Oreti River hydraulic and habitat modelling

Prepared for Cawthron Institute

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Executive summary

NIWA was engaged by the Cawthron Institute (Cawthron) to undertake a two dimensional (2d) hydraulic model study of a representative reach of the Oreti River to provide an assessment of physical habitat for trout, native fish and benthic invertebrates and to provide hydraulic data for Cawthron to perform net rate of energy intake (NREI) modelling for drift feeding trout.

The physical hazard assessment involved producing, for each species or life-stage, tables of Habitat Suitability Index (HSI) (at cell-centres for a range of flows), and a Weighted Usable Area (WUA) – flow relationship. These outputs were provided to Cawthron for analysis.

The work forms part of a wider Cawthron study, funded by Environment Southland, to provide an assessment of the flow requirements of drift feeding trout, fish and benthic invertebrates. This study will assist decision making on minimum flow and allocation rules in regional water plans for the Oreti River.

A 2d hydraulic model of a representative reach of the Oreti River, spanning one meander sequence, was built and then calibrated and validated against water depth and velocity data collected by NIWA and Environment Southland staff.

This report describes the modelling process including the calibration and validation of the model. Use of the model for habitat assessment is also briefly described. A Cawthron report (Hayes et al. 2016) provides a more comprehensive physical habitat assessment based on the model results.
1 Introduction

NIWA was engaged by the Cawthron Institute (Cawthron) to undertake a two dimensional (2d) hydraulic model study of a representative reach spanning one meander sequence (e.g., riffle, fast run, deep run/pool) on the Oreti River and to provide an assessment of physical habitat (weighted usable area or WUA) – flow relationships for trout, native fish and benthic invertebrates. Further, hydraulic data obtained from the model were to be supplied to Cawthron to perform net rate of energy intake (NREI) modelling for drift feeding trout.

The work forms part of a Cawthron study, funded by Environment Southland, to provide an assessment of the flow requirements of drift feeding trout, fish and benthic invertebrates. This study will assist decision making on minimum flow and allocation rules in regional water plans for the Oreti River.

The work involved building a hydraulic model of the representative reach, calibrating and validating the model, then running the model for a range of steady flows and, at each flow, post processing outputs to assess WUA for selected species and/or species life stages. The work included providing Cawthron with: 1) post-processed results (i.e., WUA – flow relationships); 2) hydraulic (i.e., velocity and depth) and substrate data at cell centres; and 3) a post-processed streamtube input file suitable for using as input to their NREI model. The scope of work did not cover interpretation of WUA results, as Cawthron were responsible for this part of the work. Cawthron’s work is documented in Hayes et al, 2016.
2 Methodology overview

2.1 The area of interest and model domain

A “representative” reach spanning approximately 840 m of channel over one meander sequence was delineated by Cawthron. This reach is located off Oporo Flat Road, approximately half way between Wallacetown and Winton and approximately 3 km downstream from Lochiel Bridge (Figure 2-1). This reach is referred to in this report as the “habitat assessment reach” or the “Cawthron area of interest”.

The model domain (Figure 2-2), also referred to in this report as the “modelled reach” or the “survey reach”, is mostly consistent with the Cawthron area of interest but extends approximately 120 m further upstream to provide a lead-in reach that reduces sensitivity of results to the upstream flow boundary condition, and approximately 215 m further downstream to reduce sensitivity to the downstream hydraulic gradient boundary condition. The lateral extents of the model domain were defined by digitising the top of bank line on both sides of the river.

The nearest permanent flow recorder is Oreti at Wallacetown (mean flow = 41 m³/s, mean annual low flow = 7.8 m³/s). In addition, Environment Southland set up a temporary water level recorder site, Oreti at Howden Road, on the true left bank near the middle of the reach, for the duration of the data collection exercise and subsequent survey work (Figure 2-2).
Figure 2-1: Location plan of the habitat assessment reach (or Cawthron area of interest). The location of the habitat assessment reach is shown in red in the bottom plot. This plot is an enlargement of the yellow box in the top plot.
2.2 Hydraulic modelling

Building a hydraulic model incorporating the “representative reach” involved the following eight steps:

- field survey and data collection to provide topography, bathymetry, flow, water level, velocity and substrate data;
- building a grid of the model domain;
- building a digital elevation model (DEM);
- interpolating the DEM onto the model grid;
- building the model (including specifying initial conditions, boundary conditions, hydraulic parameters, and run parameters);
- calibrating the model;
- validating the model;
- running the model.

