COMMUNITY INVOLVEMENT, SOCIAL CHALLENGES AND DAYLIGHTING IN WATER MANAGEMENT, CASE OF THE OHAKU BAY AUCKLAND

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ABSTRACT

Water flooding is an increasing problem in the Ohaku bay. Prior to 1911 Ohaku bay was an area said to drain water easily to the sea. Since the construction of the Eastern Interceptor of the Auckland Suburb Drainage Scheme the situation has changed, as it allowed the main sewer pipeline to be laid across the beach. With the height of 2.59m and the location in a low-laying land the internal pipeline as well as the construction of Tamaki Drive has created a situation which stifles the water from finding its way to the sea and hence has raised the ground water table making it susceptible to floods. Currently there is a Maori burial ground on the site, and it is said that the community faces issues during burial etc., due the higher water table.

It is expected for this location to develop more floods in the near future if the situation remains the same. This is due to the climate change, rising of sea water and the increase in extreme weather events including rainfall intensity. To resolve this problem, an investigation has been undertaken taking into consideration the community involvement which recommends the removal of the culvert and replacing it by a water channel of a 6m width and 6:1 batter slopes. The water channel will have more benefits to the environment as it provides the area with freshwater as well as marine life.

The analysis of the proposed water channel put forward a maximum flow rate of $3.4m^3/s$. This is close to meeting the requirement of a 2 year storm event. This investigation will provide the history and the present situation of the area, the previous effects of the culvert and the road and the expected effects on the future. Furthermore, this search will discuss options and provide a suitable solution and the methodology needed for the construction of the solution. Additionally, the study will deliver further details on the channel, the effect of tide on the channel flow, transmissivity, habitat creation as well as streambank vegetation.

KEYWORDS

Floods, Water Management, Daylighting, transmissivity, channel flow, Okahu Bay

1 INTRODUCTION

Okahu Bay is located in the Hauraki Gulf on the east side of Auckland city centre. It is sheltered from wave and swell action from the Pacific Ocean by seaward islands. It is located in a low-laying reserve land which has a beach as well as a cemetery owned by the Iwi. However, the beach is separated from the low-laying land by an old sewer concrete pipe and a main road is built on top of the pipe at a raised level. Although the edges of this area have a small number of residents yet, it has a substantial value to the locals. Meanwhile, The sewer line has been replaced with underground piping, Tamaki drive is a road that runs along its old route and a side road in the North-eastern corner, has been built on top of the old stream bed. The stream has been replaced by culverts that split out under Tamaki drive and close in 3 box culverts on the beach. Sewer piping runs along the piped stream just to the north of it, and gravity feeds it towards the southern ridges where it is pumped up into further infrastructure (personal communication with Watercare staff, April 2013), likely taking it towards the Mangere wastewater plant. This is a precarious situation: when flooding on the plain occurs the two opposing streams can possibly interfere with each other: stormwater can flush out wastewater in high rain events.

1.1 History

Auckland City sewage disposal in the early years of the settlement was via the Ligar Canal, which ran down Queen Street and emptied into the Waitemata Harbour. The open canal was a channelled watercourse called Waihorotiu (Horotiu Stream). The historian Graeme Easte wrote in the NZ Herald that *"in a few short years the Waihorotiu had become the infamous Ligar Canal"*. (Easte, 2008). It took 27 years to completely cover the canal in1873. Auckland Council, under pressure from citizens, investigated several options for sewage disposal methods. It was recommended by G. Midgley Taylor in 1906 to discharge screened sewage on the outgoing tide from Takaparawhau Point, Okahu Bay. City engineer Walter Bush supported the Okahu outfall scheme and Midgely was recalled to Auckland to implement the plan. (Fitzmaurice, 2009)

1.2. Okahu Bay

In the early 1900's, members of the hapu still exclusively inhabited the papakainga of Okahu Bay. The Auckland and Suburban Drainage Act 1908 began the process of legislating powers to the newly formed Auckland and Suburban Drainage Board.("Auckland and Suburban Drainage Act, New Zealand Statutes," 1908)

In 1905 an objection had been raised when the scheme was first proposed, nevertheless, were told that the only objection that would stop the development was if Maori could prove that it was not a public act. Work began on the construction of the network in October 1909, and by 1910 the pipeline had entered Okahu Bay. The route taken was across the beachhead, severing the connection between the land inhabited by the locals and the sea. With no roads, the sea was the main access to and from Okahu Bay. Okahu Creek, that used to run along the eastern edge of the low lying domain, still followed its natural course and entered the sea by flowing under the pipeline. By January 1911 the Eastern Interceptor was completed, having an internal height of 2.59m and width of 1.73m. (The Waitangi Tribunal, 1987)

