower Waitaki River is described in detail in a series of Technical Reports that form appendices to the NBT water consents application (October 2006).

The key features of the existing environment relevant to this flow and instream habitat plan are:

- Four, flowing-water habitat types have been defined (riffles, runs, pools and backwaters) and these vary in extent and distribution depending on river flows. This means that the extent of good quality habitat for different species varies. Species abundance and composition of plant and animal communities also varies with habitat quality. These are all influenced by the normal (or modal) flow levels and the magnitude and duration of high and low flows. The varial zone is the habitat zone influenced by fluctuations above the median minimum flow and is not good permanent habitat for most aquatic species.

- The periphyton and macrophyte communities reflect the flow regime that has operated in recent years i.e. they comprise a mix of native and exotic species that occupy a diverse range of habitats. Periphyton and macrophytes are photosynthesizing primary producers and constitute the base of the entire river food-chain.

- Periphyton species have (until Didymo arrived in 2006) rarely been present at nuisance levels, although nuisance blooms have occurred in some tributaries and in some small side braids at times. Generally the periphyton community has provided healthy, productive conditions for invertebrate and fish communities.

- The arrival of Didymo in January 2006 has resulted in widespread blooms that exceed NZ periphyton biomass guidelines and degrade the recreational value of the river, particularly for angling and jetboating. The development of Didymo and the extent to which it may affect invertebrate and fish communities is the subject of ongoing monitoring. This may affect the definition of the existing environment as the development of

this Plan proceeds. It is estimated that flood flows of the order of 900 m^3/s are likely to remove significant amounts of Didymo.

- Macrophytes are rarely present to nuisance levels and often provide valuable habitat for invertebrates and fish, particularly in backwater and riparian wetland habitats, and also to some extent in the single channel section of river between Waitaki Dam and Kurow.

- A specialist plant community of short-growing, turf-forming species, known as the low mound community (LMC) occupies shallow, periodically-inundated, river margins (i.e. the varial zone). The community is composed entirely of NZ native plants and is particularly resistant to invasion by exotics, giving it some botanical importance.

- The diversity and productivity of macroinvertebrate communities is influenced by the physical environment, particularly water velocity, depth, substrate type and water quality, as well as biological interactions. Typically large floods reduce macroinvertebrate productivity, moderately stable flows promote high productivity, and prolonged stable periods favour thick periphyton and small invertebrates which constitute reduced productivity for fish. In the Waitaki catchment natural lakes, constructed lakes, and regulation of flows for hydro-electricity production, have buffered flood flows in the lower river. These conditions are more favourable for macroinvertebrate communities. Macroinvertebrates are therefore more productive and provide better food resources for fish populations in the Lower Waitaki River, compared with other unregulated, glacial-fed, braided, east coast rivers.

- Four macroinvertebrate habitat zones have been defined:

  A = unproductive varial zone along the margins of the main channel or braids, dry for around 50% of the time

  B = stable, productive zone, deeper than ‘A’ and with median velocity 0.57 m/s

  C = stable, productive zone, deeper than ‘B’; median velocity 0.90 m/s

  D = low productivity zone, in the deep, main channel; median velocity 1.40 m/s.

- Instream habitat analysis indicates that optimal conditions for macroinvertebrates in single channel reaches occur in flows of between 100 and 150 m^3/s. In braided reaches higher flow

levels create a wider river, with greater total habitat area for macroinvertebrates, although the average quality of habitat can decline.

- The species composition of the native fish population of the Lower Waitaki is typical of braided rivers along the east coast of the South Island, and with the exception of longfin eels, native fish abundance is relatively high. However, the Waitaki Dam is a barrier to the movement of diadromous fish.

- Of the native fish species, eels (tuna) are the most important mahika kai species. The commercial eel fishery in the Lower Waitaki is in decline.

- The river supports a highly valued fishery for Chinook salmon, and rainbow and brown trout. The abundance of salmon and trout varies between years, particularly for salmon, which spend most of their life at sea. The estimated annual catch of salmon during the mid 1980s was between 1,700 and 19,700 fish, but this has declined dramatically in recent years. Total numbers of running salmon will have been higher than estimated annual catch rates. Trout abundance estimates range from 9,000 to over 20,000 fish for the lower river. Due to the large width and number of braids, the Lower Waitaki River supports more trout per kilometre than most other New Zealand rivers.

- Salmon and trout use different parts of the river and tributary habitats at different times of year. Juvenile salmon rear throughout the mainstem of the river and tributaries before migrating to sea. Once mature they migrate back to fresh water, moving up the river to spawn in the upper tributaries and upper parts of the mainstem during late summer. Side braids and tributaries are also particularly important for trout spawning which occurs in May to June for brown trout and late July to mid October for rainbow trout.

2.0 OBJECTIVES

2.1 Introduction

The objectives for management of flow and instream habitat management are based on three documents:

- Broad objectives for management of water allocation as set out in the Waitaki Catchment Regional Plan (September 2005),
- Objectives for management of the Lower Waitaki, as set out in the Lower Waitaki River Management Group Strategy (May 2006). The Objectives from the LWRMG's River Management Strategy are shown in Appendix B, and
- Specific objectives for the management of flow and instream habitat under NBT derived from Technical Reports forming part of the AEE for water consents. (October 2006).