All modelling was carried out using the Delft3D-Flow modelling package (Deltares 2011) in 2d (depth-averaged) mode.
For details on field survey work and data collection see Section 3. For details on the hydraulic model build, see Section 4.

2.3 Habitat modelling

Weighted Usable Area (WUA) versus flow and Combined Habitat Suitability Index (HSI) versus flow relationships were calculated by post-processing the model hydraulic outputs (depth and velocity) and substrate type using existing habitat suitability criteria. The habitat suitability criteria for the taxa of interest were supplied in spreadsheet form by John Hayes (Cawthron). To more easily read these criteria into the post-processing routines, the criteria were extracted from the supplied spreadsheet and output in Rhyhabsim preference file (*.prf) format (Jowett 2010) to a text file. This text file, which was then used as the primary source of habitat suitability criteria, is stored on the project directory as:

“O:\CAW17502\RawData\HSC curves\Oreti-HabitatSuitabilityCurves.prf”.

For each flow, HSI was calculated at cell centres on all of the wetted cells within the area of interest (Figure 2-2). These cell-based HSI results were weighted by cell area then summed and finally divided by the reach length to give an overall WUA for the reach per metre length (see Section 5.1).
3 Data collection

A three day field survey of the Oreti survey reach was conducted on 16-18 March 2016 by NIWA and Environment Southland. The objective was to collect data on channel topography, surface substrate, and hydraulics needed to build, calibrate and validate a 2d hydraulic model.

Key tasks were to:

- survey the 2d topography and bathymetry;
- survey the substrate composition within the area of interest (needed for calculating habitat statistics, including HSI and WUA);
- perform flow gaugings at two steady (or at least quasi-steady flows);
- survey cross-channel velocity and depth at four cross-sections, using an ADCP;
- collect long profiles of water surface elevation at the gauged flows; and
- establish a temporary water level recorder and collect stage-discharge rating data.

3.1 Topographic and bathymetry survey

Topographic and bathymetry survey data were largely collected by NIWA and Environment Southland staff during the three day field survey. Environment Southland staff subsequently carried out infill survey on the banks and in channel between April and August 2016. Four floods between 180 and 440 m³/s occurred over May to August but did not appreciably alter the channel where the remaining topography data were collected.

During the three day field survey, dry areas were surveyed using a combination of Total Station and RTK-GPS survey. This was supplemented by in-stream bathymetric data collected using a Trimble R10 GPS and a Sonarmite depth-sounder mounted on NIWA’s remote-controlled Arc boat.

Survey of a large, shallow mudstone shelf along the true left bank in the north-east part of the surveyed reach was attempted by Environment Southland but posed some problems as the water was too shallow for sounding and the surface too slippery for wading. In the end, no survey data was able to be collected in this area, except for a limited number of points at the true right edge. In the modelling we infilled this area with artificial points based these surveyed edge points (see Section 4.1 for further details).

All survey data is in NZTM projection. Elevations are to the Dunedin-Bluff (1960) vertical datum.

3.2 Velocity/flow gaugings

Flow gaugings using a StreamPro ADCP were performed at four cross-sections on 16-17 March 2016 during the three day field survey. Figure 3-1 shows the location of these cross-sections, and Table 3-1 tabulates their chainage. The chainage is taken as distance upstream along the main flow path from the downstream boundary of the model domain.
Figure 3-1: Detail of the modelled reach and location of flow gauging cross-sections and water-level recorder. Survey and model domain bounded in black; Cawthron area of interest bounded by yellow lines. Colour indicates elevation (blue lower, red-orange higher).