1.3 Tamaki Drive

The Eastern Interceptor sewer line was designed for sewage, however later was also used to be a sub base for a vehicular access into Okahu Bay. Construction of Tamaki Drive was completed around the Auckland waterfront in 1929, and was built on top of the sewer around Okahu Bay. The sewer by itself still allowed some overland flow of stormwater, and the Okahu Stream was still flowing along its natural course. Once the road was put through, the natural stream was diverted into a culvert. The capacity of the low-lying papakainga to drain during rain events was reduced, leading to surface flooding. Almost overnight, any rainfall would turn the papakainga into a swamp. (The Waitangi Tribunal, 1987).

1.4 Present

Since 1978, the special relationship between Ngati Whatua and Orakei was recognised. The Treaty settlement returned the mana whenua to Ngati Whatua. Combined with other legislation such as the Resource management Act 1991(RMA), Ngati Whatua are now partners with the Auckland Council in environmental management. Ngati Whatua has been investigating the possibilities for the future of Okahu Bay. Starting with the Waka Okahu Bay draft discussion document provided to the Auckland Council with regard to the upgrading of The Landing marina situated on the Western shore of Okahu Bay. The discussion document details the lack of connection between Orakei and the harbour due to the physical barrier between the two spaces, namely Tamaki Drive and the sewer line. (Blair. N, 2005)

The Boffa Miskell presentation Orakei Papakainga was an urban development design utilising matauranga Maori, sustainable management and low impact urban design principles. The development would connect to Orakei marae, Okahu Domain, the Papakainga and the Whenua Rangatira. The stormwater management plan to embody Maori values of:

- **Tinana**: Physical connections of the body to the environment through the senses
- **Hinengaro**: Enhancing the understanding of the relationship and connection of the people with the land
- **Wairua**: Spiritual connections to the land and environment be enhanced
- **Whanaungatanga**: Inherent relationship between the people and the natural environment be promoted

Extensive native plantings on the Whenua Rangatira are part of the Ko te Pukaki restoration project. Food gardens with both native and exotic plants are maintained for the benefit of the local community. 16000 to 18000 native plants are added every year, raised in the native nursery located behind the marae. Under the terms of the Orakei Act 1991, the Whenua Rangatira block was returned to Ngati Whatua on condition that it be maintained as an urban open space. Ngati Whatua have a partnership with the Auckand Council to manage the space. ("Auckland story," 2009)

2 DAYLIGHTING

2.1 DAYLIGHTING IN AUCKLAND

When mayor Len Brown was elected into office in 2010, number 20 of his “100 projects, 100 days” was an evaluation of daylighting opportunities in Auckland (aucklander.co.nz). 33 options were identified (Heijs & Young, 2012), of which a project at La Rosa street in Green Bay is currently under construction (Auckland Council). In Technical report TR 2008/027 issued by the Auckland Regional Council, opportunities around 3 streams are explored. Mark Lewis from Boffa Miskell, who had been hired by the council to study opportunities, points out benefits of daylighting in three realms (2008):

-economical: open channels are cheaper to create and easier to maintain, reduce infiltration into waste water systems and increase economic activity and land values;

- social: a sense of place and connection with the land is made, amenity is created, community building opportunities are generated;

- environmental: stormwater treatment, storage, lower velocity storm flows, more continuous base flows, habitat creation.

2.2 DAYLIGHTING AS A CONCEPT FOR RESTORATION OF MAURI

In Māori culture there is a strong focus on the principle of mauri: every object or system has a life force or is providing life force to other objects or parts of the system. If one part of the system is affected, other parts suffer the consequences. Development and degradation of the natural environment has seen the loss of mauri and in their role as kaitiaki, caretakers, doing "the right thing" can increase mana (spiritual strength). Daylighting can be a means to restore mauri: by unearthing piped up streams, ecosystems can be supported and become sustainable over time. In a highly modified environment like Auckland, the human influence can not be ignored. However, Māori values prefer a low impact approach when it comes to making land productive and have aimed to stabilise a food supply through environmental management and stewardship

The Mauri model is a decision making model weighing up effects on mauri of social, ecological, cultural & economical factors, in that order. Monetary considerations take a back seat to possible gains on spiritual aspects, according to Ngāti Whātua o Ōrākei in the document outlining their restoration plan.

2.3 RESEARCH GOAL

This can be described as:

- To determine the feasibility of daylighting for a site in the Ōrākei reserve.
- Describe and work out options for restoration of a piped-up stream at Ōkahu Bay, in the light of creating benefits for stormwater management, the community and the environment.
- Assessment of opportunities from a perspective that aims to restore mauri.