At this stage the Flow and instream habitat plan objectives focus on what can be achieved by management of the water flow (which is within the management control of Meridian) and the riverbed (which is within the management control of ECan).

The objectives of this Plan are:

1. To maintain at least sufficient diversity and quantity of aquatic habitat to maintain populations of aquatic organisms that are consistent with maintaining fish stocks, fisheries, and other instream ecological values at the levels prior to the exercise of these consents.
2. To maintain at least sufficient quality of aquatic habitat to maintain populations of aquatic organisms that are consistent with maintaining fish stocks, fisheries, and other instream ecological values at the levels prior to the exercise of these consents.
3. To maintain surface flow connections to those tributaries that have existing (2001) natural permanent connections (i.e., Awakino River, Maerewhenua River, Hakataramea River, Kurow Creek), sufficient to ensure passage for fish.
4. To maintain flow connections to braids throughout the width of the managed fairway, such as to be consistent with Objective 3 of the *Riverbed Geomorphology and Vegetation Management Plan*,

sufficient to ensure that there is a mixture of braids with and without riparian vegetation cover for fish.

5. To maintain at least sufficient quantity and quality of suitable angling conditions to maintain angler satisfaction at the level immediately prior to the exercise of these consents.

6. *Specific water quality objective in relation to recreation and public water supply –to be added*

3.0 THE BASELINE

For the early drafts of the Management Plans, the environmental conditions in the Lower Waitaki river as they existed in 2001 are considered as the "baseline" for which management objectives have been set and against which changes will be measured and reviewed in the adaptive management process. This year was chosen because:

- Considerable resources have been devoted by Meridian and others to measuring a range of environmental parameters at that time (as a basis of Project Aqua investigations and development proposals) – this includes completion of a full run of aerial photographs at a range of discharges.

- Flow simulations and models have been developed to illustrate various scenarios for the river's future, based on the 2001 datasets.

- The date at which NBT would operate (if consented) is uncertain. It would be inappropriate to automatically select the actual commissioning date as the baseline, since that would be too late to start some of the monitoring.

- Since the Waitaki Regional Allocation Plan has only been operative for a short time, and since the long term effects of its allocation rules are unknown, the most useful baseline is one that is past and measurable.

- The conditions as they existed in 2001 are broadly consistent with ECan's current aim to maintain a fairway clear of willows to a width of 400m at Kurow, generally increasing downstream to a width of 700m at the river mouth.

As investigations proceed in the period before commissioning, sufficient updated information may be gained for some parameters to reset the baseline at a more recent date. Review of the baseline date will be included in the analysis part of the monitoring process.

The key features of environmental conditions in 2001 that are relevant to this Management Plan are:

- *Mean flow:* At the Waitaki Dam, the long-term (1979-2005) average mean flow is 382 m^3/s.

- *Minimum flow:* 120 m^3/s at Waitaki Dam (as set out in the Lower Waitaki River operating rules). Historically Meridian has allowed a buffer of 30 m^3/s so that flow has rarely been below 150 m^3/s in the last 26 years (i.e. between 1979-2005).

- *Flood flows:* a 900 m^3/s flood has an annual exceedance probability of 0.53 (1.9 year return period). This gives 4.4 flood days per year greater than 900 m^3/s, with most events occurring between November and April.

- *Flushing flows:* there are currently no managed flushing flows in the system.

- *Daily flow variability:* Daily flow variability is a feature of the current operation of the Waitaki system. On average 6 hour average flows vary by 50 m^3/s over one day. For 11% of the time the daily variation in 6 hour average flow is greater than 100 m^3/s.

- *Weekly flow variability:* Periods of stable flow are rare. Weekly variation is greater than 80 m^3/s for 80% of the time.

- *Monthly flow variability:* Periods of stable flow are rare. Monthly variation is greater than 120 m^3/s for 95% of the time.

- *Connectivity:* Four tributaries have permanent natural surface water connection to the main stem of the Lower Waitaki – Awakino, Maerewhenua, Hakataramea, Kurow Creek.

- *Braiding pattern:* at a reference discharge aligning with the normal flow to be expected in the river under the NBT (median ~ 140 m^3/s), the braiding density averages 7 braids between the Waitaki Dam and Stonewall, and 9 braids between Stonewall and the sea.

- *Open/unvegetated fairway width:* The existing/baseline (2001) condition is a target average open fairway width of 400 m at Kurow, increasing downstream to 700 m at the rivermouth, with an overall average width of 600 m.

- *Habitat type diversity:* The existing/baseline (2001) condition is approximately 30% each of run, riffle and pool type habitats with less than 10% of backwater habitat.

Ongoing monitoring will be necessary to measure *habitat quality.* As such, the baseline will include 2001 and 2005 data and will continue to be collected up until commissioning of the scheme. In particular for this Plan, baseline ecological monitoring will be carried out prior to tunnel commissioning as described in section 6. As investigations proceed in the period before commissioning, sufficient updated information may be gained for some parameters to reset the baseline at a more recent date.

