FISH SCREEN CONCEPT
MEAD INTAKE - RAKAIA
DAIRY HOLDING LIMITED

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Report prepared for: Dairy Holdings Limited
Irrigation New Zealand
Fish Screen Working Group – Technical Group

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1.0 Introduction

In 2019 Irrigation New Zealand (on behalf of the Fish Screen Technical Working Group), received a grant from the Sustainable Farming Fund (now Sustainable Food and Fibre) to further research fish screen design criteria. The research ultimately aims to provide clear and simple guidance on fish screen requirements.

For the current stage of this project three locations with screens that are not compliant with current fish screen standards were chosen. The sites were also selected to provide a variety of existing fish screen types and river intake conditions. This report investigates options for achieving a compliant fish screen at the existing Mead intake on the Rakaia River.

This document includes details of the fish screening design requirements and various options of location and screen type for this intake. This is an initial assessment to enable the MPI project and Dairy Holdings Ltd (DHL) to consider which of these options for the location and screen type to consider further.

Included in this report is a suggested approach to the selection of the best location for a fish screen at a site and selection of screen types. The following stages in the development of a solution for this site including detailed design could lead to changes to meet all the requirements for a fish screen. The tables in Appendix A are drafts that have been developed with the Fish Screen Working Group which include the issues to consider in selection of the location for a fish screen and some general parameters for different fish screen types.

2.0 Background

The Mead Scheme supplies water from the Rakaia River to farmland on the north side of the Rakaia River near Highway 1. The existing scheme diverts a maximum flow of 1.5m^3/s from the Rakaia River and the current resource consent allows for 0.55m^3/s of flow for irrigation which is conveyed through the Mead fish screen.

The fish screen is located approximately 2.8km downstream from the river intake. A control gate to control flow through the screen is located immediately upstream of the rotary screen. A second control gate is located approximately 20m downstream of the screen. The fish screen is a rotary drum screen located perpendicular to the flow in the race. The screen is approximately 2m in diameter and 1.5m in length (refer to Photo 1). The fish bypass is a 1.5m wide and 1m deep channel that flows perpendicular to the flow through the screen (refer to Photo 1).

Photo 1: Existing Fish Screen

Figure 1 shows the layout of the water race and location of the Mead fish screen. We note that the intake to the water race which conveys flows to the Mead irrigation scheme is not well defined due to the morphology of the Rakia River. However, the section of the water race that does not appear to have been subjected to significant morphology in the past 16 years is approximately 3.5km in length with the fish screen located at approximately 2.8km. There is a pump intake located at 1.6km. An overflow bypass and control gate are located at approximately 2.3km along the length of the water race.

Figure 1. Current configuration of Mead Irrigation Intake

3.0 Review of Existing Intake and Fish Screen

Two RILEY staff visited the site on 11 May 2020 to enable preparation of a proposal to undertake an assessment of the existing fish screen. It was clear from our inspection of the site that there are a number of fundamental problems with the screen type and geometry as well as potential issues of location. From a simple visual estimate of screen area and flow it is clear the approach velocity would be too high.

In 2010 a detailed assessment of the fish screen was undertaken as part of a study into 6 screens in Canterbury. In 2019 Environment Canterbury (ECan) undertook a compliance monitoring inspection. These inspections of the fish screen considered the seven criteria within the NIWA Guidelines[1] as a basis of the assessment. The findings from the 2010 study and inspection by ECan in 2019 found the following key issues with the screen:

- The water approach velocity was too high; measurements taken upstream of the drum indicated that mean approach velocity was > 0.4 m/s, more than three times that recommended (0.12 m/s).
- There was little or no sweep velocity across the screen, so that fish were not swept or guided into a bypass.
- At 5 mm, the mesh in the drum was too big to exclude small fish. The recommended size is 3 mm.
- The position of the bypass is not suitable as it is located upstream of the drum.
- The bypass channel was also not well maintained and did not return bypassed fish back to the Rakaia River.
- Risk of overtopping of the screen in a flood.

[1] Jamieson, D., Bonnett, M., Jellyman, D., & Unwin, M. (2005). Fish Screening: good practice guidelines for Canterbury. NIWA, Auckland, 70pp.

From our initial observations at site it is our opinion that there are no feasible modifications to the current screen that would achieve the requirements in the guidelines. Therefore, it is recommended a new fish screen is constructed.