As a recommendation in 2012 by Morphum Environmental ltd. to Auckland Council for relieving flooding and locally obtaining soil for raising the ground level of a cemetery on Ōrākei domain, it was suggested to investigate the possibility to re-instate a piped-up stream in the northern part of this domain. The aim for this engineering development project is to determine and evaluate options for such a restoration project.

2.4 RESULTS

Below follow data and analysis of it in regards to the research goal. Part of the research is aimed towards determining long term feasibility in the light of climate change, since the low-lying land of Ōkahu Bay may catch the brunt in case of sea level rise and storm increases.

A disclaimer in regards to tidal data used below: a standard for Auckland vertical levels is expressed in the Auckland Vertical Datum-1946 (Ministry for the Environment, 2008). This is the datum used on the Auckland GIS viewer and is also used as a datum in this report. Land Information New Zealand creates tidal charts that take into account local bathymetry that may have influence over the levels of high and low tides, based on historical tide data (Matt Bloxham, personal communication). For the purpose of this report, this data is assumed to be correct and applicable for Ōkahu Bay. However, LINZ warns to not use tidal data for surveying purposes but to survey the site. So, before practical execution of works it is recommended to test for the correctness of this data on site, i.e. measure the vertical levels of tides at Ōkahu Bay and compare with LINZ data and adjust accordingly, if required.

2.4.1 TIDAL INFLUENCES

The tides currently have an influence on the stormwater piping that is in place at Ōkahu Bay and will also for any option for an open channel. Tides follow a 12 hours & 25 minutes period for one cycle, half the average time of a lunar circumnavigation. Since the moon's orbit is eccentric, the effect of moon gravity varies. This, and the effect of gravity from the sun results in different tide heights through the year. Spring tides are caused by proximity of the moon and create monthly spring tides, which form the basis of Mean High (&Low) Water Spring Tides. When the sun is in line with the moon during spring tides, further increases in tide levels can be observed and Highest and Lowest Astronomical Tide are reached (Seazone, 2006). These levels can be exceeded by other meteorological factors, which will be discussed below.

The LINZ tidal datum and Auckland Vertical Datum-1946 datum differ by 1.74m (personal communication with Glen Rowe from LINZ), which is compensated for historical sea level rise. This means that a Spring tide of 3.66m m will get up to a vertical level of 1.92m, under the assumption that tides at Ōkahu Bay will be of same heights as for the rest of Auckland Harbour. Another calculation: Auckland Vertical datum 1946 is based on Mean Sea Level of the period 1909-1923. Sea Level rise from that period till now has been 16cm (MfE, 2013) A Mean Sea Level of 1.87m above chart datum in the period of 1994 to 2012 (Land information New Zealand, 2013) would mean a MSL of 1.87 – 0.16m = 1.71m above tidal chart datum for the Vertical Datum 1946, ie a 3.66m tide above this level would reach to the 1.95m vertical level for 1946 datum, which is close to the previous calculation.

In Auckland, with a 12 hour 25 min tidal cycle, 706 high tides occur per year. Of these tides with a high tidal range are of interest. the following number of high tide heights occur:

tidal height (m)	frequency	frequency as percentage of total	cumulative frequency
3.6	11	1.6 %	1.6 %
3.5	28	4.0 %	5.6 %
3.4	55	7.8 %	13.4 %
3.3	74	10.5 %	23.9 %
3.2	94	13.3 %	37.2 %

Table 1 Tidal occurrences in Auckland in 2013

Based on this information, 37.2% of the times a high tides occurs, it has a level of 3.2m or more and 62.8 % of the times it will have a lesser tidal range. A level of 3.2 m at high tide corresponds with a low tide level of about 0.6m, which is at a level of -1.14m on Auckland vertical datum 1946.

2.4.2 CLIMATE CHANGE

The Ministry for the Environment suggests that a 0.5m sea level rise should be taken into account for the period from 1980 to 1999 till the last decade of the 21st century, as well as that a scenario of 0.8m should be considered (Ministry for the Environment, 2012).

Another expected effect is that the intensity of ex-tropical storms is likely to increase. These bring a wind from the North east, generally, therefore hitting the east coast of New Zealand, including the Hauraki Gulf.

A low pressure creates a bulge in a water body and causes higher tides. Linz states that for every millibar away from average pressure 1 cm sea level rise can be added (LINZ, 2013). So if 1013 is the norm (Metservice, 2011), a depression of 970 mb adds 0.43 m to the tides.

