Sumner Waterways:

Opportunities for Restoration

Final report for GEOG309: Research Methods in Geography prepared for Habitat Sumner

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Contents

Executive Summary

- Human modification of catchments and riparian zones results in gradual stream degradation. Restoration aims to return streams to their natural state in order to improve their functions as biological and cultural resources.

- This research examines the current physical condition of the Sumner and Richmond Hill Streams in the Sumner catchment of Christchurch, how other urban waterways have been restored and evaluates if these methods would be effective in Sumner and meet the community's values.

- Streamflow variables including velocity, turbidity, sediment concentration and dissolved oxygen were point-measured. The condition of the riparian zones assessed using a classification index, and an environmental perceptions survey of the Sumner residents was examined.

- All sites performed poorly on the riparian quality index. Sites with low modification and partially restored sites exhibited higher levels of dissolved oxygen, greater turbidity and less sediment concentration than highly modified sites, which indicates the value of restoration.

- Stage one recommendations for restoration involve addition of swales, filter strips and substrate to create more viable ecological habitats. Stage two adds meanders to the stream, de-culverting sections and creating stream-length riparian buffer zones. Stage three removes all artificial channels, and relocates the stream through available land for a biodiversity reserve.

- The limitations of this study primarily involve the accuracy and precision of equipment used and human error; frequency of point measurements and the limited number of measurement sites.

- Future research should include long term measurement of streamflow variables, macroinvertebrate examination and in-depth feasibility studies of the restoration options.

Introduction

Habitat Sumner is a community-based group interested in the recovery of environmental assets to meet the needs of the Sumner community in Christchurch. This research aims to examine the physical characteristics of the highly modified Sumner and Richmond Hill streams, and evaluate the effectiveness of potential restoration methods for the Sumner streams.

Urbanisation affects not only water quality but also water quantity. Changes to a stream's flow regime have a significant influence on the stream ecology, due to the range of in-stream habitat impacts (Elliot et al, 2004). The alteration of flow is described as the most serious threat to stream biodiversity (Arthington & Bunn, 2002). Both increased and decreased flows alter ecology as flow defines the physical space available for habitation, and the range of physical conditions and habitat complexities to which different aquatic species are suited. Urbanisation further increases the magnitude and frequency of floods and droughts by controlling the rate of groundwater recharge and stormwater entry into the stream. Occasional floods are necessary components of a healthy natural stream regime as they are a crucial element of sediment and nutrient cycles by transporting and depositing material from upstream. However, high flows also wash away many aquatic species, and an increased flooding frequency reduces the viability of the stream as a habitat to sensitive species.

The need to dispose of stormwater as efficiently as possible without causing erosion or flooding to adjacent land has lead to the piping and realignment of stream channels and the reinforcing of stream banks and beds with concrete (Collier et al, 2008). Highly modified and channelized urban streams often cater almost exclusively for drainage. Steep or vertical banks prevent the growth of native riparian vegetation (vegetation alongside the stream), offer no underwater habitat and limit access to the water edge. Smooth concrete beds and banks reduce natural friction and offer no habitation for aquatic species, and furthermore limit the activity of the hyporheic zone (the water-land interface), where much of the cleansing occurs in a natural stream as the water filters through bed sediments (TRC, 2010).

Stormwater runoff has a significant impact on urban streams, affecting their water quality, flow characteristics, biological communities and physical appearance. Channel modifications and impervious surfaces increase water velocity and lead to urban streams often exhibiting a 'flashy' and steepened storm hydrograph that is typical of urban catchments. The extent of impervious surfaces, which indicates the degree of urbanisation within a catchment, strongly influences the amount of runoff produced from rainfall during a storm.

Impervious surfaces cause most precipitation to drain as surface runoff rather than through infiltration. This reduces the interaction between groundwater and surface flow, as traditional stormwater management designs have been designed to rapidly transfer runoff away from the urban areas and into the streams. As a result, urban streams have reduced lag times from precipitation to stream flow in urban catchments and exhibit a rapid hydrograph rise and recession, with peak flow higher over a shorter duration. Where 10-20% of a catchment is covered by impervious surfaces, stormwater runoff levels are double that of a non-urbanised catchment, and tripled in a catchment with 30-50% impervious surfaces (Paul & Meyer, 2001). On a pervious surface, it takes around 5ml of precipitation before surface runoff initiates; however on an impervious surface, the amount is effectively 0 (ARC, 2008; NZTA 2010). The level of imperviousness within a catchment is therefore a strong predictor of stream health. Many degraded urban streams have been associated with thresholds of impervious surface cover of less than 10-20% (Paul & Meyer, 2001). The overall water quality of streams is highly dependent on a number of factors, of primary interest to the current application are variables of nutrients, turbidity, dissolved oxygen and temperature. Nutrients control the rate of algae and macrophyte growth in freshwater environments. Nitrogen in the form of Nitrate, Nitrite and Ammonia are predominantly responsible for biological growth (ANZECC, 2000). Nutrients are not one of the major issues in urban catchments, where the most common source is lawn fertilizer. The lack of riparian vegetation in urban catchments increases the amount of these nutrients getting into the system as there is no buffer alongside the water way intercepting the nutrients.