Additional relevant baseline conditions are:

- *Habitat quality:* The existing/baseline condition (average from 2001 up until tunnel commissioning date) of the habitat quantity and quality is sufficient to support densities and population existing prior to commissioning.

Results from this monitoring would be incorporated into the definition of baseline condition for populations of aquatic algae, plants, invertebrates, native fish and trout and salmon. Review of the baseline date and ecological data will be included in the analysis part of the monitoring process.

- *Angler satisfaction:* The existing/baseline condition for angler satisfaction is defined by available data for a series of indicators including: spawning run numbers, fingerling densities, angling effort (visiting days), annual angler harvest, angler catch rate (fish per hour), mean and maximum fish length, and fish condition factor.

4.0 MANAGEMENT OBJECTIVES, ACTIONS AND METHODS

4.1 Introduction

In this section the actions required to meet the different objectives are outlined, and the methods that are proposed to carry out the actions are described. Usually a number of actions will be required for one objective – for example, channel maintenance flows (floods) and physical clearance of vegetation will be needed to meet Objective 1.

Some of the actions that are more fully described in other plans will also contribute to objectives – for example, vegetation clearance set out in the *River Geomorphology and Vegetation Management Plan* is important in contributing to habitat diversity (Objective 2).

The section is arranged as follows:

Objective and rationale: for each objective there is a brief discussion about why the range of actions and methods proposed have been chosen and any links to other plans

Actions: The actions proposed are outlined

Methods: A detailed description of methods proposed to carry out each of the actions

4.2 Objectives, Actions and Methods

Objective 1

To maintain at least sufficient diversity and quantity of aquatic habitat to maintain populations of aquatic organisms that are consistent with maintaining fish stocks, fisheries, and other instream ecological values at the levels prior to the exercise of these consents.

Rationale

The quantity of aquatic habitat is a function of the amount of water in the river at low flows. This will be managed primarily by providing minimum flows under the environmental flow regime. However, aquatic habitat quantity and diversity is also dependent on the maintenance of a multi-channel braided river fairway, for which a number of riverbed management methods are described in detail in the Riverbed Geomorphology and Vegetation MP. These methods are listed and cross-referenced here as they contribute to the methods for achieving Objective 1.

Action 1 Environmental Flow Regime

The key elements of the managed NBT environmental flow regime are:

1. Minimum flow as follows:

Month	**Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec**
Flow below Waitaki Dam	140 150 145 125 120 110 110 110 120 125 130 140

2. Flushing flows (450 m^3/s - at least 4 annually)

3. Channel maintenance flows (tunnel shut down at 900 m^3/s)

4. Managed (reduced) short-term (daily/weekly) variability.

Of these four, it is the minimum flows that primarily determine the quantity of aquatic habitat. The latter three elements affect the quality of aquatic habitat and are described later under Objective 2.

Method

Minimum flows will be managed according to resource consent conditions and condition review processes under the RMA. They will not be subject to regular refinement via adaptive management under this plan.

Action 2 Vegetation control to maintain braided habitat diversity

The Riverbed Geomorphology and Vegetation Management Plan sets out in detail how vegetation encroaching onto the riverbed will be managed to achieve a 600 metre wide (average) fairway that is clear of mature vegetation and has an average of 7 braids between Kurow and Stonewall. This will contribute to Objective 1 by helping to maintain a dynamic multi-channel braided river fairway.

Method

The methods include spraying, snagging, and physical clearance as described in detail in the *Riverbed Geomorphology and Vegetation Management Plan*. The selection of locations for vegetation clearance and the programme for doing the work will be carried out in liaison with ECan which has a primary role in riverbed management in the Lower Waitaki River.

Objective 2

To maintain at least sufficient quality of aquatic habitat to maintain populations of aquatic organisms that are consistent with maintaining fish stocks, fisheries, and other instream ecological values at the levels prior to the exercise of these consents.

Rationale

Primary management actions for maintaining aquatic habitat quality will be via three methods:

1. Flushing flows in the river downstream of Waitaki Dam (450 m^3/s - at least 4 annually) will remove some periphyton and fine sediments, thus improving habitat quality for benthic invertebrates without moving larger surface bed materials or vegetation.

2. Channel maintenance flows (in excess of 900 m^3/s) will disturb surface bed material and redistribute gravels, remove most periphyton (including Didymo), remove some encroaching fairway vegetation and scour fine and larger deposited sediments. These flows will help maintain suitable substrate conditions for benthic invertebrates in the long term, even though in the short term they will disrupt the bed material in which invertebrates take refuge and temporarily reduce populations.

3. Short-term (daily/weekly) flow variations will be reduced compared with the pre-NBT situation. Flow will be managed by Meridian such that generation fluctuations will occur in the tunnel flow, while flow in the Waitaki River will remain relatively stable during the periods between flushing and channel maintenance flows. This will provide that a large proportion of aquatic habitat is of good quality and able to support a highly productive aquatic ecosystem.

4. A fourth set of methods for achieving good quality aquatic habitat involve wider catchment management methods for improving water quality in the Waitaki River and its tributaries. These methods might involve a suite of recognised best land management practices. Land use management in the wider catchment is beyond Meridian's immediate control and they are not able to be tightly prescribed in this management plan. However, Meridian is investigating ways of working with other land owners to improve water quality which will in turn contribute to an improvement in habitat quality in the main river.