Another factor to consider is zonal tilting, which is the effect on water levels from wind pushing up bodies of water. The maximum wind setup from available sources in recent history is considered 0.45 m (Metservice, 2011) when tropical cyclone system Wilma approached the Gulf coast, on 23-1-'11. The consequences The precautionary approach dictates to use this highest value for sea level rise.

When combining a spring tide coinciding with a 970mb low pressure with the wind setup mentioned above, tides can be expected to reach 1.92 + 0.43 + 0.45 = **2.8 m**. With a sea level rise of 0.8m by the end of the century this could increase to 3.6m. Ōrākei Domain is mainly situated in relative level of 2.5 m to 3m, so temporary flooding from saline influences needs to be considered. This value is from sea level alone, precipitation will only add to water levels on the domain.

Chances for this to occur are determined by taking the chances of such a weather system and the chance of a spring tide. When it is assumed such a storm happens every 2 years, the chance is 1/730. In 2013 there are 11 occurrences of the highest possible tides of 3.6m (LINZ, 2013), so the chance is 11/365. for the two events to coincide, the chance is 1/730 x 11/365 = 1 / 24223 , which means the Average Recurrence Interval (ARI) is 66.4 years.

To illustrate the increased likelihood of high tides occurring during storms from sea level rise the following calculation can be made: when sea level rise of 0.6m is considered, the Highest Astronomical Tide will be 4.26 m. The current Highest Astronomical Tide of 3.6 m would then correspond with a 3.0 m tide (3.6-0.6m) Based on the 2013 tides there are 297 occasions of the tide being 3m or higher, therefore the ARI of a 3m+ tide and a 2 year storm decreases to a mere **2.5 years.**

2.5 Options for Okahu Bay

Based on the above information, any opening up of culverts will have to be done with the knowledge that there may be occasions of saltwater intrusion on the plain. Due to the use of the low-lying land in Ōkahu Bay (sports fields, playgrounds, grass land) this is deemed to be an acceptable risk, other than that flooding of the urupā is not acceptable. The original starting point of this project was providing soil to raise it, so this risk is mitigated through raising of the ground level.

STREAM MOUTH

Creating a channel in the grassy flats of Ōrākei Domain is not a capital intensive exercise, however freeing up the stream under Kitemoana and Tāmaki drive will require capital expenditure on an under-bridge. The following decision matrix sums up the arguments for and against.

OPTION	*PROs*	*CONs*
Leave existing 3 way culvert under Tāmaki Drive	-No capital outlay for building wider channel	- Bottleneck remains in stormwater drainage system. - Stormwater flooding threat to urupā and fields
Upgrade culvert to larger diameter	- possible to do with directional drilling, lower capital costs than full width bridge. - Improved outflow.	- The stream mouth will still be a hard engineered feature, not resembling a natural environment.
Create bridge for Tāmaki Drive over newly created channel	- Capacity for water conveyance increased - possibility for waka launchings - maximises mauri of the environment	- capital outlay in regards to returns in increased flood safety of small number of assets. urupā=main asset → protect with terping. - disruptions to traffic - planning timeframe.

Table 2 Options for channel under roads

Elaboration: Technical Publication 108 from the Auckland Council describes stormwater capacity calculations for events with different average recurrence intervals. Calculations have shown that the capacity of the current culvert, which at some stage under the roads changes over from 2.25 x 1.2m culvert to 3 outlets of about 1m2 each, is only sufficient for a 2 year storm event, handling 6.8 m3 /s in the future situation of a fully developed catchment (Du Preez, 2012).

To create a natural-like stream mouth, a bridge under Kitemoana street and Tāmaki drive would be an optimal solution. This would most closely resemble the original landform. This was also the state the stream was in after installation of the sewerline (refer figure 4), it was only filled in at a later stage, around 1940, about 10 years after construction of Kitemoana street. However, the capital outlay for 2 bridges seems prohibitive at this point in time. A re-routing of the stream mouth westwards so only Tāmaki drive needs to be crossed under could be justified from a cost perspective, however this would alter the beach area.

A compromise could be to modify or create a culvert with a higher capacity that is also friendly for organisms like eels, banded kokopu, smelt and inanga to enter and exit freely. This could possibly be done with directional drilling and no interruption to traffic.

MAXIMUM THROUGHPUT OF UNDER-ROAD CULVERT

A consideration of the maximum flow rates of the existing culvert has been done. The calculations are available in appendix 1. A maximum flow of 3.4 m/s is calculated to be possible through the channel. Velocity rates of this level will require the installation of grates to prevent people getting sucked into the under-road culvert in high-flow situations.

