BARBADOS WETLAND HYDRO-ECOLOGICAL DESIGN

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The Barbados Wetland is located in the mid upper reaches of the Alexandra Stream, which discharges into the lower Oteha Valley Stream, on Auckland North Shore. In 2004 as part of the Streamwalk Ecological and Engineering Stream Survey, for the Northshore City Council Network Discharge Consent application, Barbados Wetland was identified as a site for erosion remediation works and ecological enhancement.

There has been a recent trend in New Zealand to use ecologically based design principles in the management of erosion in urban streams and to improve hydrologic function to wetland systems. This involves the use of bioengineering techniques, materials and natural system design such the inclusion of pools, riffles and point bars into the finished geometry.

This paper documents the biophysical process assessed in the Barbados Wetland and the ecological, morphological and hydraulic design components used to develop detailed design. This includes discussion of the design process, key elements and research outcomes that informed the final detailed design.

As the construction supervision was conducted by the designers, the learnings and construction practicalities are documented and discussed in this paper. This is of particular interest in terms of the design of a dynamic natural system, which requires informed decisions to be made, 'on the fly', during the construction phase, such as riffle and point bar placement.

The Barbados Wetland Enhancement project is award winning and is an excellent example of a multi-disciplinary approach to erosion remediation works and wetland enhancement.

KEYWORDS

Hydro-ecological, conveyance, habitat, riffle, point bar.

PRESENTER PROFILE

Damian Young is a Director of Morphum Environmental. He has been working in the areas of stream assessment and remedial design for the last 13 years across the Auckland Region. As an Environmental Engineer he has focused heavily on the ecological and utility function of urban watercourses and there environs.

1 INTRODUCTION

The Barbados Wetland is located in the mid-upper reaches of the Alexandra Stream, which discharges into the lower Oteha Valley Stream, on Auckland North Shore (refer Figure 1).

In 2004 as part of the Streamwalk Ecological and Engineering Stream Survey, for the North Shore City Council Network Discharge Consent application, Barbados Wetland was identified as a site for erosion remediation works and ecological enhancement.

This resulted in an investigation to evaluate options to improve water and habitat quality of the Alexandra Stream and more specifically the Barbados Wetland, as part of a wider catchment planning process focused on restoration works for Alexandra Stream, as part of the Oteha Catchment Management Plan (CMP).

The design and construction has been conducted in conjunction with a proposed cycleway with an additional objective to create an amenity feature to enhance the area around Barbados Wetland.

Figure 1: Subject Site Location in Unsworth Hieghts on Auckland North Shore

1.1 CATCHMENT CONTEXT

The Alexandra Stream has been identified as a Category Two stream through the CMP planning process. This classifies the stream as being of moderate ecological and social value and as such has been identified as a watercourse with enhancement potential. The relevant outcomes sought for the Oteha stormwater catchment, and this enhancement project included:

- To provide mitigation measures to enhance ecological values;
- To improve public access within the stream corridor;

- To ensure sediment control requirements are met;
- To minimise quantities of zinc entering the receiving environment;
- To recognise and protect heritage and cultural values of the stream and environment;
- To manage stream erosion;
- The use of low impact design and other on-site mitigation methods for new development or redevelopment to reduce contaminant discharge at source, manage stream erosion and protect stream health;
- Protection against future stream bank erosion and damaged native vegetation;
- Maintaining and/or enhancing amenity and ecological values by retaining existing native riparian vegetation where practicable, implementing new planting and ongoing weed management;
- Protection and enhancement of existing wetland's and its/their associated natural treatment capability by restoring and maintaining in a more natural condition;
- Enhancement of general stream ecology by other means where appropriate, for example by habitat enhancement;
- Minimising in-stream works as far as practicable;
- Encouraging current and future community involvement in stream management; and,
- Mitigation of the effects of erosion at Council outfalls.

1.2 DESIGN OVERVIEW

The main objectives of the enhancement design and subsequent works can be summarised as follows:

- Reduce sediment deposition within the stream channel;
- Remediate any damaged banks along the reach;
- Provide some treatment of the Westminster sub-catchment flows;
- Reduce contaminant loadings on downstream environments;
- Incorporate the proposed cycleway in the design concept and detail; and
- Improve habitat and local amenity with riparian vegetation enhancement and wetland planting.