The debris screen is located immediately up stream of the drum screen and was clear of debris at the time of inspection. The spacing of the debris screen bars are approximately 100mm over a length of 1.5m. We note that when debris is captured by the screen, flow through the debris screen will be filtering through the debris and in that regard could be considered as operating as a barrier to fish similar to the dimensions of the existing screen. If the fish screen is to remain at the current location, there will need design considerations that include the debris screen to ensure that flow through the debris screen also complies with the intent of the approach a sweep velocity guideline criteria.

4.0 Basis for Design of a Fish Screen

In Canterbury the recommended approach in the design of a fish screen is the NIWA Guidelines referenced in Section 3.0 and the Canterbury Land and Water Regional Plan (CLWRP) [2] Schedule 2. In most recent consents this is often used as the basis for consent conditions related to fish screening.

4.1 NIWA Design Guidelines

The NIWA guidelines outline seven design criteria for fish screens as follows:

1. Location.
2. Approach (through screen) velocity.
3. Sweep velocity.
4. Fish bypass at screen.
5. Fish bypass connectivity to river.
6. Screen materials and mesh size.
7. Operations and maintenance.

These design criteria need to be demonstrated in determining the fish screen location and fish screen type. The other considerations in the selection relate to operational actions (i.e. automated screen cleaning) and ease of operation/maintenance, construction costs, operating costs, and ongoing compliance monitoring risks and costs. Under 5. Fish bypass connectuivity to the screen, consideration of whether to allow upstream fish passage also needs to be considered which influences the overall placement and design of the bypass.

ECan is involved within the “Fish Screen Working Party (FSWP)” which is considering recommendations for fish screen requirements in Canterbury. The approach in general being discussed is as follows:

- If a fish screen meets the seven design criteria outlined in the NIWA guidelines/Schedule 2, then the design would be considered compliant and would only require verification that it meets the design criteria. Generally no ongoing monitoring of the screen effectiveness would be required.
- If a fish screen does not meet all of the seven criteria, then the criteria not being compliant would need to be described and mitigations to address such none

[2] Canterbury Land and Water Regional Plan. Schedule 2 Fish Screen Standards and Guidelines. (December 2016).

compliance described. Such a screen may be required to prove its effectiveness for all fish species and ongoing effectiveness monitoring may be required.

Attempts to perove the effectiveness of fish screens has been attempted through live fish trials, but this process is problematic and proves difficult to achieve definitive results for river intakes. The uncertainty in these trials appears to be very high and introduces a significant risk to the consent holder where plan objectives and consent conditions require monitoring to demonstrate screen effectiveness to an absolute standard (i.e. LWRP Schedule 2). Therefore an approach based on absolute design criteria is more easily measured/audited and is the recommended approach.

4.2 Design Philosophy for Velocity

The NIWA Guidelines as discussed above have seven key criteria and two relate to the velocity of flow into/through the screen (approach) and across the screen (sweep). A common discussion is whether these criteria need to be met on average or in all parts of the screen. It is recommended that any new screen should aim to not only meet the average velocity requirements but that it shows design considerations to aim for equal distribution of velocity across the screen surface.

The main two means of achieving the approach/through screen velocity is by:

1.0 Increasing the total screen area and screen open area ratio to achieve the design velocity criteria

2.0 Reducing the average velocity by providing a baffle behind the screen to control the distribution of flow. A baffle is often a plate with a variety of openings. The size and density of the openings enables the distribution of flow to be more uniform. The design of a baffle is very complex and requires some research and development depending on the shape of the screen, the flows and velocities being designed. A number of the screens available on the market have baffles within their design.

5.0 Fish Screen Location

5.1 General Process in the Selection of the Fish Screen Location

The selection of the most suitable location for the fish screen needs to take account of a variety of factors. Appendix A includes a table that details the different factors in this selection process and the questions that need to be considered in the assessment. The following is a list of the key elements that need to be considered in assessing the best location for a fish screen for a site.

- River intake conditions.
- Potential to combine river intakes and fish screens.
- Flood water levels and protection of infrastructure.
- Fish bypass location, length and connection back to river.
- Upstream fish passage in the fish bypass.
- Control of flows for the fish screen and bypass.
- Management of debris.
- River user and operator safety.

- Effective operation and maintenance.
- Monitoring of the intake and fish screen.

The following sections provide for an assessment of the intake location for the Mead fish screen with consideration of the factors listed above.

5.2 Assessment of fish screen locations for Mead fish screen

We have considered three potential locations for the fish screen (refer Figure 2):

1. At the current location
2. At the mid-section of the race adjacent to the overflow bypass.
3. Upstream a section of the race between the intake of the race and the pump intake.