Turbidity indicates a stream's water clarity and ranges from 1 in a clear mountain stream to 1000 in a muddy stream. Turbidity increases with the amount of suspended and dissolved particles in the water column. Removal of riparian vegetation can enhance bank erosion and therefore increase the sediment load within the stream; increased runoff velocity associated with urban catchments also enhances erosion (TRC, 2010).

Dissolved Oxygen is required by aquatic animals to survive, where the amount of DO water can hold is proportional to its temperature. 30°C water can hold a maximum of ~7.6mg/L while 5°C water can hold ~13mg/L (USGS, 2011). Once DO decreases below 5mg/L, aquatic life becomes stressed. DO is also influenced by the turbulence of the stream flow, as turbulent streams induce more mixing with air while stagnant streams have less DO. Nutrients also affect DO as they promote aquatic plant and algal growth.

New Zealand freshwater invertebrates can tolerate temperatures within a certain range. Richardson et al (in NZTA, 2010) found acute mortality of most fauna occurred above 25°C. An urban stream in Long Island, USA, exhibited summer temperatures 5-8°C warmer, and winter temperatures 1.5-3°C cooler than forested streams (Pluhowski, 1970, cited by Paul & Meyer, 2001). Impervious surface also resulted in summer storm runoff being 10-15°C warmer than forested streams. Modified concrete channels and the removal of riparian vegetation reduce stream shading, heating the stream in summer and cooling it in winter.

Urban streams in New Zealand are becoming increasingly valued, not only for their recreational opportunities but also their intrinsic ecological value (Elliot et al, 2004). Because of this, more effort is being put into researching the effects of urbanisation on stream catchments and refining methods of restoring them back to their natural state. Urbanisation impacts streams in numerous ways including water flow, which further negatively impacts a streams ability to support the ecological and amenity values associated with them. Restoration aims to return streams to their optimum natural condition, to support native stream life and natural processes. Restoration should focus on restoring the natural processes that create and maintain instream habitat rather than manipulating them artificially (Roni et al., 2002).

Method

Sumner Stream Physical Setting

Sumner is one of the Southern suburbs in Christchurch, 10 kilometres from the city centre. It is located in a coastal valley of the Port Hills where the catchment extends from Cave Rock to Scarborough Head and is home to around 4000 people. The Sumner and Richmond Hill Streams are the largest waterways which drain the Sumner Valley catchment, which is approximately 5.2km². Both streams are highly variable temporally and spatially as stormwater composites a large component of their flow.