Typically on-line treatment devices are not preferred in the Auckland region due to the associated loss of habitat, therefore only treatment wetlands that are off the main stream channel have been considered.

In order to develop the proposed wetland detail a design process has been undertaken. This consisted of a topographical survey of the stream channel and wetland areas. From the survey information and additional adjacent LIDAR (Light Detection and Ranging) data, a AutoCAD Civil 3D model was developed. From this model a proposed surface was rendered consisting of bund structures, conveyance channel and re-contouring earthworks. Information was taken from both the existing and proposed surfaces in order to develop a Hydraulic Model in HEC RAS software. Maximum Probable Development flows (MPD) were obtained from Oteha Catchment modelling (NSCC, 2007), and used to define water levels and velocities through the system.

As extensive online treatment devices are not preferred in the Auckland region, due to the associated loss of habitat, only treatment wetlands that are off the main stream channel have were considered. A number of possible remediation measures were investigated and the best practical works were selected. The final design and construction included the following elements and are as follows:

- Battered bank stabilisation of the main channel with point bars and riffles;
- Pool riffle sequence;
- The construction of a naturalised "weeping wall" bund to temporarily impound flows for water quality and habitat improvement purposes; and,
- Partial excavation of upper middle ephemeral wetland to 500mm to increase capacity for storage, provide flooded wetland habitat and to reduce maintenance frequency.

As the design and construction has been conducted in conjunction with the Te Ara Cycleway on numerous occasions the overall design format was modified to take into account the alignment of the Cycleway and adjustment consequently made as required.

2 HYDROECOLOGICAL SETTING

When undertaking a design project involving erosion control and water quality the setting invariably has an ecological component. In the case of the Barbados Wetland project the existing situation did in itself have a degree of naturalness with inherent ecological value. However, the degree of both local and catchment scale modifications to land use, hydrology and ecology had resulted in bank slumping, bed instability and weedy plant infestation. In order to ameliorate some of these issues a hydroecological approach was taken. This involved not just looking at bank armouring or channel protection, but how a more naturalised geomorphology could be constructed without compromising the need to have a long-term stable channel, that would not become a maintenance burden to Council and the community. This paper presents the process of identifying the key features of a hydroecological design and documents the construction process including most importantly the learnings from observing the translation of design plans into the construction phase onsite.

2.1 HYDROLOGY

The Barbados Wetland is a modified natural wetland that has a downstream flow restriction in the form of a culvert under Barbados Drive. The wetland is bounded on its upstream side by the Unsworth Reserve, downstream by Barbados Drive and on the true left and true right by residential dwellings. It appears to be an historical wetland prior to development of the surrounding area. The total area of the existing wetland was approximately 0.24 ha and includes the main channel of the Alexandra Stream.

The Unsworth Upper Catchment and Westminister sub-catchment confluence in the upper part of the Unsworth Reserve, above the Barbados Wetland. The Unsworth Upper

Catchment is serviced by two water quality treatment devices which provide treatment to stormwater before it enters the Alexandra Stream. The Westminister sub-catchment does not have any water quality treatment devices and the stormwater from this portion of the catchment enters the Alexandra Stream untreated.

At the point of confluence both channels are open and unmodified. During low flow conditions all flows are conveyed via the main channel along the northern side of the wetland and then discharge via the Barbados Ave culvert into open channel downstream in Rook Reserve. During bankfull flows water enters the southern end of the wetland via two main paths. Firstly, the Westminister sub-catchment flows overtop its true left bank just upstream of its confluence with Alexandra Stream. Secondly, the Alexandra Stream overtops its true left bank just downstream of the confluence point with the Westminister Stream. The consequence of this is that the untreated flows from the Westminister sub-catchment have the potential to be treated before being reintroduced into the main channel in the south western end of the wetland. Figure 2 shows the confluence of the Alexandra Stream main channel and current natural wetland area during storm event, this photograph represents the pre-construction situation in bankfull flow.