Action 1 Flushing flows

The requirement for flushing flows will be included as a resource consent condition. The condition will define the minimum size (450 m^3/s), frequency (at least 4 annually) and duration (24 hours) of these events, as well as prescribing some timing constraints. Flushing flows can affect some plants and animals adversely if not timed appropriately. It is proposed that flushing flows will be provided on at least three occasions during the period 24 January to 30 April, with at least one other flow provided in the period 1 July to 10 August. This timing takes into consideration:

- avoidance of the early winter spawning season to protect trout and salmon redds and emerging trout and salmon fry
- avoidance of the spring rearing season for juvenile salmon and trout, and
- avoidance of the breeding season for specialist braided river breeding birds (September to January inclusive).

While the minimum size, frequency and duration of flushing flows will be prescribed in consent conditions, thus giving some certainty for this action, this management plan provides some flexibility for adaptive management to refine aspects of these flows. The effectiveness of flushing flows will be subject to post-commissioning monitoring and review as described in Section 6. The flushing flows would be altered, while staying within constraints defined in consent conditions, if the outcome of monitoring indicates that this could better achieve Objective 2 without compromising other objectives of this or other management plans.

Method

Meridian will manage the flow at Waitaki Dam to ensure that flushing flows are provided according to the requirements of consent conditions. At an operational level, Meridian will also incorporate the following factors into planning for flushing flows:

- Meridian will avoid coincidence of deliberately released flushing flows with spring high tides in March and April each year, so as to avoid adversely impacting whitebait species that spawn in tidal reaches of the lower river at these times.

- Meridian will coincide flushing flows with naturally occurring tributary floods or freshes [where possible within consent conditions and within its operational ability to respond to short-term rainfall predictions] in order to maximise the dispersion of tributary sediments downstream.

Meridian will also undertake the flushing flow monitoring programme outlined in Section 6. The programme is designed to monitor the state of periphyton and fine sediment accumulated on the riverbed at regular intervals throughout the year, and also to monitor the state of periphyton, fine sediment and invertebrate communities, immediately before and after flushing flow events. The effectiveness of the flushing flows will be gauged by whether or not the measurements of periphyton cover on the riverbed exceed a defined trigger level. In summary the trigger level is:

- The cover of the riverbed with filamentous periphyton growths greater than 2 cm long (that does not include Didymo) shall not exceed 30% cover on average across the established monitoring transects.

If results from monitoring immediately after flushing flow events exceed this trigger, this would initiate an adaptive management review.

If results from monitoring during the two long periods between condition-prescribed flushing flows (i.e., 11 August to 23 January; and 1 May to 30 June) exceed this trigger, this would also initiate an adaptive management review under Section 1.4 of this Management Plan.

The review process would consider the level of effectiveness of the flushing flows as demonstrated by monitoring results for filamentous periphyton cover, but would also consider the simultaneously monitored effects (including any adverse effects) of the flushing flows on fine silt, invertebrate populations, salmonid redds, emerging juvenile salmonids and riverbed bird nesting habitat, as well as effects on Didymo. The outcome from this review would be a recommendation as to whether refinement of the size, frequency, duration or timing of the flushing flows could better achieve Objective 2 without compromising other objectives of this or other management plans. That recommendation would be taken through the adaptive management process outlined in Section 1.4 and set out in the conditions of the NBT consents.

If the recommendation for refinement is upheld through the adaptive management review process, this refinement could be inserted as an

adjustment to this management plan and implemented from that time forward.

An adaptive management review to refine aspects of flushing flows under this management plan could be initiated as soon as two years after tunnel commissioning or any time subsequently. Two years monitoring results would include results from at least eight flushing flows over two summer seasons and this could be sufficient for recommending whether any refinement is justified.

Refinements could include, for example, that additional flushing flows (i.e. more than the minimum of four, up to a maximum of nine per year) could be provided during the periods between condition-prescribed flushing flows (i.e. 11 August to 23 January; and 1 May to 30 June) whenever a defined and measurable trigger is exceeded. Such additional flushing flows could thus be provided only when needed and this would vary from season to season and year to year. At this time there is insufficient scientific certainty on the appropriateness of the trigger level, the relevance for a Didymo-infected river, and the relative ecological costs and benefits of flushing flows outside the prescribed time periods, to define such a flexible effects-based flushing flow programme. The monitoring programme will be been designed to address this specifically in anticipation of defining a flexible, effects-based, flushing flow programme in this management plan in future.

Action 2 Channel maintenance flows

Floods, which have the function of being channel maintenance flows, will occur when high natural inflow into the catchment (i.e. rainfall) coincides with high lake levels. Lake levels in the Waitaki catchment can only be manipulated to a limited extent by Meridian, within the constraints of electricity generation requirements, minimum and maximum lake levels under existing consent conditions, water inflow variability, and within the limits of foresight provided by weather forecasting. Typically, under historical inflows and Meridian’s current and historic management, the lake levels are lowest at the end of winter and increase during the summer to a maximum level around March. Historically, floods have occurred most frequently from November to March and this will continue under the NBT flow regime.

