UNIVERSITY OF CANTERBURY

Hydrological Characteristics of Lake Kate Sheppard and the Effects on Inanga Spawning

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1. Executive Summary

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The aim of this project was to assess and analyse the hydrological characteristics for the inputs and outputs of the Travis Wetlands and the Avon River on Lake Kate Sheppard (LKS), and the flow on effects on the physical habitat for Inanga spawning. LKS is located in the Christchurch Residential Red Zone. It is a man-made lake which was originally designed as a floodwater holding system which allows excess floodwater to travel from the Avon River into the Travis Wetland. The motivation for this project came from the Avon-Ōtākaro Network (AvON). AvON is a group who have invested their time in investigating LKS; and its suitability for Mahingā Kai, in particular, Inanga spawning.

Under the guidance of Bryan Jenkins; a representative from the AvON, and Justin Harrison from the University of Canterbury, water flow velocity was assessed while observing tidal fluctuations and consequently changing water levels. Continuous, stationary and spot handheld methods were used when conducting fieldwork.

Results have shown that the average flow velocity is higher with the incoming tide as opposed to outgoing tide, with high and low tides being identified by the flow orientation. It was found that the incoming tide was approximately four hours while the outgoing tide is approximately nine hours, creating an asymmetrical tidal pattern. Sediment samples show that rainfall decreases the clarity of the water and increases the amount of suspended sediment in the lake. Areas of vegetation on the western side of the lake have been identified as good Inanga spawning areas.

The findings of this project are a small representation of the hydrological flow characteristics of LKS. These conclusions will provide the AvON with the relevant information to build on existing research of the suitability of LKS to be an exemplar for Inanga species. This research will ultimately provide additional information on the hydrological characteristics of LKS to make an assessment on habitat suitability for Inanga.

1. Introduction

Following the 2011 earthquake sequence LKS and surrounding areas experienced severe liquefaction and lateral spreading. This raised concern for species such as Inanga and their spawning habits within the lake. Because of this the AvON has conducted extensive remediation work to remove excess sediment and add native and exotic vegetation around the area in order to induce regeneration of the area. As a point of ongoing interest in the area, AvON has taken particular interest in the hydrological characteristics of LKS and the flow on effects of Inanga spawning.

The aim of this project was to identify the key hydrological characteristics of LKS by using an intricate collaboration of equipment in specific areas of interaction between the lake and tributaries. The Avon River, Travis Wetland, and a water body to the west of LKS have been identified as key areas of interaction. Due to the data collection period being outside of the Inanga spawning period, this research has drawn little conclusion on hydrological flow on effects on the Inanga spawning within the lake.

There were several limitations for this project, the main limitation was the failure of the equipment in the field. This created restrictions to our planned time scale and meant that the collected data was not representative of the conditions. Other limitations included lack of communication between groups involved in the project, time pressures due to commitments outside of university and recording not been taken during the Inanga spawning season.

There are possibilities for future research studies at LKS. These are further outlined in the discussion of this report.

This project was supervised by Justin Harrison from the University of Canterbury's Geography department. Justin has provided technical support for the data collection phase of the report as well as providing guidance for research focus. Bryan Jenkins from AvON as the community partner liaison has provided guidance and support throughout the research process.

3. Literature Review

The literature reviews that were conducted by the research team prior to installing monitoring equipment were analysed in order to develop our knowledge on the specific wetland area of LKS. The majority of the research was based on how the presence of vegetation and the location of culverts affect the flow rates of water and therefore the ability of Inanga to migrate and spawn in the area. As this is one of the first hydrological studies conducted at LKS, there is very little prior research that has been carried out. Papers that were found to be useful included Barr et al. (2014), and Taylor & Blair (2011).

The presence of vegetation and its importance are stated by Jowett, Richardson, & Boubee (2009). The abundance of vegetation is studied in great depth, with experiments on its importance in habitat creation for Inanga being carried out. In a short term study, in-stream vegetation and debris were removed in targeted areas while other areas were left untouched. The Inanga chose to inhabit untouched areas, indicating that the vegetation and its protection from higher stream velocities are critically important. Areas that then had riparian vegetation reintroduced after being removed experienced an increase in spawning and feeding. This shows that Inanga will return to a site once it has been restored.

One of the most applicable papers studied was Richardson & Taylor (2002). Their guide to restoring Inanga habitats includes ways to locate, restore and protect spawning sites. The information used was essential to understanding where in the lake ideal spawning locations would be. Information regarding man-made culverts that separate migratory channels from the main flow and the consequential decrease in water velocity, is directly relevant to LKS. Knowledge of optimal Inanga feeding and spawning rates was obtained. Velocities between 0.03 – 0.07 m/s^{-1} and depths greater than 0.3m were preferred for feeding, and the overall mean velocity of streams used for habitat were 0.1 -0.6 m/s^{-1} (Richardson & Taylor, 2002).

Jowett (2002), discusses the flow characteristics needed for Inanga to drift feed, where they drift within the current whilst consuming nutrients needed. This maximises their food inputs while minimising the energy exerted to feed. Another key finding is that habitat selection is more dependent on flow velocities and depth of habitat is less important. Inanga were observed in water less than 0.3m but overall prefer to feed in water depths greater than 0.3m (Jowett, 2002). This is why vegetation presence within LKS is a key factor, allowing Inanga to feed in deeper eddies.