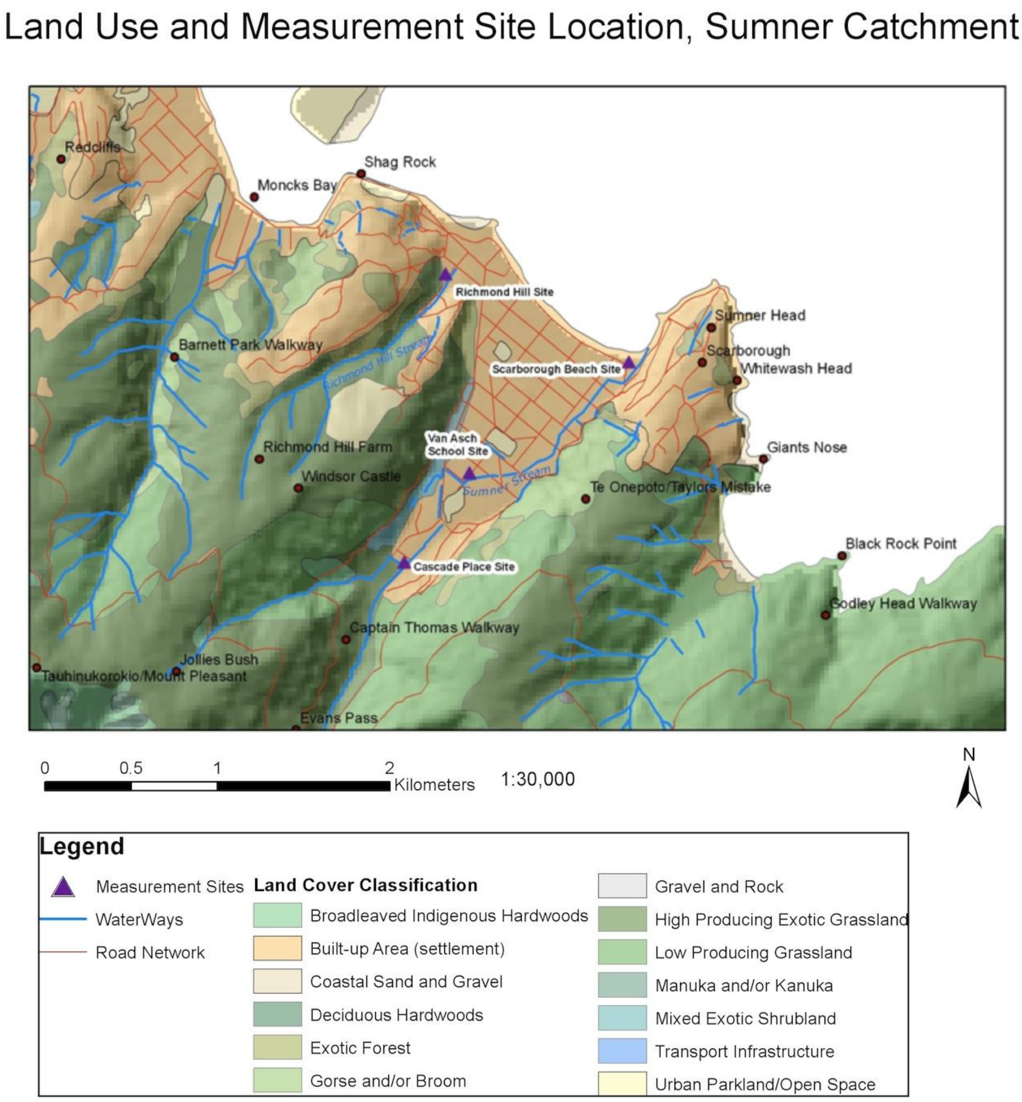


Figure 1: Sumner Catchment map indicating stream paths, land use and measurement site locations.

A number of stream sites have been identified for quantitative physical measurement and an evaluation of restoration methods. Stream flow variables including velocity, temperature, dissolved oxygen (DO), turbidity and sediment load were measured at three sites on the Sumner stream and one on the Richmond Hill Stream. DO was measured with a Eutech Cyberscan DO300 and turbidity was measured with a Eutech Turbidimeter

TN-100. Standard statistical analysis techniques were applied to the data. Data recorded from the Richmond Hill weather station in Sumner (Smith A, 2012, *pers comm,* 4 September) will be analysed in conjunction with stream flow data to examine the relationship between precipitation and stream flow. Sumner weather station data will be analysed in regards to precipitation levels prior to each measurement times and to examine past seasonal variations. At each site the Riparian Quality Index method (González del Tánago & García de Jalón, 2011) was used to characterise the surrounding riparian zone and stream banks in order to compare their human impact and degradation on a common ordinal scale. Additionally, a previous survey of the values of the Sumner community towards the streams and natural environment is examined (Osama et al., 2010). Finally, we undertook an extensive review of existing literature on urban stream restoration, stream ecology and stormwater to gain an understanding on how different techniques and concepts could be applied effectively to the Sumner catchment. This mixed-method approach allows us to combine quantitative physical measurements on stream conditions with qualitative findings on the perception of the natural environment.

Figure 2: Sumner Stream at Cascade Place: Upper end of stream, gentle slope, grass banks.

Figure 3: Sumner Stream at Van Asch School: Flat slope, lack of riparian zone.

Figure 4: Sumner Stream at Scarborough Beach: Highly modified in box culvert.

Figure 5: Richmond Hill Stream at restored site with daylighting. (Only one measurement site was identified on the Richmond Hill Stream due to the lack of access to the upper area. This site will provide a useful comparison as to its effectiveness).