CHANNEL

Length, depth, width and shape are the main considerations. The original stream hugged the eastern ridge as can be seen from figure 5. This illustration depicts a widening of about the last 100 m where it runs out of an area labelled 'willows'. This could have been previously a wetland. These days it is used as a rugby field and has a changing room nestled against the ridge. An option could be to daylight this area, however it may decrease amenity of the domain's sport fields, so it is not a preferable option. Near the stairs upto where Kitemoana street makes a hairpin turn, a manhole is situated. From here to where the culvert goes under Kitemoana street is the most easily achieved course for a channel. This is a length of about 140m. When a channel is considered towards the next manholes, some 20m away, this length becomes 160 m. However, a tapered start and end for aesthetic and conveyance consideration will decrease the volumes through this channel, so a length of 140 m is considered here with an even cross-section, ie a rectangular trapezoid.

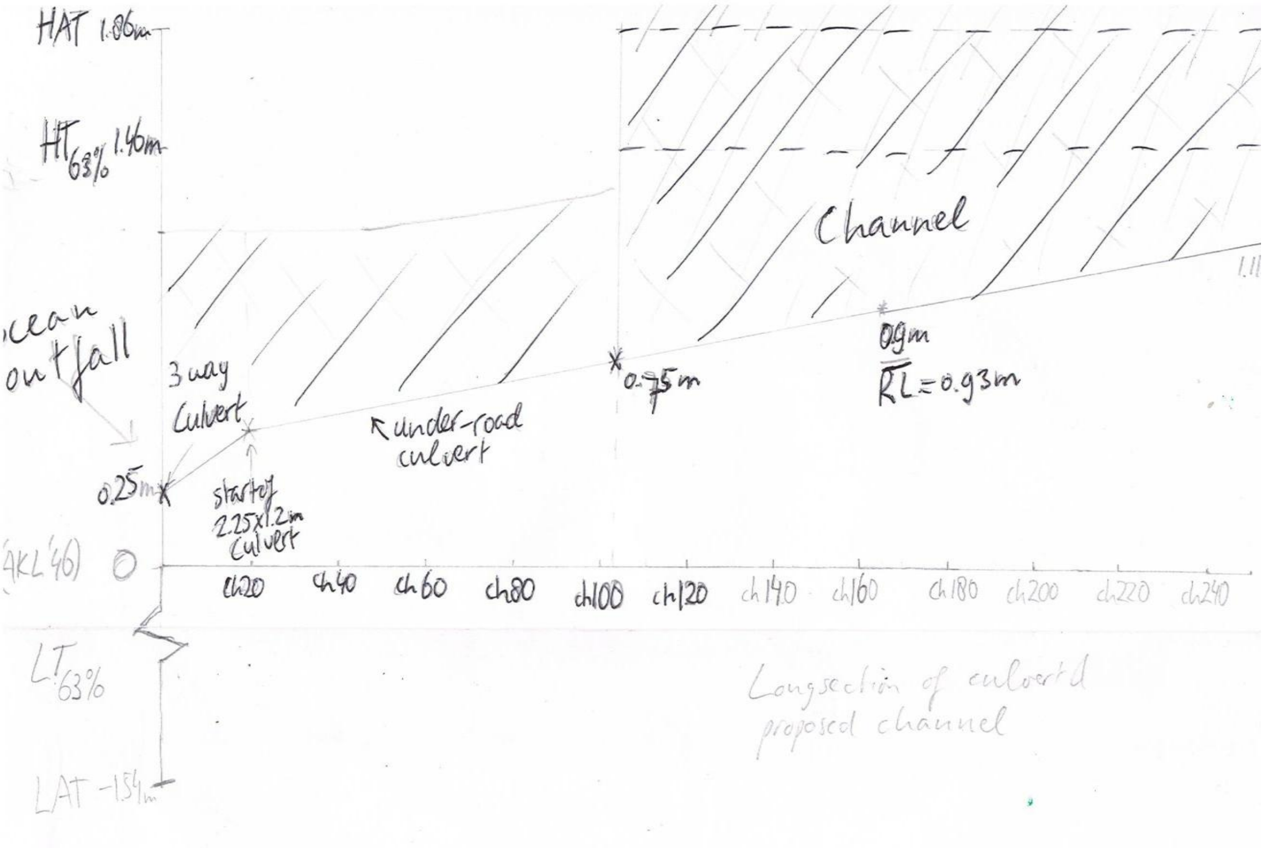

Figure 1 culvert and channel levels

The depth follows from invert levels of the manhole near the stairs and the culvert at Kitemoana. Any further depth below these points of the channel may result in sedimentation filling in to the level of concrete due to lower flow velocities (personal communication with Caleb Clarke). The invert level at the landward manhole is 1.65 m at spot height 2.74m, so channel-bed is at 1.11 m relative level (RL) against Auckland Vertical Datum 1946. The channel RL at the manhole halfway the proposed channel is 0.90m. This means a fall of 1.11-0.90 over 88m = 0.24%. The culvert is assumed to have the same gradient of fall towards the road, therefore the level of the start of the channel is taken as 0.75 m.