The available science has identified that it is necessary to maintain the existing frequency of large floods in order to:

i) avoid exacerbating nuisance growths of Didymo, that is more resistant to the smaller 450 m^3/s flushing flows than other native New Zealand periphyton, and

ii) maintain river sediment transport processes and the vegetation clearance necessary for maintaining a dynamic multi-channel braided river fairway. Both of these functions are important for the quality of braided river aquatic habitat. Floods of 900 m^3/s and greater have been identified as an appropriate definition for the size of floods to be maintained.

The requirement to maintain the existing frequency of large floods will be included as a resource consent condition. This will require Meridian to operate Waitaki Dam and the NBT intake so that whenever the flow reaching Lake Waitaki (as measured through Aviemore Dam) equals 900 m^3/s or greater, the tunnel would be shut down so that the full flood flow passes through and/or over Waitaki Dam, and down the river for a period of 48 hours.

Method

Meridian will operate Waitaki Dam and the NBT intake according to the requirements of consent conditions.

Meridian intends to continue to operate the Waitaki hydroelectric generation system above Waitaki Dam in a way that does not significantly alter the existing frequency and seasonal timing of flood events, notwithstanding that there is significant natural variability with these events over decadal time scales, and climate change may affect flood characteristics irrespective of Meridian's management.

Meridian will also undertake the channel maintenance flow monitoring programme. The programme[1] is designed to monitor the state of periphyton, in particular in this case Didymo, accumulated on the riverbed at regular intervals throughout the year, and also to monitor the state of Didymo and invertebrate communities before and after channel maintenance flow events. The effectiveness of channel maintenance flows will be gauged by whether or not the measurements of Didymo cover on the riverbed exceed a defined trigger level. In summary the trigger level is:

[1] *To be completed, see section 6*

- The cover of the riverbed with Didymo growths greater than 2 cm long shall not exceed 30% cover on average in wadeable areas across the established monitoring transects.

If results from monitoring after 900 m^3/s or greater floods exceed this trigger, this could initiate an adaptive management review under Section 1.4 of this Management Plan.

The review process would consider the level of effectiveness of the channel maintenance flows as demonstrated by monitoring results for Didymo cover, but would also consider the simultaneously monitored effects (including any adverse effects) of the channel maintenance flows on invertebrate populations, salmonid redds, emerging juvenile salmonids, native fish and riverbed bird nesting habitat. The outcome from this review would be a recommendation as to whether refinement of the 900 m^3/s tunnel shut-down condition could better achieve Objective 2 without compromising other objectives of this or other management plans. That recommendation would be taken through the adaptive management process outlined in Section 1.4 and set out in the conditions of the NBT consents.

An adaptive management review to refine channel maintenance flows under this management plan would need to occur over a longer timeframe than reviews of flushing flows because large floods occur with much less frequency. A review could be initiated following monitoring of several 900 m^3/s or larger events. A minimum review period of seven years would possibly provide for monitoring results from three floods, given that 900 m^3/s events occur approximately every two years on average.

Action 3 Managing short-term flow variability

The environmental flow regime has been designed to deliberately manage flow to be steady at or near the proposed monthly minimums and reduce the existing short-term variability which can be detrimental to ecological values. This will provide that a large proportion of aquatic habitat is of good quality and able to support a highly productive aquatic ecosystem.

Method

Flow will be managed by Meridian such that short-term generation fluctuations to meet variable power demand will occur in the tunnel flow, as far as practicable, while flow in the Waitaki River will be operated to remain relatively stable (daily/weekly) for most of the time during the periods between flushing and channel maintenance flows.

Some flow variability will still occur in the river due to tributary inflows, and some minor variability will result from the fact that Meridian operators must rely on imperfect forecasting of weather, inflows, power demand and occasional unforeseen maintenance issues. These minor variations are not expected to adversely affect aquatic ecosystems and may in fact provide minor benefits.

Action 4 Wider catchment management

Any wider catchment management methods that reduce water quality contaminants (e.g., micro-organisms, nutrients, and sediment) will help achieve good quality aquatic habitat in the Lower Waitaki River.

Method

Methods need to involve a suite of recognised best land management practices such as detailed farm management plans including stocking rate, fertiliser and irrigation budgets, planting and exclusion of stock from drains and streams, use of wetlands as buffer between surface drains and streams and many other methods. The management of land use in the wider catchment is beyond Meridian's immediate control and is of interest to a wide range of individuals, stakeholder organisations, regional and district authorities. Methods cannot therefore be tightly prescribed in this management plan.

Meridian will, however, investigate ways of working with all interested parties to improve water quality. *To be completed.*

Meridian will continue to implement a water quality monitoring programme that provides ongoing fundamental information about the spatial and temporal distributions of water quality contaminants in the wider catchment downstream of Waitaki Dam. This includes monitoring sites at key locations down the length of the Waitaki River as well as sites on all major tributaries.

Meridian will also implement a water quality monitoring programme following commissioning of the NBT to determine the extent to which the reduced flow in the river has any effect on the microbiological quality of the Kurow, Oamaru, Pukeuri and Waitaki Rural water supplies. Meridian will discuss with the District Councils how it could assist in mitigating any specific issues with maintaining safe community water supplies as a result of any increased microbiological contamination levels resulting from the NBT.