<table>
<thead>
<tr>
<th>Cross-section</th>
<th>Chainage (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS-1</td>
<td>130</td>
</tr>
<tr>
<td>XS-2</td>
<td>355</td>
</tr>
<tr>
<td>XS-3</td>
<td>880</td>
</tr>
<tr>
<td>XS-4</td>
<td>970</td>
</tr>
</tbody>
</table>

Flow was gauged at 11.1 m$^3$/s on day 1 (16 March) and was very steady over the day. A small fresh arrived overnight, raising the flow on day 2 (17 March). The flow peaked at around 23.6 m$^3$/s between 3am and 6 am NZST on 17 March then receded slowly (Figure 3-2). This recession is not observed in the flow gaugings that were taken on day 2 at the four cross-sections over a 2 hour period in the morning (between 9:30 and 11:30 am NZST). These gaugings indicated constant flow at 21.1 m$^3$/s. In any case, the recession is slow enough, over the period of data collection, that a quasi-steady flow assumption on day 2 is reasonable.
3.3 Visual assessment of substrate

Substrate composition was visually assessed on a 20 x 20m grid by wading and from a cata-raft and Arc boat using the RTK GPS or total station to mark survey points. The assessment of in-river substrate composition was complemented by underwater video and photographs taken with a GoPro and Fish Phone. The substrate composition where GoPro footage was taken was visually post processed on computer screen. At each substrate survey point, the percentage of surface area covered by eight substrate classes (Table 3-2) was assessed. A total of 951 substrate points were collected (Figure 3-3).

Table 3-3 provides details of measurement date, measurement technique, number of data points, and descriptive information pertaining to each collection of substrate sampling points. **Table 3-2:** The eight classes used to characterise substrate.

<table>
<thead>
<tr>
<th>Class</th>
<th>Class description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vegetation</td>
</tr>
<tr>
<td>2</td>
<td>Mud/silt (&lt; 0.06 mm)</td>
</tr>
<tr>
<td>3</td>
<td>Sand (0.06 – 2 mm)</td>
</tr>
<tr>
<td>4</td>
<td>Fine gravel (2 – 8 mm)</td>
</tr>
<tr>
<td>5</td>
<td>Coarse gravel (8 – 64 mm)</td>
</tr>
<tr>
<td>6</td>
<td>Cobble (64 – 246 mm)</td>
</tr>
<tr>
<td>7</td>
<td>Boulder (&gt; 256mm)</td>
</tr>
<tr>
<td>8</td>
<td>Bedrock</td>
</tr>
</tbody>
</table>
Table 3-3: Substrate survey data attributes.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Measurement Date</th>
<th>Measurement Technique</th>
<th>No. of data points</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIWA_1</td>
<td>17-18 March 2016</td>
<td>Video (GoPro)</td>
<td>100</td>
<td>Zig-zagging down river</td>
</tr>
<tr>
<td>NIWA_2</td>
<td>17-18 March 2016</td>
<td>Video (GoPro)</td>
<td>175</td>
<td>Longitudinal profile</td>
</tr>
<tr>
<td>NIWA_3</td>
<td>17-18 March 2016</td>
<td>Field observation</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>ES_1</td>
<td>17-18 March 2016</td>
<td>Field observation</td>
<td>320</td>
<td>On dry banks</td>
</tr>
<tr>
<td>ES_2</td>
<td>12 April 2016</td>
<td>Field observation</td>
<td>254</td>
<td>In wetted channel</td>
</tr>
</tbody>
</table>

Figure 3-3: Substrate sampling points. Samples are categorised by a sample ID that comprises the organisation of the field team collecting the data (NIWA or ES for Environment Southland) and a sampling group number that differs according to the sampling technique (Table 3-3).
4 Building the 2d hydraulic model

4.1 Creating the DEM

Figure 4-1 shows the location of survey data points used to generate the DEM, with points symbolised by data source (i.e., total station and RTK-GPS on dry land and in shallow water; RTK-GPS with echo-sounding in deeper water).

![Survey data and break-lines used to build the digital elevation model.](image)

To create the DEM, all data points were converted into a Triangular Irregular Network (TIN), which was cleaned of outliers and then converted into a raster with 0.5 m resolution. The outliers were mainly echo-sounding points. The echo-sounder was prone to give bursts of obvious erroneous values due to the build-up of an air bubble below the sounder. Such points were eliminated.

In Figure 4-2, the area of river bed on the true left bank bounded by a yellow line shows the submerged mudstone shelf that could not be surveyed (as discussed in Section 3.1). The true-right edge of this submerged shelf was visible in aerial photos. This edge was digitised as a break-line and a few artificial points, with elevations similar to the points surveyed on the shelf, were inserted in the data-free areas. Break-lines were also inserted along some banks and at abrupt slope changes to reduce interpolation error across these lines.
4.2 Creating the grid

The model domain was discretised by building a curvilinear grid, fitted to the boundaries of the domain. The grid comprised 1296 by 108 cells with an average spatial resolution of 0.85 m. Spatial resolution varies within the domain, being smaller on the inside of bends and larger on the outside. The minimum cell dimension was 0.43 m and the maximum was 1.60 m.