Suspended sediment in the water column was discussed by Baker & Smith (2014), who suggested that Inanga have adapted to travel further upstream during nightfall to evade capture by animals and humans. However when they do travel during daylight hours, a higher concentration of suspended sediments may impair their vision; leading to a higher catch rate. Therefore it can be inferred that the turbulent water velocities ($>1m/^{S-1}$) that are typical of floods; increase the turbidity in the water column which increases potential for capture.

4. Methodology

This research was conducted using instruments that recorded both spot and continuous data. The duration of this sampling was approximately three and a half weeks long which accounted for a wide range of climatic environments at the sample area. The length of time coincided with periods of high temperatures and low precipitation levels; low temperatures and high rainfall levels; and average climatic conditions for the area. The data was formatted into excel spread sheets which made it easier to condense the results. The large datasets that were created meant that they had to be divided into smaller groupings (days, hours) which have led to the data being presented in graphs and tables. The graphs have led to the identification of anomalies and trends within the data.

4.1 Hydrological measurements for flow velocity

Measurements of flow velocity at inlets of the lake to ascertain the tidal behaviour of LKS was conducted by using a number of instruments. The Valeport model 106 current meter (Appendix 1.) was placed at the entrance of the culvert where the Avon River feeds into LKS. The Valeport took constant flow velocity measurements which were then averaged over a two and a half hour period. This period was spread from the 27th of August – 9th of September. The intention of this was to ascertain whether there was a tidal influence on LKS from the Avon River, and what was the intensity of the flow. The Valeport was suspended from a secured pole via a chain and weighted at the base in order for it to freely move around with minimal obstruction. The Nortek Acoustic Doppler Velocimeter (ADV) (Appendix 2.) was positioned on the Travis Wetland side culvert which fed into LKS. The ADV recorded flow velocity, distance of the instrument to the base of the wetland, and it also logged temperature. The intervals were set at every five minutes which averaged a set of 10 measurements over a period of 10 seconds. The ADV was attached to a purposely built stand which allowed it to continuously log data with minimal obstruction.

Datasets deduced from both the Valeport and ADV have been condensed into workable groupings which allowed for separation of dates and different events. This was achieved by converting the data into excel format, which resulted in graphs being produced. The graphs identified fluctuations in flow velocity and highlighted hourly, daily and longer term trends and anomalies. The CT2X logger was secured against the jetty on the eastern side of the lake in order to provide continuous measurements of the lakes depth. This would have been correlated with data from the Valeport and the ADV in order to identify tidal movement.

Spot measurements were taken with more simplistic instruments that were easier to manoeuver and transport to different sections of the sample area. Manual flow probes were deployed at inlets to Lake Kate Shepherd from the smaller streams to the west of the Lake, as well as being used in an identified area that would have possibly served as an Inanga spawning zone. The flow probes values were averaged over a period of thirty seconds. The flow probes were the least reliable of all equipment due to them requiring a moderately strong flow velocity in order to register a value.

4.2 Suspended Sediment

A total of five suspended sediment samples were taken at various locations at the sample area (figure 7). There were four separate locations with one location having two samples taken at differing times. This was done in order to assess whether there was variation of suspended sediment before and after precipitation events. The samples were collected in standardised containers in order to collect approximately the same amount from each site. The suspended sediment was measured by draining the samples through filters (Appendix 3.) which resulted in the water passing and sediment being retained. The filters were then left in a 60 degree Celsius oven for a period of three days and then weighed again to obtain a difference. This difference in weight represented the amount of suspended sediment.

5. Results

5.1 ADV Data

Figure 1 shows the average flow velocities recorded form the ADV to and from Lake Kate Sheppard and Travis Wetland. Maximum flow was 0.1m/s, flowing into Lake Kate Sheppard.

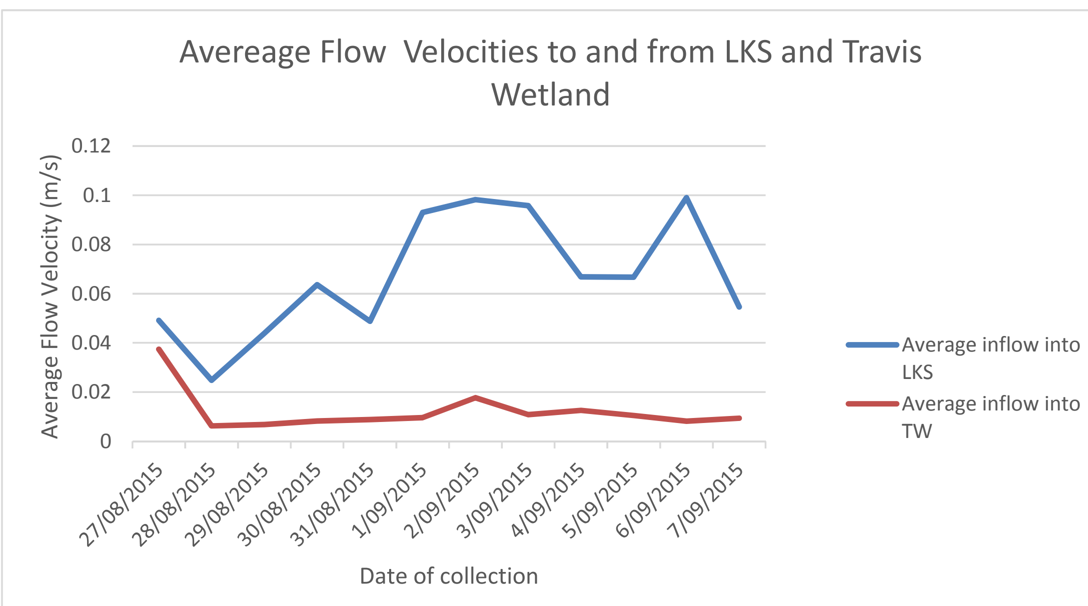

Figure 1 Average Flow Velocities between LKS and Travis Wetland, recorded by the ADV.

