THE METHODOLOGY FOR DEVELOPING STORMWATER MANAGEMENT AREAS FOR FLOW CONTROL FOR THE AUCKLAND UNITARY PLAN

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ABSTRACT (200 WORDS MAXIMUM)

In preparing input into the Auckland's Unitary Plan it became clear early on that to better protect good quality urban streams in the Auckland region from the effects of impervious development there needed to be a set of policies and rules to manage stormwater flows from both infill and new development areas. Traditional rules have proven to be inadequate to protect the quality of these streams. Increasing evidence is showing that to maintain stream health you have to reduce both volumes and peak flows from those frequent small events up to the 1 in 2yr recurrence interval. The paper describes the development of a set of Unitary Plan overlay maps defining specific Stormwater Management Areas for Flow control (SMAF1 and SMAF2 areas) which require stormwater management for stream health. Due to the need to cover all the urban streams in the Auckland region, the challenge was to have a process that could use the efficiencies of Council's GIS mapping data base while including catchment specific characteristics. The development of the overlay maps included an initial GIS mapping of three 'primary criteria' (stream slope, cumulative impervious and Macroinvertebrate Community Index), followed up by a set of workshops with catchment planning and freshwater council staff and further catchment specific 'moderating factors'. The paper explains the process and gives examples of how to meet these stream health controls and indicative costs. This new approach is building on similar approaches in recent plan changes in the Auckland Region that have gone through very extensive technical work and legal challenges and are now operative.

KEYWORDS

Stormwater, stream health, imperviousness, stormwater volumes

PRESENTER PROFILE

David Kettle has 35 years of experience as a geotechnical, civil and environmental engineer. In the last 15 years he has specialised in more sustainable urban stormwater management with input into design, stormwater management guidelines and structure planning.

1 INTRODUCTION

Urban development has a profound effect on the quality and quantity of stormwater runoff. The removal of pasture and bush and its replacement with hard surfaces such as roads, buildings and even grassed areas that have been heavily compacted during earthworks, reduces the infiltration of water and increases the volume and rate at which it runs off. The impacts of the increase in stormwater runoff can be broadly divided into four zones, refer Figure 1.

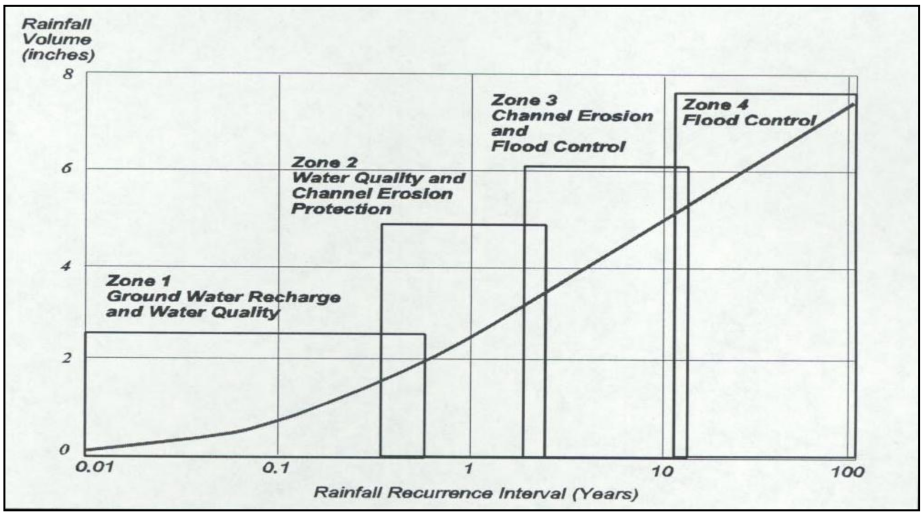

Figure 1: Effect versus Rainfall Recurrence Interval (USEPA 1999)

This paper presents the methodology used to develop Stormwater Management Areas for Flow Control (SMAF) as proposed to be used in the Auckland Unitary Plan to manage the small frequent flows up to the 1 in 1 to 2-year ARI that have the most impact on channel erosion and stream health, that is, zones 1 and 2 in the above figure. The 1 in 1 to 2-year event corresponds approximately to the natural 'bank full' condition (the top of the banks formed in the natural channel cross section) and thus have a significant impact on the erosion of the channel.

The increase in these small frequent events from increasing impervious areas also have an impact on stream health by way of altering the flow regime (volumes and frequency of events) within the stream channel and hence impact on the ecological biodiversity. The focus on managing these frequent small events for stream health is also important as they show the greatest proportional change in flows between pre-development (before urbanisation) and post-development (after urbanisation), refer Figure 2.

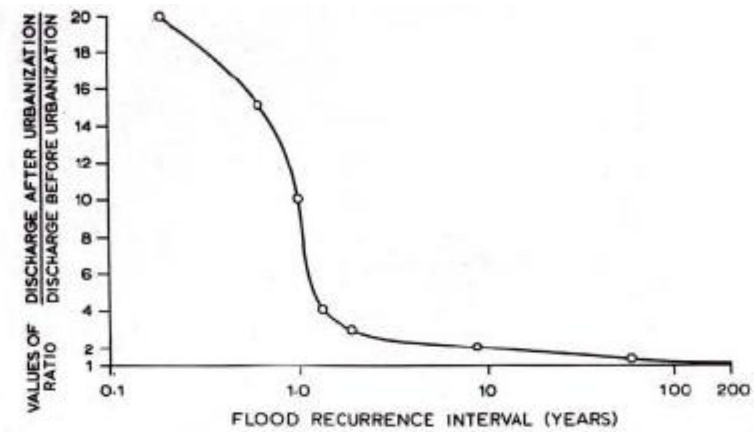

Figure 2: Ratio of Stormwater Discharges Before and After Urbanisation (Schueler 2003)

Figure 2 shows the much greater ratio of 10 to 20 for discharges after urbanisation to before urbanisation for the smaller events less than the 1-year ARI. The management of water quality (the removal of contaminants) and flooding is covered by other parts of the Unitary Plan and is not covered by the SMAF controls. It is also important to note that the SMAF areas focus is on mitigating the impact of future probable increasing impervious areas and is NOT a stream prioritisation framework for deciding, for example, where council stream restoration work should be carried out. As such, in catchments with existing medium to high imperviousness (say greater than 40% impervious) with limited potential further new development or re-development, there may be minimal benefits from controls on future increasing imperviousness and hence not warrant the more strict SMAF controls. But the stream may very well benefit from ongoing stream maintenance and restoration works such as riparian planting and removal of weed infestation.

The approach proposed in this paper has built on similar work carried out for recently approved and operational plan changes in the Auckland region. The need for this new approach of more comprehensive stormwater controls in the land use planning provisions is more beneficial for several reasons: It provides greater clarity to developers and consenting authorities over the level of stormwater controls necessary to achieve the stated stormwater objectives; the traditional case-by-case individual consenting process has provided fragmented outcomes to what needs to be an integrated land use planning approach; retrofitting new devices to traditional approaches seldom gives the most optimal outcome, resulting in a more costly, less efficient system.

2 WHAT ARE THE STORMWATER FLOW CONTROL AREAS?

Stormwater Flow Control (SMAF) Areas are catchments, or sub-catchments in which stormwater flows are required to be managed to prescribed levels to protect or enhance stream quality. In particular, those catchments that are susceptible to increases in stormwater flows. This is done by managing the small frequent flows of up to the 1 in 1 to 2-year ARI event. There are two SMAF areas, defined as SMAF1 and SMAF2:

- SMAF1 areas have the more strict flow controls with the requirement to mitigate 100% of the impervious area. SMAF1 areas are generally located in moderate to steep catchments (slope > 3%), low imperviousness (< 25% imperviousness) and good urban stream quality (MCI > 80).