4.3 Calibrating the model for roughness

The model was calibrated for roughness by simulating the steady flow conditions on 16 March 2016. The Inflow at the upstream boundary was taken as 11.1 m³/s, as gauged, and the water level at the downstream boundary was set by assuming a uniform flow boundary condition based on bed slope. The bed slope was taken as 0.00074 to give a water level of 19.65 m, as measured at chainage 68 m, near the downstream boundary.

Roughness over the reach was assumed to be spatially uniform. This is appropriate given the shortness of the reach and the purpose of the modelling, which was to assess habitat at moderate to low flows.

Results from roughness calibration trials were compared by plotting the modelled longitudinal water surface profile against a surveyed water surface profile. Figure 4-3 shows a comparison for the final roughness trial in which a Manning’s n roughness of 0.040 was simulated.
Good agreement is shown between modelled and surveyed water surface elevations within the extents of the habitat assessment reach which are shown in grey. Within this reach, the mean difference between modelled and surveyed water levels for the profiled data points (calculated as modelled less surveyed) was just 0.008 m, indicating that the overall bias in modelled water levels was small. The root mean square (r.m.s) difference was 0.04 m, which is also acceptable.

Figure 4-3: Comparison between modelled and surveyed water surface profiles - final calibration run. (Flow = 11.1 m$^3$/s, Manning’s $n = 0.040$). The extent of the habitat assessment reach is shown in grey.

4.4 Validating the roughness calibration

The calibrated model was validated against a higher near-steady flow of 21.1 m$^3$/s gauged on 17 March 2016. This was modelled assuming steady flow.

Figure 4-4 compares modelled and surveyed water surface profiles, with the grey area again representing the extents of the habitat assessment reach.

Agreement between modelled and surveyed water levels within the habitat assessment reach for the profile data points is good downstream of chainage 700 m. Upstream of this point, the model slightly over-estimates water levels. The mean difference in water levels (modelled less surveyed) within this reach is 0.025 m, the root mean square (r.m.s.) difference is 0.05 m, and the maximum difference is 0.16 m.

We consider the agreement acceptable for the purpose of this study which is focussed primarily on flows that are lower than the validation flow.
Figure 4-4:  Comparison between modelled and surveyed water surface profiles – validation run. (Flow = 21.1 m$^3$/s, Manning’s n = 0.040). The extent of the habitat assessment reach is shown in grey.

4.5 Validating modelled velocities and depths

In addition to validating the model for Manning’s n, velocities and depths extracted from the final model calibration run outputs were validated against velocities and depths obtained from ADCP gaugings. The comparison was done using data from the four gauging cross-sections established in the 16-18 March 2016 field work using data from day 1 (16 March).

Figure 4-5 plots modelled depth and velocity (in green) against ADCP surveyed data in red. Note, depth is plotted negative in order to invert the plots so that they resemble cross-section profiles. Gauged velocities were post-processed using U.S.G.S’s Velocity Mapping Toolbox (VMT) (Parsons et. al. 2013) to give depth-averaged velocities that could be readily compared with the modelled depth-averaged velocities.

In general, the modelled cross-channel water depth at the four cross-sections show reasonable agreement with surveyed depths. There are some differences e.g., the modelled thalweg in cross-section 3 underestimates the surveyed thalweg depth and modelled depths in cross-section 2 are low by around 0.05 – 0.1 m. Such localised differences are to be expected given that the digital elevation model of the wetted model has been derived from surveyed point data that is more detailed across channel than along the channel. This means that some loss of topographic detail due to interpolation error is inevitable.
Figure 4-5: Comparison of modelled (green) and ADCP surveyed (red) water depth and velocity at the calibration flow. Flow = 11.1 m$^3$/s, Manning’s $n = 0.040$. Cross-sections located on Figure 3-1.
Modelled velocities show a slightly different picture. Reasonable agreement is shown in the two mid reach cross-sections (XS-2 and XS-3). However, agreement is less good in the two cross-sections near the start and end of the modelled reach (XS-1 and XS-4). We note, though that cross-section XS-1 is outside the area of interest for the HSI and WUA analysis so it represents area of the domain that is not actually used. Further, cross-section XS-4 is just downstream from the mudstone shelf. Given that the bed topography on this shelf had to be approximated by interpolating between artificial points, it is likely that the representation of the topography in this area was smoothed out. This could account for the apparent flatness of the modelled velocity profile in the XS-4 cross-section.