Objective 3

To maintain surface flow connections to those tributaries that have existing natural permanent connections (i.e. Awakino River, Maerewhenua River, Hakataramea River, Kurow Creek), sufficient to ensure passage for fish.

Rationale

Only four tributaries have permanent surface water connections to the main river between Waitaki Dam and Stonewall (Awakino River, Maerewhenua River, Hakataramea River and Kurow Creek) but these links are important for migrating fish and the recolonisation of invertebrate populations after flood events.

If bed material from tributary floods were to accumulate in the fans at the tributary confluences with the Waitaki River, this could increase the risk of losing surface flow connections, particularly during summer tributary low flows.

Action 1 Maintain frequency of large flood flows

The proposed NBT flow regime, and in particular the maintained frequency of large flood events via the 900m^3/s tunnel shut-down condition, is predicted to shift tributary fan material in the long term and alleviate the risk of losing tributary surface flow connections, provided that active vegetation control is also employed.

Methods

Meridian will operate Waitaki Dam and the NBT tunnel intake according to consent condition requirements to shut down the tunnel at flows of 900m^3/s and greater, thus allowing large floods to pass down the river, shifting tributary fan material in the process.

Action 2 Manage vegetation for a clear fairway

To ensure that floods are effective at moving tributary fan material, it will also be important to manage the encroachment of vegetation into the flood fairway so that vegetation does not become sufficiently established to stabilise the tributary fans. Vegetation

management needs to go hand in hand with the maintenance of large floods.

Methods

See Objective 1, Action 2

Action 3 Mechanical maintenance as a back-up measure

Despite the management of floods and vegetation control described in Actions 1 and 2 above, it is possible that tributary fan material could accumulate at the tributary confluences for some years before being shifted by a large flood in the Waitaki mainstem. Some of the tributary surface flow connections could be temporarily lost when periods of extended low flows in the tributaries coincide with extended periods without any large floods in the Waitaki mainstem. The risk of this may also increase as demand for water takes from the tributaries increases.

Therefore Meridian will also monitor surface flow connectivity of these four tributaries and will implement back-up mechanical river excavation works when necessary.

Method

A mechanical excavator will be used to ensure that the channel through tributary fans is sufficient to maintain surface flow connections in the four tributaries that have existing natural permanent connections.

Objective 4

To maintain flow connections to braids throughout the width of the managed fairway, such as to be consistent with Objective 3 of the *Riverbed Geomorphology and Vegetation Management Plan*, sufficient to ensure that there is a mixture of braids with and without riparian vegetation cover for fish.

Rationale

The proposed NBT flow regime, and in particular the maintained frequency of large flood events via the 900 m^3/s tunnel shut-down condition, combined with active vegetation control as described in

the Riverbed Geomorphology and Vegetation Management Plan, is predicted to maintain a dynamic braided river with a mixture of braids with and without riparian vegetation cover for fish.

Action 1 Maintain frequency of large flood flows

As per Objective 3, Action 1

Action 2 Manage vegetation for a clear fairway

As per Objective 3, Action 2

Action 3 Mechanical maintenance as a back-up measure

Despite the general methods to maintain a dynamic braiding pattern, via management of floods and vegetation control described in Actions 1 and 2 above, it is possible that some braids in some parts of the river may tend to migrate in ways that cause specific management problems. Meridian will monitor the braiding pattern between Waitaki Dam and the tunnel outfall and will identify areas where the braiding pattern is causing local problems such as increased erosion or flood risk for neighbouring landowners, excessive migration of braids away from the willow side-berms or important riparian wetlands where flow from river braids is important.

Method

The results from Meridian's monitoring will be submitted to ECan together with recommendations for mechanical maintenance. If the recommendation is upheld through the adaptive management review process, then the mechanical maintenance will be implemented.

A mechanical excavator will be used to ensure that important braid paths are maintained for a variety of reasons. For example;

- maintaining major braids away from the side berms if they are aggressively eroding the berm and creating erosion risk to neighbouring land;
- maintaining some braids towards the side berms if all braids are migrating toward the centre or to one favoured side of the fairway;

- maintaining braids near the willow side berms helps ensure maintenance of the existing braided character of the river, ensures good riparian cover habitat for fish and in particular eels, and helps ensure hydraulic connectivity to riparian wetlands.

Objective 5

To maintain at least sufficient quantity and quality of suitable angling conditions to maintain angler satisfaction at the level immediately prior to the exercise of these consents.

Rationale

It is anticipated that Objectives 1 to 4 will provide suitable habitat for brown and rainbow trout and salmon. The flow regime outlined in the consent conditions will also provide for good quality salmon angling conditions during the angling season from December to March inclusive.