- SMAF2 areas are less strict, with the requirement to mitigate 80% of the impervious area. These SMAF2 areas occur over the full range of slopes, have a higher moderate imperviousness (from 25 to 60% imperviousness), while still maintaining a moderate to good urban stream quality (MCI > 70).

2.1 DEFINING THE SMAF 'EQUIVALENT RUNOFF' TARGET CRITERIA

For defining the SMAF areas an 'equivalent runoff' target criteria has been proposed based on retention of the post development stormwater volumes. This focus on the reduction of stormwater volumes (and peak flows) of these small frequent events is now recognised as best practice stormwater management for protecting and enhancing stream health (Alliance of Rouge Communities et al. 2012, Argue et al. 2012, Schueler and Lane 2012, Fassman et al. 2012).

In SMAF1 areas, mitigation of 100% of the impervious area gives an 'equivalent runoff' of 0%, while SMAF2 areas with mitigation of 80% of the impervious area, give an 'equivalent runoff' of 20%. Stormwater management devices are ranked based on their ability to reduce runoff volumes through processes of infiltration, evapotranspiration, wetting/drying of device media and water use from rainwater tanks. Device Technical Reports will provide details on how these requirements are achieved in design for each stormwater device.

2.2 SMAF1 CRITERIA OF 0%

The selection of the upper bound 0% 'equivalent runoff' for SMAF1 areas was based on the increasing amount of evidence that relatively small increases in imperviousness (as low as 3 to 6% impervious) can have a noticeable negative impact on stream health (Schueler and Fraley-McNeal 2008, CSN 2008, Coleman et al. 2005). One such plot is the 'Impervious Cover Model', originally developed by Tom Schueler at the Center for Watershed Protection (2003) and then developed further with the most up to date version being that in 2008, refer Figure 3.

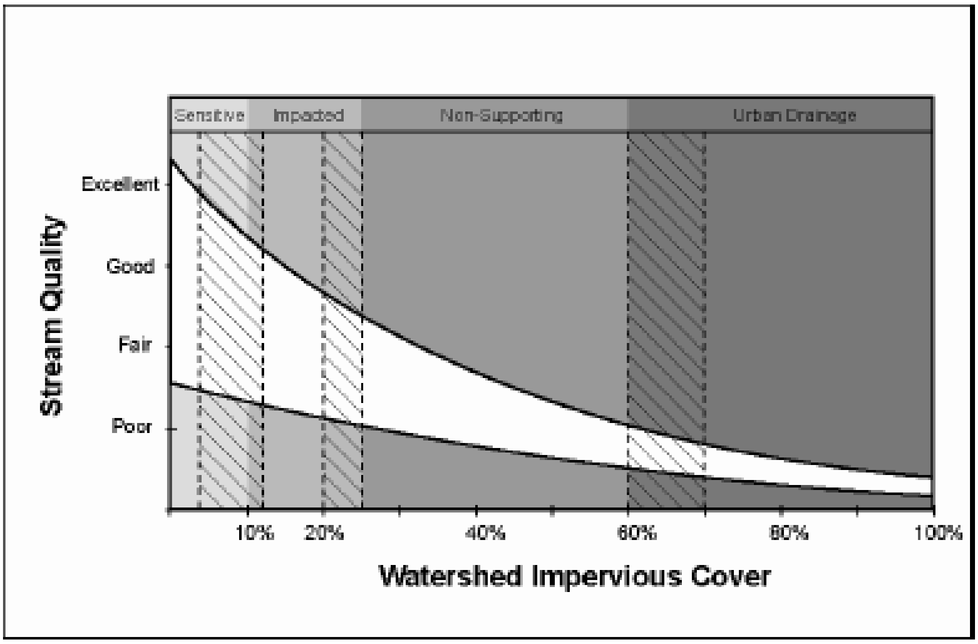

Figure 3: The 2008 'Impervious Cover Model' (Schueler and Fraley-McNeal 2008, CSN 2008)

While some research in Auckland reinforces these similar trends, (refer Figure 4) additional work is currently underway by the Auckland Council using more accurate data and additional monitoring points.

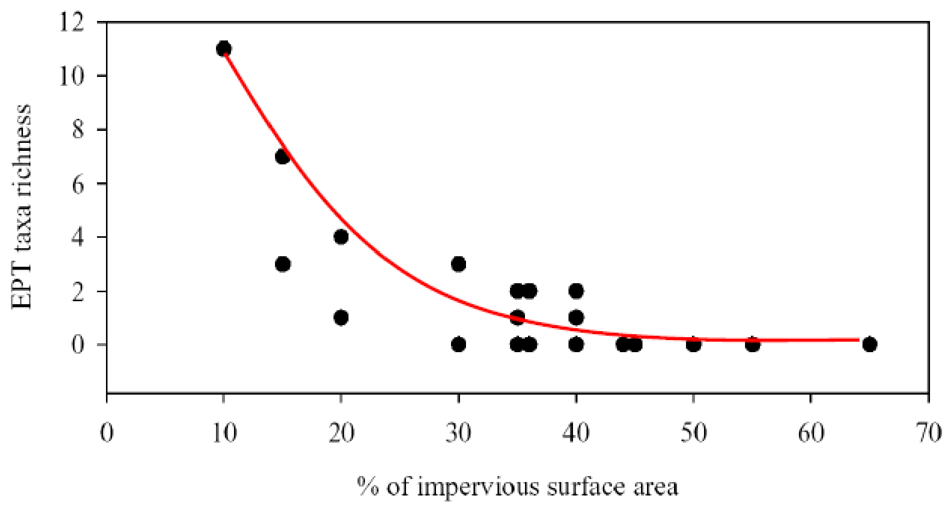

Figure 4: Auckland EPT Taxa Richness vs % Impervious Surface Area (Alibone et al. 2001)

2.3 SMAF2 CRITERIA OF 20%

SMAF2 criteria was used for those areas that had an existing higher moderate imperviousness (from 20 to 60% imperviousness), and still maintained a moderate to good urban stream quality. Due to the greater existing imperviousness in these areas, a lower target 'equivalent runoff' of 20% was allowed, equating to retention of 80% of the imperviousness.

However, it is important to note that although the device is 20% smaller than that required in SMAF1 areas, it will still catch more than 95% of the annual runoff volume. This is because the majority of the runoff volume is from these small, frequent events which are captured by both the SMAF1 and SMAF2 sizing criteria.

2.4 HOW DO THE SMAF AREAS FIT INTO THE UNITARY PLAN?

The SMAF areas have been developed at a sub-catchment scale within the metropolitan urban limit (MUL). The areas have been mapped and are proposed as spatial overlays in the Unitary Plan. Spatial overlays are controls that apply depending on location rather than on a land use type (ie residential/commercial etc) or activity-type (earthworks/stormwater discharge) basis.

The SMAF provisions are applied as land use controls that are triggered with the development (or redevelopment) of impervious surfaces within the SMAF areas – as it is the runoff from impervious surfaces that result in the flow effects that are being managed. Other than for the development/redevelement of small impervious areas (up to 25 m2) the provisions require runoff from the impervious surface to meet an equivalent runoff to that of:

SMAF 1: 0 % impervious;

SMAF 2: 20 % impervious

If this level of runoff performance is met then the development is assessed as a controlled activity. Where this performance is not achieved, the development/redevelopment of the impervious surface becomes a discretionary activity.