Figure 2: Confluence of Alexandra Stream main channel and current natural wetland area during storm event (photo taken by local resident Nicholas Mayne)

The culvert under Barbados Drive acts to throttle high flows that are then impounded on the upstream side of the road inundating the associated flood plain area. The road crest level acts to govern the maximum water level in the wetland before overtopping and crossing the road to discharge back in the open channel of Alexandra Stream in the Rook Reserve. The existing wetland area acts to improve water quality, buffer flood flows and provides ecosystem services.

The current and future peak flow rates for the Upper Unsworth and Westminister sub-catchments are shown in Figure 3. These flows were used to run and calibrate the HEC RAS model for the existing and proposed scenarios and subsequent final design.

Catchment	Upper Unsworth Catchment	The Westminister Sub-Catchment	Totals
QP ID	1020775	1025819	
Upstream Catchment Area(Ha)	68.43	25.72	94.15
Fut Peak Flow Rate 100yr ARI (m^3/s)	24.09	9.62	33.71
Fut Peak Flow Rate 10yr ARI (m^3/s)	14.21	5.68	19.89
Fut Peak Flow Rate 2yr ARI (m^3/s)	6.89	2.75	9.64
Future Impervious (%)	70	70	70
Catchment Average Slope (%)	5.38	6.41	-
Catchment Longest Flow Path (km)	1.4	1.07	2.47
Ex Peak Flow Rate 100yr ARI (m^3/s)	19.14	7.77	26.91
Ex Peak Flow Rate 10yr ARI (m^3/s)	11.29	4.61	15.9
Ex Peak Flow Rate 2yr ARI (m^3/s)	5.36	2.21	7.57
Existing Impervious (%)	48.42	51.82	-
Notes	Predicted flow rates use TP108 graphical methodology with no allowance for flows in pipe network or within catchment storage. Future flow rates use increased imperviousness (70%) and rainfall. Future 100 yr ARI rainfall is 255mm, Future 10 yr ARI rainfall is 157mm, Future 2 yr ARI rainfall is 82mm.		

Figure 3: Upper Unsworth and Westminster Sub-Catchment Hydrology

A HEC RAS model was used to determine the spill points from which water would be entrained to the wetland from the stream. The storm event and water flow rate which would be required to cause the spill points to be engaged were also determined. The HEC RAS model was also used to investigate the velocity of water in the wetland to estimate residence time and the velocities through the proposed design.

2.2 ECOLOGY

Along the subject reach, from the upper Unsworth Reserve to Barbados Drive, the aquatic ecological habitat varies from stormwater ponds and open stream channel in the Unsworth Reserve, through to densely vegetated wetland environments above Barbados Drive. Some sections of the stream banks, which are actively eroding, have bank scour.

It is considered that historical earthworks undertaken during subdivision have resulted in unconsolidated, unstable material that is highly erodible being pushed in to the stream corridor. The material can be described as light brown clayey silt, with traces of sand and being slightly too moderately plastic.

There is riparian vegetation along the entire length of the stream ranging from stands of native bush within Unsworth Reserve to weedy scrub and wattle dominated canopy either side along the watercourse downstream of the Barbados ave culvert. In its lower reaches, before it passes under Rosedale Road, the stream is dominated with willows. The Barbados Wetland contained a range of native wetland plants including; Rushes, Comprosma, Tree ferns, Cabbage trees, Flax, Manuka, Raupob and Kahikatea.

The wetland's proximity to a remnant bush reserve on the upstream side further contributes to the significance of the area. No fish records exist within the wetland area, although common bully and banded kokopu have been recorded both up and downstream.

A Stream Ecological Valuation (SEV) assessment was carried out on 29th May 2009 (see Rook Reserve & Barbados Wetland SEV Report, Morphum Environmental Ltd, 2009). Macroinvertebrate samples were collected following Protocol C2 (Stark et al., 2001) and processed in the laboratory. Fish data was collated from previous studies, the NIWA Freshwater Fish Database (NZFFD) and through net-fishing carried out during the assessment (Refer Figure 4).