We have also considered a location at the intake but conclude that this location is not feasible due to river morphology and issues with regards to flood protection, discussed further below.

Figure 2. Proposed Location Best Suited for a New Fish Screen

The fish bypass is an important component of an effective screen and needs to provide a link back to a river channel. The location and route back to the river is only indicated in the following figures as general concept. Once a preferred option is selected, during a detailed design phase the location and geometry of the bypass will need to be investigated further. The design of the fish bypass will also include a means to control flows in the bypass and consideration of the fish passage downstream in the bypass and a means to avoid upstream fish passage from the river.

In addition to fish screening criteria there are additional design issues relating to debris/sediment management, flood protection of infrastructure, safety of operators and river users, and flow control. It is important to note that these issues should not be considered in isolation and an integrated option may prove most cost effective.

5.3 Location 1: At the Current Location

A new fish screen could be constructed at the existing fish screen location – Figure 3.

The advantages of this location are:

- It is close to existing infrastructure.
- Naturally protected from minor to moderate flood events.
- It is easily accessible.
- Sediment loads in the diverted flow is significantly reduced due to the deposition of sediments along the 2.8km of the race between the intake and the screen.
- There is currently off-grid solar power at this site which could be upgraded to suit the power demands of the new fish screen.

Disadvantages include:

- In its current configuration fish are diverted 2.8km along the water race and then a further 1.6km along a bypass to the outfall. Care and maintenance will be required to ensure that the risk of predation is not increased while fish are conveyed through the water race and bypass.

- Willow trees along the banks of the water race upstream of the screen will likely contribute a significant amount of fallen leaves and branches that will accumulate as debris on the debris screen and fish screen. While the new screen will have a self-cleaning function, ongoing maintenance will likely be required to remove fallen tree branches from the debris screen to ensure that the debris screen does not inadvertently constrict fish passage.

Figure 3. Location No.1 - Current Location of the Fish Screen

5.4 Location 2: At the bypass.

At this location, the screen is located approximately 2.1km downstream of the intake, with a 75m long bypass back to the Rakai River. Advantages of this location include:

- Sediment loads in the diverted flow are still significantly minimised as deposition will occur along the 2.1km of race upstream of the screen.
- This site is easily accessible via existing vehicle tracks.
- There is a control gate at this location that can be used to control flows through the bypass back to the Rakai River.
- The diversion channel back to the Rakai River is significantly shortened in length, down to 75m, reducing the time that fish are exposed to bird predation.

Disadvantages include:

- This site is much closer to the Rakia River and may be subjected high flows and debris during flood events. Further assessment will be required to determine the flood risk at this site.
- A new fish bypass channel will need to be constructed – approximately 75m in length
- Vehicle tracks may need to be upgraded to allow for safe access to the site during periods of poor weather (when unscheduled maintenance or control is potentially required).
- The site may require additional earth works to shape the site to accommodate the function of the new screen.
- There is still a significant source of debris from bankside willow trees upstream of the screen.
- There is currently no power at this site.

Figure 4. Location No.2 - At the Race Bypass

5.5 Location 3: Upstream of the Pump Intake.

This site is location approximately 1km downstream from the current intake and 600m upstream of the pump intake. This site provides a fish screen for both the Mead intake and the Pump intake. This site would require the construction of a fish bypass linking back to the Rakaia River, approximately 200m long.

Advantages of this site include:

- Provides screened flows to the pump intake as well as the mead irrigation scheme.
- Reduces length from intake to outlet of bypass to 1.2km in total length.
- Site is easily accessible across farmland.
- The site is located at distance inland the main flow of the Rakai River, which will provide some flood protection.
- There are less willows along the banks of the race upstream of the site, which will result in less leaf and branch debris being captured in debris screen.

Disadvantages include:

- A control gate will need to be installed to control flows though the bypass.
- A 200m long bypass channel would need to be constructed back to the Rakia River.
- Minor earthworks would be required to shape the race and intake to the bypass to install the screen.
- The screen is located 600m downstream of the intake, which will mean sediment loads in the water will be relatively higher than at the locations described above.
- There is currently no power at this site.
- Further assessment will be required to determine the flood risk at this site.

Figure 5. Location No.3 - 1km Downstream from the Current location of the Intake

5.6 A Fish Screen Located at the Intake

This site is not specifically located as it appears to be transitional depending on the flow conditions and morphology of the Rakai River. Likewise, we note that this location is undesirable due to the likelihood of damage to the fish screen during flood events, but has been included in this assessment as a reference case as it is in general the most desirable location with regard to not requiring a bypass.
In general, we note the following advantages from installing a fish screen at the intake of the water race:

- There is no need to construct a fish bypass as fish deflected from the screen are immediately conveyed back into the river.
- This site would provide a fish screen for to both the pump intake and the Mead irrigation scheme.