Importantly, the SMAF provisions establish a threshold of 50% of the site area that is being development/redevelopment – below which the flow controls only apply to the new/redeveloped areas and above which the flow controls are applied to the entire site runoff to incrementally reduce flows over time.

The SMAF controls also apply to roads as they usually comprise a significant proportion of catchment imperviousness in urban areas. Given the nature of roading activities, different thresholds are applied. However, the same level of flow performance is required.

3 SMAF AREA METHODOLOGY

3.1 OVERVIEW

There were five steps to develop the SMAF overlay areas:

Step 1 – Assess an initial set of trial catchments and flow control criteria.

Step 2 – Agree on the set of three 'primary criteria' and use the council's GIS datasets to map these criteria along stream lengths.

Step 3 – Develop a set of catchment specific 'secondary moderating factors' and undertake a first set of workshops with each of the north, west/central and south stormwater catchment planners and Council freshwater technical staff. Used the GIS mapped 'primary criteria' along with the 'moderating factors' to develop initial SMAF areas.

Step 4 – Second combined workshop with all three catchment management teams to review initial SMAF areas in terms of regional consistency.

Step 5 – Preparation of SMAF overlay maps generated along property boundaries.

3.2 STEP 1 – INITIAL TRIAL CATCHMENTS AND CRITERIA

The previous work by the legacy North Shore City Council for their Plan Change 22 – Addressing the Effects of Stormwater Runoff from Development on Stream Health – was used as a base to develop these initial criteria, along with several workshops with representatives from the Stormwater Unit and wider stormwater council staff.

The basic criteria used for these initial trials were stream gradient (measured at 100m intervals); cumulative impervious area (measured at a mesh block level); and location of permanent, intermittent and ephemeral streams (as indicated on GIS stream layers).

Next, twelve trial catchments were selected from the north, west/central and south catchment areas and a semi-manual mapping of the initial criteria carried out.

It soon became apparent that in order to carry out this assessment for all of the streams in the Auckland region in a timely manner it was important to make use of the council's geographic information system (GIS) and as much as possible have an automated mapping system.

This lead to Step 2 - the agreement of three primary criteria that could be generated through an automated GIS mapping system.

3.3 STEP 2 – AUTOMATED GIS MAPPING OF THREE PRIMARY CRITERIA

Through further council workshops two sets of SMAF criteria were established:

Primary Criteria – prioritised criteria that could be combined and mapped in an automated way using regional datasets and ARCGIS to give an indication of the priority streams for managing flows for stream health and erosion.

Secondary Moderating Factors – these criteria were more catchment specific and applied in a workshop environment with catchment management team members familiar with the specifics of the catchment, to 'moderate' the automatically generated divisions according to the primary criteria (refer Section 3.4, for explanation of the use of these moderating factors in Step 3).

Defining Stream Reaches - Since there were inconsistencies between the existing council GIS stream layers (the RiverNZMS260 series and the ephemeral/intermittent/permanent stream layer) it was decided to use the council created overland flow paths that had been generated using complex geographic information system (GIS) tools. Overland flow paths indicate the path where stormwater will flow overland in storm events. As the entire stream length is important to its overall health, no distinction was made between permanent, intermittent and ephemeral streams, with a catchment area of 2ha being used to identify the start of a stream for practical purposes (Storey and Wadhwa 2009). This provided a good indication of where streams are located and also a general location of where streams were in the past, i.e. where streams have now been piped or built over.

The stream reach used for calculation and presentation purposes was defined as the length of stream between two branching tributaries, that is, from one stream junction to the next.

The three agreed upon primary criteria were: stream slope, cumulative impervious percentage and MCI score (Macro-Invertebrate Community Index Score). A score was calculated for each of these criteria and then summed to get an overall score, as described below.

3.3.1 STREAM REACH SLOPE

The likelihood of streams eroding is heavily dependant on the slope of the stream bed and soil type (NIWA 2010). The NIWA classification guide has three landform categories:

- Low-gradient: less than 0.02 valley slope
- Medium-gradient: 0.02 to 0.04
- High-gradient: greater than 0.04

Where the valley slope is high (>0.04), erosion dominates, where the valley slope is low (<0.02), deposition dominates.

The slope of each stream length was calculated from the regional 2m digital elevation model (DEM), given a unique score between 0 and 10 and colour coded as per Figure 5.

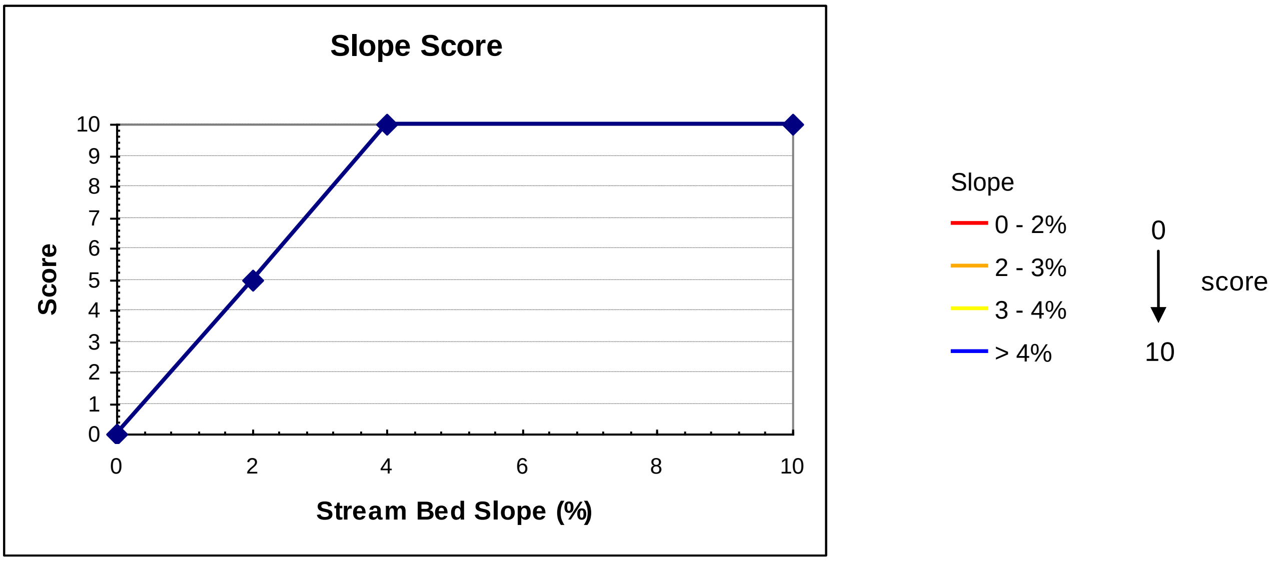

Figure 5: Stream Bed Slope Scoring

The cut off gradient of 4% stream slope was chosen based on the 'Valley-Landform' factor in the New Zealand River Environment Classification User Guide (NIWA 2010) and the general shape of Auckland streams that have a flatter lower section with a transition to steeper upper reaches at stream slopes greater than approximately 0.04 (4%).