The site above Barbados Drive scored an overall SEV value of 0.60. The breakdown of each of these scores per function is as follows:

- Hydraulic Function: 0.70
- Biogeochemical Function: 0.63
- Habitat Provision Function: 0.52
- Biodiversity Function: 0.48

Overall the scores obtained from the survey are indicative of fair water quality. The SEV method suggests sites with scores between 0.4 and 0.8 would benefit from on-site remediation and restoration.

Figure 4: Main stream channel and SEV site location (Barbados Wetland)

3 DESIGN ELEMENTS AND CONSTRUCTION

The following design elements make up the works undertaken:

- Battered bank stabilisation, toe armouring with point bars and riffles/run features;
- Spillway conveyance channel (for improvement of conveyance from spill point);
- Wetland configuration (for wetland shape and configuration);
- Naturalised 'weeping wall' bund;
- Partial excavation of wetland; and,
- Existing outfall erosion mitigation.

3.1 BANK AND BED STABILISATION

The banks of Alexandra Stream, on both the true left and true right, 70 – 80m immediately upstream of the Barbados Drive culvert were unstable and slumping into the main channel (refer Figure 5). There was evidence of bank undercutting along much of the reach. The bank material seems to be of poor quality, unconsolidated non-engineered fill.

An attempt has been made in recent years to stabilise the banks using a geotextile layer and planted grasses (through council supported local community action). However, this has proved unsuccessful with slumping and benching into the main channel being observed ongoing. This has been reducing the cross section of the channel and the flow area, resulting in reduced instream habitat quality and amenity value, as well as presenting a health and safety risk for the public using the reserve for recreation.

Figure 5: Showing previous attempts to arrest bank slumping and the reduction in channel cross-sectional area

The continual and ongoing slumping had resulted in a shifting and unstable substrate with lowered water depths. The effects of this being reduced macroinvertebrate habitat quality and the movement of mobile sediments to reaches downstream.

Figure 6: Showing previous attempts to arrest bank slumping

The works to arrest and mitigate bank slumping involved cutting back the existing bank material to a slope at which the soil is was stable at around 1 in 3 generally. This increased the cross sectional width of the stream and would include the installation of point bars and rock riffles to dissipate some of the erosive energy of the stream reducing ongoing erosion.

Figure 7: Showing battering of the banks the laying of geotextile cloth for planting

Bank and toe protection measures included rock lining of the toe, geotechnical fabric pinned and closely spaced planting for future biological stability enhancement. This has resulted in increased habitat value of the stream through improving habitat complexity and heterogeneity. This is particularly relevant when point bars are used in conjunction with designed riffle features to create a varying depth profile of pools and the aerating effects of the rock riffles which increased the function of the stream to support fish and other aquatic organisms. Revegetation of the stream banks has improved overhead cover and now provides overhanging vegetation which provides a stable substrate for macroinvertebrates.

Figure 8: Showing toe armoring and planting after 6 months

3.2 POOL RIFFLE SEQUENCE AND HABITAT CREATION

Pool, riffle run sequences are important geomorphic and ecology features of a habitat diverse natural stream system. In this instance the design has had to mimic nature through channel design and substrate placement. Figure 9 shows this partially through the works and six months after. The design was based on the existing pool run sequence and directly reflects the pre works hydraulics in this regards. The maximum pool depths targeted to 500mm and small point bars used to create riffles and increase substrate heterogeneity. The minimum run depths being 50mm but this understandably depends on baseflow regime.

Figure 9: Showing bank and bed modifications through pool and run sequences

3.3 ROCK RIFFLE

In the lower reaches a nick point, where erosion had been migrating back up through the system was treated through the design and construction of a rock riffle. This acts to the protect bed and re-oxygenate the water flowing through and over it. The design is based on the Newbury rock riffle but is modified to suit the site conditions (refer Figure 10).