Issues that make this location infeasible Include:

- Floods events (even potentially minor floods) will risk damaging the screen and/or inundate the screen and debris.
- It is difficult to manage velocity around the screen.
- It is not certain that it would be even possible to consistently maintain a compliant flow through the screen without significant ongoing maintenance and earthworks given the nature of shifting flow channels associated to braided river dynamics refer to Figures 6 and 7.

Figure 6. Rakaia River in 2004 - The current race is annotated as a reference.

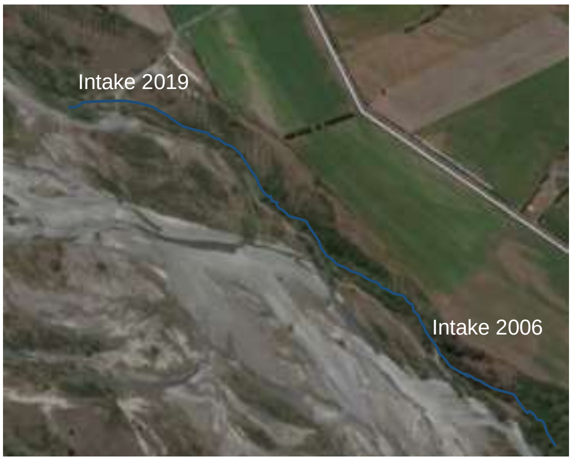

Figure 7. Same frame as Figure 6, taken in late 2019. Figures 6 and 7 indicate the degree of river morphology that alter the location of the intake.

6.0 Fish Screen Type

There are several different types of fish screen that have been considered. The NIWA guidelines include a summary of several different types of screens. The screens considered as potentially appropriate for the Mead intake based on the flows, previous trials on physical screens, results from recent testing of screens, and the design of recent fish screens are:

- Rotary cylinder screen (automatic cleaning) with an electric motor.
- Rotary cylinder screen (automatic cleaning) with a hydraulic turbine.
- Cone Screen
- Fixed Flat screen.
- Travelling flat screen.
- Other Screen Options

6.1 Rotary Cylinder Fish Screen

There are a number of manufacturers of rotary screens. We are familiar with the screens provided by AWMA as have observed them in New Zealand, Australia and USA. There are other manufacturers in New Zealand. AWMA provide both types of rotary screen mentioned based on design by Intake Screens Inc (ISI), Sacremento, United States. These screens are rotated by a motor and have either bush cleaning system or water jets to facilitate cleaning from within the screen. Figure 6 shows an example of a design for an installation in the United States of these cylinder screens (ISI). These types of screens have recently been installed by Amuri Irrigation, Kurow Duntroon Irrigation, Pukaki Irrigation and are the basis of current design being undertaken by the RDR.

Figure 8: Cylinder Screens Design in United States (Intake Screens, Inc.)

The screens in Figure 8 would be installed at an angle to the flow. The first one is a "T" shape and has electric motor to rotate occasionally when required for cleaning and usually on a timer. The second screen is driven by a propeller and continuously rotates. The screens can be installed on rails so that they can be retrieved for maintenance. The alternative would be to dewater the race to undertake any maintenance work which may be a better option for the Mead scheme.

The screen with an electric motor can operate over a full range of flows and only rotates as required. The screen with a propeller requires a minimum of approximately 40% of the full flow to operate and rotates continuously. The operating range can be extended by using more than one screen or having different sizes.

These screens include an internal baffle and also have a slide gate to control the flows which is important where multiple screens are required to balance overall flows. The baffles have been designed based on modelling and physical testing.

6.2 Cone Screens

These screens are similar in design and concept to the cylinder screens but are designed to sit on the invert of a channel and have main advantage of being suitable for shallow channel water depths. They include the same brush cleaning system and baffle to distribute the flow evenly across the surface.

Figure 9: Cylinder Screens for Cohuna and Trangie Nevertire Irrigation (AWMA, Australia)

6.3 Travelling Flat Screens

Travelling screens are mechanical screens installed vertically. The screens operate by rotating around a drum at the top and bottom of the screen with the motors above the water. The screens are self-cleaning through air or water jets at the top of the screen. Like the rotary cylinder screen, they are widely used in the United States and considered just as effective. Figure 10 shows an example of a screen from Hydrolox and located at Fall River in the United States.