Method

As per Objectives 1 to 4 - In particular, minimum flows during the salmon angling season will be 140 m^3/s for December, 140 m^3/s for January, 150 m^3/s for February and 145 m^3/s for March. Flows will be managed to be reasonably stable close to these minimums, although some variability will come on top of these flows as a result of tributary inputs below Waitaki Dam. These flows are close to the optimum salmon angling conditions at flows of 150 m^3/s identified by technical salmon angling flow assessment methods. In addition it is likely that at least two and possibly three flushing flows would occur during the salmon angling months. These flushing flows, together with naturally occurring tributary and mainstem floods that are most common during the summer months, will provide the flow variability and flood/fresh recessions that are often favoured conditions for salmon anglers.

Objective 6

Specific water quality objective in relation to recreation and public water supply – still to be added

4.3 Secondary management options and methods

It is anticipated that the primary management actions described above will, in combination with the proposed consent conditions and other Management Plans, be sufficient to achieve the objectives of this Plan.

There is inevitably some uncertainty associated with environmental predictions and for this reason a range of secondary management actions have been identified that could be employed as adaptive / additional measures in the event that monitoring) identifies that objectives are not being fully met.

These secondary management options could include:

- **Fisheries Enhancement**

  For example, spawning enhancement, hatchery development

- **Habitat creation**

  For example, Low mound communities habitat creation, enhancement initiatives

  The effect on LMC cannot be managed through the flow regime. Instead, channel and bed manipulation may need to take place to protect or enhance existing habitats and create new areas.

- **Wider Catchment Management Initiatives**

  For example, stock exclusion, fencing waterways, community participation / management,

These will be explored in subsequent versions of this Plan.

5.0 MONITORING

To be completed

Monitoring will inform the assessment of the success of the flow regime and other proposed management actions and methods in achieving the objectives set out in this Plan.

The monitoring described here specifically relates to flow and instream habitats but will be considered alongside the results of a wide range of monitoring activities to assist decision-making about adaptive management change.

The flow and instream habitats monitoring is based on a co-ordinated monitoring programme for a number of components of the aquatic physical and biological environment. Co-ordination will consider timing, location, nature of sampling visits, and the indicators measured. The results of monitoring will contribute to an assessment of the condition of the aquatic habitat, species, and ecosystem.

Further monitoring is described in the *River Geomorphology and Riverbed Vegetation, Riverbed Birds, and Wetlands Management Plans.*

5.1 Periphyton and Macrophytes

Objectives of monitoring

- To review what changes occur to periphyton and macrophyte populations over the life-time of the project,
- To establish whether the proposed flushing flows are appropriate to manage the effects of fine sediment deposition and nuisance periphyton growths and provide information for adaptive management,
- To detect any macrophytes that are regarded as plant pests and ensure that they do not become established in the river as a result of NBT,
- To monitor and review whether the creation of artificial backwaters with a varial zone is suitable for the establishment and maintenance of the existing diversity of Low Mound Community (LMC) species.

This monitoring addresses flow and instream habitat Management Objectives 1, 2 and 5.

5.1.1 Flushing flow monitoring

Indicators and triggers

Periphyton: Because of the need for regular monitoring, and likely delay between sample collection, sample analysis, and review of results, the MfE (2000) guideline for percentage cover by filamentous algae greater than 2cm long will be used (rather than the guideline for chlorophyll *a* or AFDW biomass) as this provides immediate data. The threshold will be 30% cover of filamentous algae of the portion of riverbed that is of wadeable depth, (rather than 30% of the whole riverbed because it would be very difficult to survey for algal cover in the deep, fast, unwadeable channels.)

Didymo will not be included in the determination of filamentous algal cover that is tested against the 30% cover threshold for determining the need for additional flushing flows. This is because flushing flows are unlikely to remove significant amounts of Didymo and it is therefore not appropriate to trigger additional flushing flows on the basis of Didymo. This may be reviewed once the current 'in progress' Didymo study is completed.

Programme

Pre-commissioning: Begin periphyton state monitoring to establish a good baseline for the post-commissioning monitoring.

This will allow any changes in the average state of the ecosystem to be analysed and solutions adjusted or designed. It also allows natural variability to be defined, against which the magnitude of hydro development effects can be gauged. This should be coordinated with similar baseline state monitoring for other aquatic ecosystem components i.e. water quality, macroinvertebrates, native fish, and salmonids.

Post-commissioning: Periodic monitoring of the state of filamentous periphyton cover throughout the year.

This will inform the decision on the need for additional flushing flows beyond the proposed four per year. Ministry for the Environment guidelines (MfE 2000) are recommended for the protection

of trout habitat and angling values be provisionally adopted as a basis for triggering additional flushing flows.

Post-commissioning: Monitoring of the effectiveness of flushing flows (i.e. before and after effects monitoring to test the appropriateness of magnitude, duration, and frequency of flushing flows).

This will include monitoring of periphyton cover as above, but also monitoring of the effect of flushing flows on fine bed sediment, invertebrates, juvenile salmonids, salmon redds and nesting birds.

5.1.2 Floods or channel maintenance flow monitoring

Indicators and triggers

To be completed. Measures are likely to include: for periphyton, didymo, and silt/sediment,

Programme

Pre-commissioning: Continue with the current study in progress on the nature of establishment of Ddidymo and response to flow changes in the Lower Waitaki River.

This will allow for refining of the extent of problem and the basis for the proposed 900 m^3/s channel maintenance flows.

Post-commissioning: Periodic monitoring of the state of didymo cover throughout the year.