5.2 Valeport Data

Figure 2 shows the average flow velocities and the tidal influence on LKS from The Avon River. The anomalies on the graph indicate obstruction of weeds on the Valeport propeller. The peak flow was ~0.35m/s, flowing into LKS.

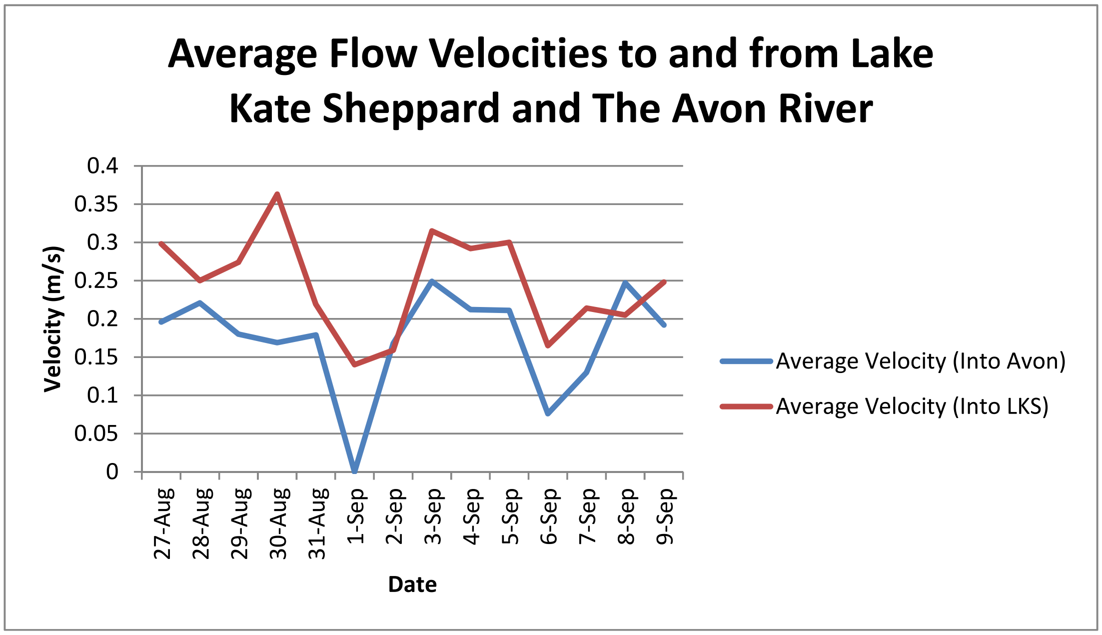

Figure 2 Average Flow Velocities to and from Lake Kate Sheppard and The Avon River, recorded by the Valeport.

Figure 3, is a pie graph showing that the water flow orientation at the Avon River culvert. It indicates that majority of the flow is directed towards the South to South East, which is flowing out of the Lake and into the Avon River.

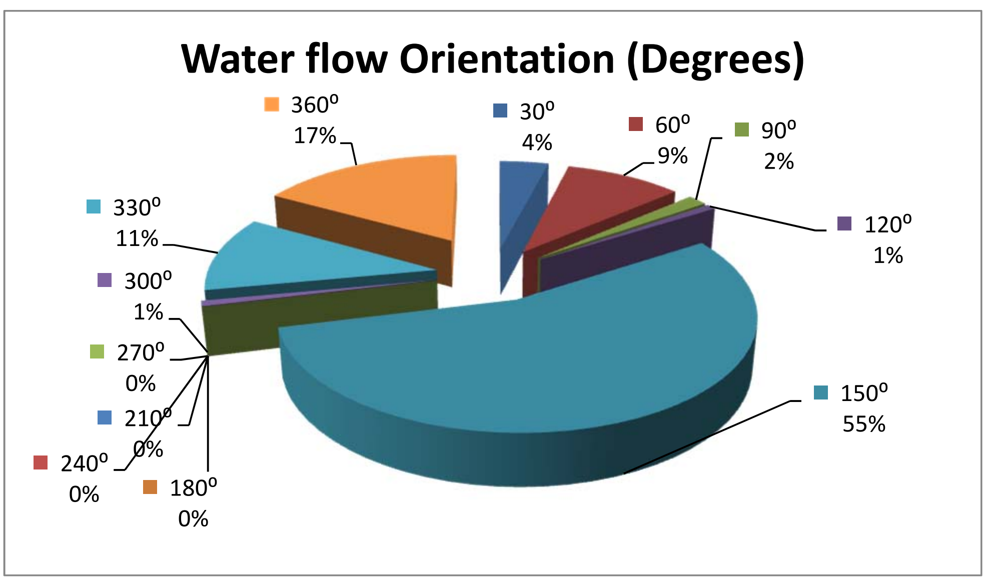

Figure 3 Pie Graph, indicating the flow orientation at the Avon River Culvert.