While it is recognised that soil type also plays an important role in the susceptibility to soil erosion, there is no regionally consistent GIS soil layer of soil erodibility and so soil type was taken into consideration in the moderating factor of existing erosion (refer Section 3.4.1)

3.3.2 STREAM REACH CUMULATIVE IMPERVIOUSNESS

As presented in Section 2.2 the imperviousness of a stream catchment has a significant impact on stream health and likelihood of stream erosion due to the imperviousness of the catchment affecting the flow regime. The higher the imperviousness, the greater the existing potential adverse impact on stream health.

The percent impervious was calculated using the "Flow Accumulation" tool in ARCGIS and Auckland Council's impervious and building footprint layers (a regional GIS layer). The cumulative imperviousness was calculated for each 2m section of stream and then averaged to get a value for each reach of stream. The average imperviousness was calculated and colour coded as per Figure 6.

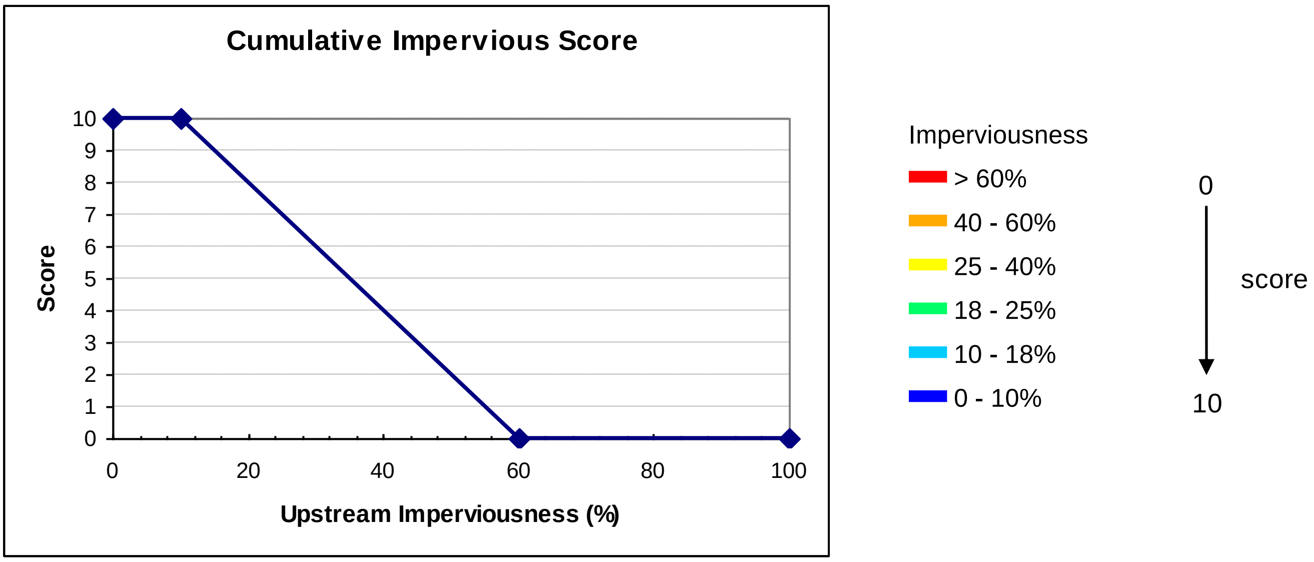

Figure 6: Cumulative Imperviousness Scoring

The high score of 10 was given to stream reaches of 0 to 10% imperviousness as protection of these low impervious catchments are of the highest priority. A score of zero was given to streams with a catchment imperviousness of greater than 60%, representing 'urban drainage' functionality.

3.3.3 STREAM REACH QUALITY

While it is recognised there are many ways to measure stream 'quality' it was important to choose a measure with good GIS data over the entire Auckland region to fit in with the proposed automated SMAF GIS mapping process. In discussions with Auckland Council freshwater experts it was agreed to use the 'observed' MCI (Macroinvertebrate Community Index) values from the Department of Conservation funded study on the relationships between land use and stream ecology (Department of Conservation 2011). While the MCI values from this study may not accurately indicate the absolute quality of the stream at each location, a simple analysis of the MCI values showed that they could confidently be used as an indicator of the relative quality of sites over the Auckland region that could be used for allocating a 'relative' score in the SMAF scoring matrix (Neale 2012).

The MCI is an index of the types and numbers of invertebrates found at a river sampling site. Many different types of invertebrates live in rivers and they react differently to various environmental pressures and therefore offer a good system of measuring a wide variation in water quality. Essentially, the MCI assigns a score to each invertebrate found at a sampling site, based on its sensitivity. The MCI score for a site is calculated based on the average score for all the invertebrates found at that site. In the wider regional context MCI values are generally divided up into approximately four bands (Auckland Council 2009a):

- Greater than 120 – excellent quality
- 100 to 120 – good quality
- 80 to 100 – fair quality
- Less than 80 – poor quality

The above range covers the full spectrum of stream quality from pristine natural streams to modified urban streams. In the Auckland region the MCI values of urban streams typically range from 60 to 100, with a 'good quality urban stream' being in the range of 80 to 100.

The MCI observed score was attributed to each stream reach and colour coded as per Figure 7.

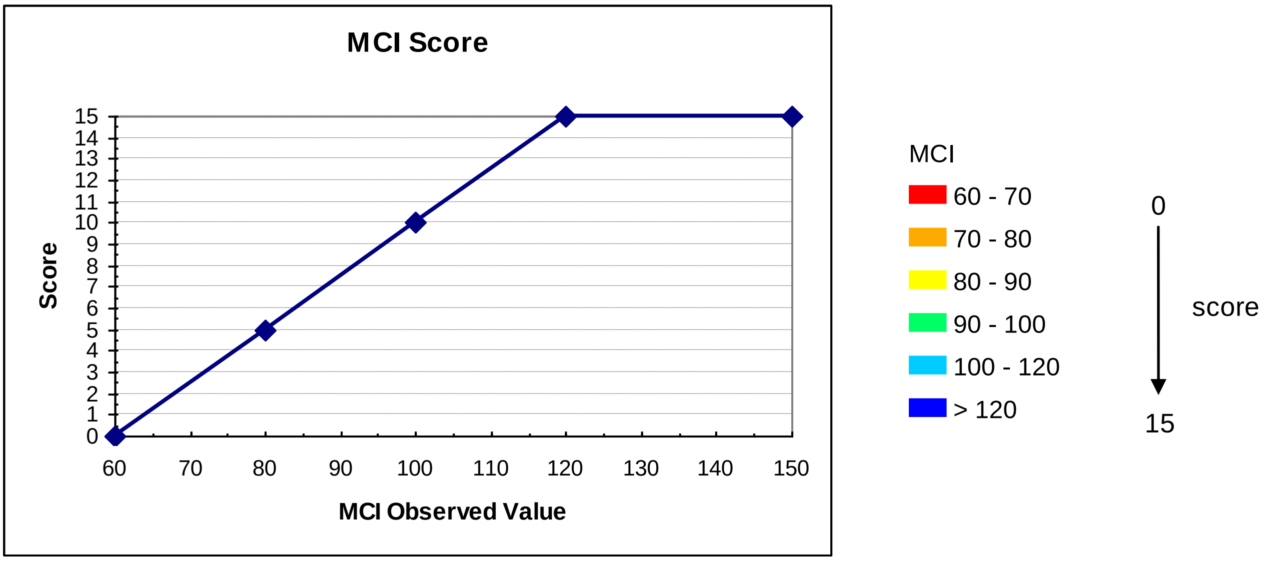

Figure 7: MCI Scoring

Although the MCI score was scored potentially out of 15, the existing streams in the urban area were generally from 60 to 100, corresponding to a score of 0 to 10 respectively which was consistent with the slope and imperviousness scoring.