Based on the shape of the channel and the tides, there will be volumes of water flowing through the culvert. When a channel shape of 6m base and 1:6 batter slope is created, the volumes of the tidal body can be calculated: the average RL is (0.75 + 1.11)/2 = 0.93m and for the maximum tide the level goes up to 1.92m. This gives a cross-sectional area of figure 9.

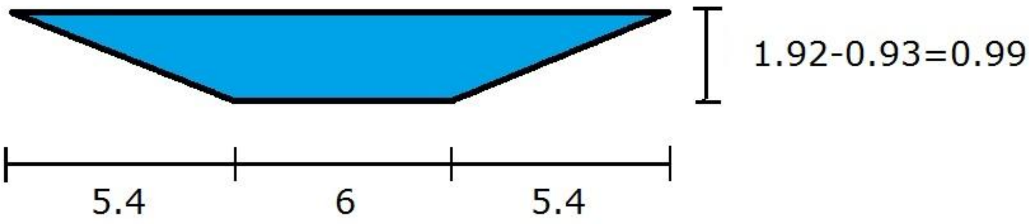

Figure 2 cross sectional area for highest astronomical tide

The cross section is (5.4 + 6) x 0.99 = 11.3 m^2. Over a distance of 140m this will mean a volume of about 1600 m^3 will have to be conveyed with every highest astronomical tide. For a more common tide of 3.2 m there is 800 m^3 water inserted into the channel. A sketch of a possible channel with a swale pointing towards the urupā entry is given in figure 10.

EFFECT OF TIDES ON CHANNEL FLOW

When looking at a pure sine pattern for a tide it becomes clear that the effect of the highest astronomical tide on conveyance is at around half tide on the incoming tide, since it will reach the invert level of the outlet culvert at half tide and affect flow for about 6 hours, as detailed in appendix 2. For these calculations, however, the end of the channel is assumed to be the point at where the single culvert flows into the the 3 piece culvert, which level may be higher. But seawater within the 3way culvert may interfere with assumed free flow, so when the tide reaches the 0.25 m level, it is assumed to start creating counter-pressure. The rate of flow for a sine pattern is such that half of the volume will be transported in over just 1 hour, see figure 11.

A flow of 0.5 x 1600 = 800 m3 / hour through a 2.52 m2 cross-section will generate flow velocities of 0.09 m/s, and half that for the 64% tides, so insignificant rushes in and out of an assumed empty channel.

What is significant, however, is the effect of tides on conveyance of stormwater: appendix 2 shows that a water level of more than RL=1.5m with a corresponding flow of 6m3/s will lead to overflowing of the banks. The principle that is at work here is that a head difference will need to be maintained as the tide makes its effect known at the ocean outlet. Without an upgrade to the under-road culvert, a slightly less than 2 yearly stormwater event in a fully developed catchment in combination with a high tide will break the banks. A suggestion for prevention of saline encroachment through a one-way flap may deal with keeping the seawater out but the pressure difference from tidal influence will still limit through-put, as well as that the perceived effect on mauri associated with such a classic engineering solution may be negative.

TRANSMISSIVITY

The effect of creating an open channel will not only be an increased reservoir for storage and an entry point for overland flow, but also the creation of drainage for the surrounding land, since the current culvert is not able to exchange fluids with its surroundings. An unearthing of a pipe and replacing it with an open channel may bring into existence transmissivity, which can be defined as the movement of water from the soil into the channel and vice versa, depending on pressure differences.

The severity of this drainage depends on the type soil that is encountered. It may be expected that the original soils would be alluvial, so sand and silt. However, fill would have been brought in at the time of infilling of the stream. It is possible that during the construction of Kitemoana street, cut materials would have found their way into the old streambed, which had been culverted up by then, which according to figure 5 would be clay and sandstone.

With the high ground water levels experienced in winter (upto 1 m below ground level) and the creation of a channel with depths below ground water levels it is foreseen that the channel will have a draining function at times when the channel is not filled up. At times of high levels in the channel, the draining function will not or only to a lesser extent be available, or the stream may even soak the surrounding land. The rate of drainage can be approximated through geotechnical study, however not exactly, due to the possible different layers of soil present. Therefore, it is recommended to start off this daylighting project with the existing under-road culverts left in place to minimize costs and see how an open channel holds itself up for a few seasons and how transmissive it is.