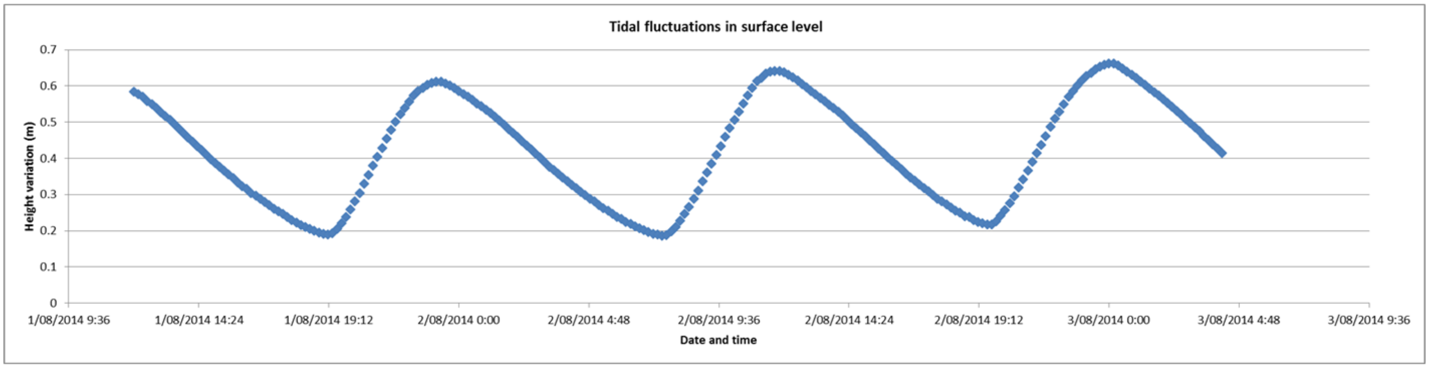

Figure 4 Tidal Fluctuations within Lake Kate Sheppard.

Figure 4 is a graph showing the tidal fluctuations within the Lake. The data that was collected and used to generate this graph was from a previous year's CT2X Logger. However, it correlated well to the Valeport data collected this year. It indicates that there is a long outgoing tide of 9 hours and a short steep incline of incoming tide for 4 hours.

5.3 Flow Probe Data

Table 1, shows measurements taken on the two western horizontal culverts that also feed into Lake Kate Sheppard. The measurements were taken using the flow probes, which lack sensitivity. However these give a good enough indication of the average flows at both 10cm and 20cm depth.

Table 1 Flow Probe Measurements indicating average flow velocities at 10 and 20cm depths.

Flow Probe Data		
	10cm depth	**20cm depth**
Culvert 1 (South)	0.3m/s-1	0.2m/s-1
	0.1m/s-1	0.05m/s-1
	0.4m/s-1	0.2m/s-1
Culvert 2 (North)	0.2m/s-1	0m/s-1
	0m/s-1	0m/s-1
	0.4m/s-1	0.1m/s-1

5.4 Cross Sections

Figure 5 is a cross section of the bathymetry of the Lake at the Avon River Culvert. It shows that the lake floor is not completely flat therefore the topography on the lake bed provides variation in flow velocities. The red arrow indicates where the Valeport was located (in front of the culvert).

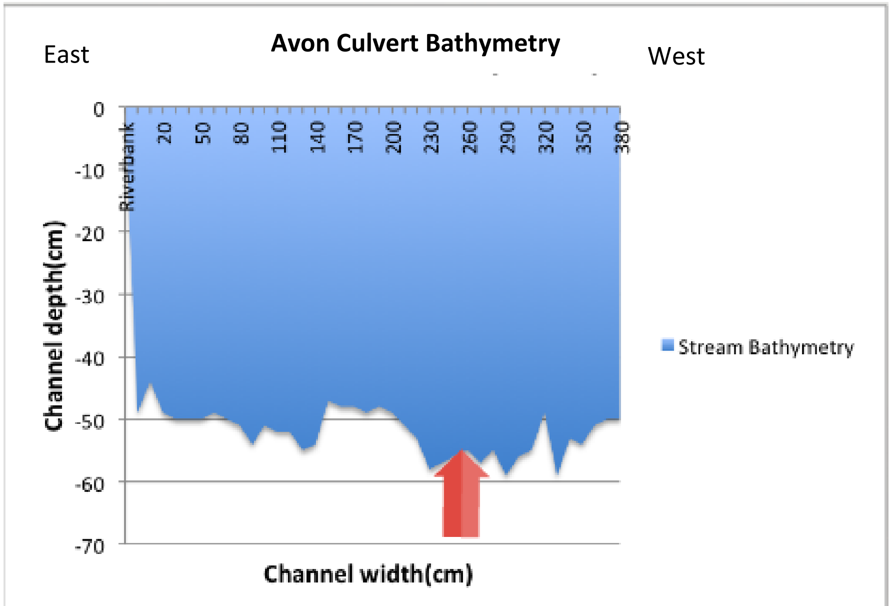

Figure 5 Cross Section of the Lake at the Avon River Culvert, showing the Bathymetry.

Figure 6 is another cross section, however shows the bathymetry of the Travis wetland culvert. This too, does not have a flat bed and therefore the flow velocities are manipulated by it. The red arrow indicates where the ADV was situated.