Results

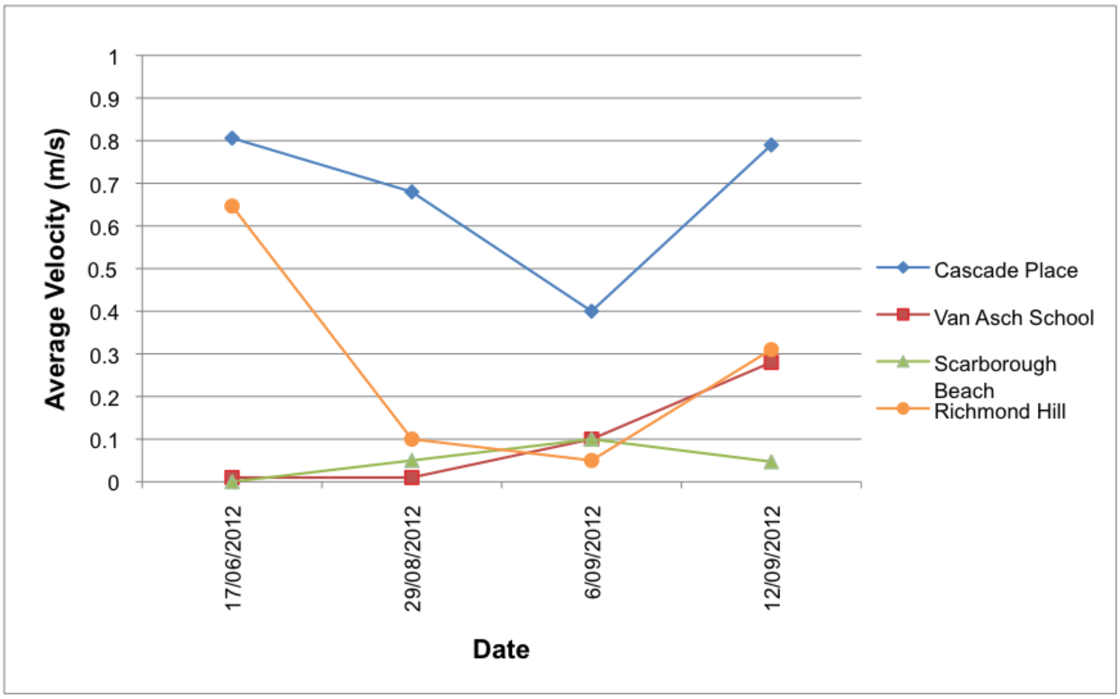
Stream sampling results

Sampling Date	Rainfall in Preceding 24 hours (ml)
22/08/2012	2.1
29/08/2012	0
06/09/2012	0
12/09/2012	20.2

Table 1: Rainfall received 24 hr before sampling took place. (Smith, A. 2012, *pers comm 4 September)*

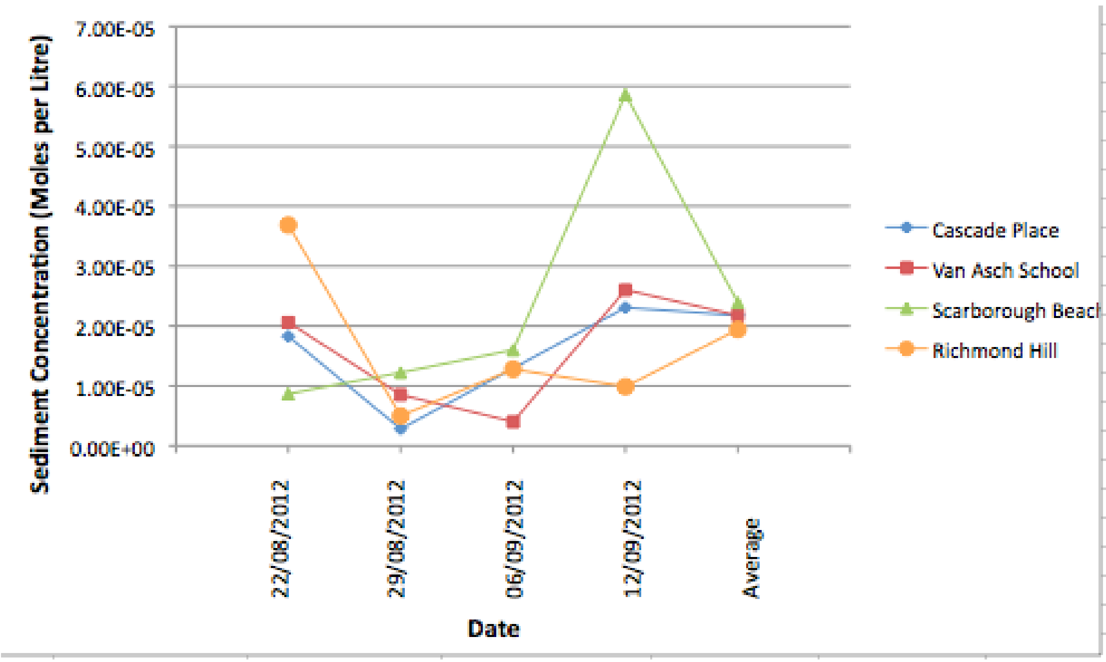
Variable		Cascade Place Site, Sumner Stream	Van Asch School Site, Sumner Stream	Scarborough Beach Site, Sumner Stream	Bowling Club Site, Richmond Hill Stream
Velocity (m/s^{-1})	*Minimum*	0.400	0.010	0.047	0.050
	Maximum	0.806	0.280	0.050	0.640
	Average	0.669	0.100	0.065	0.270
Discharge (m^3/s)	*Minimum*	0.008	0.001	0.016	0.003
	Maximum	0.096	0.004	0.220	0.019
	Average	0.044	0.003	0.090	0.010
Turbidity (NTU)	*Average*	73.78	54.399	60.590	76.63
Dissolved Oxygen (mg/L)	*Average*	9.65	7.55	7.42	9.29
Temperature (°C)	*Minimum*	11	11.5	11.3	9.1
	Maximum	16.6	15.1	15.1	16.5
	Average	12.5	13.1	13.08	13.0

Table 2: Streamflow Results Descriptive Statistics



Graph 1: Average velocity measurements for each site.