3.3.4 MAPPING OF SCORES

Two sets of colour coded maps were generated for each catchment. A 'combined score' map (Figure 8) and individual scores for each of the three primary criteria, an 'individual score' map (Figure 9).

These maps were then used for assigning preliminary SMAF1 and SMAF2 areas based on the combined score of up to a maximum of 35 and approximate boundaries drawn in a white marker.

In general:

Combined scores of 25 – 35 (light and dark blue lines) indicated SMAF1 areas, where increased flows are likely to have a significant impact on erosion and stream health, generally with, moderate to high slope, low existing imperviousness and good urban stream quality.

Combined scores of 20 to 25 (green lines) indicated areas in that mid-range between SMAF1 and SMAF2 (these were initially assigned SMAF1 or SMAF2 depending on the relationship to adjacent areas and the 'moderating factors', discussed in the next Step 3)

Combined scores of 15 to 20 (yellow lines) indicated SMAF2 areas, where increased flows have potential impact on erosion and stream health, generally on any slope, with moderate imperviousness and moderate urban stream quality.

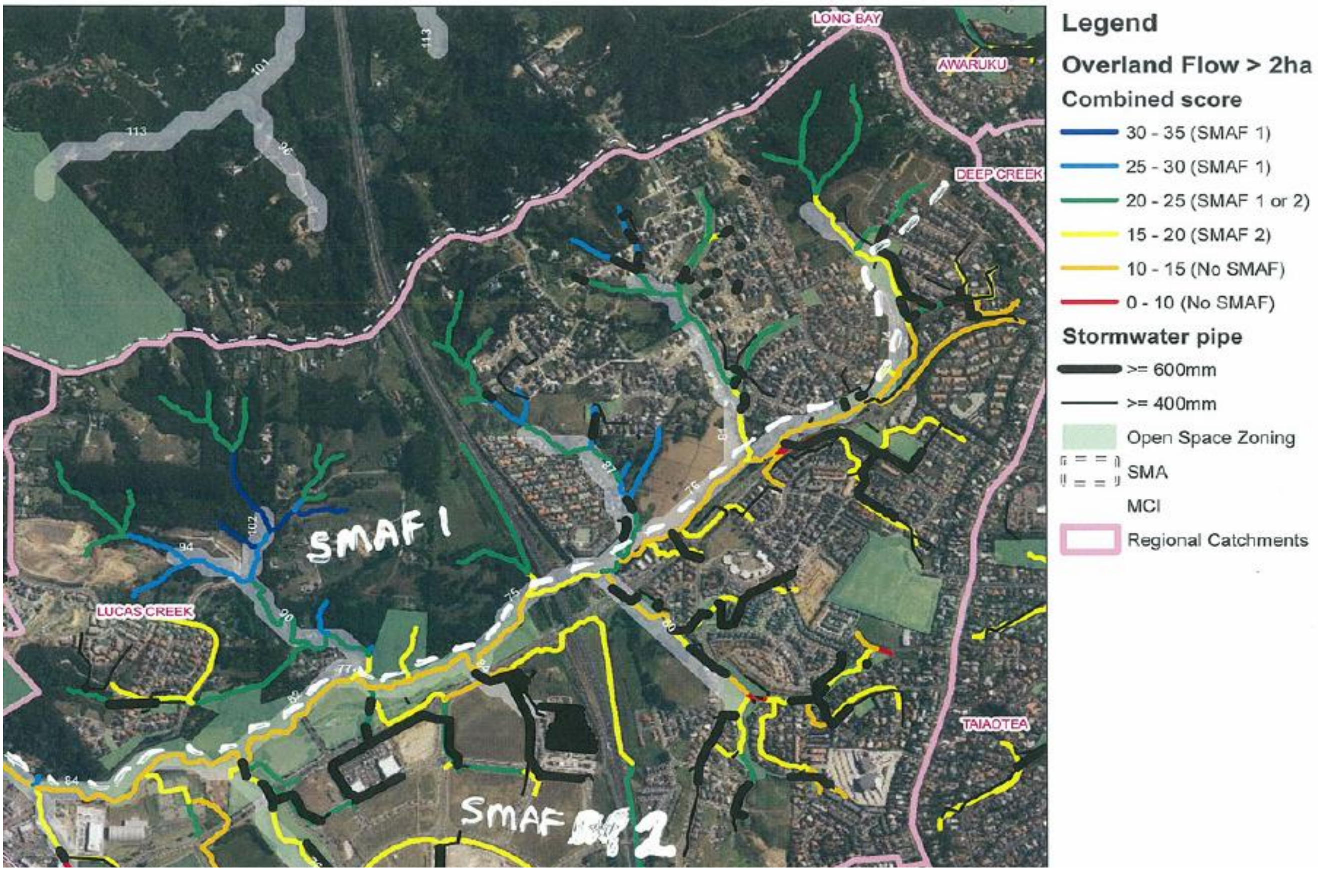

Figure 8: Combined Score Map

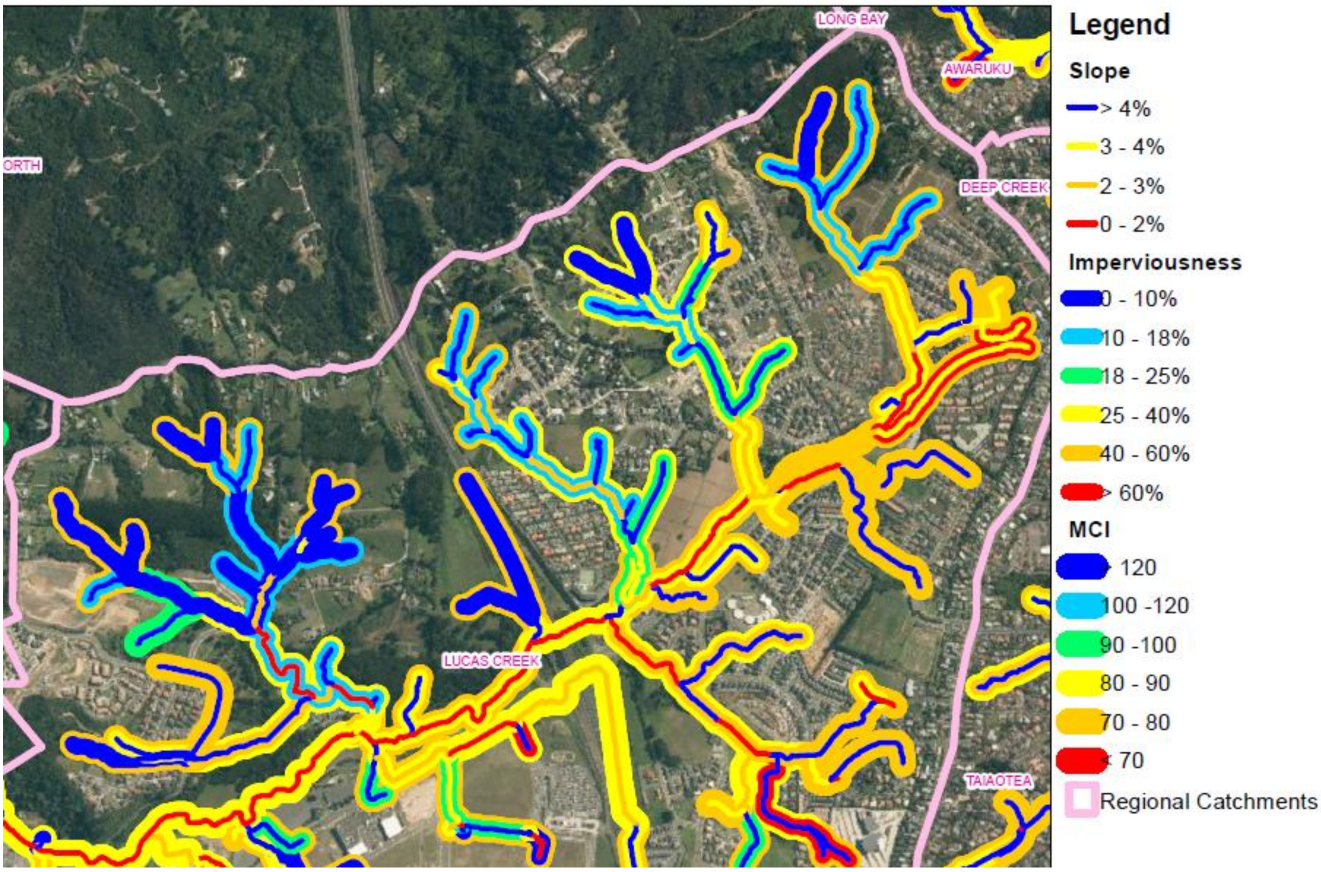

Figure 9: Individual Score Map

Combined scores of less than 15 (orange and red lines) indicated no SMAF areas, where increased flows are likely to have lesser impact on erosion and stream health, generally with, low to moderate slopes, moderate to high imperviousness and moderate to poor urban stream quality.

The 'combined score' maps also showed the location of the Council's GIS stormwater pipe network as solid black lines (for the pipes of greater than 400mm and 600mm in diameter). These black lines were used to visually omit piped streams and assess the percent of natural streams left in the catchment (one of the moderating factors).

In areas of doubt between different classifications, the make up of the combined score could be investigated by looking at the underlying set of base maps with the colour coded individual scores of the three primary criteria, refer Figure 9.

Note that the three primary criteria have different thickness lines for each stream reach (the stream reach being defined as the length of stream between two tributaries) so that when the lines are superimposed, all three values can be seen, such that:

- The outer colour is the MCI score
- The middle colour is the cumulative imperviousness score
- The inside line is the slope.

In situations where the stream only has two colours, these stream reaches have two criteria with the same colour score.

These preliminary SMAF GIS maps were then taken into the 'moderating workshops' held with each of the north, west/central and south catchment management teams and 'ground proofed' using the moderating factors and local knowledge of the team members described in the next Step 3 moderating workshops.

3.4 STEP 3 – MODERATING WORKSHOPS

The preliminary SMAF GIS maps from Step 2 were used along with a set of moderating factors to assess whether the proposed SMAF1 and SMAF2 areas were a good representation of reality. The assessment was based on the local knowledge of Council stormwater catchment planning staff during workshops and consultation with freshwater technical staff across Council, including the Research Investigations and Monitoring Unit and Biodiversity departments. The set of agreed moderating factors included:

3.4.1 EXISTING EROSION

The erosion of stream banks and channel forms have obvious negative effects on stream ecological and aesthetic values and are directly affected by increasing stream flows, particularly the smaller more frequent flows of less than the 1 in 2 year return interval. This moderating factor was also used as an indicator of soil type, as the more erodible soils would exhibit more pronounced existing erosion, all other factors being the same.

Information available from different legacy councils varied from the more technically robust 'Pfankuch Bank Stability Method (which contains criteria that address both the existing condition, 'mass wasting' and the potential conditions of 'landform slope', 'debris jam potential' and 'vegetative bank protection'), to more generic words in a report text describing the severity of erosion and bank stability.

3.4.2 COMMUNITY USE

While community use may not necessarily correlate to the erosion potential and stream health, the community 'ownership' and commitment to looking after a stream is a clear indication of the value of that stream to the community. Community use is seen as an important indicator of the stream's social and amenity value.