This will inform the desirability for channel maintenance flows in relation to Didymo. The MfE guidelines for the protection of trout habitat and angling values will be adopted as a basis for determining the desirability of channel maintenance flows. Note this does not 'trigger' provision of channel maintenance flows as it is proposed that these will be largely naturally timed events.

Post-commissioning: Monitoring of the effectiveness of the 900 m^3/s channel maintenance flows (i.e., before and after effects monitoring to test the appropriateness of magnitude, duration and frequency of the 900 m^3/s flows).

5.1.3 Macrophyte monitoring

Indicators and triggers

To be completed. It is likely that measures fro Lagarosiphon major, Egeria densa and Low Mound Communities will be used.

Programme

Pre and post-commissioning: Continue and expand existing surveillance programmes for invasive species such as L. major and E. densa.

Post-commissioning: Periodic monitoring of the effectiveness of constructed LMC habitat at maintaining representative examples of LMC communities.

Responses: review size, duration, and frequency of flood flows.

5.2 Macroinvertebrates

To be completed.

5.3 Native fish

To be completed

5.4 Salmon and trout

Objectives of monitoring

To be completed but may include the following objectives:

- To determine whether the NBT flow regime has any major effects (more than ±30%) on the numbers of salmon and trout spawning.
- To assess the probable impacts of the NBT flow regime on salmon and trout habitat, food supplies and vital fish population statistics (species composition, size, abundance, condition).
- To determine whether the NBT flow regime has any major impacts on angler satisfaction and catch-rates.

Indicators and triggers

To be completed – salmon and trout stocks and fisheries

Programme

The purpose of the salmon and trout monitoring programme is to assess fish stocks and fisheries compared with the baseline conditions. The salmon and trout monitoring programme will be integrated and coordinated with a number of other monitoring programmes

To be completed

Planning and integration with other monitoring programmes -To be completed.

Pre-commissioning monitoring and investigations - Baseline monitoring e.g. annual salmon spawning surveys; comparative analysis with other rivers; annual trends in the abundance of juvenile salmon and trout in the mainstem and major tributaries, biennial drift netting surveys

Post-commissioning monitoring and investigations – to be developed; information would assist the adaptive management programme.

6.0 Programme of Management and Monitoring

The Annual Environmental Report will summarise the results of the management and monitoring outlined in the flowing table.

Objective 1: To maintain at least sufficient diversity and quantity of aquatic habitat to maintain populations of aquatic organisms that are consistent with maintaining fish stocks, fisheries, and other instream ecological values at the levels prior to the exercise of these consents.			
Action	**Performance measure**	**Monitoring**	**Plan**
Environmental Flow Regime	• *To be completed*		
Vegetation control to maintain braided habitat diversity	• *To be completed*		
Objective 2: To maintain at least sufficient quality of aquatic habitat to maintain populations of aquatic organisms that are consistent with maintaining fish stocks, fisheries, and other instream ecological values at the levels prior to the exercise of these consents.			
Action	**Performance measure**	**Monitoring**	**Plan**
Channel maintenance flows	• *To be completed*		
Flushing flows	• *To be completed*		
Managing variability	• *To be completed*		
Wider catchment management	• *To be completed*		

Objective 3: To maintain surface flow connections to those tributaries that have existing (2001) natural permanent connections (i.e., Awakino River, Maerewhenua River, Hakataramea River, Kurow Creek), sufficient to ensure passage for fish.			
Action	**Performance measure**	**Monitoring**	**Plan**
Manage vegetation	• *To be completed*		
Flood flows	• *To be completed*		
Mechanical Maintenance	• *To be completed*		
Objective 4: To maintain flow connections to braids throughout the width of the managed fairway, such as to be consistent with Objective 3 of the Riverbed Geomorphology and Vegetation Management Plan, sufficient to ensure that there is a mixture of braids with and without riparian vegetation cover for fish			
Manage vegetation	• *To be completed*		
Flood flows	• *To be completed*		
Mechanical Maintenance	• *To be completed*		
Objective 5: To maintain at least sufficient quantity and quality of suitable angling conditions to maintain angler satisfaction at the level immediately prior to the exercise of these consents			
Action	**Performance measure**	**Monitoring**	**Plan**

Variable flow regime	• *To be completed*	• Plan creel surveys taking into account the variability of the data, the number of days surveyed and fish samples required in order measuring significant ±30% trends. • Stratified creel surveys to obtain accurate information on angling effort and catches. • Distribution of a post season questionnaire about changes to the fishery and angler satisfaction to regular anglers contacted during creel surveys at 3 year intervals. • Post season data entry analysis and reporting historical trends	
Objective 6: Specific water quality objective in relation to recreation and public water supply – still to be added			
To be completed			

7.0 REVIEW AND RESPONSE

To be completed.

The Meridian programme for making sure that monitoring happens, funding it, receiving results, peer reviewing and/or making public, responding through operational changes if possible, or other works/actions. The resource consent conditions will also be subject to specific reviews.

Appendix A

List of North Bank Tunnel Assessment of Environmental Effects Technical Reports

Appendix B

Lower Objectives from the LWRMG's River Management Strategy