Cascade Place has the highest velocity readings compared to the other locations which are all similar other than the reading for Richmond Hill on the 12th of August where it was 0.647 m/s.



Graph 2: Suspended sediment concentrations for each site.

Scarborough beach has the highest reading of 0.0000586 g/L on the 12th0 of September and Cascade Place has the lowest of 0.000002825 g/L on the 29th of August. The highest turbidity reading within the Sumner stream was 140 NTU at Cascade Place on the 12th of September. This coincided with 20.2 ml of rain the area received in the previous 24 hours increasing the runoff into the stream, this also corresponded with the increased suspended sediment concentrations on that particular day. Cascade Place had a suspended sediment reading of 0.000023091 g/L on the 12th of September which was on average 0.0000117403 g/L greater than the other three readings taken on the 22nd and 29th of August and the 6th of September. Further downstream at the Scarborough beach site the highest suspended sediment concentrations were recorded (*Table 1*) and this site had an average water depth of 10.7 cm. Average velocities throughout the stream ranged from 0.100 at the Van Asch School to 0.669 m/s at Cascade Place. Sediment load varied spatially and temporally, and increased by ~0.0004 g/L following significant rainfall of 20ml.

Riparian Quality Index Results (González del Tánago, M., García del Jalón, D, 2011)

Richmond Hill - Score: 66

Poor (most attributes are moderately altered. Riparian systems need rehabilitation or restoration measures to reintroduce or gradually improve hydrological and ecological riparian functions. Reduce pressures and impacts as much as possible and design compensation measures to ameliorate environmental conditions)

Cascade Place and *Van Asch School* - Score: 29 and 21 respectively.

Bad (Several attributes are poorly altered. Riparian systems need rehabilitation or restoration measures to reintroduce or gradually improve hydrological and ecological riparian functions. Reduce pressures and impacts as much as possible and ameliorate the social perception of river degradation)

Scarborough Beach - Score: 9

Very Bad (Most of the attributes are badly altered. Riparian systems need new rehabilitation or remediation works, to recreate and reintroduce riparian functions. Improve environmental conditions for good potential status and ameliorate the social perception of the river degradation).

Sumner Residents Survey Results

The survey of residents social perceptions of the Sumner catchment (Osama et al., 2010) received 50 out of 500 responses, and the demographics of the respondents are believed to be representative of Canterbury. The survey indicated the respondent's value of water quality in the catchment most, followed by drainage, biodiversity, plantings and physical appearance respectively. Respondents perceived the current waterway management to be average with a bi-modal response of 5 and 7 out of 10, and ranked the level of current environmental health as above average with a mode of 8 out of 10. The perception of stormwater quality was perceived as above average with a mode of 7, while stream water quality was viewed as neutral with a mode of 5.

Discussion and Recommendations

This report aimed to examine the current physical condition of the Sumner waterways through streamflow measurement and riparian zone characterisation, and provide recommendations for improvement based on these results. Residents perceptions of the natural environment and waterway value were assessed through previous survey data. The recommendations of this research project will be presented to Habitat Sumner and potentially incorporated in the Sumner Recovery Plan, which is being produced as a result of the damage sustained, and new risks presented by the Canterbury Earthquakes.

According to the Auckland Regional Council's stream classification method (2010), the Sumner and Richmond Hill stream's would be categorized as type 5, as >50% of the channel is artificial while <50% is piped underground. This indicates a significant level of human intervention with the natural stream flow. Richmond Hill is similarly highly modified as it flows within underground pipes over a significant distance and emerges at a daylighting site where it enters a drain. The impact of human modification extends beyond the stream channels. Additionally ~30-45% of the Sumner catchment is covered by impervious surfaces. As Paul and Meyer (2001) noted, this triples the quantity of surface runoff when compared to a naturalised catchment. These findings indicate the extent of human impact and modification within the catchment area and account for the two most significant areas in need of improvement to contribute to the restoration of the Sumner waterways. However, while restoration must attempt to restore the streams to their natural condition, it cannot compromise the stream's capacity for drainage of the urban catchment.