As can be expected the different legacy councils recorded stream community use in a wider variety of ways from a more technical scoring of 1 to 10, to staff local knowledge.

3.4.3 POTENTIAL GROWTH

Areas of potential growth are both a pressure (threat) on increasing stream flows and an opportunity to make a difference if the right stormwater flow controls can be implemented, particularly if incorporated in the early planning stages. Increasing impervious areas (in this case from future urban development) are the single most important factor affecting increasing flows in the urban environment, impacting on potential erosion and degradation of streams.

Where available data of projected population growth to 2050 was used for the ranking, with high is 100% population increase from 2011 to 2051, medium being 35 to 100%, and low less than 35% growth.

3.4.4 EXISTING INVESTMENT

Some catchments have already had significant stormwater management in the form of natural, social, human and financial investment, such as Project Twin Streams in Waitakere and Lucas Creek in North Shore. In these areas it would be prudent to look after these assets into the future both from a financial and public amenity value. In areas where there is already significant flow mitigation (such as existing rain gardens and or wetlands) then the measured imperviousness would give a higher than actual 'effective' imperviousness. The ranking depended on catchment staff knowledge.

3.4.5 PERCENT NATURAL STREAMS

The percentage of the catchment that remains in natural streams is an indicator of the potential impact of increasing flows from increasing impervious areas. If the majority of the catchment is piped (especially with a moderate to high existing imperviousness) then the impact of increasing imperviousness is going to be relatively minor compared to a catchment that still has most of its waterways still in a natural condition.

The council GIS stormwater pipe network data base was used to give a visual approximation of the length of the overland flow paths that had been piped. The location of pipes with diameters of greater than 400mm and 600mm were plotted on the SMAF individual criteria maps (refer Section 3.3). A visual assessment was then used to estimate the approximate ranking as high (for less than 50% pipes), medium (50 to 75% pipes) and low (greater than 75% pipes). The length of continuous stream was also taken as an important factor to be protected when ranking as high, medium or low.

3.4.6 SENSITIVITY OF FISH SPECIES TO INCREASING STREAM FLOWS

In general, an increase in stormwater runoff from increasing imperviousness produces the same kind of impact on fish diversity as it does for aquatic insects (Schueler 2003); a reduction in fish diversity is typified by a reduction in total species, loss of sensitive species, a shift toward a more pollution-tolerant species, and decreased survival of eggs and larvae.

Council data on the total number of fish species, records of threatened fish species, IBI score (the Index of Biotic Integrity – a predictive model of fish distribution which takes into account the threat status of the fish species and an indication of which stream reaches are most likely to be important for fish populations) and Council's freshwater technical staff local knowledge was used to rank the subcatchments' as high, medium or low.

3.4.7 OTHER

This was an additional catch-all category that could be used to highlight other factors with notes being included in the moderating factors tabulated workshop comments column, such as:

- The quality of the headwaters and amount of existing reserves
- Areas of combined sewers
- Pipe daylighting opportunities and/or proposed naturalisation of concrete channels
- Existing stormwater management already installed in the catchment which could mean that the existing 'effective imperviousness' could be lower than the GIS mapped impervious area.
- Existing community programmes
- Areas where coastal erosion is more of the issue
- Noted areas of peat where 'peat recharge' rules apply

- Noted that in some areas the low MCI readings may be due to farming practices and should therefore not be taken as a stream quality baseline

Where possible, before going into the moderating workshops these moderating factors were given a three tier ranking of high, medium or low priority, based on existing information currently available from previous council work. As discussed, the content of this information was highly variable between catchment areas and within individual catchments due to the wide variation of available information. An example of a moderating workshop tabulated output is given in Figure 10.