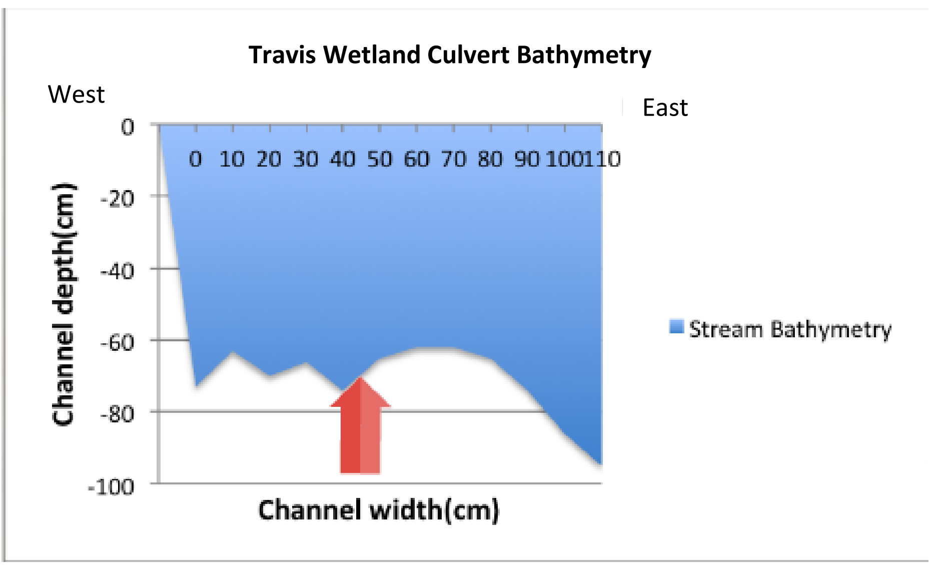

Figure 6 Cross Section of the Travis Wetland Culvert, showing the Bathymetry.

5.5 Sediment Samples

Table 2 represents the weight of the filter before and after the sediment has been filtered through. The bigger the difference in weight, the more suspended sediment there is. E and E2 are from one sample taken after a rainfall event. Samples E and E2 had to be averaged in order to obtain a percentage change in suspended sediment weight. This value came to 6.59% (2dp) weight difference. In order to compare a rainfall event with an undisturbed setting, samples D, E and E2 have to be further interpreted. To find a percentage change between the undisturbed setting and the rainfall event, calculations were conducted on samples after filtration. This was done by averaging the change in weight (g) for E and E2 (7g and 9g) which was 8g. This value was subtracted by the change in weight of sample D which was 6g. This gave a difference of 2g which was then divided by the original change (6g). This gave a percentage change of 33.33% (2dp). Figure 6 indicates the location in which the samples were taken throughout the lake.

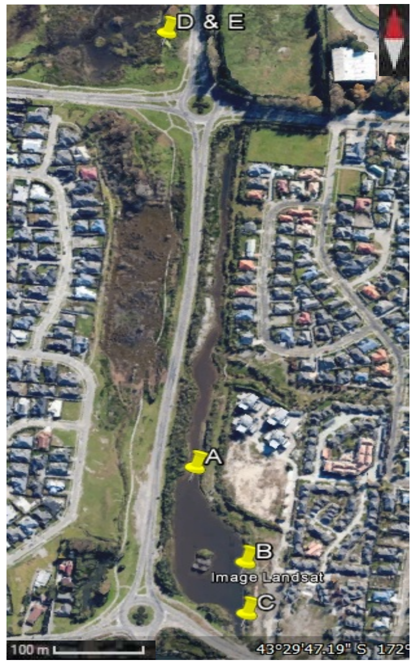

Figure 7 Map of Lake Kate Sheppard, indicating location of sediment samples.

The sediment samples were collected from a wide spread area in order to obtain a representative indication of suspended sediment levels in LKS. Sample A was taken on the western side of the lake which is headed in the direction of where ideal Inanga spawning conditions were observed.

Table 2 Sediment Samples taken before and after filtration.

Sample	Before Weight	After Weight	Change in weight	% change in weight
A	0.120g	0.134g	14g	11.67%
B	0.122g	0.127g	5g	4.10%
C	0.123g	0.128g	5g	4.07%
D	0.121g	0.127g	6g	4.96%
E	0.123g	0.130g	7g	5.79%
E2	0.122g	0.131g	9g	7.38%