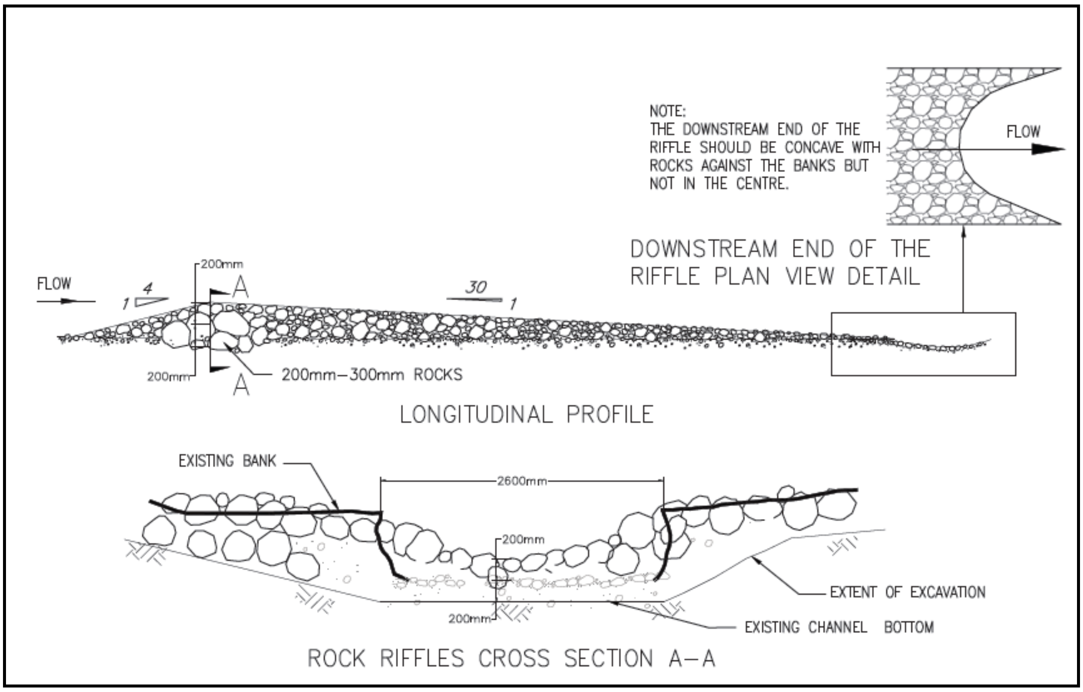

Figure 10: Rock Riffle Design Drawings

Figure 11: Rock riffle pre and immediately after works

3.4 POINT BAR

The area with the most erosion, in the subject site, was the reach immediately upstream of the Barbados Ave Culvert. The design solution being bank recontouring and the construction of a point bar to protect the bed and banks. This is essentially a gravel bench underlain with larger angular rocks to provide a tight stable matrix (refer Figure 12).

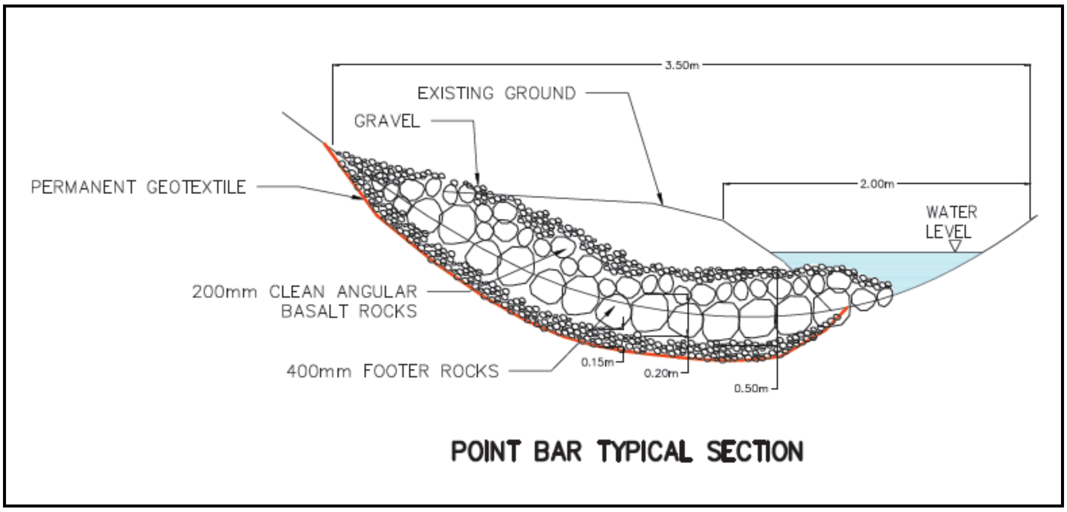

Figure 12: Point Bar Typical Section

The works resulted in a dramatic transformation of banks that had been slumping and unstable with high flows rushing toward the culvert entrance, to a stable widened section creating an eddy, capturing sediment and reducing peak flow velocities (refer Figure 13).