That transmissivity is an effect to be taken into consideration, is illustrated by the bubbling during flooding of the plain, when the water is infiltrating into the soil.

2.5.1 HABITAT CREATION

The principle of mauri puts great attention to the restoring of living environments. Therefore for this project to be a success, it will be measured in the return of species that have vanished from Auckland urban streams. Species that are associated with Auckland's coastal streams are, amongst others, but not limited to: long-& shortfinned eel, kokopu varieties, bullies, smelt and inanga. Inanga are juvenile fish form the galaxias family, spotted small fish of a diadromous character (moving between fresh and saline water). However, these are what can be considered 'trophy' species, since they are visible inhabitants in an ecosystem that contains flora, invertebrates and algae that form a symbiosis of a food pyramid. With a focus on inanga, their lifecycle can be illustrated with figure 12.

Inanga live generally only for one season, who spend that in a marine and freshwater environment. When hatched from eggs in autumn, they wash out to sea as larvae, where they spend winter. In spring, they migrate up freshwater streams and spend the summer in streams. In autumn, at a perigee springtide they lay eggs in grasses at the saltwater level, that get washed out to sea on the next spring tide a month later and the cycle repeats. From an engineering perspective, to provide an environment that is conducive, a slow flowing environment is required and freshwater streambanks need to provide shelter. Overhanging growth is preferred, however, with the hydrological characteristics of a developed catchment with greater peak flows than in a natural environment, challenges in this respect are encountered. It is envisaged that the planting of grasses on a low gradient streambank will create greater opportunities for inanga eggs to be laid at the perigee high tide since the level of the interface of the salt and fresh water will vary in time (the saltwater wedge), and gradual slopes will create a bigger area for where the salt meets the fresh water.

There is then also the need for a freshwater environment for inanga to spend a season in. As from the previous information, in the current situation (sea level rise will raise this) the sea level will reach to a relative level of 1.92m. Introduction of a weir can create a boundary for a freshwater environment.

For inanga to be able to access this freshwater channel they will need to be able to scale any structure. However, their climbing ability is limited: 50mm is considered the maximum that they are able to scale. A fish ladder or a series of small jumps can support fish mobility. Eels may be able to climb the steeper tributaries coming off the ridge of Kitemoana street.

A friction is foreseen between the requirement for slow flow and the reality of this catchment that creates high volumes of runoff. This freshwater environment needs to be slow flowing with overhanging shading growth. A possibility to look into is the maintaining of the stormwater pipe till this boundary and only use a fraction of the stormwater to fill the freshwater section. Taking this idea further, an option may be to create a daylighted channel that is disconnected form the whole catchment and only gets gets fed by a smaller portion of the catchment so as to create more favourable conditions for inanga to take a foothold. This will also alleviate the predicted +-2 yearly flooding. When a goal is to clean the bay, vertical storage tanks can catch sediments and stormwater pollution from run-off of hydrocarbons, heavy metals and other contaminants.

STREAMBANK VEGETATION

Raupō, harekeke, tī kōuka (cabbage tree), pōhutukawa and pīngao are suggested for upper reaches of the streambanks, with saline sedges/grasses like seagrass and sea rush at lower levels. Mangroves may establish, which may require active control so as not to smother other plants or hinder conveyance. Ideally seedlings are locally sourced or grown up in the local nursery and planting these can be a good way to involve the community with this project. It is also foreseen regular maintenance can address wandering willy (tradescantia) running wild.

2.5.2 WATER TREATMENT OPTIONS

To create a volume of water that handles a water quality storm as per TP108 it was found a higher volume for a channel is required (Du Preez, 2012). When a wetland is created in the 4000 m2 available towards the rugby fields, water quality downstream may be expected to improve. However, this size wetland is inadequate for the treatment of the run-off from an 89 ha catchment. An option to catch sediment and settle pollutants is the installation of underground storage tanks further up in the catchment that can be accessed by a digger for periodical emptying and disposing to land. The option of having a settlement pool in the channel of a length of 140 m that can be accessed by machinery could have too high a visual distraction from what is intended to resemble natural surroundings.