4.6 Sensitivity to horizontal eddy viscosity

The Delft3D-Flow model solves the Reynolds-averaged Navier-Stokes (RANS) equations (in which turbulent fluctuations in velocity are eliminated by time-averaging the equations) and uses a closure model to define turbulent stresses in terms of mean velocity values. Closure is achieved using an eddy viscosity model which relates turbulent stresses in terms of eddy viscosity, mean velocity gradients, and turbulent kinetic energy.

Horizontal eddy viscosity is another parameter, along with roughness, that can be used to calibrate a 2D hydraulic model. In the eddy viscosity model, turbulent stresses are proportional to eddy viscosity, so increasing horizontal eddy viscosity increases turbulent stresses thereby increasing lateral momentum transfer between faster and slower moving water masses. Hence increasing the horizontal eddy viscosity tends to flatten cross-channel velocity gradients and produce a more uniform cross-channel velocity distribution. Conversely, decreasing the horizontal eddy viscosity will tend to increase cross-channel velocity gradients.

The calibration run was modelled with a spatially uniform horizontal eddy viscosity of $10^{-6}$ m$^2$/s, which we have found to acceptable results.

To investigate the sensitivity of cross-channel velocity distributions to horizontal eddy viscosity, we re-ran the calibration run with a range of spatially uniform horizontal eddy viscosity values between $1$ m$^2$/s and $10^{-16}$ m$^2$/s and compared cross-channel velocity distributions at the four cross-sections.

A complicating factor is that increasing eddy viscosity, by increasing exchange of momentum between adjacent high and low velocity areas (e.g., at the boundary between the main channel and a floodplain) also effectively increases channel roughness and hence water levels. Therefore, it was found necessary to reduce global roughness when increasing horizontal eddy viscosity and conversely to increase roughness when reducing horizontal eddy viscosity. For example, with horizontal eddy viscosity set to $10^{-6}$ m$^2$/s, a good roughness calibration was achieved with a global Manning’s $n$ of 0.04 (as described in Section 4.4). However, if eddy viscosity is increased to $1$ m$^2$/s, then Manning’s $n$ needs to reduce to 0.035 to achieve the same overall calibration.

Our investigation showed that, when co-adjusted with roughness, horizontal eddy viscosity had only a minor effect on the cross-channel velocity distributions.

4.7 Mapping substrate for habitat assessment

Calculating a combined habitat suitability index and weighted usable area requires depth, velocity and substrate composition (by areal proportion) to be known at each grid cell. Velocity and depth are obtained from the hydraulic model, whereas substrate composition is estimated outside the model.
We derived a grid of areal proportion for each substrate class from the substrate sampling points by first producing a TIN of the data. This TIN was then interpolated onto the model grid. We used the ‘natural neighbour’ interpolation method as this method preserved a total fraction of one summed across all substrate classes and gave a fairly natural looking pattern of substrate distribution. The interpolation was done in model grid coordinates (i.e., in the curvilinear m, n space) rather than in easting-northing coordinates to reduce interpolation error along the edges of the channel.

The output of this process was eight grids of substrate coverage, one for each substrate class. Figure 4-6 shows maps of substrate coverage for substrate classes 1 to 4 (i.e., for vegetation, mud/silt, sand, and fine gravel). Likewise, Figure 4-7 maps substrate coverage for classes 5 to 8 (i.e., for coarse gravel, cobble, boulder, and bedrock).
Figure 4-6: Substrate fractional coverage for vegetation, silt/mud, sand and fine gravel classes.
Figure 4-7: Substrate fractional coverage for coarse gravel, cobble, boulder and bedrock classes.
5  Steady flow simulations

The calibrated model was used to simulate a range of steady base flows from 5 m$^3$/s to 17 m$^3$/s at 1 m$^3$/s increments, and also for four moderately high flows at 22, 28, 34 and 40 m$^3$/s. In both cases, a ramped inflow hydrograph was used, in which flow was held constant at each of the desired flow values for a sufficiently long period to ensure steady flow. We note that the model has been validated only as has high as 21 m$^3$/s, and so model results for the two highest flows should be used with caution as they may not be reliable.