Figure 13: Shows before and after point bar construction

3.5 NATURALISED 'WEEPING WALL' BUND

The main element required to retain water in the wetland was a weeping wall bund at the lower extent of the wetland, before it rejoins the Alexandra Stream. This bund was constructed using compost filled geotextile socks which are secured in place and vegetated to provide long-term stability (refer Figure 14). Piles were driven some 3-6 metres down to form the main strength components to ensure no movement occurred during flood flows. This type of semi-permeable structure has been designed to temporarily detain water whilst enhancing the wetland system and was cost effective to construct. The permeability of the bund was pre-determined by the selection of compost suitable fill material. This allows water stored behind the bund to be released over a number of hours. It is anticipated over time fine sediments will fill the interspaces and result in less permeability. The design caters for these in two ways; a) the upstream levels will increase through sediment deposition and b) additional compost filled geotextile socks can be added to increase the impoundment level.

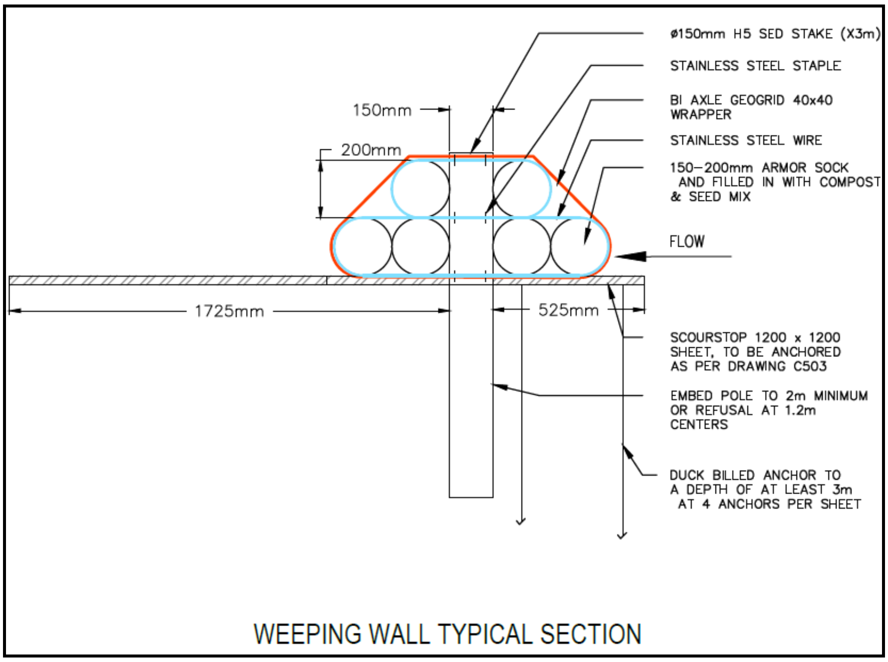

Figure 14: Weeping Wall Bund Typical Section

Figure 15: Weeping Wall Bund During and 6 Months After Construction

One of the main aims in the design and construction of this element was for it to blend into the environment. Even after six months this has begun to occur with seed stock from the remnant wetland plant assemblages beginning to take hold and sprout through the geotextile (refer Figure 15).

3.6 PARTIAL EXCAVATION OF EXISTING WETLAND AND CONVEYANCE IMPROVEMENT

Modelling of the open channel flow and observations made onsite tended to indicate that spill from both the upstream and downstream of the confluence was not frequent (i.e. possibly less than four or five times a year based on observation alone). The HEC RAS model indicated that discharge occurs at the current Alexandra and Westminster spill point during the water quality storm (1/3 of the 2 year ARI). If minor re-contouring along the conveyance channel was undertaken the spill point and wetland would only be engaged 4 – 5 times per year.