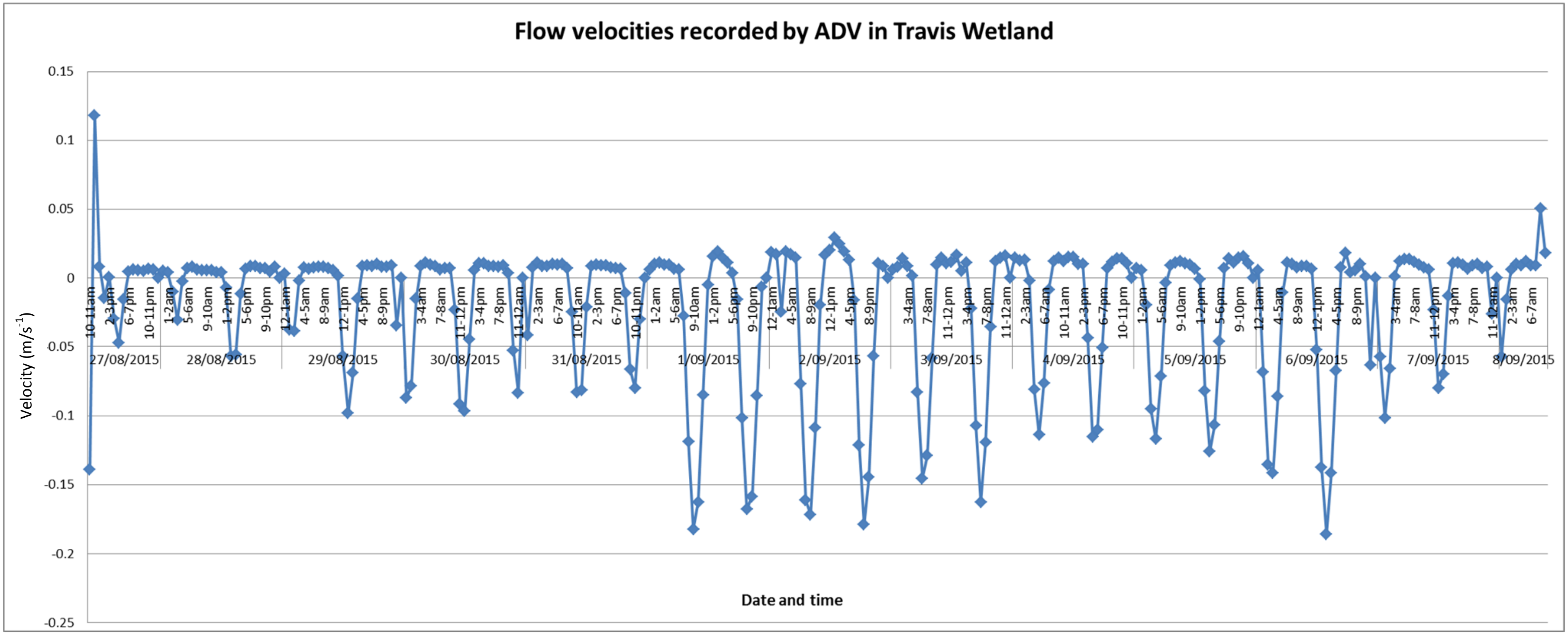

Figure 8. ADV data shown in a daily average format from the 27-8-15 – 8-9-15.

Figure 8 is a greater capitulation of tidal fluctuations observed by the ADV. This cross-correlates with data obtained from the 2014 data, and from the CT2X logger which shows the four hour inflow – eight and a half/ nine hour outflow regime of LKS.

Table 3: Showing average instantaneous discharge at Avon Culvert.

Date and time collected	Maximum Velocity (M/s^{-1}) (3dp)	Direction of Flow (^{o})	Estimated Discharge (m^3/s^{-1}) (2dp)
27/08/2015 17:21	0.366	335.1	1.53
28/08/2015 3:21	0.321	342.0	1.34
29/08/2015 16:51	0.352	324.1	1.47
30/08/2015 17:51	0.581	329.6	2.43
31/08/2015 6:21	0.368	332.9	1.54
1/09/2015 19:51 (Weed effected)	0.444	326.0	1.86
2/09/2015 20:51	0.325	343.6	1.36
3/09/2015 9:21	0.428	333.9	1.79
4/09/2015 10:21	0.492	319.4	2.06
5/09/2015 23:51	0.408	328.9	1.71
6/09/2015 12:21	0.451	332.2	1.89
7/09/2015 13:21	0.383	346.3	1.60
8/09/2015 1:51 (Weed effected)	0.386	349.4	1.61

As is shown in Table 3, data obtained from the Valeport was used to calculate an estimated discharge in 'cumecs' (m^3/s-^{1}).

6. Discussion

6.1 Tidal Processes

Tidal fluctuations within LKS proved to have a considerable impact on the flow regime. (Figure 4) shows the significance of the tidal fluctuations within the lake, with the incoming tide occurring over a period of four hours whereas the tide takes a period of eight and a half to nine hours to flow out. This could be largely due to the placement of the Travis Wetlands and the water body having further to travel. As there is more water entering through the Travis Wetland into LKS, it takes a longer period of time to drain out. When the tide is incoming it takes a long time to travel up the Avon River. It is important to note that high and low tides were estimated by the flow orientation, which was taken from the Valeport and ADV.

On August 1st 2014, low tide in LKS was recorded at 1910 (7:10pm) and high tide at 2310 (9:10pm), while high tide at Lyttelton was recorded at 2022 (8:22pm) and low tide at 1407 (2:07pm). This provides evidence to show that low tide at LKS is one hour before high tide at Lyttelton. The height of this tidal fluctuation in the LKS was from 0.192m to 0.612m showing the water raised a total height of 42cm. For August 2nd and 3rd 2014, a similar pattern was repeated (figure 8).

6.2 Sediment Analysis

(Table 2) shows the percentage change before and after a rainfall event which has an impact on the clarity of the water. As aforementioned in the results, the suspended sediment sampling from within the lake modelled a variety of different climatic conditions. It has been concluded that a precipitation event lead to an increase in suspended sediment by 33.33% as opposed to no precipitation. This in turn, has an effect on the site for Inanga to spawn as it increases the turbidity in the water column which causes visual impairment as the sediment disperses through the water. This can lead to the Inanga becoming disorientated or less likely to inhabit the area (Baker & Smith, 2014). As table 2 has shown, there is a relatively similar distribution of suspended sediment throughout LKS with the exception of site A.