		2012 Unitary Plan - Stormwater Flow Controls								
		MODERATING FACTORS								
Catchment	KC70 2004 NSCC Stream Category	Erosion - Instability	Community Use	Potential Development - Redev.	Existing Investment	Percent Natural Streams	Sensitivity of Fish Species	Other	SMAF	Workshop Comments
Deep Creek	3	H	L	L		M	L			
Upper Catch									NO SMAF	Have as NO SMAF due to many piped tributaries, 40 to 60% impervious and erosion issues of main stem have had extensive work on them in terms of gabions etc to minimise erosion impacts.
Middle Catch									NO SMAF	
Oteha Valley	2	H	H	H						
West					M	L	L		NO SMAF	No SMAF due to highly piped developed with minimal streams.
East					H	H	H		SMAF2	SMAF2 due to: high moderation factors; very high existing council investment in stream rehabilitation/riparian revegetation; proposed naturalisation of concrete channel; and extensive existing mitigation (hence will have a lower equivalent imperviousness than that shown by GIS mapped impervious areas).
Lignite	1	H	L	M		H	H			
Upper Catch - Nth									SMAF1	SMAF1 blue green, high moderating factors, NSCC 2004 Category 1 stream.
Upper Catch - Sth									SMAF2	SMAF2 yellow with some green, high moderating factors, NSCC 2004 Category 1 stream, stream connectivity with other SMAF2 areas to south in Bayview and Kaipatiki catchments.
Middle Catch									SMAF2	

Figure 10: Example Moderating Workshop Table

Figure 10 shows the tabulated H (high), M (medium) and L (low) ranking, the agreed SMAF and any relevant comments from the workshop.

Working through the workshops it was evident that while some areas were clearly SMAF1 or SMAF2, there were certainly some stream reaches in the 'grey' area between classifications. A list of these 'grey areas' were tabulated and brought back to a combined workshop in the next Step 4.

3.5 STEP 4 – COMBINED WORKSHOP FOR REGIONAL CONSISTENCY

To ensure the classification system was consistent across the Auckland region and to help answer some of the catchments with outstanding questions, a combined workshop was then held with representatives from the north, west/central and south catchment areas.

3.6 STEP 5 – FINAL SMAF OVERLAY MAPS

The last step was to finalise the boundaries between the different SMAF areas. In the previous steps the boundaries between the different SMAF areas were approximately hand drawn onto the GIS colour coded maps. For final map production, these boundaries were drawn along the property boundaries and drawn to represent where the piped stormwater discharges to. For example, even though the property may be within the roughly drawn upper SMAF1 area on the GIS colour coded map, if it is piped to a discharge location in a lower SMAF2 area, then the property is assigned a SMAF2.

In addition to the areas which had a low combined score as described in Step 2, the other areas that were not assigned a SMAF1/2 were those areas that discharged directly to the tidal areas of the stream near to the coastline. For these tidal reaches of the stream there is limited benefit from placing these flow controls on additional impervious areas as these bottom reaches have a near-horizontal stream slope (less prone to erosion from high flow velocities) and are more impacted by tidal influences of the coastal environment. A reduced elevation of RL2m was used to indicate this tidal influence zone.

An example of the SMAF1 and SMAF2 areas for the upper Waitemata is in Figure 11.

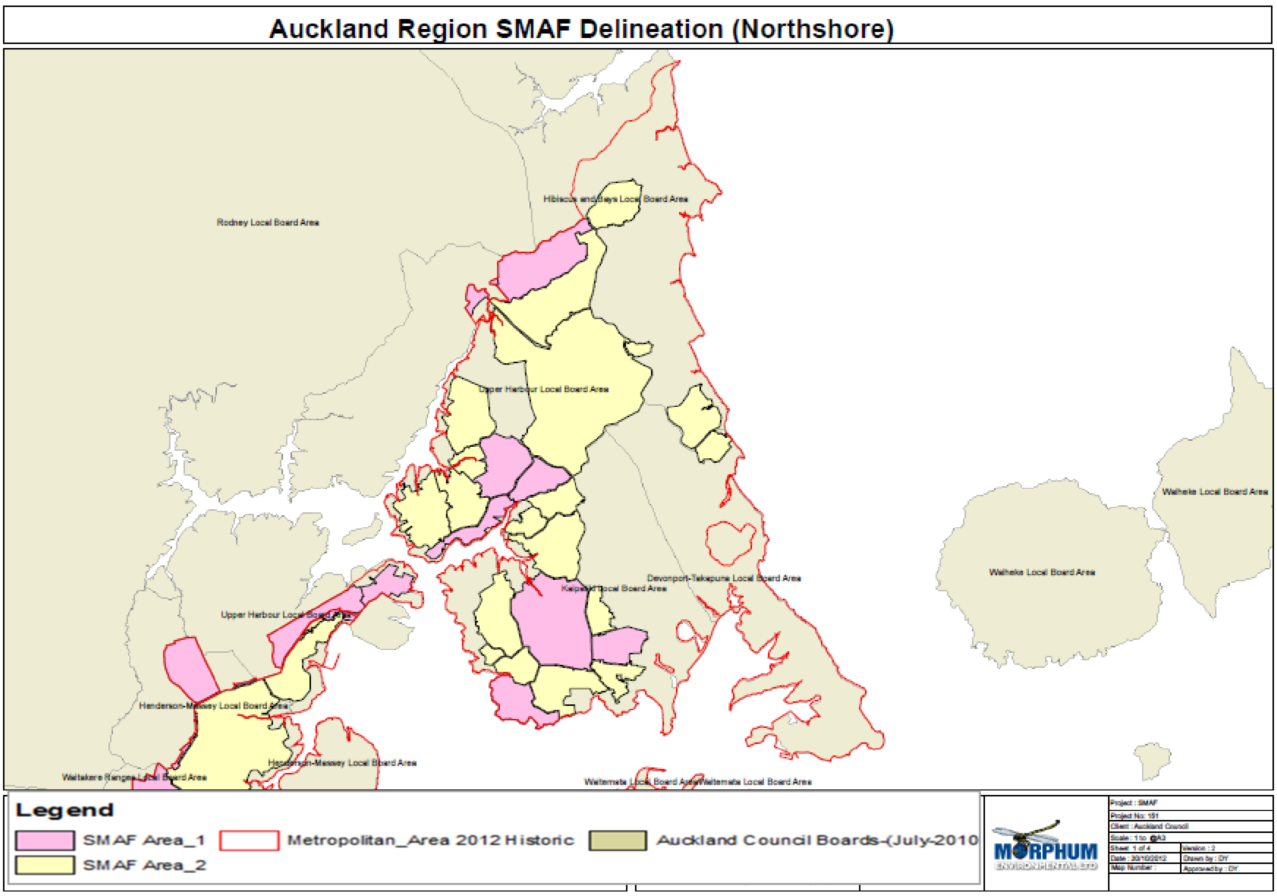

Figure 11: SMAF1/2 Areas for Northshore (Legacy North Shore City)

4 HOW TO MEET THE SMAF CRITERIA

The sizing of specific devices will be coming out in Technical Device Guidelines with the new GD01 document (updating of the existing Auckland Council TP10 – Design Guidelines Manual: Stormwater Treatment Devices, 2003).