Travelling screens require a longer length of screen in comparison to rotary screens but are more suited for narrow channels.

Figure 10: Example of Travelling Screen (Fall River, Hydolox Screen)

6.4 Fixed Flat Screen

As with the travelling flat screen an advantage of this type of screen is that they are constructed on the side of the channel and therefore there is less disturbance to the flow than what a cylinder has. They also allow for a narrow section at the downstream end to help maintain good velocity to a bypass.

The proposed flat screen being designed for the RDR will include an adjustable baffle system which is needed in this case due the combination of rotary and flat screens. However this does highlight the possibility of this approach for providing greater ability to distribute flows evenly.

6.5 Other Screen Options

Other screen options have been identified by the Technical Group and are noted in the Decision Tables (see appendix A)

6.6 Screen Selection

Appendix A includes a table with some of the common issues associated with various screen types and this needs to be considered in selecting a suitable option. The selection of the preferred screen type will depend on the following:

- Location and geometry of the location.
- Depth of water and available head loss through screen.
- Intake flow and available flow for the bypass
- Issues of flow control.
- Sediment/debris management.
- Electricity at site (or alternatives)
- Construction and Operational costs.

For a cylinder screen there needs to be sufficient water depth both below and above the cylinder, whereas a cone screen or flat screen can operate in a shallower depth of water.

Given the type of screen selected for the differing water depths, the length of the screen will differ. For a flat screen, if we assume a 1m water depth the screen would need to be 4.6m long and similarly, 1.5m water depth would require a 3.1m long screen. For a cylinder screen, if we assume a 1m water depth, the screen would be 3.6m long with a maximum cylinder size of 0.4m diameter. Similarly, for 1.5m water depth, the screen would be 1.6m long with a maximum cylinder size of 0.9m diameter. For the cylinder screen this would allow for a 0.3m water depth both above and below the screen.

7.0 Construction Issues

The construction of a new fish screen unless located at the river intake, should be relatively straight forward. The construction could be undertaken outside normal irrigation period and the scheme shut down. A screen at the intake would require management of water from the river and be at greater risk from floods during construction.

The screen could be constructed on a concrete wall or using embankments with the screens on the ends of a pipe through the embankment. Figure 11 shows a variety of different options for construction of a cylinder screen including at the end of a pipe through an embankment, on an embankment slope with pipe through embankment or on a concrete wall.

If modifying the existing screen was the preferred option, there would be less work done than the construction of a new screen. For all options a new fish bypass would be required.

Figure 11: Cylinder screen construction types

7.1 Construction Costs

When a preferred location and screen type is selected then a cost estimate can be undertaken. The cost of the construction of a new mechanical fish screen including all of the civil works is typically in the order of $100,000 to $400,000 per 1 m^3/s.

8.0 Recommended Option

The initial assessment of the location of a fish screen by the FSWG has concluded that the best location is upstream of the pump intake as this enables a combination of both the Mead and pumped intake and provides for a much shorter distance for fish from the intake back to the river. The depth of water for this location would suggest that the suitable screen needs to be designed for relatively shallow water depths. It is expected that in general most of the issues of the water flows, depths and flood may be similar to the existing location.

It is likely that the water depths will be relatively shallow and limited head loss available at all of the sites. There will be fluctuations in water levels in flood and also risk to some infrastructure from flood at these locations. This would suggest a submerged cylinder screen or cone screen may be the best option for this site if there is sufficient head loss available at the screen.

9.0 Next Steps

The main purpose of the fish screen concept report is to consider options for the location of a fish screen including consideration of the bypass and possible screen types. The order of this process is to first agree on the best location for the fish screen which requires consideration of the fish screen requirements, existing infrastructure and all aspects of the intakes design. Once a location or locations are selected then a more detailed assessment of the hydraulic conditions at that location and confirmation of most suitable screen type can be progressed. This assessment may require a topographical survey if LiDAR is not available or suitable which may be due to vegetation around the intake and fish screen location. A survey of the channels from the intake to the fish screen and downstream and proposed fish bypass will also need to be undertaken.

10.0 Limitation

This report has been prepared solely for the benefit of MPI, Irrigation New Zealand and Dairy Holdings Limited as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

The hydraulic analyses and recommendations contained in this report are based on our understanding and interpretation of the available information. The recommendations are therefore subject to the accuracy and completeness of the information available at the time of the study. Should any further information become available, the analyses and findings of this report should be reviewed accordingly.