6.3 Flow Regime

When looking at the flow velocity in LKS it was found that the incoming tide has a higher average velocity as oppose to the outgoing tide. The reason why there is a higher average for the incoming tide is because of the one-way flap on the Avon River culvert, as well as the fact that as the water body flows in through a narrow culvert its velocity will naturally increase.

Flow probe measurements taken were of low accuracy due to the low sensitivity of the instrument. It had a minimum detection velocity of $0.5m/s^{-1}$. This is why when referring to Table 1; it can be seen values fall within $0.5m/s^{-1}$. The flow probe measurements were also predominantly taken on the understanding of 'high tide' from the previous year's study. This supposed tidal lag of approximately 2.5 hours has since been proven incorrect. Another issue with the flow probe data is that it lacks sensitivity which means that it requires a moderate flow of approximately $0.3m/s^{-1}$.

When comparing with the ADV values, which can be seen in Figure 1, it shows that the velocity never exceeded a level $0.118m/s^{-1}$. This indicated the ADV was a more accurate form of measurement to give a more reliable data set. It has been suggested that Inanga prefer to inhabit in water bodies with a velocity ranging from $0.1\text{-}0.6m/s^{-}1$. This provides evidence to suggest that the flow velocities in LKS are suited to those preferred by Inanga to spawn. What is also evident from comparisons in the data is that the Travis Wetland flow velocities are three orders of magnitude lower than the Avon River flow velocities. This is consistent with measurements taken from the Valeport and the ADV. This therefore infers that Travis Wetland has less of an influence over the tidal characteristics of LKS. This could also provide contributing evidence that supports our assumption of an asymmetrical tide.

6.4 Flow Orientation

Another important aspect to consider when investigating hydrological characteristics in LKS is the orientation of the flow. This is dictated by the asymmetrical tidal pattern affecting LKS. The previously mentioned approximately four hour incoming tide and approximately nine hour outgoing tide both correlate with the dataset for the ADV, Valeport and last year's CT2X Logger. As can be seen in Figure 3, the water was flowing between 150° and 180°, 55% of the time.

6.5 Lake Bathymetry

Figure 5 and Figure 6 show the bathymetry of LKS. The graphs show variations in depth across the lake bed in both LKS and the Travis Wetland. The uneven surface can contribute to the changes in velocities as in areas of the lake where the water is at a greater depth, the velocity is lower and the shallower areas indicate where the velocity is higher. It was found that the maximum velocity was located at 60% of the water depth. The equipment was positioned in front of both culverts to ensure an accurate data set. These placements were appropriate to show the flow inputs and outputs from both Travis Wetland and The Avon River culverts.

6.6 Inanga

When considering the suitability of the hydrological flow characteristics in LKS to support Inanga populations for spawning, the results allowed us to conclude:

- Tidal data (Figure 4) shows the significant influence of the tides on LKS. This is crucial for Inanga to be able to migrate upstream from the Avon River into LKS.
- It was found that the ideal location for Inanga spawning grounds was located on the western side of LKS. This is due to the dominance of the riparian vegetation that grows along the banks.

6.7 Instantaneous discharge

- Discharges were calculated from the assumed previous high tide mark; this was a water mark measured from the centre of the culvert. The depth was found to be 1.09m above base of stream. The width of the stream at the Valeport's location was measured to be 3.80m. These were measured using a tape measure with mm accuracy.
- The estimated average maximum discharge was found to be 1.71 (m^3/s^{-1}). These values were calculated using the maximum velocity recorded per day and were all recorded during the incoming tide (table 3).
- Discharges were calculated using the formula: width of stream X average depth X average velocity. Units used are m^3/s^{-1} (cumecs).
- Discharges in the TW were not calculated in cumecs as they were too small when converted to recognise any significance; therefore the data is more significant when left in m^3/s^{-1}.

6.8 Limitations

- Time constraints encountered throughout this process hindered our original time management plan surrounding time for data collection and a short time period for setting up the equipment.
- Limited data collection time due to deadlines within the restricted time frame.
- General accessibility issues of not being able to take velocity measurements from certain parts of the lake.
- The equipment required is very expensive.
- The Valeport had never been used; therefore the software and the process of installing the hardware was a new method.
- The ADV had not been used in approximately four years, hence preparation took longer.
- Failure of equipment, in particular, the CT2X Logger.
- The lack of sensitivity of the flow probes used.
- The Inanga spawning season did not coincide with the period in which data was collected. This meant that the aspect of visual assessment of the whitebait migration was not possible.
- Due to the lack of prior research conducted in the LKS vicinity, it was difficult to come to any substantial conclusions. The conclusions made in regards to the hydrological requirements for Inanga spawning, are based on literature viewed in a wider context and case studies from similar types of projects.

6.9 Future Research

- More of a focus on the Western Culvert in terms of flow to correlate with research surrounding salinity.
- Conduct additional field studies using this research as a baseline for a long-term case study.
- Conduct research over the entire spawning season.
- The total count of the number of whitebait located in the Avon River versus LKS at the time of spawning. As well as the effects from the changes in velocity as the flow moves from the Avon River into LKS.
- Water Quality and what impacts that has or could have on Inanga survival rates.