3 CONCLUSIONS

When it is accepted that the limited through-put of the under-road culvert may lead to flooding of the plain that is Ōrākei domain, the creation of a day-lighted channel has a good chance to create habitat for wildlife and provide amenity to people. Mitigation of flooding will require the raising of the urupā and use of saline-resistant vegetation. Mitigation of the flows through the channel will require grates to prevent people from getting washed into the culvert under the road, as well as the creation of low-velocity habitat refuges so weaker swimmers like inanga won't get flushed out. Mitigation of the flow also comprises of protecting the wastewater system that is hugging the ridge of Kitemoana street, which can be done by rock-armouring the banks where erosion may expose the wastewater system. The transition from the channel to the culvert needs to be gradual, streamlined and armoured to limit the effect of the minor loss from a reservoir into a pipe.

A thorough scrutinizing of the data and calculations that is presented here is advised, since it is done at an abstract and fairly theoretical level. Tidal data needs to be verified to see if it is applicable to Ōkahu Bay. Specialised stream modelling software that allows for tidal influences can be employed to get a more complete picture of the effect of a channel. Isis & Mike 11 software seem to be able to work with tidal streams (Crowder et al., 2004).

To create habitat for inanga, a freshwater component of a stream is required. This can be created by the employment of several jumps of 50 mm only at the level of 1.92m, so outside the tidal influence. When the area in between the sport fields and the Kitemoana stairs (about 4000 m2) is incorporated as a wetland, with about half the channel tidal and saline and the other half containing freshwater, a reasonable sized freshwater stream is created. However, to create a slow flowing environment, bypassing of the run-off from the catchment may have to be considered to create a conducive environment for inanga to establish. Depending on available funding a secondary outlet can be considered. Input from freshwater ecologist Matt Bloxham at Auckland Council can provide valuable input to maximise the value of this stream as habitat.

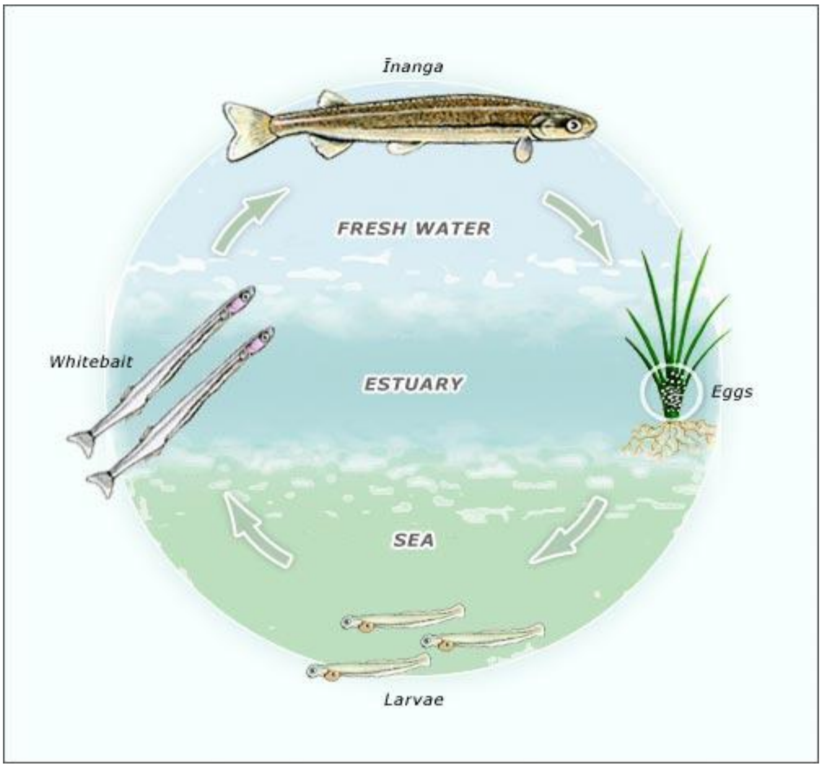

Figure 3: *inanga lifecylce (source: teara.govt.nz)*

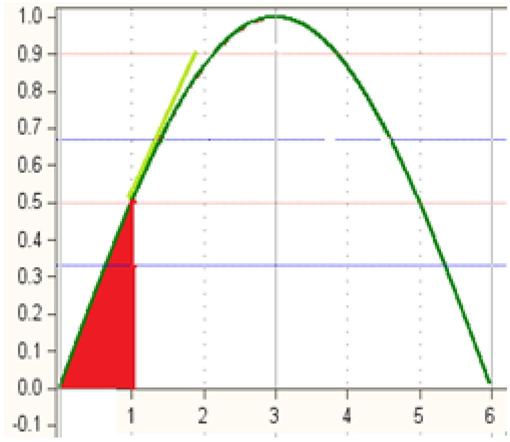

Figure 4: *sine tide (adapted from caskaorg.typepad.com)*

Figure 5: *possible channel and swale plan*

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