Streamflow Sampling

As indicated in *Table 1,* the physical conditions on the Sumner streams are highly variable between sites. Significantly, sites with lower human modification exhibited the most favourable water conditions in terms of ecological function and aesthetic value. Cascade Place indicated higher velocities, greater dissolved oxygen and turbidity when compared to highly degraded and stagnant sites of Van Asch School and Scarborough Beach. As expected, this indicates that better conditions for ecological communities are associated with areas that have been subject to low human modification.

The Scarborough Beach site, where the stream is contained within a box culvert, performed the most poorly on the riparian quality index as the stream has been completely modified. Box culverts are poor practice for streamflow management as "during low flow periods, box culverts do not concentrate flows to maintain water depth as circular culverts and natural stream beds and consequently result in a thin sheet of water covering the full width of the culvert" (Speirs & Ryan, 2006). This site exhibited the highest discharge of 0.9 m^3/s which is attributed to the wide culvert. Contrary to expectations, the average suspended sediment concentration did not decrease further downstream, it would be expected to decrease as velocity decreases (*graph 1*) which should allow the sediment particles to settle out of the water column reducing turbidity and suspended sediment concentrations. This may not be the case because the Van Asche site was quite shallow, on average 5 cm deep, which could have contributed to the increased suspended sediment concentration as it was shallow muddy layer of reasonably still water (average velocity of 0.1m/s). The lack of riparian vegetation surrounding the streams could have contributed to the low dissolved oxygen readings and reduced the amount of shading there was over the streams therefore increasing the temperatures of the water (Table 1).

In comparison to the highly modified Sumner Stream, the restored site on the Richmond Hill stream adjacent to the bowling club presented well. Overall, as indicated in *Tables 1 and 2,* Richmond Hill Stream had lower sediment concentration, high turbidity and high dissolved oxygen. These findings are attributed to the stream being piped underground which reduces the amount of sediment suspended within the water load. Furthermore the restored area is narrow channels with a wide floodplain relative to the stream's size; this allows water velocity and discharge to increase, increasing dissolved oxygen while allowing flood events to be contained effectively. Significantly, the results from this site are similar to those measured at Cascade Place, which indicates the ability of restoration methods such as daylighting and channel alteration in returning the stream to a condition similar to a natural site.

Restoration Recommendations

The restoration options for each site environment along the stream are specific to the physical characteristics and parameters measured of each site. The recommendations for each site are provided in stages that increase with cost, feasibility and the level of environmental modification, and are designed to be cumulative and progress from the stage before. The stage one recommendations are primarily aesthetic as they are low in impact and will increase the natural character of the stream which was identified as an important consideration by the Sumner residents (Osama et al., 2010). Stages two and three will address other factors found to be important to residents, predominantly water quality which was viewed as a poor 5 out of 10.

1. Cascade Place Site, Sumner Stream

Stage One, Low Impact

- Native riparian planting
- Replace concrete streambed with natural coarse substrate
- Proper fencing of stream to prevent livestock access

Planting native riparian vegetation is a standard starting point for each site along the streams and it is recommended that a variety of native plant types are used to create diverse habitats and encourage development of biological communities. Overhanging vegetation provides habitat, shade and a food source for aquatic species, while marginal vegetation provides food sources in the form of vegetation and also the insects that the vegetation attracts (CCC, 2003). Planting vegetation with deep roots is recommended along the stream banks to aid stabilisation and to act as a buffer zone to loose sediments washing into the stream. Furthermore plantings filter sediments and contaminants from stormwater, contributing to increased water quality. As indicated in *Table 1,* Cascade Place recorded the highest velocities of water flow; as a result vegetation planted within the channel itself must be able to withstand complete or partial inundation during high flows. The stream cross-section can be divided into different zones to accommodate plants of differing tolerance to disturbance from flow, and sediment, and moisture, shade, shelter and frost. Replacing the concrete bed with cobbles and gravels is also recommended. This would provide more habitat space and reconnect the stream flow with the hyporheic zone, while also slowing water velocity. The substrate replacing the concrete bed will need to consist of larger cobbles and stones, as substrate too small (e.g. sands and silts) will be washed away during high velocity flow. Livestock in the reserve land at the head of the Sumner Valley should also be properly fenced to prevent them having access to the stream. This will help to prevent bacteria, nutrients and pathogens entering the stream from animal waste. Stage One restoration is focused on small areas of the stream around each study site, where space permits.

Figures 6 & 7 show an impression of converting the bed from concrete to cobbles. Figures 8 & 9 show what native grass plantings may look like.