For each steady flow, hydrodynamic outputs including cell area, cell-centred depth, and cell-centred velocity were extracted from the model and used along with substrate maps and habitat suitability curves to calculate habitat statistics for the full range of species/life-stages listed in Appendix A.

5.1  Habitat statistics

The following habitat statistics were produced and have been supplied to Cawthron to use as inputs to their wider study:

1. Tables of Combined Habitat Suitability Index (HSI) at cell centres (for each flow).
2. Weighted Usable Area (WUA, m$^2$/m) versus flow.

Both statistics were calculated within the Cawthron area of interest not within the wider reach.

HSI and WUA for a given species/life-stage were calculated as given in Equations 1 and 2 respectively.

\[ hsi = h_v * h_d * \sum_{k} (h_{sk} * p_{sk}) \]  

\[ WUA = \left( \sum_{i=1}^{i_{max}} hsi * A_i \right) * \frac{1}{L_R} \]  

where:

hsi = combined habitat suitability index at a given cell

h$_v$ = habitat suitability index for velocity based on the velocity at cell centre (m/s)

h$_d$ = habitat suitability index for depth based on the depth at cell centre (m/s)

h$_{sk}$ = habitat suitability index for substrate class k

p$_{sk}$ = areal fraction of substrate class k at the given cell

WUA = weighted usable area (m$^2$/m)
$A_i$ = plan area of the given cell ($m^2$)

$L_r$ = reach length (m) (equals 840 m for the representative reach defined by the Cawthron area of interest)

and the indices $i$ and $k$ are cell number and substrate class, respectively.

The habitat suitability indices for velocity and depth in equation 1 are determined by interpolating habitat suitability curves of index values versus velocity and depth, respectively. The habitat suitability for substrate is slightly different in that an index value is given for each of the 8 pre-determined substrate classes (see Table 3-2) and therefore no interpolation is required.

In this study we used habitat suitability curves for species/life-stages that were supplied by Cawthron (see Section 2.3 for further details).

We note that the above equations for determining HSI and WUA are consistent with the approach applied by the Rhyhabsim program.

### 5.2 Map sequences

Example map sequences of HSI by flow were produced for flows of 5, 8, 11, 14, 17 and 22 $m^3/s$ and for the four species/life stages given in Table 5.1. Map sequences of water depth for these six flows were also produced.

Figure 5-1 shows map sequence plots of HSI for adult brown trout (Code-TR3) at a steady flow of 8 $m^3/s$ (top plot) and 17 $m^3/s$ (bottom plot). Figure 5-2 shows the corresponding maps of water depth.

<table>
<thead>
<tr>
<th>Species/Life-Stage Code</th>
<th>Species/Life-Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF1</td>
<td>Upland bully</td>
</tr>
<tr>
<td>NF7</td>
<td>Longfin eel &gt; 300 mm</td>
</tr>
<tr>
<td>TR3</td>
<td>Brown trout adult</td>
</tr>
<tr>
<td>TR7</td>
<td>Brown trout juvenile</td>
</tr>
</tbody>
</table>
Figure 5-1: Map sequence plots of combined HSI for adult brown trout. Steady flow of 8 m$^3$/s (top plot) and 17 m$^3$/s (bottom plot).
Figure 5-2: Map sequence plots of water depth Steady flow of 8 m$^3$/s (top plot) and 17 m$^3$/s (bottom plot).
5.3 Conversion of model results into streamtubes

Cawthron’s drift-NREI model requires input from hydrodynamic models to be in the form of streamtubes. Streamtubes are defined at multiple cross-sections along the length of the reach. At each cross section the geometry of the streamtubes are defined so that they each convey the same flow. Streamtube data are read into the drift-NREI model using a standard text file format. Existing conversion utilities are available to develop streamtubes from 2d hydrodynamic model River2D outputs and also from the Rhyhabsim model but not for the Delft3D-Flow model output. For this project a new utility was developed in Matlab for converting Delft3D-Flow hydrodynamic model output into streamtubes. For each modelled flow, the utility was used to produce a separate streamtubes file with the standard text file format. These files have been forwarded to Cawthron. The streamtubes were created with one cross-section every two model cells (cross-section spacing of approximately 1 to 3 m) and 100 streamtubes per cross-section (20 across the width of the river and 5 vertically). A logarithmic vertical velocity distribution was assumed during the conversion.
6 Summary

A two-dimensional hydraulic model of a representative reach of the Oreti River, spanning one meander sequence, was built.