Preliminary indicative sizes and costs on one specific example are given below in Figure 12 for a selection of devices which reduce volumes of stormwater runoff through some or all of; evapotranspiration, infiltration and wetting/drying of media.

Figure 12 presents gross and net costs for the SMAF1 and SMAF2 controls for a typical residential 500m^2. Net costs are equal to the gross total construction cost less the construction cost of a similar feature that does not have the stormwater management component. For example, for rain gardens the net cost is less the cost of similar standard landscaping costs, and for porous paving the net cost is less the cost of a standard concrete driveway. Also, some devices, such as rain gardens, have a fixed cost (such as inlet/outlet structures) with a variable cost for volume of materials etc. Figure 12 shows that the porous driveway provides the least net cost because the cost of a concrete driveway (at \$105/m^2) is only \$35/m^2 less than the cost of porous paving at \$140/m^2. The costs in Figure 12 are for a clay subgrade with a minimal infiltration rate of 2 mm/hr, the size (and hence costs) are reduced with increasing infiltration rates. In geotechnically sensitive areas susceptible to water infiltration, lining of the device would be required, adding another \$10 to \$50/m^2. Maintenance costs vary depending on the device and again need to be assessed in terms of gross and net costs with general upkeep of the device able to be carried out by the landowner. Regular technical/structural inspections by Council are recommended at one or two yearly intervals, especially in the initial years of the device.

For Residential - 500m^2 lot			
Roof = 200m^2; Pavement = 100m^2; Pervious = 200m^2			
Percent Impervious = 60%			
Mitigated to % Imp.	**WATER VOLUME MITIGATION**		
	Size (m^2)	**Gross \$\$**	**Net \$\$**
	Standard Raingarden		
	Size (m^2)	Gross \$\$	Net \$\$
SMAF1 (0%)	19	\$ 14,300	\$ 12,200
SMAF2 (20%)	12	\$ 11,200	\$ 9,800
	Deep Raingarden		
SMAF1 (0%)	10	\$ 11,700	\$ 10,500
SMAF2 (20%)	7	\$ 9,400	\$ 8,700
	Gravel Trench		
SMAF1 (0%)	25	\$ 6,400	\$ 6,400
SMAF2 (20%)	16	\$ 4,600	\$ 4,600
	Porous Paving (driveway)		
SMAF1 (0%)	100	\$ 14,000	\$ 3,500
SMAF2 (20%)	80	\$ 11,200	\$ 2,800

Figure 12: Indicative Device Sizes and Costs

5 OTHER BENEFITS

The multiple benefits of the devices are environmental, economic, social and cultural. Environmental benefits are clearly the protection and enhancement of urban streams using natural water cycle processes of filtration, infiltration and evapotranspiration, thus maintaining more natural stream flows, including base flows, volumes and peak flows. Rain gardens provide a greater biodiversity and social amenity within the urban built environment. Economic costs of prevention versus fixing it up afterwards are often less, with avoided costs associated with rehabilitation and maintenance of eroded streams from increased flows. Increased property values have also been reported for properties adjacent or near to healthy streams in natural environments. The use of filtration media (planting media or gravel) also provides for the stormwater filtration cultural requirement for treatment prior to discharge to water ways.

6 CONCLUSIONS

The five step process described above has provided an efficient, practical method to identify those stream reaches (and their respective sub catchments) in the Auckland region that are susceptible to increased erosion and degradation of stream health from increasing stormwater runoff flows from future development. It is important to note that this method focuses on the impacts from increasing flows and is not a stream works 'prioritisation' tool. There are numerous other factors that need to be taken into account with stream restoration works, such as levels of contaminants, riparian planting, culverting and fish passage, existing stream protection works such as gabion baskets, access to the site etc. The SMAF1 and SMAF2 areas have been mapped as spatial overlays to be used as regional land use controls for the Unitary Plan, as one of the ways the Council is using to protect, maintain and where possible, enhance our valuable natural streams, now and into the future.

The methodology was able to meet the challenge of how to map all the streams in the Auckland region by utilising existing Council GIS data followed up with a series of workshops to 'ground proof' and modify the initial 'ranking' using an additional set of catchment specific moderating factors combined with the knowledge of Council staff working in those catchments.

The impact of these additional SMAF1 and SMAF2 controls on existing implementation practices varies across the Auckland region as the previous individual legacy councils had quite different stormwater management policies and practices. While the stormwater management devices required to meet the new SMAF controls (such as raingardens and porouss paving) are relatively new in some areas of the Auckland region, other areas, such as the legacy North Shore City Council, have been implementing these practices over the last 3 to 5 years, and they are increasingly being accepted internationally as 'best practice'.

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REFERENCES

Alliance of Rouge Communities et al. (2012). Rouge River Watershed Management Plan, January 2009, revised June 21, 2012.

Allibone, R., Horrox, J., Parkyn, S. (2001). Stream Classification and Instream Objectives for Auckland Urban Streams, NIWA Client Report: ARC00257.

Argue, J.R., D. Pezzaniti and G.A. Hewa (2012). Design criteria for channel-forming flows in waterways of urbanising catchments. Australian Journal of Water Resources, Vol 15 No 2.

Auckland Council (2009a). Formerly Auckland Regional Council, State of the Auckland Region, 2009.

Coleman, D., MacRae, C., & Stein, E. (2005). Effect of Increases in Peak Flows and Imperviousness on the Morphology of Southern California Streams. Technical Report 450. Southern California Coastal Water Research Project, Westminster, CA 92683, USA. April 2005. www.sccwrp.org

CSN (2008). Chesapeake Stormwater Network (CSN) Technical Bulletin No. 3, Implications of the Impervious Cover Model: Stream Classification, Urban Watershed Management and Permitting, Version 1.0, 2008, USA.

Department of Conservation (2011). Relationships between multiple land-use pressures and individual and combined indicators of stream ecological integrity. DOC Research and Development Series 326. Refer www.doc.govt.nz under Publications, then Science & Technical.

Fassman, E., A., Voyde, E.A., Liao, M. (2012). Hydrologic basis of stormwater device design. Prepared by Auckland UniServices Ltd. For Auckland Council.

Neale, M. (2012). Email correspondence between Martin Neale, Project Leader Freshwater, Auckland Council and David Kettle, D&B Kettle Consulting Ltd (author) et al, 9th May 2012 with respect to the use of regional MCI scores in the SMAF scoring matrix.

NIWA (Updated June 2010). New Zealand River Environment Classification (REC) User Guide. Produced for the Ministry for the Environment by the National Institute of Water and Atmospheric Research (NIWA). Ministry for the Environment Publication Number: ME 1026.

Schueler, T. (2003). Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1, Center for Watershed Protection, Ellicott City, Maryland, USA.

Schueler, T. and Lisa Fraley-McNeal (2008). Caveats and Proper Use of The Impervious Cover Model, Symposium on Urbanisation and Stream Ecology, May 23-24, 2008, USA.

Schueler, T. and C. Lane (2012). Recommendations of the Expert Panel to Define Removal Rates for New State Stormwater Performance Standards. Prepared by Tom Schueler and Cecilia Lane of the Chesapeake Stormwater Network, submitted to Urban Stormwater Group, Chesapeake Bay Partnership.

Storey, R.; Wadhwa, S. (2009). An Assessment of the Lengths of Permanent, Intermittent and Ephemeral Streams in the Auckladn Region. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report 2009/028.

USEPA (1999). Preliminary Data Summary of Urban Stormwater Best Management Practices EPA-821-R-99-012. USA.