Stage Two, Moderate Impact

- Reshaping stream channel to include physical instream variation
- Improving stormwater devices

Restoration along this section of Sumner stream is less complicated compared to areas within the township, as it is a lower density residential area. There is a wider riparian zone, therefore channel reshaping is recommended to restore natural meanders and instream features. Meanders will eventually change the distribution of bed sediments as they cause variation in water velocity across the channel. They can also lead to the eventual undercutting of banks to allow shelter under ledges. Riffles, runs and pools are three important areas of a stream that provide different conditions for different species and are therefore valuable for stream restoration at this site. Riffles are shallow, swift flowing sections with broken water surface and larger substrate due to the high energy environments (CCC, 2003). The increased turbulence created by the water tumbling over larger substrate increases the exchange of dissolved gases, nutrients and organic material between the water flow and the substrate layers, and provides good habitat for EPT taxa. Runs are the main instream habitat for the majority of Christchurch's lowland streams (CCC, 2003) and are characterised by an undulating, but relatively unbroken water surface, with a bed of a mixture of small and large substrate. Pools are deeper, slow moving areas with a smooth water surface. They often have fine bed substrate and they act as important storage basins for organic detritus that can be slowly released into the stream (CCC, 2003).

Stage Two for Cascade Place also involves some improvements to current stormwater devices. Currently there are many stormwater pipes that extend out of the stream bank and contribute directly to the stream. These pipes should be replaced with gravel lined drains that catch litter and help to filter out sediment and contaminants before they enter the stream. While the extensive impervious surfaces within the Sumner stormwater catchment is considered a diffuse source of pollution to the stream and is harder to remedy, each individual stormwater drain into the stream can be managed as a point source pollution input. If feasible during earthquake damage repair, the extent of impervious surfaces should be reduced where possible. Stage Two involves the same ideas as stage one, and like stage one restoration is restricted to only short lengths of the stream, where there is enough space to accommodate it.

2. Van Asch School Site, Sumner Stream

Stage One, Low Impact

- Native riparian planting
- Placing natural coarse substrate in the streambed

As with Cascade place, increasing levels of natural vegetation is highly recommended, as is creating a bed consisting of natural coarse substrate. This will increase the visual character of the site which is highly beneficial to the school that the stream runs through. As one side of the channel is buffered by a concrete wall, the removal of this will further add to the visual amenity and natural character the stream could provide.

Stage Two, Moderate Impact

- Reshaping stream channel to include natural physical variation
- Improving stormwater devices

Again, similar to Cascade Place it is recommended that meanders and natural stream features be added to the stream channel. Sumner Stream at Van Asch School is surrounded on both sides by flat grassed areas, so any reshaping of channel would have minimal impact on surrounding amenities. The channel here has a flatter profile, so it could potentially be narrowed to encourage higher water velocity, which would facilitate more gas and nutrient exchange and prevent stagnant flow. As with Cascade Place, redevelopment of stormwater drains into the stream is also an integral part of stage two for Van Asch School.

Figure 10: Example of restored stream (Radcliffe Road Drain, Christchurch)

3. Scarborough Beach Site, Sumner Stream

Stage One, Low Impact

- Box culvert removed on park side
- Native riparian zone, instream vegetation
- Placing natural coarse substrate in the streambed

Redevelopment of the Scarborough beach site is complex due to the riparian zone being constricted, not only by the concrete culvert but by the road and toilet block located directly either side of the channel. As an initial low impact measure, it is recommended that the box culvert be removed on the park and toilet side and to create a natural sloping bank in its place. This will open the space up as a resource for the park rather than concealing it. Once again, native vegetation should be planted and natural substrate be added to the bed to increase the potential for habitat.

Stage Two, Moderate Impact

- Remove box culvert

Building on the partial removal of the channel in stage one, stage two involves complete removal of the box culvert from Scarborough Beach. As the stream is closely bounded by the road leading up to Scarborough Head, it is recommended that the stream channel be narrowed to create room for a natural bank and riparian area, which will also increase stream velocity. EOS Ecology (2012) has already indicated a promising result from the removal of a box culvert from a stream in Christchurch's northern suburbs. The redesign of the channel was aimed at providing a healthier habitat for the Bluegill Bullies within the stream and restore the freshwater environment.

4. Daylighted Section, Richmond Hill Stream

Stage One, Low Impact

- Improving native riparian zone

Richmond Hill site indicated positive impacts from previous restoration measures of daylighting, channel landscaping to narrow flows, while providing a flooding area within the channel and limited riparian planting. This site exhibited increased dissolved oxygen and lower sediment concentrations than highly degraded sites on the Sumner Stream. The stage one recommendations for this site therefore aim at improving the current measures. Increasing vegetation around the stream would create more shaded areas within the stream. There is little impact that a Stage Two method would have on the Richmond Hill site, therefore Stage Three method would follow on from stage one method. This is discussed below.