To increase this frequency re-contouring from the Westminster spill point to the head of the ephemeral wetland area was initially designed. However, the depth and location of a sewer through the site resulted in an amended design and a reduced scope of works and full re-contouring reduced only to the middle and lower approach to the exiting wetland and weeping wall bund.

The final design included two depression areas separated by a low earth bund which were lined with geotextile and planted with wetland species. This has acted to increase the conveyance capacity which provides flows to the ephemeral wetland and has provided deep water wetland habitat with associated storage that recharges the downstream reach with treated waters that augment low summer base flows (refer Figure 16).

Figure 16: Improved conveyance channel and constructed depression wetland

4 CONCLUSIONS

An opportunity existed at the Barbados Wetland to enhance the water quality treatment and habitat value of an existing system. The capture and entrainment of contaminants, from the untreated Westminster sub-catchment, will reduce the volume of sediment and dissolved contaminants in Alexandra Stream and the downstream Oteha Stream and Upper Waitemata Harbour receiving environment.

The replacement of a weed infested wetland with eroded and unstable banks, with a system now enhanced in habitat value and structural resilience, is a positive outcome from the project. The design integrated a cycleway and created a high value amenity feature (refer Figure 17).

Figure 17: The finished works looking along the new Cycleway

This design and physical works construction, in a dynamic changing system, was challenging. Conveying the right sense and understanding to contractors, especially the driver of the excavator when trying to construct a natural looking point bar, being the ultimate example.

The question of "where do we stop" was a challenge in particular designing the interface between the un-remediated sections and the remediated sections so they did not undermine the intended works.

In Auckland the use of rock in streams can be beneficial. Depositional zones re-create the silty bottom, while rock prevents scouring, and allows for the aforementioned depositional zones to remain more stable.

Critical to the success of channel modification and erosion protection works is how they are able with stand the force of erosive flows. During final construction phases the site experienced approximately annual peak flows and responded well (Figure 18).

Figure 18: Showing flood flows during final stages of site works

There has been a recent trend in New Zealand to use ecologically based design principles in the management of erosion in urban streams and to improve hydrologic function to wetland systems. This involves the use of bioengineering techniques, materials and natural system design such the inclusion of pools, riffles and point bars into the finished geometry.

The Barbados Wetland Enhancement project is award winning and is an excellent example of a multi-disciplinary approach to erosion remediation works and wetland enhancement.

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REFERENCES

Applied Project Solutions (2009) Goldfinch Rise to Rosedale Road Off Road Cycle Path – Preliminary Design Report. ARC, Auckland

Auckland Regional Council (2003). Design Guidelines Manual for Stormwater Treatment Devices, Technical Publication No. 10. ARC, Auckland.

Auckland Regional Council (1999). Guidelines for Stormwater Runoff Modelling in the Auckland Region, Technical Publication No. 108. ARC, Auckland.

Morphum Environmental Ltd, 2009 Rook Reserve & Barbados Wetland SEV Report.

North Shore City Council (2008). Oteha Valley Stormwater Catchment Modelling Report. NSCC, Auckland.

Morphum Environmental (2009) Opportunities for Restoration and Improvement Works - Alexandra Stream. Auckland.

Morphum Environmental (2009) Rook Reserve & Barbados Wetland SEV Report. Auckland.

Rowe, D.; Collier, K.; Hatton, C.; Joy, M.; Maxted, J.; Moore, S.; Neale, M.; Parkyn, S.; Phillips, N. and Quinn, J. (2008). Stream Ecological Valuation (SEV): a method for scoring the ecological performance of Auckland streams and quantifying mitigation. Auckland Regional Council Technical publication 302, 2nd Ed. January 2008. ARC, Auckland.

Unitec Landscape Unit (2009) Alexandra Stream Enhancement Project '09 - Barbados and Alexandra Lower Wetlands Concept Designs. Auckland.

Wong, T.H.F, Breen, P.F., Somes, N.L.G., and Lloyd, S.D. (1999). Managing Urban Stormwater Using Constructed Wetlands. Catchment Hydrology and Department of Civil Engineering, Monash University, and the Cooperative Research Centre (CRC) for Freshwater Ecology and Melbourne Water Corporation.