The model was calibrated and validated against water level and velocity data that were collected in the field by NIWA and Environment Southland staff.

The model was then used, along with habitat suitability curves for depth, velocity and substrate, to assess habitat (WUA) – flow relationships for key species / life-stages and to supply hydraulic data to Cawthron.

In addition, a Matlab utility to convert Delft3D model results into a streamtube format suitable for use as input to the drift-NREI model has been produced.
7 Acknowledgements

We thank the following Environment Southland staff for assisting with the topographical survey of the survey reach and providing flow data: Darren May, Abbas Akbaripasand, and Chris Jenkins.

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References


## Appendix A  Species/life-stage coding

For convenience, species/life-stages that have been used in this study, and their respective habitat suitability curves, have been assigned a Species code. The following table maps this species code to a full descriptor which typically includes a source reference for the habitat suitability curves. Note, some species/life-stages are not relevant to this study but are included for completeness.

### Species/Life-Stage Code

#### Trout
- **TR-1**: Brown trout spawning (Shirvell and Dungey 1983)
- **TR-2**: Brown trout adult (Hayes and Jowett 1994)
- **TR-3**: Brown trout adult - South Platte (depth modified) (Bovee 1993)  
- **TR-4**: Brown trout adult (Clutha - depth modified) (Jowett & Davey 2007)
- **TR-5**: Brown & Rainbow trout adult (T2) (from Appendix 2 in Wilding, T. K. 2012. Regional methods for evaluating the effects of flow alteration on stream ecosystems. PhD, Colorado State University.)
- **TR-6**: Brown trout yearling (Raleigh et al. 1986)
- **TR-7**: Brown trout juvenile - South Platte (Bovee 1993)
- **TR-8**: Brown & Rainbow trout juvenile (T1) (from Appendix 2 in Wilding, T. K. 2012. Regional methods for evaluating the effects of flow alteration on stream ecosystems. PhD, Colorado State University.)
- **TR-9**: Brown trout (< 100 mm) (Jowett & Richardson 2008) (depth modified)
- **TR-10**: Rainbow trout > 40 cm (Clutha) depth modified
- **TR-11**: Rainbow trout adult (depth modified) (Thomas & Bovee 1993)
- **TR-12**: Rainbow trout juvenile (Thomas & Bovee 1993)

#### Native Fish
- **NF-1**: Upland bully (Jowett & Richardson 2008)
- **NF-2**: Common bully (Jowett & Richardson 2008)
- **NF-3**: Bluegill bully (Jowett & Richardson 2008)
- **NF-4**: Torrentfish (Jowett & Richardson 2008)
- **NF-5**: Inanga feeding (Jowett 2002)
- **NF-6**: Longfin eel LT 300mm (Jowett & Richardson 2008)
- **NF-7**: Longfin eel GT 300mm (Jowett & Richardson 2008)
- **NF-8**: Shortfin eel LT 300mm (Jowett & Richardson 2008)
- **NF-9**: Shortfin eel GT 300mm (Jowett & Richardson 2008)
- **NF-10**: Koaro (Jowett & Richardson 2008)

#### Invertebrates
- **IN-1**: Food producing (Waters 1976)
- **IN-2**: Deleatidium (mayfly) (Jowett et al. 1991)
- **IN-3**: Aoteapsyche (net-spinning caddis) (Jowett et al. 1991)
- **IN-4**: Aphrophila (Diptera) (Jowett et al. 1991)
- **IN-5**: Maoridiamesa (Diptera) (Jowett et al. 1991)
- **IN-6**: C. humeralis (mayfly) (Jowett et al. 1991)

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IN-7 Hydrobiosidae (free-living caddis) (Jowett et al. 1991)
IN-8 O. feredayi (horny-cased caddis) (Jowett et al. 1991)
IN-9 Pycnocentrodes (stony-cased caddis) (Jowett et al. 1991)
IN-10 Zelandoperla (stonefly) (Jowett et al. 1991)

**Periphyton**
PE-1 Diatoms
PE-2 Short filamentous
PE-3 Long filamentous
PE-4 Phormidium
PE-5 Didymo (Waitaki)