5. Restoration of entire Sumner and Richmond Hill Stream lengths

Stage Three, High Impact

Stage three is the most expensive option and will have the largest impact on properties and infrastructure adjacent to the stream, however it offers the most extensive ecological, aesthetic and recreational benefits. Stormwater management devices throughout the Sumner township should be ideally re-designed to manage smaller rainfall events and promote water infiltration to maintain groundwater storage and base flows. A reduction in impervious surfaces where possible will have a significant quantifiable benefit on overall stream health. A stream buffer corridor through private properties (Booth et al., 2004) would also be highly beneficial, due to the significant proportion of the stream that flows in backyard culverts. Swales are vegetated areas that aid stormwater management by removing contaminants and chemicals from stormwater runoff and slowing the velocity of runoff and its entry into the stream (ARC, 2008). Swales are recommended as the most effective stormwater management method to counteract the impact of increased stormwater runoff. Swales must be located between the streams and roads or footpaths or other runoff sources to be effective.

Stage three for the Scarborough Beach site involves relocating the stream to the base of Scarborough Head to where properties are red zoned. This recommendation utilises the available land to create a natural park with walkways and seated areas, similar to the planned biodiversity corridor for red zoned area surrounding the Avon River. (CCC, 2012; Avon-Otakaro Network, 2012). The Avon-Otakaro River biodiversity corridor is aimed at creating a ecological and recreational reserve to restore the indigenous habitat natural to its historic ecology (Avon-Otakaro Network, 2012). The implementation of such an idea in Sumner would not only increase water quality, stream health and create a valuable resource for the community; it would also acknowledge the value of environmental health and serve as a space dedicated to the community following the impacts of the earthquakes as in the centre city.

Figure 9: This figure shows the restoration method taken place on a bow culvert located in a Northern suburb of Christchurch.

Limitations

The equipment used for streamflow data collection involves inherent error rates of precision and accuracy, while operational errors may also result from post-collection handling of data. The number of measurement sites along the Sumner and Richmond Hill Stream was restricted by the extent of accessible stream which is limited by residential housing, earthquake road closures in the upper catchment and underground sections of stream culverts, which affected our ability to evaluate the stream at a finer scale. The survey of the Sumner community is limited in its sample size of 58 respondents, which decreases the confidence level of the surveys input into our project. As there was no pre-earthquake streamflow data available, weather station precipitation measurements were used as an indicator, to supplement collected precipitation and corresponding Streamflow measurements from this study. This data is further limited as unquantified changes in water storage and release from the catchment may have occurred as a result of the recent seismicity. Furthermore, stream baseflow and storm response curves cannot be derived from the point measurements collected in this research or the previous precipitation data. This significantly limits the analysis of streamflow response. This analysis also did not include an aspect of macroinvertebrate sampling, which is generally considered to provide the best indication of stream health due to limited time, resources and expertise. The Macroinvertebrate Community Index (MCI) can be used to determine the quality of stream water based on the type of invertebrates that are present, rather than the traditional chemical sampling (Stark & Maxted, 2007). Future studies should therefore implement use of the MCI index. As the outcome of this project will be primarily advisory and focussed on the implementation of restoration options rather than the accuracy and precision of the data collected, these limitations are not significant in this context. It should also be noted that due to financial restrictions, recommendations from our research may not be viable courses of action. Future studies should incorporate a feasibility analysis of recommended actions. Variables should also be monitored constantly over a long-term basis at multiple sites along each stream to examine the relationship between rainfall into the catchment and resulting base flows and storm responses. This would allow for a more accurate understanding of the hydrological system and therefore a stronger basis for restoration recommendations. This was not possible for our project as only one long-term water level device was available and was found to be ineffective due to the low flow rates and water heights present in these streams.

Conclusions

This report has analysed the current condition of the Sumner Streams through quantitative measurement of physical parameters and qualitative assessment of riparian conditions. This study also examined the potential for waterway restoration to meet the community's needs through a previous survey of resident's perspectives and evaluating stream restoration methods. Environmental conditions varied significantly along the streams, however all performed poorly in terms of water flow and riparian zone characteristics. Their current degradation is due to the high level of human modification to the stream channels and the catchment area. This has resulted in water quality and quantity decreases and a decline in the ability of the stream to support diverse ecosystems. The restoration options recommended here ranged from initial measures that primarily address aesthetics and natural character to intensive measures that are designed to increase the health of the stream as an ecosystem. Swales and filter strips are highly recommended as methods to slow stormwater runoff from the high proportion of impervious surfaces into streams, reduce temperature and remove contaminants. More intensive restoration options include major alteration of the stream to remove culverts and channels, add meanders and divert streams through natural open land. The Sumner residents valued the waterways as more than aesthetic resources and would support their restoration and improvement, therefore education and involvement of the community is key in the restoration process.

Acknowledgements

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