7. Conclusion

Investigations into the hydrological flow characteristics of LKS and its suitability for Inanga spawning revealed that there was a significant tidal influence within the lake. This provides evidence of the preferred velocities for Inanga to spawn and was reflected in data from both the ADV and the Valeport. The tidal influence showed that there was a nine hour outgoing period and a four hour incoming period which limits the time in which Inanga can migrate into LKS.

It was concluded that the velocities recorded within the lake were suitable for Inanga migration, however not during peak high or low tide. It was also found that at sites close to the areas of ideal vegetation, the flows were significant enough for migration to occur.

The conclusions that have been drawn from this research project are precise and accurate despite limitations and have built a solid framework for future research. This will, in addition, assist the Avon-Ōtākaro Network build on existing hydrological measurements.

8. Acknowledgments

The authors of this paper would like to thank Professor Bryan Jenkins and the wider Avon-Ōtākaro Network for their contribution and support during this project. Professor Eric Pawson and the University of Canterbury's Geography department should be thanked for initiating this research opportunity. Finally, a very special thank you must go to Justin Harrison of the University of Canterbury's Geography department, who as tutor has assisted this research through providing technical support and guidance throughout the entirety of this project.

9. References

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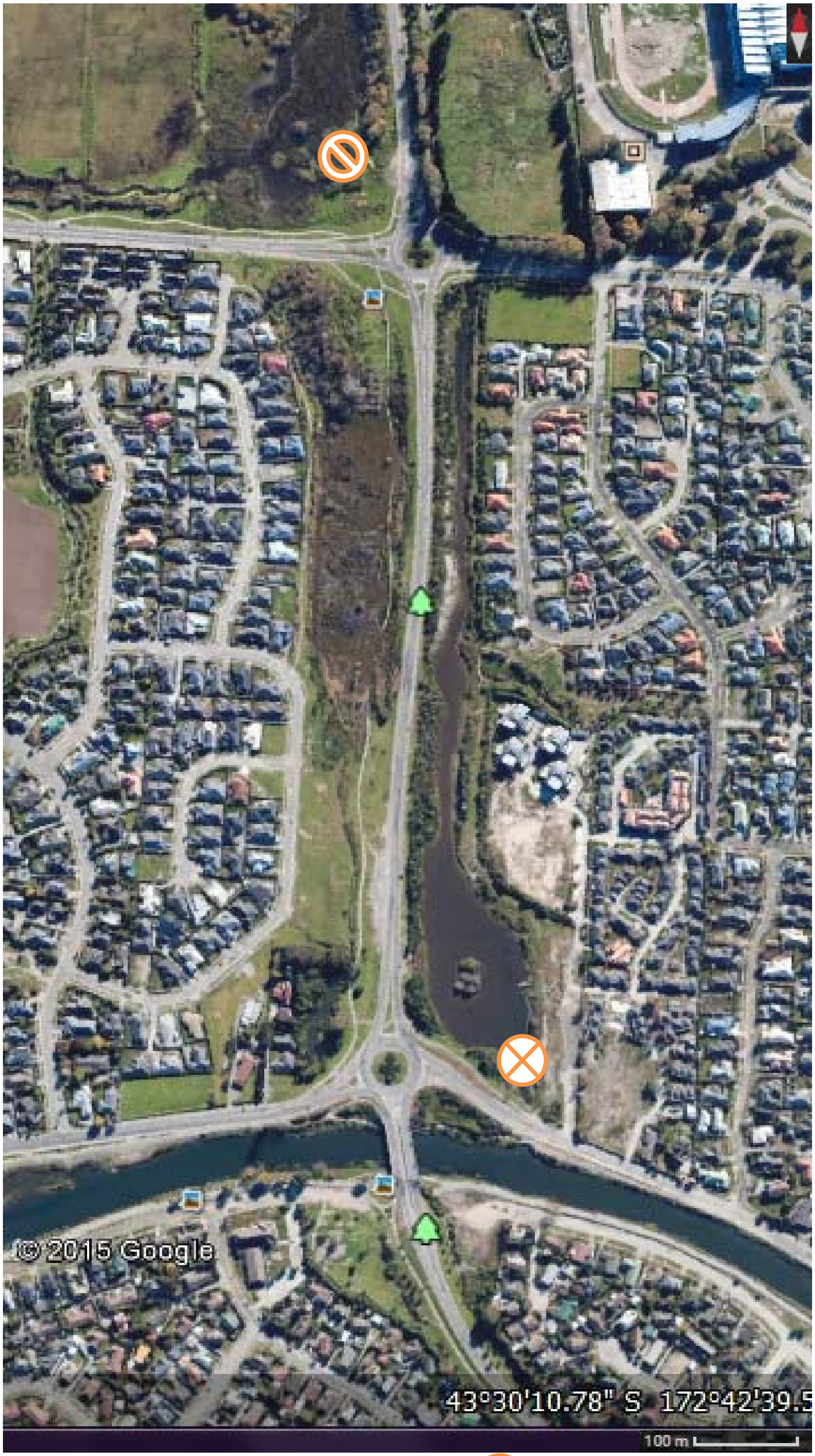
10. Appendices:

Appendix 1. The Nortek Valeport which is secured to a metal beam in front of the Avon River culvert.

Appendix 2. The Accoustic Doppler Velocimeter (ADV) secured to a metal stand that was place in front of the Travis Wetland Culvert.

Appendix 3. One of the five sediment samples being processed through the filtration system.



Appendix 4. This map indicates the location of both the ADV and the Valeport within the research area.